

Pursuing Pig-Poop Power

A situation assessment of Duke University's proposal to power a CHP plant using renewable biogas

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April 27, 2018

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University

Executive Summary

Duke University knows that becoming a climate neutral institution requires creative thinking. The university's resourcefulness has led it to the cusp of harvesting methane from swine-waste lagoons, a source of renewable biogas located in North Carolina. The Green Devil is in the details, however; the renewable biogas market does not yet exist on a scale sufficient to meet Duke University's needs. The purpose of this project is to explore how Duke University might achieve climate neutrality and, in the process, contribute to an effective solution to the problem of swine-waste in North Carolina.

Having the ability to power its campus with renewable biogas would catapult Duke University beyond its carbon neutrality goals. To turn swine-waste into a resource, Duke University will need to overcome several technical and economic barriers that have previously prevented the implementation of the technologies Duke University is considering. The university has the potential to be a missing link that could align the interests of Duke Energy and Smithfield Foods, the owner of many of the hogs that create the manure currently filling swine-waste lagoons in eastern North Carolina. By providing leadership and market demand, Duke University can play a formative role in the creation of a market for renewable biogas.

Duke University must exercise its leadership to ensure that biogas from swine waste is a sustainable resource. A systems analysis of North Carolina's pork industry reveals many questions about the long-term viability of biogas as a resource. The industry's hog-production relies on millions of tons of imported feed and recovers only a fraction of the nutrients used to grow feed-crops. Current swine-waste management practices impact air quality, water quality, soil health, human health and the global environment, with the majority of the impacts being borne by the poor, non-white residents of eastern North Carolina. Containing these negative externalities would cost North Carolina's hog producers an estimated \$286 million per year over a ten-year period.

In order to act effectively as a responsible purchaser of biogas, Duke University must reconcile conflicting opinions on its own campus. Duke University's decision-making needs to reflect the interests of pragmatic and idealistic voices – pragmatists for providing the university with the best immediate options, and idealists to chart a far-seeing path towards climate neutrality. The university must create more robust infrastructure to allow these separate voices to communicate.

In addition to acting as a source of demand for swine-biogas, Duke University can make valuable contributions to the development of a sustainable swine-biogas market by conducting research that will ensure superior technology is available and implemented on all swine farms in North Carolina. To ensure a healthy biogas market that can serve as a viable energy source for the future, Duke University must also propose creative solutions that thoroughly address the negative externalities of swine farming.

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I. Introduction

A. Purpose and Format of report

In 2009, Duke University published its Climate Action Plan (CAP), committing its academic, facility and personnel resources towards achieving climate neutrality by 2024. In this document, the university defines climate neutrality in terms of greenhouse gas (GHG) emissions and details the approaches it will take to meet its goal. Since then, Duke University has decreased its campus GHG footprint by 24%; with only 7 years left before the target date and over three quarters of the university's baseline footprint remaining, the university continues its search for pathways to climate neutrality. One of Duke University's newest and most promising strategies to achieve climate neutrality is to build a combined heat and power (CHP) plant on campus and power it with renewable biogas rather than natural gas.

The essential and currently unavailable component to this proposal is a viable source of renewable biogas. Duke University is exploring the possibility of obtaining this biogas from swine farms in Eastern North Carolina, where manure from North Carolina's 9.7 million hogs is currently stored in open lagoons. As the waste sits in these lagoons, naturally occurring bacteria break down organic material in the waste, releasing methane into the atmosphere as a byproduct. Methane is both a potent greenhouse gas and the combustible ingredient in natural gas. By capturing and burning the methane that is currently an unused byproduct of pork production, Duke University could generate both electricity and the offsets needed for it to reach its goals of climate neutrality.

Duke University is one of many stakeholders interested in changing how swine waste is managed in North Carolina. Hog producers, hog farmers, residents of eastern North Carolina, state regulators, academic researchers and electric utilities are just some of the stakeholders invested in containing emissions from swine waste lagoons. In spite of the wide range of stakeholders who share the common goal of improving how swine waste is managed, North Carolina has made little progress addressing the externalities of these lagoons over the past twenty years. As Duke University contemplates the possibility of capturing and burning methane from these lagoons, it would be helpful to understand the challenges that have made progress in this field so elusive.

The term "wicked problem" first originated in paper published in 1973 co-authored by Horst Rittel and Melvin Webber.¹ As scientific knowledge expanded throughout the twentieth century, the authors identified persistent challenges in solving social problems. Addressing wicked problems requires a thorough understanding of entire systems; even then, there is no guarantee that planners can determine the appropriate solution for a desired result. Rittel and Webber proposed several traits that characterize wicked problems. These include:

- There is no definitive formulation of a wicked problem.
- Wicked problems have no stopping rule, i.e. it can be difficult to know when the problem has been "solved".
- Every wicked problem is essentially unique.
- Every wicked problem can be considered to be a symptom of another problem.
- Any planner attempting to solve a wicked problem has no right to be wrong.

On all counts, swine waste is a wicked problem. Swine waste lagoons are directly linked to the agricultural practices that define the hog industry of North Carolina and have both global and local environmental impacts. In addition to leaking methane, the lagoons affect soil quality, water quality, air quality and human health, creating negative externalities that fall mostly on the poor, non-white residents of eastern North Carolina.

By announcing its intention to purchase biogas to meet its climate neutrality goals, Duke University might provide the demand needed to spur the creation of a market for renewable biogas, but the university is wading into the midst of a wicked problem. Actions that Duke University takes in the coming years will play an influential role shaping the nascent biogas market. Because any “solution” to the swine lagoon problem in North Carolina will impact global climate change, the methods of pork production and the lives of the people who live next to these lagoons, Duke University has no right to play any role implementing a bad solution.

This master’s project seeks to provide the planners at Duke University with relevant information to make an informed decision about how to best pursue swine-biogas.

It begins with a stakeholder analysis of three key players. Those are:

1. Duke University, the research and education institution for whom this report was prepared
2. Smithfield Foods, the largest pork producer in the state (and the world)
3. Duke Energy, the electric utility that provides Duke University with energy.

It then focuses on the technology and policy drivers that have led to the current usage of waste lagoons.

With this background, I discuss how Duke University has approached the issue to date, analyzing the linkage between Duke University’s proposed CHP plant and swine-biogas. I use data from previous studies to quantify the costs of the negative externalities associated with waste lagoons and I also discuss issues of nutrient cycling and environmental justice that are not accounted for when only methane reductions are considered. The paper concludes with recommendations for committing to biogas production specific to Duke University as well as an example of what a true solution might look like.

II. Stakeholder Analysis

This report considers the role of three stakeholders who would be involved in the creation of a biogas market in North Carolina. Those are Duke University, Duke Energy, and Smithfield Foods. Smithfield Foods was selected for analysis because their pigs provide the manure from which biogas would be captured. Duke Energy was selected because of its relationship as the energy service provider to Duke University and its own interests in the development of a biogas market.

A. Duke University

1. Operations and Energy Consumption

Duke University is an educational and research institution located in Durham, North Carolina. It has ten distinct schools and colleges and 11 research institutes. The university has roughly 38,000 employees and 15,000 students who work and sometimes even reside in the campus’ 256 buildings. Operating costs for Duke University make it a large economic driver in North Carolina; it’s annual operating expenditures in 2016 were 5.5 billion dollars.

As a research facility whose school of medicine overlaps with a hospital, Duke University is also a large energy customer. In 2016, Duke Utilities and Energy reported that Duke University purchased 450,000 MWh of electricity for campus operations, a sizeable 0.3% of North Carolina's total electricity consumption that year.^{2,3}

In addition to the quantity of energy Duke University purchases, its extensive existing district heating and cooling system make it an unconventional utility customer. Power for building heating and cooling does not come directly from electricity; instead, Duke University operates centralized plants to create chilled water for cooling and hot water and steam for heating. These fluids are circulated in underground pipes around campus. This infrastructure has an estimated replacement value of \$800 million; these costs are justified by the savings created by having more efficient, centralized heating and cooling plants as opposed to less efficient infrastructure in each building.⁴

Duke University's district heating and cooling system is efficient but still reliant upon fossil fuels. The energy used to heat and cool Duke University's campus comes from purchased electricity or natural gas. The steam plants use boilers powered by natural gas (themselves an upgrade from the original coal furnaces completed in 2011) to generate steam which is then distributed through 35 miles of pipes. The chilled water plant on campus is powered by electricity and sends chilled water through 14 miles of pipes.⁵

2. Climate Action Plan and Duke Carbon Offsets Initiative

In 2007, Duke university joined the American College and University Presidents Climate Commitment (ACUPC), a group of Universities with a shared goal of achieving climate neutrality.⁶ Part of the contract of the ACUPC requires a Climate Action Plan (CAP) documenting how the institution will achieve their goals be published within 3 years.⁷

Duke University created a new committee, the Campus Sustainability Committee (CSC), to develop a CAP that would include a target date as well as strategies and milestones to reach neutrality. The CAP was published in October of 2009 and set an ambitious goal of carbon neutrality by 2024.⁸ Notably, climate neutrality does not require the university to stop burning fossil fuels. Duke University aims to reach carbon neutrality through a combination of energy efficiency, electricity emission reductions, transportation emission reductions and carbon offsets. The inclusion of carbon offsets allows Duke to continue to generate CO₂ from fossil fuel combustion, but it must find an equivalent amount of carbon offsets. To locate and purchase these offsets locally, Duke University created an internal office, the Duke Carbon Offsets Initiative (DCOI).⁹

3. Proposed CHP plant

a) *Original Proposal*

Duke University announced its intentions to partner with Duke Energy on May 9, 2016 to build a 21 MW CHP plant on campus. The initial announcement was released at the end of the school year through the Duke University website "DukeToday."¹⁰ The statement explained that the plant would provide electrical power to Duke Energy's grid; the plant's efficient usage of energy is improved by capturing wasted thermal energy, which Duke Energy would sell to Duke University as steam. The cost of that steam would be less than what Duke University currently pays to produce steam. To pay for the CHP plant's construction, Duke Energy would finance the majority of the \$55 million in construction

costs, with Duke University contributing \$5-7 million. In the initial announcement, the university claimed that the plant would reduce its carbon footprint by 25%.¹¹

b) Differing Opinions on Campus

When students returned to campus in the fall of 2016, an unexpectedly fierce debate ensued; in the end of the first week of September, the Duke Climate Coalition, an undergraduate-led student group, accumulated 500 signatures on a petition asking then-President Brodhead to stop construction of a new plant on the grounds that it relied on natural gas, a fossil fuel, rather than renewable energy.¹² Debate across campus continued throughout the spring. To give voice to the differing opinions on the CHP plant, the university held a number of forums; faculty and staff also published a number of reports and articles debating the merits and drawbacks of the proposal.

(1) Support for the CHP

A number of voices on campus made compelling arguments in favor of the CHP plant. This debate extended to the highest level of the university; at the end of November 2016, then-President Brodhead published a letter in the Duke Chronicle explaining his rationale for why the university should build the plant and what its considerations were.

The argument in favor of the CHP was most clearly laid out by report written by Facilities Management in partnership with Sustainable Duke. Published on October 6, 2016, the report details the university's energy needs and explains how the proposed CHP plant fits into the university's CAP. The report also included a cost comparison with similar energy services provided by other renewables; while pursuing alternative technology is not mutually exclusive to building the CHP plant, there is no cost competitive technology that offers the same benefits of CHP.

Key arguments given in favor of the CHP plant are provided in the table below.

Benefit of proposed CHP plant	Description
- CAP reductions	<ul style="list-style-type: none"> - The CHP plant can convert natural gas to electricity and heat at 80% efficiency, with a lower anticipated emission factor than Duke Energy's generating fleet. - The plan would create an 23% reduction in the University's CO₂-equivalent emissions as compared to purchasing electricity from Duke Energy.
- Electricity resiliency	<ul style="list-style-type: none"> - In the event of a regional blackout, the CHP plant could "island" itself, isolating itself from the Duke Energy's larger grid and continuing to provide energy services to the hospital and vital campus operations.
- Cost savings	<ul style="list-style-type: none"> - The savings realized by the cheaper steam production lead to a quick payback time of 2-3 years for the CHP plant.
- Future hot water needs	<ul style="list-style-type: none"> - Facilities anticipates adding a new hot water plant to convert some campus heating needs to hot water instead of steam. The CHP plant would replace plans for a new hot water heater, saving an addition \$2.5 million.

	- A later report indicated that the CHP would allow the university to avoid \$18 to \$28 million in new heating infrastructure.
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Table 1: Summary of arguments in support of the proposed CHP plant

(2) *Concerns with the CHP proposal*

Faculty, staff, students and Duke University's neighbors raised a variety of concerns about the proposed CHP plant. These views were expressed at public demonstrations, at forums, and editorials published in the Chronicle. A recurring theme in these concerns is the interaction between the proposed CHP plant and Duke University's carbon neutrality goals. A particularly troubling letter came from Nicholas School of the Environment's faculty Drew Shindell and Prasad Kasibhatla; their report questioned the carbon accounting principles that led to the claimed 23% reduction in the university's carbon footprint. They provided an alternative accounting and reached a much more modest claim of less than 4% reduction in emissions.¹³

The content of other issues raised by Duke Community are summarize in the table below.

Issue	Description
- Timing of announcement	- Proposal was issued after most students had left campus for summer, precluding discussion. ¹⁴
- Carbon Accounting Principles	- Nicholas School faculty published an article in the Chronicle detailing their perspective on how emission reductions should be accounted for. Their accounting indicated less than a 4% reduction in CO ₂ e emissions ¹⁵
- Social Justice	- Duke Energy's costs of plant are passed on to residents of North Carolina ¹⁶ - Amounts to a subsidy from NC ratepayers to reduce Duke University's carbon footprint
- Fossil Fuel Usage	- Contractually commits Duke University to 35 years of dependency on fossil fuels ¹⁷

Table 2: Summary of Duke University community concerns with initial CHP

Woven into each concern with the proposed CHP plant is a common theme that Duke University must consider the long-term sustainability of its energy sources, and carefully consider the potential impacts of its choices. To its credit, Duke University has slowed down the process of building the CHP plant and is actively responding to the concerns raised by faculty, students and staff.

c) *Subcommittee to the Campus Sustainability Committee*

To resolve the conflict surrounding the proposed CHP plant, the CSC, formed a subcommittee (SCSC) composed of faculty, staff and students to write a report. As part of the fact-finding process, the SCSC also hosted a public forum to provide an opportunity for stakeholders to voice opinions. The report provided a detailed analysis of the proposal, analysis of alternatives and final recommendations that were delivered to University administrators in April of 2017.¹⁸

The SCSC was unable to reach a decision on the proposed CHP plant on its merits alone. What emerged as a consensus, however, was that the university should link the construction of the CHP plant

to the availability of a renewable alternative – namely, swine biogas. The ultimate recommendation is reproduced below.

“...the subcommittee recommends that Duke University procure sufficient volumes of directed biogas in year one to render the CHP plant carbon neutral in its first year of operation, and that the plant be fully powered by directed biogas, with the goal of achievement within five years of operation [...] The subcommittee recommends that the University not move forward with the plant if these biogas objectives cannot be met.”¹⁹

d) *Current Status of CHP*

As of the publication of this report in April, 2018, Duke University has announced that construction of the proposed CHP has been put on hold indefinitely.²⁰ If the university demonstrates that it can procure sufficient quantities of renewable biogas to render the plant carbon neutral, the university may choose to continue proceedings and ask Duke Energy to apply for a certificate of necessity from the North Carolina Utilities Commission.

4. *Loyd Ray Farms*

The report by the SCSC references the university’s earlier investments in swine biogas; these investments provide proof of concept as well as demonstrated expertise in a challenging field. DCOI helped launch an existing project that captures and burns swine biogas to generate offsets and Renewable Energy Certificates (RECs). The project is located at the Loyd Ray Farms, a hog farm permitted for 8,600 market weight hogs located to the west of the University in Yadkin County, North Carolina.²¹ Duke University, Duke Energy and Google, Inc. partnered to upgrade the farm’s waste management system.²² The system was designed to meet current environmental performance standards for new hog farms in North Carolina. The upgrades installed on the lagoon include:

- An in-ground lined and covered anaerobic digester to capture methane from swine waste
- A 65 kw turbine that burns renewable biogas generated on site to produce electricity
- An aeration basin to remove nitrogen and pathogens from the liquid waste stream, a process that also reduces odors.

The Loyd Ray Farms digester has provided Duke University the opportunity to research and develop digester technology; the system has created data for three peer-reviewed publications as well as a “Best Practices” report.²³ As a result of this project, DCOI has already accumulated a valuable (and still fairly unique) skill set, i.e., creating a combination of biogas, electricity, carbon offsets and RECs from swine waste while proving the viability of the pollution control technology.

While successful as a pilot, the Loyd Ray Farms digester also highlights the challenges facing the renewable biogas industry. Estimating productivity has been challenging as well; after the first year of operation, the system produced only half of the estimated number of offsets.²⁴ Furthermore, the system had a total cost of 1.2 million dollars, which represents a major investment for individual farmers. In this case, the farm’s digester was funded by external resources that did not require any farmer contribution,²⁵ but such resources will not be available for each farm that installs such a system in the future. The cost of installation, when spread over a ten-year period, would amount to \$462 per 1,000lb-

Steady State Live Weight²⁶ (reporting the cost in \$/1000lb-SSLW was done to facilitate comparisons to similar technologies discussed later in this report).

B. Duke Energy

1. Business Strategy and Operation

Duke Energy is an energy company headquartered in Charlotte, North Carolina. Duke Energy operates through its subsidiaries which include a number of electrical utilities. Duke Energy serves 7.5 million electrical customers located in the Southeast and Midwest of the United States, a territory of 95,000 square miles with an estimated population of 24 million. Along with its electrical utilities, Duke Energy owns Piedmont Natural Gas, an energy company in North Carolina that distributes natural gas to over 1 million customers.²⁷ As a customer located in Durham, Duke University purchases electricity from Duke Energy Carolinas, a Duke Energy subsidiary.

a) *Generating fleet*

Duke Energy generates electricity from a mixture of generating plants that includes natural gas, coal, hydro-power and nuclear power. Recently, Duke Energy has been adding natural gas capacity; in 2016, 38% of Duke Energy's generating capacity came from natural gas. While it has increased its ownership of natural gas plants, the utility still sources more of its electricity from coal and nuclear power (see figure 1).²⁸

Natural gas plays a significant role in Duke Energy's plans for the near future. This is evident in its sustainability reports and each subsidiaries' integrated resource plans. Every subsidiary of Duke Energy operating in North Carolina must publish its plans for its generating capacity every other year. In Duke Energy Carolina's 2016 integrated resource plan, they lay out their plans for new investments in natural gas capacity. In the near term, this subsidiary alone plans to bring a 683 MW combined cycle natural gas boiler online in South Carolina in 2018 as well as 109 MW of power from smaller combined heat and power plants by 2021.²⁹ Other subsidiaries have similar plans. Duke Energy will sell its customers electricity produced from natural gas for the foreseeable future.

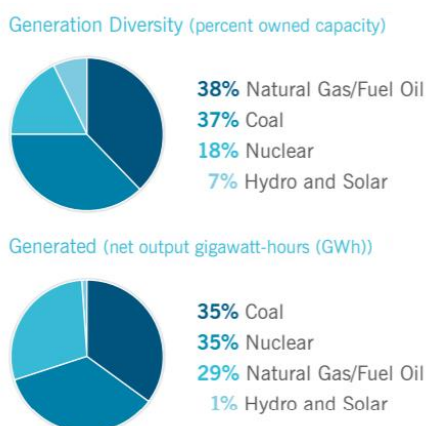


Figure 1: The generating mix of Duke Energy Carolina's as reported in their 2016 Integrated Resource Plan

2. Recent Publicity

Even though Duke Energy operates as a regulated monopoly in its service territory, it must maintain a good reputation to ensure it can borrow money at reasonable rates. Should Duke consistently make imprudent investments, it runs the risk of not being allowed to recover its costs through ratepayers. Recent coverage of Duke Energy has included a number of reputation-damaging, high profile news stories surrounding their past methods of disposing of coal ash.

a) Coal ash

Coal ash is the byproduct of burning coal and contains contaminants such as mercury, cadmium and arsenic. Duke Energy has traditionally stored this byproduct in unlined pits located next to coal plants.³⁰ This was a decision driven by practicality - coal plants are often located next to rivers and streams needed to provide the water needed to operate the plant.

On February 22, 2014, an estimated 39,000 tons of coal ash spilled from a Duke Energy coal ash basin into the Dan River.³¹ The resulting federal investigation involved the Department of Justice and the Environmental Protection Agency as well as North Carolina investigators and found a number of violations of the Clean Water Act. On May 14, 2015, Duke Energy plead guilty to nine criminal violations of the Clean Water Act stemming from their handling of coal ash. These federal pleas were accompanied by a fine of \$102 million dollars (separate from state and civil fines).³²

During hearings, prosecutors unearthed several actions indicative of a habitual negligence concerning the Duke Energy's management of coal ash. In addition to the fines, Duke Energy had to create compliance plans to manage their coal ash basins. This is no small task – the company has approximately 108 million tons of the residue in North Carolina alone.³³ After pleading guilty to violations of the Clean Water Act, Duke Energy released statements indicating that shareholders and not ratepayers would shoulder the fines.³⁴

While Duke Energy shareholders are responsible for the direct fines associated with the Dan River spill, the North Carolina Utilities Commission (NCUC) recently allowed the company to recover compliance costs for coal ash disposal from its rate payers. In Duke Energy's most recent rate case, the NCUC approved \$232.4 million over a five-year period for Duke Energy subsidiary Duke Energy Progress' coal ash compliance costs.³⁵ Duke Energy Carolinas has a similar case pending.

Even though the NCUC determined that Duke Energy can pass costs on to its customers in this case, Duke Energy would be prudent to avoid creating similar environmental risks in the future. As noted in the dissenting opinion, the allowable costs include costs to dispose of coal ash that the company generated and stored with the knowledge that its storage method failed to meet federal and state standards.³⁶ A pattern of repeated negligent behavior might not be viewed as favorably in future hearings.

3. Interest in CHPs and Clemson University

Duke Energy has been actively pursuing CHP plants at universities, military installations and other industrial applications.³⁷ While Duke University's CHP plant has stalled, it is not the only CHP plant Duke Energy is considering. Duke Energy Carolinas alone intends to install 108 MW of capacity from small CHP plants by 2021, the equivalent of 5 power plants similar to the one proposed for Duke University.³⁸

University campuses make ideal sites for small CHP plants. They have reliable demand (for both thermal power and electricity) and available land. Duke Energy sees building rate-based small CHPs on university campuses as a promising area for business growth.³⁹ Duke Energy has partnered with Clemson University on a similar CHP plant that has been progressing smoothly. In February 2017, Duke Energy Carolinas proposed a 16 MW CHP on Clemson University in South Carolina; like the one on Duke University's campus, it would be able to power a microgrid in the event of a larger grid outage.⁴⁰

Clemson University also has climate neutrality goals; their target date is 2030.⁴¹ The proposal for the plant at Clemson did not meet the same amount of opposition as that of Duke University, and South Carolina's Public Service Commission does not require approval for plants smaller than 75 MWs. Neighbors complained about the initial siting of the plant, but after moving the plans 400 yards Clemson has been able to proceed and hopes to have it operational by 2019.⁴²

C. Smithfield Foods

1. Business description

Smithfield Foods (or simply "Smithfield") is a global food company that sells pork and processed meat, much of which comes from company-owned hogs. In 2015, Smithfield produced 15.9 million market hogs.⁴³ Waste from hogs owned by Smithfield is the source of a large quantity of methane - either an unwanted byproduct of hog production or a wealth of renewable biogas, depending on your perspective. Because of this, decisions they make regarding their own operations will play a large role in determining the availability of renewable biogas in North Carolina.

2. Pressures from Walmart

Walmart is partially responsible for moving Smithfield Foods towards reducing its emissions by capturing methane. Walmart is a large customer that is able to influence its suppliers' operations. In April 2017, Walmart announced "Project Gigaton," its plan to reduce its GHG footprint by 1 gigaton before 2030 by working with its suppliers.⁴⁴ Walmart specifically mentions agriculture as a goal area for CO₂e reductions.

Walmart has successfully partnered with Smithfield Foods to implement emission reducing technologies in the past. In collaboration with the Environmental Defense Fund, Walmart and Smithfield worked with Smithfield's grain suppliers to improve fertilizer efficiency and reduce Nitrogen Oxide emissions. These changes were made at a farm level - the program worked with over 200 farmers and changed management practices on 100,000 acres.⁴⁵ In addition to using optical sensors to optimize fertilizer applications, farmers were encouraged to plant cover crops to reduce the need for nitrogen fertilizers.⁴⁶

Following Walmart's reveal of Project Gigaton, Smithfield has publicly committed itself to installing anaerobic digesters on 30 percent of its farms.⁴⁷ Given their successful record of working with EDF, the public nature of their commitment and the possible risk of losing Walmart as a customer if they do not meet their goals, it seems likely that Smithfield will soon have a supply of methane available to flare or sell as natural gas.

3. Supply Chain

What began as a single meatpacking plant has transformed itself into the world's largest pork processor and hog producer.⁴⁸ In 1981, Smithfield purchased a rival company, a move it describes as

“the first of some 40 company-defining acquisitions.”⁴⁹ Smithfield now effectively controls its entire supply chain, from sourcing feed-grain to sealing the packaging on a cured spiral ham. Smithfield’s pork packaging (the butchering of hogs) and hog production play a key role in creating the conditions that make a biogas market possible.

a) *Pork Packaging*

Pork packaging is the process of slaughtering and butchering hogs. It is a vital step in pork production that transforms live animals into the sealed cuts of meat sold in supermarkets. Smithfield’s market power in North Carolina is derived from its control of the pork packaging industry. In 1998, Smithfield’s acquisitions and construction of the Tarheel Plant (the largest plant in the world) led to it becoming the largest pork packager in the world, a position it has held since then.⁵⁰

The market for pork packaging is a regional market. Packaged meat can be distributed at relatively lower costs around the globe; shipping live hogs is a more expensive proposition. Pork packaging is therefore a regional market; the average distance hog farmers ship their animals to packagers is 150 miles.⁵¹ Smithfield is the only major pork packager near the pork producing regions of North Carolina (see figure 2).

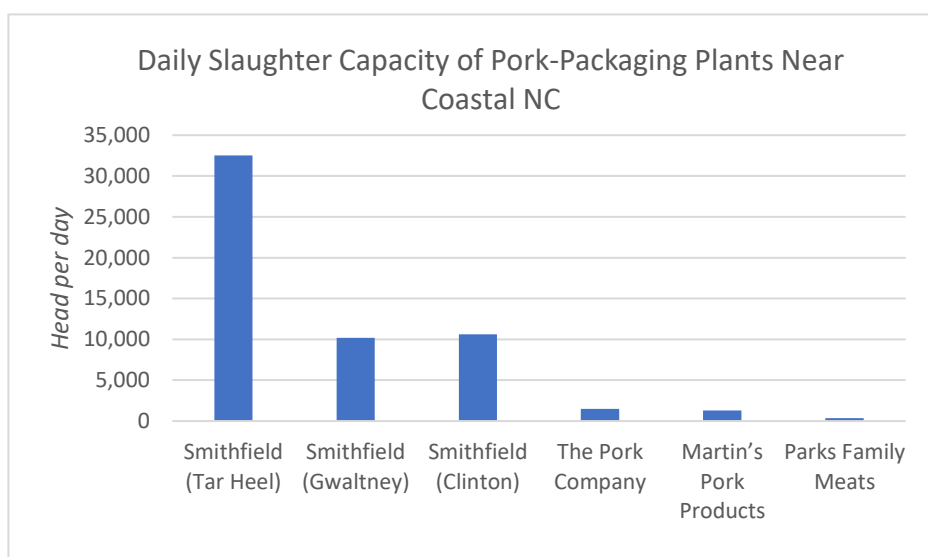


Figure 2: The vast majority of slaughtering capacity near hog farms in North Carolina is owned by Smithfield

This concentration of buyer power (known as monopsony) allows Smithfield to influence the price for hogs, but more importantly, to favor farmers who produce hogs that meet Smithfield’s standards. By purchasing large herds of uniformly sized hogs, Smithfield has shifted North Carolina’s hog production model away from the smaller sized farms and towards what Smithfield refers to as their “advanced management techniques.”^{52,53}

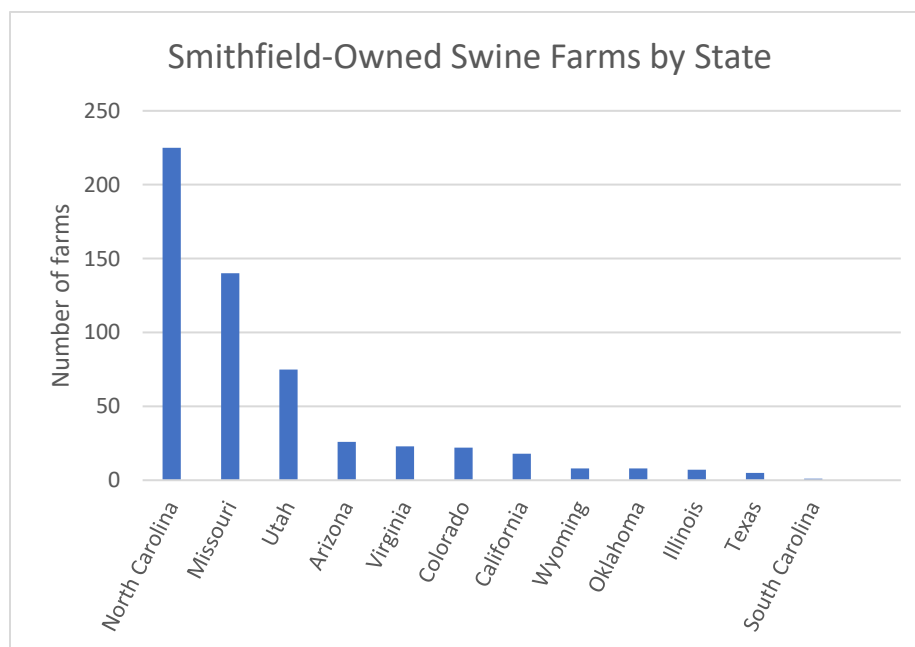
b) *Hog Producing*

As Smithfield grew, it began to vertically integrate by constructing its own farms and purchasing rival hog producers. It constructed its first farm in 1987, but it wasn’t until 2000 when its purchase of Murphy-Brown made it the world’s largest pork producer in addition to the largest pork packager. Since turning to pork production as well as packaging, Smithfield has acquired or built a total

of 558 farms spread across 12 states (see figure 3).⁵⁴ North Carolina has the most Smithfield-owned farms of any state with 225, followed by Missouri (notably, Smithfield has no company farms in Iowa, the nation's largest pork producer, where laws ban corporations from owning farms⁵⁵).

In addition to company farms, Smithfield relies on a network of contracted farms that are independently owned and operated but that raise hogs owned by Smithfield Foods; Smithfield reported that 81% of its hogs were raised this way in 2015. Sandwiched between rising feed costs and a limited selection of pork processors, contract farms have become the most common type of production in North Carolina.⁵⁶ Under these multi-year contracts, farmers are paid to provide the facilities and labor, but Smithfield owns the animals and feed (notably, animal waste is the property and responsibility of the contract farmer).⁵⁷ Regardless of the ownership, farms that produce Smithfield hogs must operate in accordance with the techniques specified by Smithfield.⁵⁸

These company-owned and operated farms are the ones on which Smithfield intends to install new anaerobic digesters. To meet its goal of installing digesters on 30% of its company farms, Smithfield would need to build 167 digesters.



III. Drivers

One of the characteristics of wicked problems is that there is no single cause that can be identified as the origin of the problem. This is particularly true of swine waste in North Carolina. The almost exclusive usage of open lagoons to manage swine waste in such high concentrations is unique to North Carolina and the result of a confluence of drivers. Driver analysis included in the scope of this project focuses on key technological and political drivers that have entrenched waste lagoons in the landscape of eastern North Carolina.

A. Technology

1. Consolidated Animal Feeding Operations

The type of farm used to raise hogs in North Carolina is itself technology; the implementation of modern methods of livestock management drives the need for open lagoons. Today, pork is an international commodity; hogs that are slaughtered in North Carolina are sold as pork products across the globe.⁵⁹ The existence of specialized hog farms relies on inputs of feed grain as well as access to a global market that is only made possible by refrigeration and vast shipping networks, both of which are recent innovations in the development of agriculture and global trade.⁶⁰ Modern live-stock operations must be understood in comparison to conventional methods of livestock farming which relied on on-farm production of animal feed used to raise animals intended for local consumption.

North Carolina experienced a shift towards large, specialized hog farms that was coupled with an increase in the state's hog population between 1974 and 1997. In that time, the number of hog farms in the state decreased from 22,975 to 3,582 while the hog population increased from 1,414,751 to 9,631,290.⁶¹ This shift represents a change from an average of 61 hogs per farm in 1974 to 2,688 hogs per farm in 1998, a trend that has only continued as farm ownership has further consolidated since then.

To handle such large populations, hogs were moved from pastures into large barns where they sleep, eat and defecate. Accumulated manure is removed; the treatment of that manure varies by location. As this technology of animal management proliferated, the environmental costs of the manure produced by animals became more apparent. In 1972, these livestock operations were identified as a source of pollution by the Clean Water Act (CWA), which named them Consolidated Animal Feeding Operations (CAFOs).⁶² CAFOs are defined by the number of animal units housed in barns. They must abide by regulations set by local agencies that dictate how they treat and manage their waste.

2. Open Lagoons/ spray-field irrigation

The technology used by hog CAFOs to manage waste in North Carolina is known as a waste lagoons, and it is paired with sprayfields, cropland that is used to absorb nutrients in the manure. These lagoons are permitted and overseen by the North Carolina Department of Environmental Quality. Waste from hogs falls through slats in the barn floor and is flushed out pits where the slurry sits. Solids accumulate in the bottom of the lagoons (as the technology matured, these became lined with either clay or plastic); liquid from the lagoons is sprayed through sprinklers as irrigation and fertilizer on spray-field that grow crops not intended for human consumption.⁶³

While open lagoons and sprayfields comply with North Carolina's regulations, there are a number of negative externalities associated with these technologies. These include

1. Surface water and groundwater pollution from excess nitrogen and phosphorous contained in feed grain and excreted in manure
2. Atmospheric pollution from methane, ammonia and particulate matter
3. Proliferation of antibiotic-resistant bacteria
4. Odors and airborne residue from lagoons and spray-fields
5. Soil contamination from metals and salts contained in trace amounts present in grain and concentrated in manure

These impacts are a direct result of how CAFOs are managed today. CAFOs rely on large imports of grain-feed; this animal feed is further supplemented with antibiotics to suppress disease and encourage growth. Hogs absorb many of the nutrients, but their manure contains large amounts of nitrogen and phosphorous as well as traces of the antibiotics used to keep animals healthy; when this waste is flushed into lagoons, none of those nutrients or chemicals is eliminated.⁶⁴

Lagoons and spray fields were selected in North Carolina not because they are the best system for managing waste but because they are the cheapest.⁶⁵ They have adverse effects on air quality, water quality soil health and human health.

Air quality is affected by emissions of ammonia, methane and particulates volatilized by spraying. Lagoons release ammonia and methane as naturally occurring bacteria break down organic molecules in manure. The liquid in lagoons contains high amounts of nitrogen and phosphorous which can impair local waterways if discharged. Unsurprisingly, the process of aerosolizing the liquid to spray on crops creates odors that make it unpleasant to live near these farms – and while unpleasant for humans, the waste attracts large numbers of flies that feed off manure. Those flies act as disease vectors and can transfer bacteria grown in pools of antibiotic rich sludge to anyone in the vicinity.

There are multiple pathways through which nutrients and metals stored in lagoons can contaminate waterways. Some lagoons were constructed with plastic liners meant to prevent contamination from seeping into the soil; others were not. Contamination can seep into soils through unlined lagoons or slow diffusion through the clay or plastic basins.⁶⁶ There is still a risk for runoff even when water from lagoons is applied as irrigation – rainfall can carry nitrogen and phosphorous from fields into waterways, a problem worsened by over-application.⁶⁷

CAFO swine production is also responsible for a significant imbalance of nutrient cycling. On traditional diversified farms, manure is applied to the fields from which the feed grain is grown; local production recycles nitrogen, phosphorous and other nutrients to soils by applying manure to farmland as fertilizer. CAFOs in North Carolina rely on imported feed (grown with synthetic fertilizers) that contains these nutrients.

While crops grown on spray-fields can absorb some of the nutrients in swine manure, there is simply too much manure to apply locally. In 2003, the EPA promulgated new rules requiring CAFOs to create a nutrient management plan. The EPA also analyzed the expected results of their new rules; by their estimates only 4.5% of large hog CAFOs in the Mid-Atlantic region have enough land available to appropriately recycle as much nitrogen as their hogs produce. None has enough land to recycle the phosphorous.⁶⁸

3. Alternate Technologies

In 2000, Smithfield entered into an agreement with then-Attorney General Roy Cooper to fund the research of what were termed “Environmentally Superior Technologies” (ESTs) to treat the manure from swine farms. Under the terms of the agreement, Smithfield contributed \$15 million for the research of ESTs and agreed to install those technologies on farms if they were permissible, met pre-determined performance standards, and were economically feasible. The performance standards were that the technology must:

1. Eliminate the discharge of animal waste to surface water or groundwater
2. Substantially eliminate atmospheric emissions of ammonia
3. Substantially eliminate odor detectable beyond the borders of the farm
4. Substantially eliminate disease vectors and airborne pathogens
5. Substantially eliminate nutrient (nitrogen and phosphorous) contamination of soils and groundwaters⁶⁹

Researchers tested and analyzed a total of 18 candidate technologies by installing them on farms, measuring inputs and outputs, and reporting on their operations. Meeting all five criteria required a combination of technologies – one to treat the liquid portion of the waste, the other to treat the solid – but was possible. The final report identified any combination of one liquid-waste treatment and four solid-waste treatment technologies as capable of meeting the environmental performance standards; anaerobic digesters fall into the category of solid-waste treatment.⁷⁰ In short, Smithfield has tested and implemented ESTs that can manage pollutant discharge, odors, and disease transmission on farms.

While the studies conducted for the Smithfield Agreement identified technologies that met the performance criteria necessary to be considered ESTs, none of the technologies were deemed economically feasible, and as a result, existing farms were not obliged to install any upgrades as per the terms of the agreement.⁷¹

B. Policy

The North Carolina General Assembly is aware of the environmental and social issues caused by swine farms and has passed legislation in the past aimed at addressing issues surrounding the waste lagoon management practices. Policy-makers in North Carolina must respond to their constituents. In many cases, this includes farmers alongside the local residents who are directly impacted by the farms' operations. While legislators agree that there are many problems with how swine waste is managed, they have been unable to come up with an effective solution that represents the interests of all stakeholders. There have been three notable pieces of legislation that directly address waste-lagoon management: the Swine Lagoon Moratorium, the Renewable Energy Portfolio Standard, and the Forestry and Agricultural Nuisance Act.

1. Swine Lagoon Moratorium

After the rapid expansion in the number of swine farms and waste lagoons in North Carolina that occurred throughout the 1990s, the general assembly passed a session law in 1997 placing a moratorium on both the construction of new swine farms or waste lagoons. The stated purpose of the law was to allow time to complete studies of the impacts of swine farms authorized by the General Assembly in 1995 and allow for time to determine an appropriate course of action upon receiving the results of those studies.⁷² As written, the moratorium did not require any changes to existing lagoons and allowed for already constructed lagoons to continue operating as they had been before the law was passed.

What was originally intended to be a two-year moratorium was periodically extended until 2007. By this time, the results of the Smithfield Agreement were complete, and the General Assembly passed a new law allowing for construction of new farms and the expansion of existing farms if they

were built using waste management systems capable of meeting the environmental criteria laid out in the Smithfield Agreement.⁷³

These laws have effectively limited the number of swine waste lagoons in the state but have in also hindered the development of new technologies in at least two ways. First, by allowing existing farms to continue operating with waste lagoons and sprayfields but requiring new farms to operate at higher standards, the law forces new hog farms to compete against farms that have significantly lower costs. Second, by limiting the supply of available farms, the moratorium encouraged the consolidation of the industry. To grow, pork producers had to choose between constructing new, more expensive farms or purchasing competitors who owned existing lagoons.⁷⁴ Smithfield chose the latter.

2. Renewable Energy and Energy Efficiency Portfolio Standard

To date, North Carolina is the only state that requires electrical utilities to sell electricity produced from swine waste. In 2007, the North Carolina Senate enacted the Southeast's first Renewable Energy and Energy Efficiency Portfolio Standard (REPS).⁷⁵ The law was intended to promote renewable energy and energy efficiency in the state and mandates the inclusion of those sources in investor owned utilities' electricity production fleet. One of the sources included in the legislation is swine waste. As written, the law required any investor owned utility to sell electricity produced from swine waste resources by 2012, and gradually increased the amount to a total of 0.2% of the utility's total sales by 2018.⁷⁶

While the senate law created the requirement for utilities to sell electricity from swine-waste, it did not specify who would be responsible for generating the electricity. At the time the law was passed, the results of the Smithfield Agreement would have been available. The results of the Smithfield Agreement indicated that financing ESTs would rely on saleable byproducts and still might not be competitive with waste lagoons.

The REPS required utilities to begin selling electricity from Swine Waste resources in 2012, but no utility has been able to meet the required amount of electricity. Normally, non-compliance would result in a fine. In this case, the North Carolina Utilities Commission has opted not punished any utility for not meeting this portion of the REPS because of the economic challenges of producing electricity from swine waste in a cost-effective manner.

3. Agriculture and Forestry Nuisance Remedies

The most recent law specifically targeting swine waste lagoons in North Carolina was 2017's House Bill 467, titled *Agriculture and Forestry Nuisance Remedies*. The bill limits the compensatory damages awarded to plaintiffs in nuisance lawsuits against hog operations to the difference in the plaintiff's property value as caused by the nuisance.⁷⁷ The law does not affect any lawsuit initiated before it was passed. At the same time, it also demonstrates the unwillingness and inability of the current legislature to seriously address the damages caused by waste lagoons. As evidenced by a law protecting hog farming operations from the nuisance of having to defend their practices in court, the current legislature prioritizes the protection of waste lagoons.

C. Environmental Justice

Hog production in North Carolina displays characteristics consistent with environmental racism. Hog farms are geographically concentrated and located in areas with high percentages of non-white residents, a relationship that has been extensively documented by researchers at UNC Chapel Hill.⁷⁸

Building the infrastructure to capture renewable biogas creates an opportunity to address these problems. Installing technologies that meet the Smithfield Agreement’s environmental performance criteria will reduce the impacts of swine farms on their neighbors. A crucial question for the nascent biogas industry is if these technologies penetrate enough farms to improve conditions for residents of eastern North Carolina.

1. EPA Investigation

The EPA is currently investigating the process through which the NCDEQ issues permits to swine farms to determine if it violates Title VI of the Civil Rights Act of 1964.⁷⁹ The process was initiated in 2014 and was described in a letter from the acting secretary of the EPA sent a letter to the incoming administration at NCDEQ sent at the start of 2017. While the letter is not a statement of findings, it alleges troubling practices that include documented instances of improper spray-field management and intimidation of community members by farm employees and National Pork Council representatives.

During its investigation, the EPA’s External Civil Rights Compliance Office (ECRCO) conducted interviews in North Carolina with residents adjacent to swine farms to better understand the impacts of these operations. Respondents noted

- “An overpowering stench [...] so strong it causes gagging, nausea and vomiting”
- “Increases in cases and severity of asthma and other respiratory illnesses”
- The appearance of Pork Council representatives at what was supposed to be a confidential meeting between NC-DEQ and complainants.
- Regular incidents of “harassment, intimidation, and retaliatory behavior, including physical and verbal threats, by swine facility owners and/or operators and their employees.”
- A particularly alarming event when a “local industrial swine farm operator [entered] the house of an elderly African American woman and [shook] the chair she sat in while threatening her and her family with physical violence if they continued to complain about odors and spray.”⁸⁰

While the EPA report is ongoing, Mustafa Ali, the EPA’s head of its Environmental Justice department, resigned in March 2018 in protest of the EPA’s lack of commitment to its own environmental justice initiatives.⁸¹ It is unlikely that the EPA under its current administration will take major steps to address its own findings of environmental discrimination.

2. Lawsuits against Smithfield Foods

Smithfield subsidiary Murphy-Brown currently faces 26 lawsuits on behalf of 516 plaintiffs alleging nuisance from the operations of farms adjacent to the plaintiffs’ properties. The lawsuits include complaints consistent with reports on the impacts of swine farms in North Carolina that go back as far as 1995.⁸² The case includes alleges that operations from the farms cause nausea, unpleasant odors, burning eyes, and loss of enjoyment of property.⁸³ The first of these lawsuits is scheduled to begin in April 2018. While the outcome is uncertain, the results of past lawsuits shed some light on how Smithfield may respond to this legal pressure.

In 2010, Smithfield Foods subsidiary *Premium Standard Farms* (PSF) lost a court case on similar grounds in Missouri.⁸⁴ In that trial, 15 plaintiffs with land adjacent to a PSF finishing farm were awarded \$11 million dollars by the court, an average of over \$700,000 per plaintiff.⁸⁵ As a result, PSF

- 1) Immediately threatened to never make any future investments in Missouri,⁸⁶ and
- 2) Invested “tens of millions of dollars” in odor control systems (such as barn scrapers) on company-owned farms in Missouri.⁸⁷
- 3) Reached a settlement with an additional 287 plaintiffs for an undisclosed amount 2 years later.⁸⁸

While the terms of the agreement were confidential, the joint statement indicated that PSF’s investments in odor-controlling technologies were a critical factor in deciding to settle rather than continuing each case.⁸⁹

IV. Analysis

The purpose of this section is twofold. The first goal of analysis is to quantify the scale and approximate costs of the negative externalities caused by hog farming using current technologies in North Carolina. This analysis draws from information available from North Carolina’s Department of Environmental Quality and the results of the Smithfield Agreement. Second, it seeks to understand the decision facing Duke University by creating a visual framework to explore the options available to the university.

A. Externalized Costs of CAFO Hog Production

1. Smithfield Agreement Cost Estimates

By identifying specific environmental issues and calculating the costs required to address those same issues, the report that originated from the Smithfield Agreement creates the opportunity to put a dollar cost on the externalized costs created by lagoon sprayfields. These costs are borne primarily by neighbors of hog farms, excepting greenhouse gases such as methane or nitrous oxide, which are a global pollutant.

Technologies were evaluated using the unit cost of dollars per 1,000 lb Steady State Live Weight (SSLW) on a ten-year annualized basis.⁹⁰ SSLW is the metric that the North Carolina Department of Environmental Quality (NCDEQ) uses to determine the regulatory cap on animal operations.⁹¹ By data from the list of permitted facilities with information on the average hog weight of each type of operation, it is possible to estimate North Carolina’s current swine inventory. Multiplying this number by the cost of each technology yields a rough estimate for the cost to meet the targets set in the Smithfield Agreement.

The cheapest combination of liquid and solid technologies in 2010 was the third generation TerraBlue system (\$132.24/1,000lb-SSLW) in combination with the SuperSoils composting system (\$83.27/1,000lb-SSLW).⁹² Using these estimates, a total cost of \$215.51/1,000lb-SSLW would translate to \$286 million of expenses to implement these technologies on all permitted swine farms in North Carolina (see table 3). Increasing the costs to the reported \$460/1,000lb-SSLW of the digester at the Loyd Ray Farms would increase this value to almost \$611 million.

Farm Type	Total Permitted Count (Head)	Average Weight (lbs)	SSLW (lbs)	Cost At \$215/1,000lb-SSLW
Swine - Boar/Stud	5,062	400	2,024,800	\$ 436,365
Swine - Farrow to Feeder	40,219	522	20,994,318	\$ 4,524,485
Swine - Farrow to Finish	9,813	1417	13,905,021	\$ 2,996,671
Swine - Farrow to Wean	894,482	433	387,310,706	\$ 83,469,330
Swine - Feeder to Finish	5,819,260	135	785,600,100	\$ 169,304,678
Swine - Gilts	17,246	150	2,586,900	\$ 557,503
Swine - Other	19,870	200	3,974,000	\$ 856,437
Swine - Wean to Feeder	2,418,277	30	72,548,310	\$ 15,634,886
Swine - Wean to Finish	487,440	80	38,995,200	\$ 8,403,856
Total	9,711,669		1,327,939,355	\$ 286,184,210

Table 3: Annual costs of applying ESTs to Farms in NC spread over 10 years

This is likely an overestimation of the actual cost if these technologies were to be implemented. As these systems are deployed and refined, costs would likely decrease. That is evident from the difference in price between the second and third generation Supersoils liquid treatment, which dropped from \$322/1,000lb-SSLW to \$132/1,000lb-SSLW between 2007 and 2010.⁹³ On the other hand, this assumption ignores the challenges of scaling these technologies up to meet the current inventory of 9.7 million hogs. Still, this is a valuable ball-park estimate of how much it would cost hog producers in North Carolina to fully internalize the cost of their environmental impact.

2. Externalized Costs of Nutrient Cycling

A suitable method to dispose of and pay for the disposal of the solid byproducts of anaerobic digestion is a large and unresolved question facing the biogas industry. Because of their concentrations, nitrogen and phosphorous contained in manure are currently treated as a waste that has to be disposed of, but both elements are essential for plant growth. Too much nitrogen creates soil toxicity detrimental to plants; while phosphorus is less damaging to crops, amounts in excess of what crops can uptake runoff to streams where it causes eutrophication, damaging waterways and aquatic life.

ESTs as described in the Smithfield Agreement are capable of managing the externalities experienced by the communities surrounding swine farms, but while they are more effective at containing the nutrients included in swine waste, they do nothing to resolve the end fate of the byproducts of the digestate. Creating a soil amendment as a byproduct of an EST does not also create a local market where it might be responsibly land-applied. Solids left over from anaerobic digestion accumulate, and the liquid waste often contains more nutrients than can be applied on land near farms.⁹⁴

The EPA performed an economic analysis of the costs of applying their nutrient management rules to CAFOs and found that costs increase depending on the Willingness to Accept Manure (WTAM)

of nearby farms; transportation is the largest component of land application costs, and if fewer farms are willing to accept manure as a fertilizer, then the swine farms must transport the manure farther. Percentage changes in costs are largest for large farms (defined as more than 1,000 animal units) and can increase costs by 1-2%.⁹⁵

3. Quantity of Imported Nutrients

The quantity of nutrients contained in manure produced by hogs in North Carolina is an unresolved question that must be answered to address issues of sustainability created by CAFO production of hogs. Grain fed to animals contains nitrogen and phosphorous, soil nutrients that are absorbed by plants. When crops transported away from the soils they are grown in, those nutrients must be replaced with fertilizers. When consumed by animals, some of the nutrients are absorbed, but significant quantities are excreted as manure. Constantly importing feed without returning manure to cropland creates an imbalance in nutrients that will eventually need to be addressed.

In 2016, hogs in North Carolina consumed 5,038,800 tons of animal feed. Corn makes up 62% of the mass of this animal feed, yielding a corn consumption of 3,129,095 tons.⁹⁶ This is compared to the 620,000 tons of silage corn North Carolina produced in 2016⁹⁷. Even this is likely an overstatement of the corn available for hog-feed, as North Carolina also contains poultry farms that create a demand for silage corn.

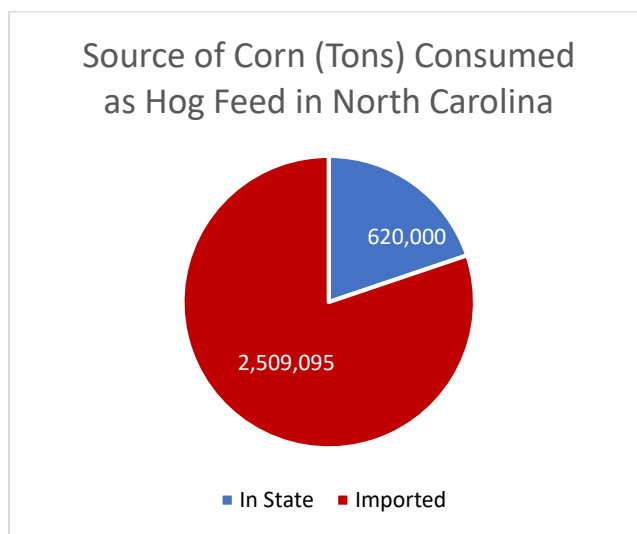


Figure 3: A comparison of the source of corn used to produce hog feed in North Carolina. Most of the corn originates out of state.

The Smithfield Agreement reports include a useful anecdote to understand the scale of the nutrient imbalance created by swine CAFOs. One of the candidate technologies used nitrogen and phosphorus from swine waste instead of artificial fertilizers to grow greenhouse tomatoes. This provided a natural way to recycle these nutrients, but the quantity of tomatoes that would be needed to absorb the available inputs created problems of its own.

The constructed greenhouse used 5% of the effluent from its 4,000 sows (0.04% of North Carolina's hog population) to provide nutrients and irrigation tomatoes grown in a 28,000 ft² greenhouse. Using the entire volume of effluent would have cost \$12 million and required a 560,000 ft²

greenhouse. At the time, the production from the greenhouse was estimated to account for 10% of North Carolina’s tomato consumption; a greenhouse twenty times that size would reduce the price for all greenhouse-tomato growers in North Carolina, destabilizing the market.⁹⁸ The state’s production would almost triple, and the resulting massive greenhouse would be responsible for 69% of the resulting market. This technology was deemed economically infeasible.

B. Decision Space

The analysis in this section focuses on two separate decisions facing Duke University. One is to determine the appropriate level of commitment to the CHP plant; the other is the university’s commitment to renewable biogas. These are not binary decisions; they can be seen as a continuum ranging from “no commitment” to “fully invested.”

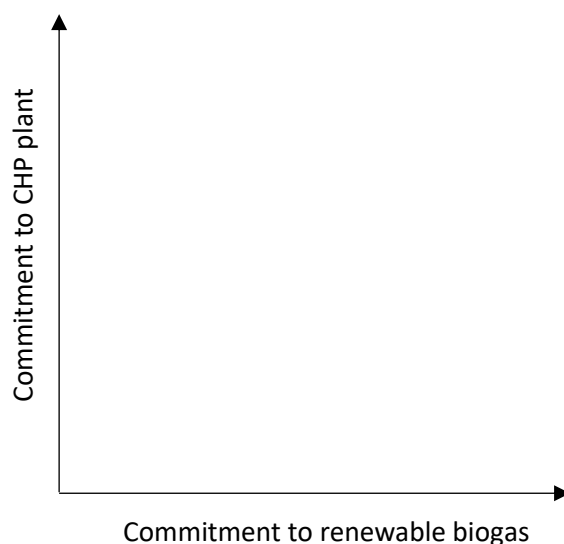


Figure 4: Decision space for Duke University considered in analysis

This analysis recognizes the SCSC’s recommendation of linking the CHP plant with biogas availability as a legitimate option with many advantages, but also explores how Duke University might advance its own interests by considering other regions of the decision space. Analysis focuses on five locations of this decision space: no commitment to either, a commitment to the CHP plant with no commitment to renewable biogas, a commitment to renewable biogas absent a commitment to the CHP plant, a commitment to the CHP contingent on the availability of biogas, and a full commitment to both. The last region requires reframing the conflict on campus, which will be considered in the next section.

1. No commitment to CHP, no commitment to biogas

This position occupies the bottom left corner of the decision space and represents a return to the status quo of two years ago. The University will continue to burn natural gas at its boilers and will need to expand its steam plants to meet new demand on campus. Duke University will continue to purchase electricity from Duke Energy at the carbon intensity of Duke Energy’s regional grid mix. Given the cancellation of Duke Energy’s planned nuclear power plants, Duke University will need to find new sources of emission reductions or carbon offsets to make up for the absence of new, low-emission nuclear electricity to meet its CAP.

2. Full commitment to CHP plant, no commitment to biogas

This position occupies the top left corner of the decision space and represents the Board of Trustees' original plan for procuring the necessary energy infrastructure to operate a modern research university. The university will use the carbon accounting proposed by Nicholas School Faculty and accepted by the SCSC to claim a 3% reduction in campus emissions. Purchasing steam from the plant will create between one to two million dollars of savings per year. A CHP plant will also remove the need to install additional steam boilers to meet predicted growth in heating needs. Even using the strictest carbon accounting principles as recommended by Nicholas School faculty, there will be moderate reductions in Duke University's calculated emissions, but the university will still need to find new emission reductions and offsets to meet its CAP.

3. No commitment to CHP, full commitment to biogas

This position occupies the bottom right corner of the decision space and, as of April 6, represents the university's current position. Duke University already purchases some natural gas to power its steam generators. Absent the savings created by the proposed CHP plant, this option will be more expensive, but avoids putting the university in the position of building a new fossil-fuel-powered plant on its campus.

This option increases the university's heating costs and would require allocating funds that do not currently exist to purchase a product that similarly does not yet exist. While implementing this proposal, the university will continue to purchase electricity from Duke Energy's grid, which is generated from a mixture of coal, natural gas, nuclear and renewable fuels. By pursuing this option, the university's carbon emissions will remain the same; the combustion of renewable biogas generates an equal amount of CO₂ as does the combustion of natural gas. However, the university will be able to claim offsets that are created when methane produced by the agricultural sector that would otherwise be released to the atmosphere is destroyed.

By pursuing this approach, the university will clearly signal its intention to move away from fossil fuels. This proposal does not address the fact that the university's electricity consumption will continue to come from Duke Energy's generating fleet, which still heavily relies on coal and natural gas. As a result, the university will need to identify new sources of emission reductions and offsets

4. Commitment to CHP, commitment to biogas

This position is a compromise between conflicting voices on campus – those advocating for a fossil-free future and those trying to provide the university with the energy services it demands. Linking the commitments to the CHP plant and Biogas restricts the decision space to the curve I have titled "Curve of coupling" in the graph below. This position hinges on unknown factors, so the university cannot possibly fully commit to both options without knowing how the biogas market will develop. To visualize this uncertainty, I have added the "curve of compromise." The location of intersection is lower on both axes than if each is made independently, illustrating the conditional nature of the commitments.

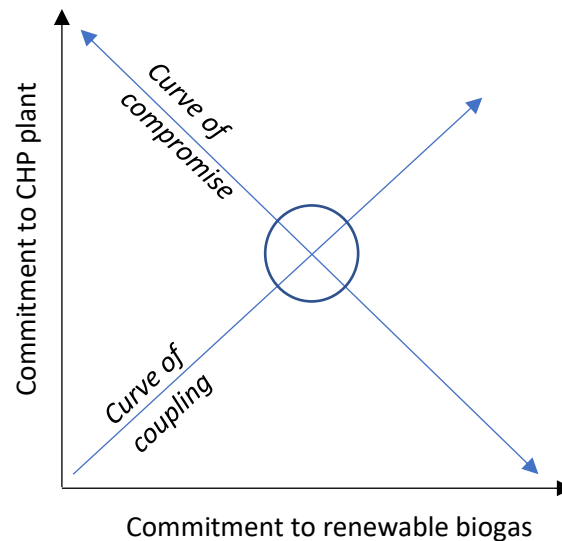


Figure 5: The compromise suggested by the subcommittee to the CSC exists at the intersection of two curves

Under this scenario, the University will continue to purchase electricity and natural gas from Duke Energy until it becomes apparent that it can meet its procurement goals. If that day comes, it can seek approval for the CHP plant and begin construction. Once operational, the savings from the CHP plant could be used to purchase the renewable biogas. If the university can power the CHP entirely with renewable biogas, it would easily meet its CAP goals.

C. Reframing the conflict within Duke University

Accessing the top right corner of the decision space requires reframing the conflict within Duke University. The apparent conflict surrounding the proposed CHP plant masks a large overlap of interests between internal university stakeholders. There is no debate about whether the university should continue to aspire to meet its CAP goals, but rather of how. The proposal sparked a clash between what I am labeling as pragmatic and idealistic voices on campus.

Duke University's diversity is a strength; the well-being of the university relies on the existence of multiple viewpoints. Energy services are vital to the university's 53,000 employees and students; continued availability of electricity and heat is non-negotiable. Employment, education, healthcare and research all require reliable sources of energy. To continue to exercise environmental leadership, Duke University must respond to both pragmatic and idealistic concerns. The campus requires energy to operate; pragmatists on campus must make sure that the university has access to the best options available. At the same time, the university is committed to acting on climate change. Idealistic voices that push the university to consider larger questions of sustainability are every bit as essential for ensuring the continuing leadership of Duke University.

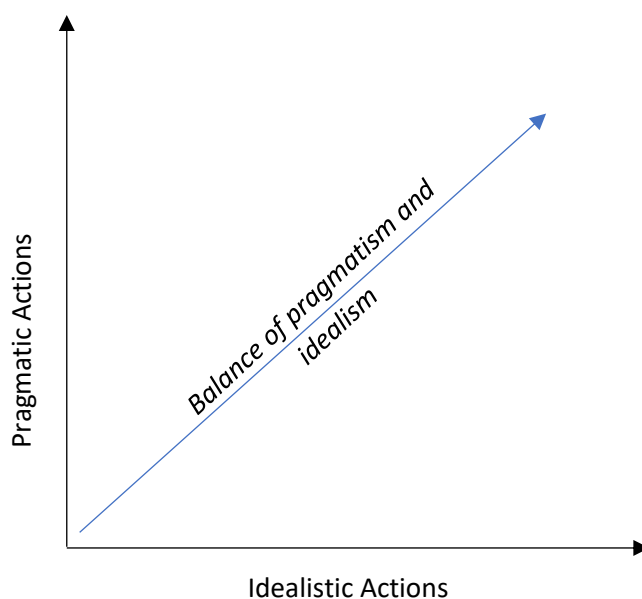


Figure 6: Changing the axes to reflect pragmatic actions and idealistic actions rather than positions on the proposed CHP and renewable allows the University more freedom to pursue its interests.

Pragmatists and idealists must coexist on campus, but linking their actions limits their strengths. Asking the pragmatic voices to include unknown variables such as the biogas market in their plans limits their ability to effectively make the decisions that sustain the university's operations. At the same time, linking idealistic goals to the university's pragmatic voices limits the idealists' ability to advocate for truly sustainable solutions that can consider the implications of energy decisions on a longer timeframe.

Reframing the conflict as a search for balance between pragmatic actions and idealistic actions allows the university to fully consider the strengths of both positions. The chief benefit of this decoupling is that it removes the limiting "curve of compromise." Recognizing that the university can take independent pragmatic and idealistic actions creates a new line which I have (unoriginally) titled "balance of pragmatism and ideals" (see figure 6). Acting along this line allows the university the benefits of both pragmatic and idealistic decision making. By separating these two voices, the university can fully commit to both actions.

V. Discussion

The following section raises three concerns Duke University must consider as it decides how it will pursue biogas in the near future. First, Duke University can only act decisively if it reconciles differing idealistic and pragmatic voices on campus. Second, the university must determine if the source of its renewable biogas is itself sustainable. Lastly, the university must consider how a biogas market might develop absent its involvement, and what improvements to the market Duke University's involvement might bring.

A. Reconciling conflict in Duke University

Without resolving the conflict between idealistic and pragmatic voices on campus, the University cannot make decisions concerning environmental issues without generating controversy. As

demonstrated by the by the university's pursuit of the CHP plant, conflict between these voices can derail the University's plans, hindering its ability to act quickly to change how it produces and consumes energy. In order to act more effectively to reach its climate neutrality goals, Duke University must create new channels of communication to build trust, understanding and exchange of ideas between pragmatists and idealists on campus. Future decisions that are made with transparency and inputs from both perspectives will be better received by the entire Duke University community.

1. The Pragmatic Perspective

a) Benefits

A pragmatic point of view argues for building the proposed CHP plant regardless of the availability of biogas. It recognizes that the electricity Duke University purchases from Duke Energy comes from the existing mix of nuclear, coal, natural gas and renewables and that the emissions from the CHP plant are comparable to if not lower than the emissions from purchased electricity. The university will benefit from the savings created by a plant that is more efficient than its existing heating sources and will avoid anticipated additions to its current steam generating fleet. There is also no better option in the short term; waiting for technology to develop might not bring benefits in a short time-span, and there is no guarantee these technologies will be available or cost-competitive.

b) Challenges

It is important to recognize that the pragmatic approach may not be sufficient to meet Duke University's CAP goals, and that by burning natural gas, is contributing to the rapid changing of earth's environment. A visible sign of the university's long-term commitment to fossil-fuels such as a natural gas plant will tarnish the Duke's reputation as a leader of sustainability, unless it is balanced by highly visible actions that shift the university away from fossil fuels. Pragmatic voices are better at responding to the immediate needs of the university, but because of this, they are less effective at envisioning the carbon-neutral future of the university, which may look significantly different from Duke University today.

2. The Idealistic Insights

a) Benefits

The idealistic viewpoint offers the University valuable perspectives that create opportunities for Duke University to become a leader in addressing climate change. It recognizes that long-term commitments to fossil-fuels undermine the university's ability to influence the energy industry to shift away from those same fossil fuels and proposes innovative solutions to the challenges facing the university. Idealistic voices can push the university to surpass its own goals and initiate large-scale changes in existing systems.

Idealistic perspectives also challenge the university to question assumptions of the pragmatists that might commit the university to long-term reliance on fossil fuels. An example of this is the letter from faculty members Drew Shindell and Prasad Kasibhatla urging a different accounting for the carbon offsets. Between May of 2016 and 2017, the stated CO₂ equivalent reductions of the CHP plant decreased from 25% to 3%. It is unlikely that the university would have adopted this more stringent accounting were it not for idealistic voices on campus making themselves heard. By contesting the university's initial carbon accounting, their letter obligated Duke University to more carefully consider what actions can enable it to reach true carbon neutrality.

b) Challenges

Idealistic proposals can be unrealistic and conflict with the present days needs of the university. For example, as analyzed by facilities Management, no existing renewable technology can meet the university's current demand at a price competitive with the university's current utility costs. Allowing the idealistic perspective to determine all campus decisions is incompatible with the university's current demand for energy and budgetary constraints. This disconnect is a necessary component of the university's progress towards carbon neutrality; achieving its goals requires embracing idealistic suggestions and criticisms even as they challenge current assumptions about energy consumption and how much money the university needs to spend to achieve climate neutrality.

The idealistic view is important but can be prone to overly optimistic prediction. Furthermore, it cannot provide for the day-to-day operation of the university on which 53,000 people depend. It is better suited for envisioning what Duke University's future energy consumption might look like than it is at providing power in the short term.

3. A Healthy Balance

Duke University must include both pragmatic and idealistic voices in its decision-making process but should allow each to work independently. The proposed CHP plant is an example of the best decision-making strategy pragmatists can offer Duke University. This report accepts the SCSC's assessment that no alternative energy choices can provide a similar level of energy services at a comparable price. This report also assumes that natural gas prices will remain low and that building the CHP would generate \$1-2 million dollars in savings per year. It ensures energy reliability for the campus, creates millions of dollars in savings and creates reduces the University's carbon footprint by 3%.

Despite the apparent benefits of the proposed CHP plant, the university community rejected it as originally proposed because while the proposal ostensibly addressed the university's energy consumption, it lacked a long-term vision of how the university would achieve climate neutrality while continuing to burn fossil fuels. Providing such a vision falls on the shoulders of idealists on campus; because they were not included in the decision-making process, their interests and positions were not reflected in the proposal. As a result, the opposition from Duke University community members for whom idealistic concerns are paramount disrupted the university's plans.

As the University chooses how it will proceed in its pursuit of biogas, it must avoid repeating the mistake it made when proposing the CHP plant. Whatever its ultimate decision, the degree to which the community accepts the university's plans will be determined by the transparency of the decision-making process and the inclusion of concerns from both idealists and pragmatists.

B. The Water-Energy-Food Nexus

The Water-Energy-Food Nexus refers to the inextricable linkage between all three systems. Understanding interactions that exist at the nexus is crucial to building a sustainable future that guarantees food security, clean water, and energy access to a growing population. It would be imprudent for Duke University to consider using swine biogas for energy without considering the implications of that decision on food production and water quality.

Hog production in North Carolina provides a perfect example of the Water-Energy-Food Nexus. The farms affect both water demand and water quality; large volumes of water are required to flush the barns, and seepage and run-off from lagoons and sprayfields affects local water quality. Pork production

also competes with energy production for feedstock; ethanol is made the same corn as animal feed. This has contributed to the rising feed prices that have challenged the economic viability of CAFO hog farming in North Carolina. Additionally, transporting grain from the Midwest to the east coast requires a substantial amount of energy that is accompanied by its own greenhouse gas emissions. In the words of Todd See from NCSU, CAFO swine production is “a system based on cheap energy and cheap feed - a different scenario than exists today.”⁹⁹

Duke University exposes itself to unnecessary risk if it commits to powering a CHP plant with biogas before understanding the sustainability of pork production in North Carolina. The existence of biogas in North Carolina depends on the continuation of CAFO production of pork. Growing awareness of the damages caused by improper nutrient management intrinsic to CAFOs provides sufficient reason to question their continued viability. Smithfield has demonstrated that the current system of pork production in North Carolina is profitable; no one has demonstrated that it is sustainable.

C. Biogas Market Forecast

A functioning biogas market in North Carolina has been an aspirational goal since 2007’s REPS. Past barriers and complications notwithstanding, there is reason to believe that the market for biogas will develop rapidly before 2025 even without market demand provided by Duke University.

1. Existing Barriers to EST Implementation

The primary barrier to the implementation of ESTs such as anaerobic digesters has been, and will remain, price. The costs of installing and operating digesters must also be compared to its competition, i.e. waste lagoons. Even with the saleable byproducts including carbon offsets, soil amendments and renewable biogas, digesters installed on swine farms incur large costs that are not recoverable in a time frame that would makes them attractive investments for independent farmers.

This barrier is one that is specific to North Carolina. While hog farms with technology better suited to addressing the environmental impacts of manure may be profitable elsewhere, those farms do not compete against farms that are allowed to operate with permitted open-lagoons and sprayfields. Open lagoons will continue to be the cheapest technology available to farmers in North Carolina. Without effective policies mandating the usage of ESTs, Smithfield will continue allow contract farms to use open lagoons. Independent farmers will be unable and unwilling to shoulder the costs and additional labor required to install and operate ESTs on their farms.

2. Probable Forecast of Market Development

It is the author’s opinion that Smithfield Foods will successfully install anaerobic digesters or a similar technology on over 100 of their company owned farms in North Carolina by 2025 regardless of Duke University’s decision to purchase renewable biogas.

The primary justification for this assumption comes from Smithfield’s statement to this effect included in its 2016 sustainability report. Smithfield has made a public commitment to installing digesters to reduce its companies footprint; its word is backed by pressure from Walmart. Its success implementing emission-reducing changes in grain production is an example of how they are willing to change practices on individual farms. Anaerobic digestion is a more expensive and complicated shift, but it is technically feasible as demonstrated by the Smithfield Agreement and the digester on the Loyd Ray Farms. By 2025, Smithfield will have installed anaerobic digesters to manage the waste from 167 of their company-owned farms.

The assumption that these digesters will be built in North Carolina is backed by policy, precedent and pigs. First, North Carolina is unique in its inclusion of swine biogas in its REPS. If Smithfield can produce renewable biogas, utilities that operate in North Carolina will be obligated to purchase it. This is in contrast to other states, where biogas would have to compete against natural gas prices. Second, the outcome of the lawsuit against PSF in Missouri indicates that Smithfield is willing to install new technology to settle costly battles. Lastly, anaerobic digestion of swine waste requires large volumes of manure to produce meaningful quantities of biogas. The density of farming operations in North Carolina provides the necessary concentration of swine waste to bring digesters closer to becoming a profitable enterprise.

VI. Recommendations

The key to successfully committing the university to renewable biogas is to ensure that the university's plans effectively address pragmatic and idealistic concerns. While ambitious, pursuing biogas is a pragmatic choice for reaching carbon neutrality; it relies on existing technology and makes use of a nearby resource. In order to convince idealists that biogas is the best pathway to meeting its CAP goals, Duke University must demonstrate its commitment to ensuring the long-term sustainability of its proposed biogas plans. At the same time, the University should actively explore other energy conservation measures that will help reduce its own emissions.

Duke University's interest in renewable biogas from hog farms in North Carolina originates from two sources: an abstract commitment to environmental leadership, and a concrete commitment to climate neutrality by 2024. Recommendations in this section are the author's best judgment of what the university must do to fully realize each of those commitments. Specific actions the university needs to take are grouped into three categories: Research, reassessments, and proposed solutions.

A. Research

Duke University's strength as compared to Duke Energy and Smithfield Foods lies in its ability to conduct unbiased, interdisciplinary research. As a result, it should prioritize conducting research that leads to the identification of a viable, sustainable long-term solution to swine waste in North Carolina. Conducting that research should be the university's priority. The university can conduct that research while also purchasing renewable biogas, but it must not conflate being an early purchaser of biogas with solving North Carolina's growing swine waste problem. Fortunately, Duke University has a wealth of resources perfectly suited to researching these topics. These include:

- The Duke University Energy Initiative
- The Nicholas School of the Environment
- The Sanford School's World Food Policy Center
- The Fuqua School of Business
- The Pratt School of Engineering
- The Duke School of Law
- The Duke Carbon Offsets Initiative
- Bass Connections
- Duke University Facilities Management
- The Campus Sustainability Committee
- The Nicholas Institute.

1. Necessary Research Topics

Duke University's goal must be a biogas market that fully addresses the negative externalities of swine farms in North Carolina. Such a market will must overcome the barriers that have stopped large-scale implementation of ESTs. If anaerobic digesters are only used on a relatively small number of Smithfield-owned farms, then the majority of the environmental impacts caused by swine waste in eastern North Carolina will continue unabated. This will help Duke University achieve its stated climate neutrality goals, but, because of the lingering environmental justice and nutrient cycling issues, might damage the university's reputation by linking it to that of Smithfield Foods.

To address its interest in being an environmental leader, Duke University must research strategies that will enable decision makers in regulatory agencies, utilities and elected officials throughout North Carolina to fully address issues of nutrient cycling and environmental justice. This is a more important role than acting as source of demand for an unsustainable product.

a) Contract Farms and Environmental Justice

Issues of environmental justice arise from the widespread use of the lagoon/sprayfield system of hog farming. Even if Smithfield opts to install all new digesters in North Carolina, their 167 farms would amount to less than 10% of permitted swine operations in North Carolina. Smithfield has not committed to installing any digesters on contract farms; adequately addressing the environmental justice issues will require changing waste management practices of these farms as well as Smithfield-owned farms. Absent this step, anyone involved in the creation of a biogas market risks being tied to an industry that exploits the population of eastern North Carolina in the name of sustainability.

Duke University should focus research on ensuring that farmers who want to upgrade their existing waste management systems can do so. As demonstrated by the Smithfield Agreement and Duke University's own experience with the Loyd Ray Farms digester, the primary barriers to this are cost and labor (i.e., the work needed to install, operate and maintain a digester). Duke University should encourage its individual schools and internal offices to facilitate and conduct research specifically aimed at removing these barriers. Potential research topics are listed in the table below.

School/Office	Action
Fuqua School of Business	- Financial mechanisms to allow farmers to pay partner to install a shared centralized digester
Nicholas School of the Environment	- Spatial modeling of swine farm density to identify most promising locations for centralized digesters
Pratt School of Engineering	- Creation of saleable materials from solid byproducts of anaerobic digestion
Duke University School of Law	- Identify new permitting requirements that would require implementation of ESTs on farms - Assistance in contract negotiations for to help farmers shoulder costs of swine waste

Table 4: Possible research contributions to ensure 100% market penetration from Duke University schools

b) Nutrient Cycling

Identifying beneficial uses for the nutrients contained in manure is a tremendous challenge for the sustainability of hog production in North Carolina. These nutrients accumulate in sludge or are precipitated out of liquid, but there is no existing cost-effective infrastructure to return these byproducts to the soils from which they originate. “Solving” energy sustainability by making unsustainable decisions concerning the food and water systems is not a meaningful use of the word “sustainable.” To avoid making this mistake, Duke University should pursue research and advocate for policy solutions that will address nutrient cycling in hog production. Potential research topics and actions are listed in the table below.

School/Office	Action
Nicholas School of the Environment	<ul style="list-style-type: none"> - Modeling to quantify available nutrients from swine waste - GIS analysis of location and quantity of farmland needed to land-apply available nutrients
Nicholas Institute	<ul style="list-style-type: none"> - Cost/benefit analysis of policies mandating complete nutrient cycling for byproducts of pork production

Table 5: Possible research contributions from Duke University institutions to ensure proper nutrient cycling of hog production

c) Carbon Footprint of North Carolina’s Hog Industry

CAFO pork production in North Carolina creates greenhouse gas emissions from a variety of sources in addition to the methane released from lagoons. Every step of production, from growing feed grain to shipping the final, packaged product to stores around the country requires energy inputs that are for the most part derived from fossil fuels. Examples of other sources of emission include:

- Electricity required to turn atmospheric nitrogen into fertilizer for crops
- Fuel for tractors that harvest grain fed to animals
- Fuel for rail-transport of animal feed
- Fuel to transport of hogs between farms as they grow and require different facilities
- Fuel to ship packaged pork to distant locations

In the short term, CAFO production will continue to be North Carolina’s primary method of hog production, but that does not mean it is the an environmentally sound method, even if biogas capture is implemented on all farms. The CAFO system of hog production is the result of a combination of drivers that include grain subsidies and political regulation (or the lack thereof that allows externalized costs). It is unclear if efficiencies inherent to CAFO production would have led to the same outcome domination of farming styles in North Carolina if corn-feed prices had not been kept low by federal subsidies, for example.¹⁰⁰ On the other hand, regenerative agricultural practices that use livestock to effectively cycle nutrients back to the soil is a promising strategy for combatting climate change by sequestering carbon in healthy soil.

A life cycle analysis of hog production in North Carolina that compares CAFO production with smaller, pasture-raised hog farming operations would be an invaluable tool for decision in North Carolina. This analysis should compare CAFO hog production with and without methane capture to

pasture raised operations that return carbon to the soil by using manure as fertilizer. Duke University's Nicholas School of the Environment has the in-house expertise required to perform this analysis; this report could also strengthen ties to other universities with knowledge and interest in the field such as NCSU's Animal and Poultry Waste Management Center and Eastern Carolina University.

B. Reassessing Duke's Climate Action Plan

Duke's involvement in the wicked problem of swine waste originates from its desire to become carbon neutral by 2024. Creating offsets by burning agricultural methane for electricity is an appealing way to meet this commitment, but given the complications and lingering questions about the actual sustainability of this plan, Duke University needs to have alternate strategies available to meet this goal.

As written, the university's CAP calls for reductions in emissions coupled with high quality, local carbon offsets. Reduction in emissions can come from technical and behavioral changes in the university's operations. To date, the majority of Duke University's progress in reducing its footprint has come from improvements in building efficiency and changes in on-campus fuel consumption such as replacing coal with natural gas as fuel for boilers. The university and its staff should be proud of these changes and the resulting reductions in emissions they have created.

At the same time, Duke University must do more to incentivize the behavioral changes needed for a climate neutral future and implement new strategies to further reduce its emissions. At times, it appears as if the university is contradicting its own stated goals. For example, investments in new parking on campus seem inconsistent and incompatible with the university's stated goal of reducing the percentage of faculty, students and staff who commute in a single-occupant vehicle. Along the same lines, the tremendous improvements in building efficiency have been offset by growth in the university's physical footprint that surpasses the rate of growth of its population.

At the time it was signed, the Climate Action Plan was a radical document committing Duke University to dramatic changes. As demonstrated by the outpouring of opinions regarding the proposed CHP, the university has broad support from in its mission to achieve climate neutrality. It need not be afraid to ask students, faculty and staff how they are willing to support its transition away from fossil fuels.

Ideas for how the university might reassess its approach to achieving climate neutrality largely fall outside of the scope of this master's project. However, it is apparent that existing efforts to disincentivize behavior such as driving to campus without providing viable alternatives has not proven effective. Rather than continuing to create barriers to behaviors, the university should investigate strategies to incentivize more sustainable options. As possible discussion starters, I offer three options for the university to continue to reduce its emissions.

Issue	Description	Suggestion
- Building Energy	- Growth of physical space on campus means building energy emissions remain constant despite large gains in energy-efficiency	- Creation of Space Optimization and Efficiency Office to make sure all existing and planned space is used to full potential

<ul style="list-style-type: none"> - Single Vehicle Commuting 	<ul style="list-style-type: none"> - Duke employee Drive Alone rates remain high. 	<ul style="list-style-type: none"> - Financial incentives such as reduced tuition for students who bike or walk to school - Create a more bike-friendly campus (e.g. lanes, ramp access) - Partner with local bike store and fund incentives (e.g. one-time cost share for bikes) to increase bike ownership - Partnership with Durham Bike Co-op to recycle used bikes back into the community
<ul style="list-style-type: none"> - Faculty flights to conferences 	<ul style="list-style-type: none"> - Faculty continue to fly to conferences rather than driving or telecommuting 	<ul style="list-style-type: none"> - Reimburse faculty who attend conferences by video for a fractional price of avoided cost of tickets

Table 6: Possible energy conservation incentivizes Duke should consider to reduce its emissions

VII. Conclusions and Solutions

There is no “correct” solution to wicked problems such as swine waste in North Carolina, just like there is no “correct” solution to climate change. Duke University acted appropriately when it paused construction of the proposed CHP plant to ensure that it could make the best possible decision before committing itself to a decision with long lasting implications. Duke University is aspiring to turn a currently wasted and environmentally deleterious byproduct of pork production into a viable energy source.

Duke University’s goals are complicated by the fact that what, for the University, is a resource, is a blight for the communities who live adjacent to the swine farms. Duke University must be honest about its ability to address all of the issues of swine waste in the short-term, but offer a viable, long-term vision for how the issue of hog waste can be solved for eastern North Carolina. Duke University can accomplish that by being fully transparent about its goals and interests while also actively researching technological, environmental and political solutions to address the mismanagement of waste lagoons. One possible option Duke University should propose is presented below.

A. A Solution North Carolina Deserves

Swine-waste in eastern North Carolina is a wicked problem that touches on energy, climate change, food production, water quality and environmental justice. A truly sustainable solution must address each of these topics, and have the following characteristics:

- It must be scalable for *all* waste lagoons in the state
- It must contain atmospheric emissions of methane and nitrogen oxide

- It must contain and treat the solid and liquid waste streams generated by hogs kept in CAFOs to the standards of ESTs
- It must provide a method to return nutrients to soils used to produce the feed grains used for hog production
- It must be politically feasible and benefit the economy of North Carolina

Identifying and implementing such a solution would create a revolution in food and energy production that would originate from North Carolina, and Duke University is in an ideal position to do so.

There are many similarities between coal ash and the solid sludge that is a byproduct of anaerobic digestion. Both are regulated under North Carolina Administrative Code Title 15A, Subchapter 2T: *Waste Not Discharged to Surface Waters*. If methane is captured and burned as a source of electricity for Duke Energy, then the solid sludge left in digesters becomes a byproduct of Duke Energy's electricity generation, just like coal ash. Duke Energy accepts that it is responsible for the responsible disposal of coal ash, and its customers must pay those costs. By the same logic, once Duke Energy sells electricity derived from swine waste, it will be responsible for responsible for the disposal of the solid byproducts required to make energy.

Unlike coal ash, the sludge byproduct of biogas production contains valuable nutrients that are necessary for the agricultural industry, and the Smithfield Agreement demonstrates that there is existing technology for turning that sludge into a safe and effective soil amendment. Duke Energy's service territory includes regions such as Ohio that grow corn that is used as animal feed. Furthermore, as demonstrated with its most recent rate case in North Carolina, it is Duke Energy's prerogative to include the costs of the safe disposal of solid byproducts in its rate-base.

At the same time, distributed renewable energy generation such as wind and solar threatens Duke Energy's business model because once installed and fully amortized, provide free electricity to the electric grid. The creation of infrastructure and operational costs to return soil amendments derived from anaerobic digesters would be a used and useful cost that could become a key component of Duke Energy's business model in the future. By making themselves a key player in a revolution towards more sustainable agriculture, Duke Energy could bolster its reputation as an environmentally conscious energy utility. Furthermore, creating a new revenue stream from byproducts of biogas might incentivize Duke Energy to purchase more biogas, further reducing the carbon intensity of its grid.

Smithfield Foods finds itself in a precarious position as well and would benefit from its participation in such an ambitious project. The outcome of the lawsuits against Murphy Brown is uncertain at the time of this report, but what is certain is that they will be facing increasing scrutiny as a result of their operations. *Rolling Stone* published an unflattering article titled "*Why is China Treating North Carolina Like the Developing World?*" on March 19, 2018, and included critical comments from Senator Cory Booker, who plays a role in creating the federal Farm Bill.¹⁰¹ Whether because of lawsuits, gathering political pressure, or lagoons that will eventually overflow, Smithfield will need to address the externalities its hog farming creates at some point in the future.

Duke University should support the biogas industry by proposing a framework for Duke Energy to transport soil amendments created from the byproducts of biogas production back to grain producing areas from where Smithfield sources its animal feed.

The phrase "*knowledge in the service of society*" as a core tenet of Duke University's strategic plan. There is no topic that captures more issues of local and global significance than swine waste in North Carolina. By focusing the university's research capabilities on this topic, Duke University can light the way towards sustainable energy and agricultural systems at a time when such leadership is desperately needed.

VIII. Acknowledgments

This project would not have been possible without the support and guidance of many mentors over the past year. First and foremost, I would like to thank Michelle Nowlin, my adviser. Her knowledge and instruction were instrumental in my understanding of the topic, and her support and timely reminders about deadlines I missed along the way were critical to the completion of this report. Tatjana Vujic provided an invaluable perspective and useful prods to keep my work relevant. Ryke Longest's encyclopedic knowledge of swine waste regulations gave me useful direction at the start of this project and an excuse to stay in touch after learning from him in the Environmental Law and Policy Clinic. I am also grateful to Mark Rice for his insights on the importance of nutrient cycling and his ability to track down anything having to do with the Smithfield Agreement. Lastly, I would like to thank Lou Addor who helped provide a framework in which I could assemble the jumble of information I accumulated in my head over the course of the past year.

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