A Look At Concentrated Animal Feeding Operations in North Carolina

The Problems with Animal Waste & A Framework to Solve Them

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I. Introduction

This paper offers a review of the problems and potential solutions regarding animal waste management. We begin by describing the status quo of intensive animal operations in North Carolina, with a focus on hog production. Throughout this paper we refer to such operations as Concentrated Animal Feeding Operations (CAFOs) for simplicity's sake, although we are not necessarily using the term as defined in the Clean Water Act. We offer an overview of the structure of CAFOs and where they are located both in the United States generally and specifically in North Carolina, and describe normal waste management practices. We then describe the drawbacks and benefits of producing meat using confined operations. After assessing current policies that regulate the industry and technology policies relating to the handling animal waste, we identify strategies for mitigating its impacts and describe practices for comparing such strategies. We conclude with a set of information-based recommendations for both consumers, in the form of ecolabels, and producers, in the form of a website about waste-to-energy technology.

II. The Current Status of CAFOs

In North Carolina, Concentrated Animal Feeding Operations (CAFOs) are used extensively for meat production.[1] Though the term Concentrated Animal Feeding Operation bears a technical definition under the Clean Water Act,[2] we use it here to refer generally to a production model that raises large numbers of animals in confinement where they are fed and watered until they are ready to be slaughtered.[3] Unlike traditional models of livestock husbandry, animals raised in CAFOs do not roam to forage and the feed is produced off-site.[4]

The CAFO model of production is used to produce beef, dairy, hogs, poultry, milk, and eggs. The majority of CAFOs in North Carolina produce either broiler chickens or hogs, as is shown in the following heatmaps.

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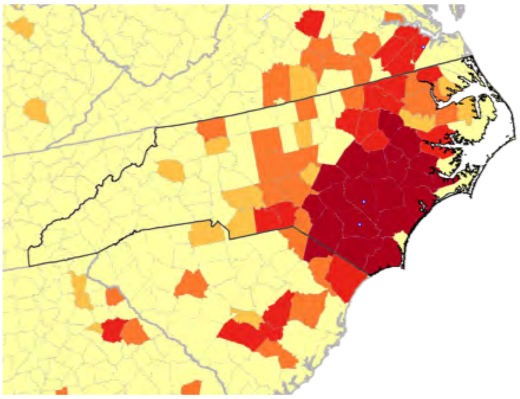
[1] Food & Water Watch (2015). Factory Farm Map. http://www.factoryfarmmap.org.

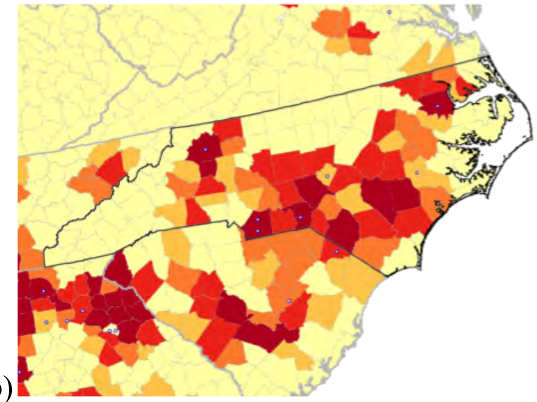
[2] Animal Feeding Operations are defined as operations where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period and where vegetation is not sustained in the confinement area during the normal growing season," 40 C.F.R § 122.23(b)(1). If an Animal Feeding Operation has 1,000 animal units it constitutes a "Large CAFO". 40 C.F.R § 122.23(b)(4). But even an Animal Feeding Operation with fewer animals may be a CAFO if it is "a significant contributor of pollutants to the waters of the United States." 40 C.F.R § 122.23(c).

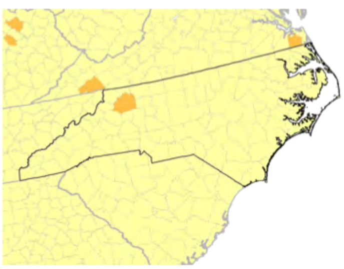
[3] Nowlin, M. B. (2012). Sustainable Production of Swine: Putting Lipstick on a Pig. *Vt. L. Rev.*, *37*, 1079.

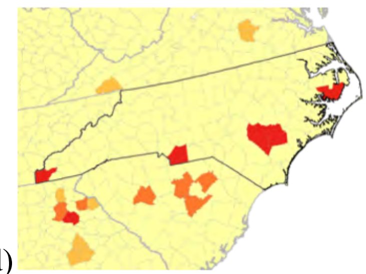
[4] Ibid.

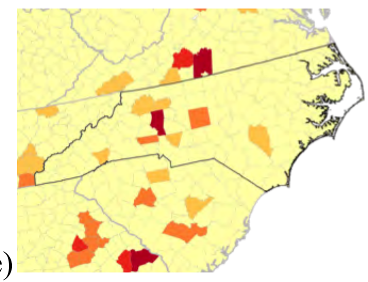
Heat Maps Showing Density of (a) Hog CAFOs, (b) Broiler CAFOs, (c) Cattle CAFOs, (d) Egg CAFOs, and (e) Dairy CAFOs in North Carolina as of 2012. Source: Food & Water Watch analysis of U.S. Department of Agriculture Census of Agriculture data.[5][6]

(a) 

(b) 

(c) 

(d) 

(e) 

Density	Map Color	All Livestock (Animal Units)	Dairy Cows	Beef Cattle on Feed	Hogs	Broiler Chickens Sold	Egg-Laying Hens
Extreme	Dark Red	More than 13,200	More than 4,200	More than 17,400	More than 48,500	More than 2.75 million	More than 1.25 million
Severe	Red	5,200 –13,200	2,100 –4,200	7,300 –17,400	19,000 –48,500	1 –2.75 million	750,000 —1.25 million
High	Orange	2,000 –5,199	1,200 –2,099	2,175 –7,299	9,500 –18,999	350,000 –999,999	500,000 –749,999
Moderate	Light Orange	Fewer than 2,000	Fewer than 1,200	Fewer than 2,175	Fewer than 9,500	Fewer than 350,000	Fewer than 500,000

[5] Food & Water Watch (2015). Factory Farm Map. http://www.factoryfarmmap.org.

[6] In this paper the term CAFO is used to refer to a model of livestock production, rather than the legal definition. Since maps produced by the EPA only include producers that are permitted as CAFOs (which differs by state, often requires a showing that the producer discharges into waters of the United States, and usually fails to account for poultry production), they would not reflect the production discussed in this paper. The Food & Water Watch report uses U.S.D.A. county data to locate producers with either >500 beef cattle on feed (opposed to pasture), >500 dairy cows, >1,000 hogs, annual sales of >500,000 broiler chickens, or >100,000 egg-laying hens. For further information on the methodology employed can be found at http://www.factoryfarmmap.org/data-and-methodology/.

None	Yellow		None	None	None	None	None	None

Though swine and poultry CAFOs differ in some respects, they share the defining feature of animal confinement. A typical swine CAFO has between 2 and 6 long metal buildings, each holding 800-1200 pigs.[7] The waste produced by the animals generates numerous air pollutants including ammonia and hydrogen sulfide that concentrate in the CAFO production barn.[8] For this reason, the barns must be ventilated so that the animals do not die.

Due to the number of animals raised in a concentrated location, CAFOs produce massive volumes of waste.[9] In traditional production models, animal waste is deposited throughout the environment as the livestock forage. However, in the CAFO model of production, the waste accumulates within the barn. In swine CAFOs, each pig remains in a space of about 8 square feet.[10] The floor of the swine barns is made of concrete with slats, allowing the urine and feces excreted by the hogs to fall into an underground storage pit below the barn. Depending on the design of the CAFO, the waste either remains in the pit for months before it is scraped out or is flushed out with water throughout the day.[11] In North Carolina, there has been a significant shift towards flush systems that remove the waste from barns more frequently.[12]

Once removed from the storage pit, the waste is transferred into an open-air retention pond or "lagoon" that stores millions of gallons of animal waste.[13] Waste is naturally teeming with bacteria. Engineers manipulate the pH, temperature, nutrients, and other variables in the lagoon to favor helpful bacteria, which anaerobically digest the waste. The liquid waste rises to the top and nutrient rich sludge forms at the bottom.[14] The sludge is periodically removed and applied to

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[7] Nowlin, M. B. (2012). Sustainable Production of Swine: Putting Lipstick on a Pig. *Vt. L. Rev.*, *37*, 1079.
[8] Barker, J. C. (1990). Swine Production Facility Manure Management: Underfloor Flush–Lagoon Treatment. *North Carolina State Cooperative Extension Service, Publication No. EPBAE*, 129-88.
[9] National Risk Management Research Laboratory (2004). Risk Management Evaluation for Concentrated Animal Feeding Operations. EPA/600R-04/042. https://nepis.epa.gov/Exe/ZyNET.exe/901V0100.txt?ZyActionD=ZyDocument&Client=EPA&Index=2000%20Thru%202005&Docs=&Query=%28undefined%29%20OR%20FNAME%3D%22901V0100.txt%22%20AND%20FNAME%3D%22901V0100.txt%22&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C00THRU05%5CTXT%5C00000011%5C901V0100.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=3#.
[10] Nowlin, M. B. (2012). Sustainable Production of Swine: Putting Lipstick on a Pig. *Vt. L. Rev.*, *37*, 1079.
[11] Ibid.
[12] Barker, J. C., Driggers, L. B., & Sneed, R. E. Design Criteria for Swine Waste Flushing Systems. *North Carolina State Cooperative Extension Service, Publication No. EPBAE*, 080-81.
[13] Ibid.
[14] Barker, J. C. (1990). Swine Production Facility Manure Management: Underfloor Flush–Lagoon Treatment. *North Carolina State Cooperative Extension Service, Publication No. EPBAE*, 129-88.

land.[15] The liquid waste is frequently applied as fertilizer to growing fields, known as spray-fields, via high-pressure sprayers.[16] The spray-fields grow crops such as hay and Bermuda grass in order to absorb the nutrients contained in the waste.[17] In North Carolina, over 2,227 swine operations are permitted to use this kind of waste management system.[18]

Source: Travis Dove, Bloomberg Businessweek.[19] Source: Donn Young Photography [20]

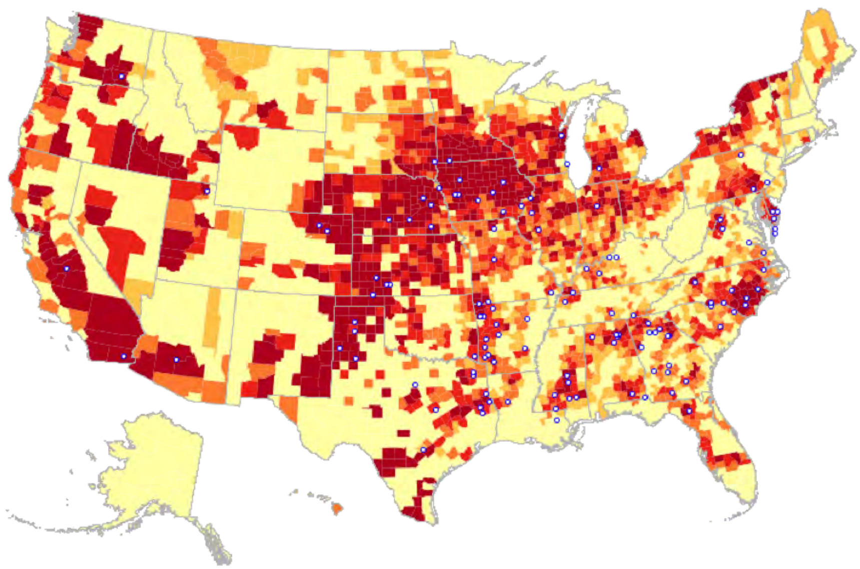
According to the most recent USDA Agriculture Census, the U.S. hog industry produced 66 million hogs and made $22.5 billion in sales during the 2012 fiscal year.[21] Over half of the nation's hogs were produced in just three states: Iowa, North Carolina, and Minnesota. The most productive counties are located in North Carolina. In 2012, Duplin County was the top ranked county in the nation for hog sales, with sales of $614 million. Sampson County came in at a close second, with $518 million. Together these two counties accounted for over 5% of total national

[15] Ibid.
[16] Nowlin, M. B. (2012). Sustainable Production of Swine: Putting Lipstick on a Pig. *Vt. L. Rev.*, *37*, 1079.
[17] Ibid.
[18] ND DEQ. (n.d.). NC DEQ: Animal Facility Map. Retrieved from https://deq.nc.gov/cafo-map (Containing a link to "List of Permitted Animal Facilities" excel spreadsheet); Though only 1,222 are considered to be Large CAFOS. See EPA. (2015, December 31). NPDES CAFO Permitting Status Report -- National Summary, End year 2015, completed. Retrieved from https://www.epa.gov/sites/production/files/2016-06/documents/tracksum_endyear2015.pdf.
[19] Drajem, M. (2015, August 20). The EPA Doesn't Know How to Deal With 300 Million Tons of Animal Poop. *Bloomberg Businessweek* (Duplin, NC). Available at https://www.bloomberg.com/news/articles/2015-08-20/the-epa-doesn-t-know-how-to-deal-with-300-million-tons-of-animal-poop.
[20] Nicole, W. (2013). CAFOs and Environmental Justice: The Case of North Carolina. *Environ Health Perspect* 121:A182-A189. http://dx.doi.org/10.1289/ehp.121-a182.
[21] USDA. (2014, June). USDA - NASS, Census of Agriculture - Publications - 2012 - Highlights - Hog and Pig Farming. Retrieved from https://www.agcensus.usda.gov/Publications/2012/Online_Resources/Highlights/Hog_and_Pig_Farming/.

sales.[22] Overall, North Carolina produced 9 million hogs, accounting for 13.6% of the nation's total hog production.[23]

North Carolina, however, is not unique in its use of CAFOs. Most of the livestock produced in the United States today comes from CAFOs.[24] As seen in the map below, CAFOs are present throughout the country.

Heat Density Map Showing Hog, Broiler, Cattle, Egg, and Dairy CAFOs in the United States in 2012.



Source: Food & Water Watch analysis of U.S. Department of Agriculture Census of Agriculture data.[25] See page 2 for legend.

Contract System/Structure

Most swine CAFOs are owned by family farms and small farming businesses, but operate under contracts for large corporations such as Smithfield Foods and its hog division, Murphy-Brown. Production and Marketing are the two common types of commercial contracts in the hog-raising

[22] USDA National Agricultural Statistics Service North Carolina Field Office (2012). 2012 Annual Statistical Bulletin. https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/AgStat/Section04.pdf.

[23] USDA National Agricultural Statistics Service and North Carolina Department of Agriculture and Consumer Services (2013). North Carolina Agricultural Statistics. https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/AgStat2013.pdf.

[24] National Research Council. (2003). *Air emissions from animal feeding operations: Current knowledge, future needs*. National Academies Press.

[25] Food & Water Watch (2015). Factory Farm Map. http://www.factoryfarmmap.org.

industry, mainly distinguished by which actor owns the animals.[26] Production contracts are formed between integrators who own the hogs (often large corporations, such as Smithfield Foods, which process the hogs after production) and independent farmers. The farmers raise and care for the livestock, but do not own the animals. The farmers provide buildings and land, manage manure, hire and manage labor, and repair and supply the farm itself. The integrators typically provide the animals, feed, medication, and veterinary support. The integrator then pays the farmer for the meat produced, usually per head.[27] Marketing contracts, on the other hand, provide a base price to the farmer based on various characteristics of the animals produced, such as weight. The farmers own the livestock and provide all necessary supplies until they deliver the hogs to the processor.[28]

Hog Farm Locations & Community Impacts

Hog production in North Carolina is overwhelmingly centered in the Eastern Coastal Plain, particularly in Robeson, Columbus, Bladen, Sampson, Pender, Duplin, Onslow, Wayne, Lenoir, Greene, and Pitt counties.[29]

Swine CAFOs in North Carolina are often located in communities with high poverty rates and high percentages of minority groups.[30] As a result, low-income, minority groups are disproportionately affected by pollution due to the geographic distribution of CAFOs. According to Wing et al. (2000), CAFOs are most highly concentrated in areas with the highest levels of poverty.[31]

III. Why CAFOs Are Important to Policymakers

CAFOs have a significant impact on the environment, surrounding communities, and the economy. This section focuses on the negative impacts of CAFOs on air quality, water quality, climate change, vulnerability to extreme weather, and public health; as well as the positive impacts of CAFOs on North Carolina's agricultural economy.

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[26] National Research Council. (2003). *Air emissions from animal feeding operations: Current knowledge, future needs*. National Academies Press.

[27] Ibid.

[28] Ibid.

[29] Environmental Working Group & Waterkeeper Alliance Fields of Filth: Landmark Report Maps Feces-Laden Hog and Chicken Operations in North Carolina. (n.d.). Retrieved January 17, 2017, from http://www.ewg.org/interactive-maps/2016_north_carolina_animal_feeding_operations.php.

[30] Bauer, S. E., Tsigaridis, K., & Miller, R. (2016). Significant atmospheric aerosol pollution caused by world food cultivation. *Geophysical Research Letters*, *43*(10), 5394-5400..;
See also Wing, S., & Johnston, J. (2014). Industrial Hog Operations in North Carolina Disproportionately Impact African-Americans, Hispanics and American Indians. *North Carolina Policy Watch. In University of North Carolina. http://www. ncpolicywatch. com/wpcontent/uploads/2014/09/UNC-Report. pdf (Page consultée le 15/04 2016)*.

[31] Ibid.

Air Pollution

One of the main drawbacks of CAFOs is their effect on air quality. CAFOs are significant contributors to air pollution, which often disproportionately impacts low-income and minority communities.[32] Although pollution is generally associated with urban environments and heavy industries, such as industrial manufacturing, chemical production and electricity generation, studies show that agriculture is actually one of the primary sources of harmful air pollution, including particulate matter, ammonia, and hydrogen sulfide.[33] Particulate matter, formed when ammonia emissions combine with other atmospheric substances, is especially dangerous because the particles are sufficiently small to be inhaled, and can lodge deep within lung tissue. A study of CAFOs in the Netherlands found that, after controlling for other factors, the lung function of people living within one kilometer of more than 15 farms is 5% worse than people living further away.[34] CAFOs create areas of highly concentrated air pollution that impair the quality of life of nearby communities.[35] Vulnerable populations are most at risk from the health impacts of CAFO-produced pollutants. Children, for instance, inhale 20-50% more air than adults, and air pollution can exacerbate existing health conditions in the elderly.[36] In addition to affecting health, CAFO-produced pollution has substantial social impacts. Odor, for instance, can be detected up to 6 miles from CAFOs.[37]

Despite its major impacts, air pollution from intensive livestock production is difficult to measure.[38] In addition, the Environmental Protection Agency's (EPA's) ability to monitor and regulate emissions is severely limited. The EPA is required to set National Ambient Air Quality Standards (NAAQS) for six pollutants under the Clean Air Act. However, ammonia is not on this list of criteria pollutants and thus there is no federal limit on pollution.[39] As mandated by the Clean Air Act, the EPA also regulates hazardous air pollutants (HAPS) from industrial facilities, [40] and currently targets 187 toxic air pollutants.[41] It does this by setting technology standards,

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[32] Hribar, C., & Schultz, M. (2010). Understanding concentrated animal feeding operations and their impact on communities. *Bowling Green, OH: National Association of Local Boards of Health. Retrieved February*, *18*, 2013.
[33] Bauer, S. E., Tsigaridis, K., & Miller, R. (2016). Significant atmospheric aerosol pollution caused by world food cultivation. *Geophysical Research Letters*, *43*(10), 5394-5400.
[34] Ibid.
[35] Ibid.
[36] Ibid.
[37] Ogneva-Himmelberger, Y., Huang, L., & Xin, H. (2015). CALPUFF and CAFOs: Air Pollution Modeling and Environmental Justice Analysis in the North Carolina Hog Industry. *ISPRS International Journal of Geo-Information*,*4*(1), 150-171.
[38] New Zealand Agricultural Greenhouse Gas Research Centre(2015) How we measure emissions.Retreived from https://goo.gl/Z5Ootj.
[39] The six pollutants regulated under the Clean Air Act are ground-level ozone, carbon monoxide, sulfur dioxide, particulate matter, lead, and nitrogen dioxide.
[40]EPA. (n.d.). Hazardous Air Pollutants, US EPA. Retrieved from https://www.epa.gov/haps.
[41] EPA. (n.d.). What are Hazardous Air Pollutants? | Hazardous Air Pollutants. Retrieved from https://www.epa.gov/haps/what-are-hazardous-air-pollutants.

based on the lowest emitters, and then assessing health effects.[42] In the past, the EPA's information has stemmed largely from "right-to-know laws", which mandate the public reporting of toxic air pollutants; however, these laws place no consequences on facilities that breach limits.[43] In 2005, the EPA and livestock industry agreed to conduct a more comprehensive National Air Emissions Monitoring Study (NAEMS) in 25 farms across 9 states, with the idea of generating emissions-estimating methodologies (EEMs) for quantifying ammonia, hydrogen sulfide, particulate matter, and VOC output from livestock operations.[44] The EPA agreed not to sue participants for past emissions violations in return for their compliance with the study. However, the EPA has failed to reach its stated aim of creating effective methodologies for monitoring CAFO emissions.[45] Despite the need for further information, it is clear that there are air quality impacts from CAFOs that must be considered in future policy decisions.

Water Pollution

CAFOs also significantly impact water quality. Though most studies refer to "agriculture" generally, the EPA's 2000 National Water Quality Inventory Report to Congress showed concern for CAFOs specifically. Seventeen states reported "Animal Feeding Operations" as one of their top ten sources of groundwater contamination.[46] "Intensive Animal Feeding Operations" were found to be a leading source of impairment for 9.1% of the impaired rivers and streams in the country.[47] Within North Carolina, "Intensive Animal Feeding Operations" were found to be a leading source of impairment for 253.2 miles of rivers and streams,[48] accounting for 11.8% of NC's impaired waters.[49] In 2016, the NC Division of Water Resources produced an annual report to the NC General Assembly which demonstrated that fecal coliform bacteria and nutrient contamination occurs in watersheds with high numbers of CAFOs.[50]

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[42] EPA. (n.d.). Hazardous Air Pollutants, US EPA. Retrieved from https://www.epa.gov/haps.

[43] Peterka, A. (2015, June). *EPA study of CAFO emissions grinds on with no end in sight*. Retrieved from http://www.eenews.net/stories/1060001938.

[44] Nowlin, M., Spiegel, E. *Much ado about methane: intensive animal agriculture and greenhouse gas emissions,* in RESEARCH HANDBOOK ON CLIMATE CHANGE AND AGRICULTURAL LAW (Mary Jane Angelo & Anel du Plessis, eds., 2017).

[45] Peterka, A. (2015, June). *EPA study of CAFO emissions grinds on with no end in sight*. Retrieved from http://www.eenews.net/stories/1060001938.

[46] EPA. (2002, August). *National Water Quality Inventory 2000 Report*. Retrieved from https://www.epa.gov/sites/production/files/2015-09/documents/2000_national_water_quality_inventory_report_to_congress.pdf.

[47] EPA. (2002, August). *National Water Quality Inventory 2000 Report Appendix A-5*. Retrieved from https://www.epa.gov/sites/production/files/2015-09/documents/2000_national_water_quality_inventory_report_to_congress.pdf.

[48] Ibid.

[49] EPA. (2002, August). *National Water Quality Inventory 2000 Report Appendix A-52*. Retrieved from https://www.epa.gov/sites/production/files/2015-09/documents/2000_national_water_quality_inventory_report_to_congress.pdf (indicating NC has 2143 miles of impaired waters).

[50] N.C. Department of Environmental Quality, McMillan, I. (2016). Annual report to the General Assembly, Environmental Review Commission, Basinwide Water Quality Management Planning July 1, 2015 to June 30, 2016. Available at https://deq.nc.gov/november-10-2016-agenda.

Animal waste contains a suite of contaminants including nutrients, pathogens, veterinary pharmaceuticals, heavy metals, and biochemical oxygen-demanding materials.[51] Contaminants of concern include nitrogen, phosphorus, fecal coliform bacteria strains, zinc, and copper. These contaminants can reach water sources in several ways. Waste lagoons can leak, which cause the waste to trickle down into the groundwater table and flow into surface waters.[52] Extreme precipitation events can cause lagoons to overflow, releasing the contaminated waste into the environment. Spray-fields can become saturated, allowing the land-applied waste to run off into surrounding surface waters. This can occur even when waste is applied at the recommended rates, rather than overapplied.[53] Waste nutrients can also migrate to surface waters through atmospheric deposition.[54]

Surface water contamination caused by CAFOs can have detrimental effects on the local ecology. Animal waste discharge into surface waters leads to heightened concentrations of ammonium, phosphorus, suspended solids, and fecal coliform bacteria, eventually developing anoxic conditions.[55] The resulting decrease in dissolved oxygen can lead to fish kills in the spill area.[56] Freshwater eutrophication can also occur in the absence of lagoon spills or failures. The gradual migration of waste nutrients from CAFOs to surface waters can lead to an overabundance of nitrogen and phosphorus, which causes phytoplankton to grow excessively.[57] This overgrowth results in algal blooms that release toxins or harmful metabolites and block sunlight from reaching the aquatic habitat.[58] After the algae die, they sink and are decomposed by bacteria. The decomposition depletes the oxygen supply, creating a dead zone where biota cannot grow. If an upwelling occurs, the result is fish kills at an impressive scale.[59]

CAFOs can also contaminate groundwater. Groundwater contamination is of particular concern in North Carolina due to the Eastern Coastal Plain's highly porous sandy soil.[60] E. Coli and fecal

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[51] Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thome, P. S., & Wichman, M. (2007). Impacts of waste from concentrated animal feeding operations on water quality. *Environmental health perspectives*, 308-312.
[52] Hutchins, S. R., White, M. V., & Mravik, S. C. (2015). Case Studies on the Impact of Concentrated Animal Feeding Operations (CAFOs) on Groundwater Quality. US Environmental protection policy. Nepis Epa QA ID# G-10033.
[53] Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thome, P. S., & Wichman, M. (2007). Impacts of waste from concentrated animal feeding operations on water quality. *Environmental health perspectives*, 308-312.
[54] Ibid.
[55] Ibid.
[56] Ibid.
[57] Ibid.
[58] Anderson, D. M., Glibert, P. M., & Burkholder, J. M. (2002). Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. *Estuaries*, *25*(4), 704-726.
[59] Ibid.
[60] Hog farm locations linked to poverty rates. (1999). *Water Environment & Technology, 11*(6), 17.

coliform have also been found in groundwater down-gradient of CAFOs in North Carolina.[61] In addition, 25% of newly lined lagoons are thought to cause nitrate groundwater contamination.[62] This is alarming because CAFOs in NC are disproportionately concentrated in areas with high rates of dependency on well water rather than municipal water sources. Over 30% of CAFOs are located in areas where over 96% of residents drink well water. This is more than 11 times as many CAFOs as in areas where less than 1% drink well water.[63]

GROUNDWATER CONTAMINATION: Washington County, Idaho

A recent study demonstrated that CAFOs had contaminated groundwater in Washington County, Idaho. The study sampled wells contaminated with nitrate, a form of nitrogen that is hazardous to human health, for co-contaminants that would indicate the source of the contamination. The researchers found two specific antimicrobials approved strictly for veterinary use as well as nitrate-nitrogen and ammonium-nitrogen isotope ratios that reflect a human or animal waste source.[64] The co-occurrence of these CAFO-specific contaminants provides strong evidence that CAFOs were also the source of the nitrate levels that exceeded the EPA's drinking water standard. One reason this is important for human health is that infants who consume formula prepared with nitrate-contaminated well water are at risk of "blue baby syndrome," which can result in death.[65]

Greenhouse Gas Emissions

Greenhouse Gases (GHGs) absorb heat emitted from the sun as it reflects off the Earth's surface, trapping the heat in the atmosphere.[66] Human activities have increased the concentration of GHGs in the Earth's atmosphere, causing global warming.[67] Livestock farming plays a significant role in global anthropogenic greenhouse gas (GHG) emissions, accounting for 9% of carbon dioxide emissions, 35-40% of methane emissions, and 65% of nitrous oxide emissions.[68]

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61 Sapkota, A. R., Curriero, F. C., Gibson, K. E., & Schwab, K. J. (2007). Antibiotic-resistant enterococci and fecal indicators in surface water and groundwater impacted by a concentrated swine feeding operation.*Environmental Health Perspectives*, 1040-1045.
62 Edwards, B., & Driscoll, A. (2009). From farms to factories: the environmental consequences of swine industrialization in North Carolina. *Twenty lessons in environmental sociology*, 153-175.ina, 1982–2007.https://www.academia.edu/2910910/From_Farms_to_Factories_The_Environmental_Consequences_of_Swine_Industrialization_in_North_Carolina.
63 Hog farm locations linked to poverty rates. (1999). *Water Environment & Technology, 11*(6), 17.
64 Batt, A. L., Snow, D. D., & Aga, D. S. (2006). Occurrence of sulfonamide antimicrobials in private water wells in Washington County, Idaho, USA.*Chemosphere*, *64*(11), 1963-1971.
65 Ibid.
66 Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., & de Haan, C. (2006).*Livestock's long shadow: environmental issues and options*. Food & Agriculture Org.
67 Ibid.
68 Ibid.

Methane is 23 times as potent a greenhouse gas as carbon dioxide, and liquid animal waste management at CAFOs emits vast quantities of methane.[69] Unlike dry litter manure treatment or land application of waste to pastures, lagoon systems rely on anaerobic digestion to break down the waste, which releases methane as a byproduct.[70] On a global scale, anaerobic digestion emits 17.5 million metric tons of methane - over half of which comes from pig waste.[71, 72]

Lagoon systems also indirectly contribute to nitrous oxide emissions.[73] A denitrification process occurs in the lagoon system, which releases ammonia into the atmosphere. Once the ammonia is in the atmosphere, it may be transformed into nitrous oxide.[74] Nitrous oxide is a GHG 296 times as potent as carbon dioxide.[75]

Vulnerability to Extreme Weather Events

The waste treatment lagoons that CAFOs use to manage animal waste in North Carolina are a public hazard in times of extreme weather events. In terms of human health, these events can cause lagoon overflows, which highly contaminate groundwater used for wells with nutrients and pathogens.[76] Environmentally, these events cause extreme nutrient overload in waterways, which can have a huge negative impact on entire ecosystems by causing events like algae blooms.[77] To mitigate these risks, certain guidelines for managing these lagoons exist, as outlined by the Natural Resource Conservation Service Conservation Practice Standards. Recommended protocols for waste treatment lagoons include emergency action plans, proper liners, minimum embankment elevation, emergency spillways, erosion protection, location requirements, and depth requirements.[78] Unfortunately, even if CAFO operators follow best management practices, lagoons are nevertheless prone to overflow or breach accidents, which contaminates groundwater that can harm the environment and local communities.[79]

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69 Ibid.
70 Ibid.
71 Ibid.
72 Note: This comes at a trade off. Dry waste treatment and direct land application of manure that is directly land applied are exposed to aerobic conditions, which can lead to emission of nitrous dioxide.
73 Ibid.
74 Nowlin, M., Spiegel, E. *Much ado about methane: intensive animal agriculture and greenhouse gas emissions,* in RESEARCH HANDBOOK ON CLIMATE CHANGE AND AGRICULTURAL LAW (Mary Jane Angelo & Anel du Plessis, eds., 2017).
75 Ibid.
76 Hribar, C., & Schultz, M. (2010). Understanding Concentrated Animal Feeding Operations and Their Impact on Communities. Retrieved from https://www.cdc.gov/nceh/ehs/docs/understanding_cafos_nalboh.pdf
77 Ibid.
78 Natural Resources Conservation Service Conservation Practice Standard: Waste Treatment Lagoon. (n.d.). Retrieved December 07, 2016, from https://efotg.sc.egov.usda.gov/references/public/NC/NC359WTLFeb09.pdf.
79 Nowlin, M.B. (2013). Sustainable Production of Swine: Putting Lipstick on a Pig?. *Vermont Law Review,* 37, 1079.

The location of North Carolina's swine CAFOs is a significant contributor to the high risk of overflow or failure during substantial rain events. Approximately 95% of swine CAFOs in NC are located in the low-lying Eastern Coastal Plain.[80] Because of this region's soil makeup, susceptibility to flooding, and proximity to the coast, the concentration of CAFOs in the Eastern Coastal Plain magnifies the impact of extreme weather events on these lagoons.[81]

In 1997, a moratorium was established on the construction or expansion of swine farms or lagoons.[82] This moratorium was then extended until 2007 when it was made permanent.[83] While North Carolina policymakers had been trying to move away from the construction of new lagoons throughout the 1990s, the problem gained renewed urgency in 1999 in the aftermath of Hurricane Floyd. According to East Carolina University, the storm caused more than $6 billion in property damage and more than 30,000 hogs perished in the storm.[84] The flooding of toxic lagoons into the state's waterways destroyed aquatic life and polluted drinking wells in rural communities that did not recover for years.[85]

The damage wrought by Hurricane Floyd gained national media attention and sparked public discussion on the future of swine waste lagoons in North Carolina.[86] The Attorney General, in collaboration with officials from DENR (now DEQ), worked with industry stakeholders to develop a plan that became known as the Smithfield Agreement.[87] The Agreement required Smithfield and its subsidiaries to fund development of "environmentally superior" waste management technologies. These technologies were defined by a set of performance standards and whether they were "economically feasible." After years of development and research, none

[80] Environmental Working Group, & Waterkeeper Alliance. (n.d.). *Exposing Fields of Filth: Locations of Concentrated Animal Feeding Operations in North Carolina*. Retrieved February 17, 2017, from http://www.ewg.org/interactive-maps/2016_north_carolina_animal_feeding_operations.php(maps detailing location of swing, poultry, and cattle CAFOs in North Carolina).
[81] Harmin, C. (2015). Flood Vulnerability of Hog Farms in Eastern North Carolina: An Inconvenient Poop.
[82] Barker, J. C. (n.d.). *Animal Waste Management*. Retrieved February 17, 2017, from https://www.bae.ncsu.edu/topic/animal-waste-mgmt/livestock-history.htm.
[83]Environmental Defense Fund. (2007, July). *North Carolina Bans New Hog Waste Lagoons, Sets Strict Standards for Future Systems*. Retrieved from https://www.edf.org/news/north-carolina-bans-new-hog-waste-lagoons-sets-strict-standards-future-systems.
[84] *Hurricane Floyd (n.d.). Retrieved December 07, 2016, from https://www.ecu.edu/renci/stormstolife/Floyd/environmental.html*.
[85] Ibid.
[86] [No Author] The New York Times. (1995, June). *Huge Spill of Hog Waste Fuels an Old Debate in North Carolina*. Retrieved from http://www.nytimes.com/1995/06/25/us/huge-spill-of-hog-waste-fuels-an-old-debate-in-north-carolina.html; Eisley, M. et al. (1999, September 20). NC faces staggering relief effort. *News & Observer* (Raleigh, NC).
[87] Agreement Between the Att'y Gen. of N.C. and Smithfield Foods, Inc. 8 (July 25, 2000). Available at: http://www.ncdoj.gov/getdoc/40ce62ee-d6f7-48d4-a933-86913e5a62e4/Smithfield-Agreement.aspx.

of the acceptable technologies were deemed as economically feasible as the lagoons, and none were adopted on a large scale.[88]

The year before the Smithfield Agreement was created, the North Carolina General Assembly issued a moratorium on the construction of new hog farms.[89] The moratorium on new lagoons was extended in 1999 in light of the disaster of Floyd,[90] and was made permanent in 2007.[91] While no new lagoons have been constructed for over fifteen years, the scale of hog farming in North Carolina means that a storm on the scale of Floyd has the potential to repeat the disaster of 1999.[92]

Seventeen years after Hurricane Floyd, very little in terms of waste management practices had changed. In October of 2016, Hurricane Matthew struck the coast with devastating effect. The agricultural production industry as a whole suffered more than $800 million dollars in property loss along with 4,800 dead hogs.[93] Given the nature of the lagoons and North Carolina's susceptibility to extreme weather events, it is reasonable to expect that future financially and environmentally detrimental episodes will occur.

Public Health

The transition from small-scale farming facilities to CAFOs has presented a plethora of pressing public health concerns, many of which have arisen as a result of agricultural health exposures. These industrial farming facilities are known to emit noxious vapors, gases, and particles that may have detrimental impacts on human health, ranging from respiratory disease to certain cancers.[94,95] The gas and particulate matter emissions can result in the development of

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[88] Nicole, W. (2013, June 01). CAFOs and Environmental Justice: The Case of North Carolina. Retrieved December 7, 2016, from http://ehp.niehs.nih.gov/121-a182/; Price, Jay. "After 12 years of research, hog-waste disposal still reeks - Technology leaps forward, but is costly for farmers to use," Charlotte Observer, November 26, 2012: 2B.

[89] Act to Enact the Clean Water Responsibility and Environmentally Sound Policy Act, 1997 N.C. Sess. Laws 458, § 1.1(a), *available at* http://www.ncleg.net/EnactedLegislation/SessionLaws/PDF/1997-1998/SL1997-458.pdf.

[90] Clean Water Act of 1999, 1999 N.C. Sess. Laws 329, § 2.1, *available at* http://www.ncleg.net/EnactedLegislation/SessionLaws/PDF/1999-2000/SL1999-329.pdf.

[91] N.C. Gen. Stat. § 143-215.10I(b) (2007).

[92] Barker, J. (n.d.). Animal Waste Management. Retrieved February 09, 2017, from https://www.bae.ncsu.edu/topic/animal-waste-mgmt/livestock-history.htm.

[93] Gee, K., & McWhirter, C. (n.d.). *North Carolina's Poultry, Hog Producers Bail Out From Under Hurricane Matthew*. Retrieved from https://www.wsj.com/articles/north-carolinas-poultry-hog-producers-bail-out-from-under-hurricane-matthew-1476554376.

[94] Heederik, D., Sigsgaard, T., Thorne, P. S., Kline, J. N., Avery, R., Bønløkke, J. H., ... & Kulhankova, K. (2007). Health effects of airborne exposures from concentrated animal feeding operations. *Environmental Health Perspectives*, 298-302.

[95] Kirkhorn, S. R., & Schenker, M. B. (2002). Current health effects of agricultural work: respiratory disease, cancer, reproductive effects, musculoskeletal injuries, and pesticide-related illnesses. *Journal of Agricultural Safety and Health*, *8*(2), 199-214.

agricultural respiratory diseases.[96,97] One often overlooked area of concern is the psychophysiological effect of malodorous compounds emitted from CAFOs.[98] Furthermore, industrial farming facilities may contain workplace hazards that significantly increase an individual's likelihood of acquiring injuries, noise-induced hearing impairment, and musculoskeletal ailments.[99]

Industrial swine facilities have engendered the conditions necessary for the uninhibited rise of disease transmission. The highly concentrated nature of these facilities, in conjunction with the close interaction between the animals and humans, facilitates the propagation and dissemination of zoonotic pathogens.[100] Existing waste management practices, including the use of waste as a fertilizer and the establishment of waste lagoons, provide opportunities for infectious agents to mutate and create novel disease strains, develop resistance to antibiotics, and infect susceptible host populations. There are currently over 150 enteric pathogens—including bacteria, viruses, fungi, prions, and parasites—that are known to exist in untreated animal waste deposits.[101] Increased microbial load, particularly of endotoxin exposure, can result in adverse inflammatory response, most notably the accelerated decline of overall lung functioning.[102] The development of antimicrobial resistance in bacterial pathogens has emerged as a critical public health concern, as resistant bacteria have even been identified downwind of swine facilities.[103,104] Humans may be exposed to the pathogenic microorganisms through direct exposure to the animals and their waste, as well as through inhalation and the consumption of contaminated food and water sources.[105,106]

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96 Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., & de Haan, C. (2006).*Livestock's long shadow: environmental issues and options*. Food & Agriculture Org.
97 Ibid.
98 Ibid.
99 Ibid.
100 Gilchrist, M. J., Greko, C., Wallinga, D. B., Beran, G. W., Riley, D. G., & Thorne, P. S. (2007). The potential role of concentrated animal feeding operations in infectious disease epidemics and antibiotic resistance.*Environmental health perspectives*, 313-316.
101 Gerba, C. P., & Smith, J. E. (2005). Sources of pathogenic microorganisms and their fate during land application of wastes. *Journal of Environmental Quality*, *34*(1), 42-48.
102 Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., & de Haan, C. (2006).*Livestock's long shadow: environmental issues and options*. Food & Agriculture Org.
103 Gibbs, S. G., Green, C. F., Tarwater, P. M., Mota, L. C., Mena, K. D., & Scarpino, P. V. (2006). Isolation of antibiotic-resistant bacteria from the air plume downwind of a swine confined or concentrated animal feeding operation. *Environmental Health Perspectives*, 1032-1037.
104 Ibid.
105 Silbergeld, E. K., Graham, J., & Price, L. B. (2008). Industrial food animal production, antimicrobial resistance, and human health. *Annu. Rev. Public Health*, *29*, 151-169.
106 Barrett, J. R. (2005). Airborne bacteria in CAFOs: transfer of resistance from animals to humans. *Environmental Health Perspectives*, *113*(2), A116.

Efficiency and Cost

While the problems above outline the need for reform of some aspects of the CAFO system, the benefits of CAFOs are also important to recognize. The most cited advantage of CAFOs over less concentrated methods of animal production methods is the efficiency of inputs.[107] CAFOs make particularly efficient use of labor. Producers are often able to maintain off-farm jobs and the system thus allows for higher total farmer income.[108] This efficiency translates into low product prices in the market, which in turn leads to better accessibility of meat and other animal products even to low-income individuals.[109]

Meeting Growing Global Demand

As our global population continues to grow and global demand for meat and other animal products continues to rise, particularly in developing countries, our ability to efficiently raise, slaughter, process, and distribute livestock will become increasingly important.[110] It is thus imperative that we establish long-term strategies for resolving the problems associated with CAFOs cited above.

IV. Current Policies for Addressing CAFO Environmental Health Impacts

There is not a single comprehensive regulatory regime governing CAFOs. Instead, there is a diverse set of policies and regulatory schemes that each address the environmental health threats posed by CAFOs. Below is an overview of these federal and state policies.

The Clean Air Act

Air pollution is regulated by the EPA under the Clean Air Act (CAA). CAFOs contribute ammonia, hydrogen sulfide, and particulate matter to the air. The EPA regulates six criteria pollutants: lead, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter, and ground level ozone pursuant to the CAA.[111],[112] Two of these six criteria pollutants, particulate matter and nitrogen oxides, are closely associated with CAFOs.[113] Another primary concern regarding air pollution caused by CAFOs is odor.

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107 MacDonald, J. M., & McBride, W. D. (2009). The transformation of US livestock agriculture scale, efficiency, and risks.

108 Key, N., & McBride, W. (2003). Production contracts and productivity in the US hog sector. *American Journal of Agricultural Economics*, *85*(1), 121-133.

109 Walsh, B. (2009). Getting real about the high price of cheap food. *Time Magazine*, 1917458-1.

110 Fiala, N. (2008). Meeting the demand: An estimation of potential future greenhouse gas emissions from meat production. *Ecological Economics*,*67*(3), 412-419.

111 Clean Air Act, 42 U.S.C. § 7408 (2012).

112 EPA. (n.d.). *Criteria Air Pollutants*. Retrieved February 17, 2017, from https://www.epa.gov/criteria-air-pollutants.

113 Copeland, C. (2010). Air quality issues and animal agriculture: a primer.*Animal Agriculture Research Progress*, 1.

The CAA has set federal air quality standards, known as National Ambient Air Quality Standards (NAAQS), that states must comply with, However, it is up to the states to regulate specific industries and pollutants. Most states have classified livestock production as a minor source of air pollutants (producing less than 100 tons per year of pollutants) and therefore do not regulate it. However, some states, such as Minnesota, require permits and air emission plans for operations before they are built.[114] Other states regulate odor with no specific guidelines or have a hydrogen sulfide (not a criteria pollutant) emission standard.[115] In North Carolina, regulation has focused on odor control, forcing CAFOs to submit odor management plans, but does not enforce technology use.[116] There are no air emission standards on ammonia, hydrogen sulfide, or odor for CAFO pollutants. In general, North Carolina lacks air pollutant regulation for CAFOs.[117]

The Clean Water Act

CAFOs that do not control their animal waste and illegally discharge pollutants to water bodies are a significant threat to water quality and human health. Under CWA, The National Pollutant Discharge Elimination System (NPDES) Permit Regulation regulates the water discharge standards of CAFOs. It defines which operations are CAFOs[118] and establish permit requirements that contain limits on what CAFOs can discharge, monitoring and reporting requirements, and other provisions to ensure that the discharge does not hurt water quality of people's health.

The NPDES program under CWA aims to protect and improve water quality by regulating point source discharges.[119] A point source is defined as any discernible, confined and discrete conveyance or floating craft from which pollutants are or may be discharged. CAFOs are defined as point sources under NPDES and are thus prohibited from discharging waste into surface waters without a permit (one exception is in the case of stormwater-related runoff).[120] If a CAFO discharges without a permit, it is strictly liable and subject to civil and criminal penalties[121]. Under a 2003 NPDES regulation, all CAFOs are required to apply for an NPDES permit whether

[114] Ibid.
[115] Ibid.
[116] Ibid.
[117] Ibid.
[118] An animal feeding operation is a CAFO if it meets the regulatory definition of a Large or Medium CAFO in 40 C.F.R § 122.23 (b), or has been designated as a CAFO by the NPDES permitting authority or by EPA under 40 C.F.R § 122.23(c).
[119] US EPA. (n.d.). *Producers' Compliance Guide for CAFOs*. Retrieved from https://www3.epa.gov/npdes/pubs/cafo_prod_guide_entire_doc.pdf.
[120] HORNE, C. (2013, November). *Agricultural Stormwater Exemption Applies to CAFOs Too*. Retrieved from http://www.dewittross.com/news-education/posts/2013/11/12/federal-court-rules-agricultural-stormwater-exemption-applies-to-cafos-too.
[121] 33 U.S.C. § 1319

or not they discharged, except for those that prove to the EPA they do not have the potential to discharge.[122]

The NPDES permits governing CAFOs in the US is restricted, however. This is due, in part, to two US Circuit Court of Appeals decisions significantly narrowing the scope of the NPDES program as applied to CAFOs:*Waterkeeper Alliance et al. v. EPA*, 399 F.3d 486 (2d Cir. 2005) and *National Pork Producers Council v. EPA*, 635 F.3d 738 (5th Cir. 2011). These cases struck down key provisions of the 2003 and 2008 CAFO Rules, respectively.

Both the Fifth Circuit and Second Circuit adopted a narrow view of what the term "discharge" means. A "discharge," as understood by the Second and Fifth Circuits, is simply an actual physical outcome—the entering of a pollutant into navigable waters—and does *not* refer to the action of the entity leading to or causing the outcome.[123] This interpretation has significantly reduced EPA's ability to create a uniform NPDES regime applicable to CAFOs since it strips the EPA of any authority to implement the NPDES program for CAFOs until after manure, litter, or wastewater from the CAFO actually enters the nation's waters. This has effectively left CAFOs themselves in charge of determining whether or not they should obtain NPDES permits. See 40 C.F.R. § 122.23(d)(1). By conditioning EPA's ability to collect information regarding the existence and characteristics of new CAFOs on the initial occurrence of a discharge, EPA has limited ability to set cap on discharge until a discharge the CWA seeks to prevent has already occurred. It is contrary to the fundamental aims of the CWA to prohibit the EPA from "require[ing] [CAFOs] to reveal their existence to the agency [through obtaining an NPDES permit]" until after the CAFO(s) have committed a discharge[124].

While the NPDES permit has been actively resisted by CAFOs, in North Carolina, the state has its own permit for the waste management systems of animal operations.[125] The "General Permit" is issued by the Environmental Management Commission (EMC) of North Carolina's Department of Energy and Natural Resources (DENR), covering more than 2600 of North Carolina's animal feeding operations. As of April 22, 2016, there were 2,614 permitted animal feeding operations operating in North Carolina.[126] This permit system received backlash from

[122] National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (CAFOs), 68 Fed. Reg. 7176, 7266 (2003) (to be codified at 40 C.F.R. pt. 6, 122, 123, 412).
[123]Brown, C. R. (2011). When the Plain Text Isn't So Plain: How National Pork Producers Council Restricts the Clean Water Act's Purpose and Impairs Its Enforcement Against Factory. *Drake Journal of Agricultural Law*, *16375*, 409-10.
[124] Ibid
[125] N.C. Gen. Stat. § 143-215.1(a)(12) (2013)
[126] NC DEQ Animal Facility Map, www.deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/animal-feeding-operation-permits/animal-facility-map (Containing a link to "List of Permitted Animal Facilities" excel spreadsheet).

environmental organizations since it puts lower environmental standards to CAFOs and provides for the persistence of pre-existing lagoons and sprayfield practices.[127]

Occupational Safety and Health Administration

The Occupational Safety and Health Administration (OSHA) was created under the Occupational Health and Safety Act of 1970 to keep workers safe through enforced standards.[128] According to the North Carolina Occupational Health Safety and Health Standards for Agriculture, OSHA has "very few standards that are applicable to agriculture."[129] Furthermore, agricultural operations that have 10 or fewer employees and lack temporary housing for workers are exempt from these regulations.[130] Since many CAFOs are smaller operations, most lack a temporary housing for laborers or employ only a few people, meaning they are typically not regulated under OSHA. Furthermore, immediate family members of farm owners do not count towards OSHA staff-size requirements, preventing certain CAFOS from becoming OSHA-regulated.[131] However, even if the employees on a CAFO are not exempt, there are few regulations that relate to livestock agriculture. Most of the regulations pertain to pesticides, harvesting, heat shock, and tractor use.[132] Some recommendations for policy change have included focusing on CAFOs, specifically concerning the number of hours of work and monitoring of dust in CAFOs that causes adverse health effects.[133]

Food and Drug Administration

Antibiotics are commonly used on livestock in the US to reduce rates of infectious disease and to enhance animal growth.[134] The U.S. Food and Drug Administration (FDA) is responsible for the regulation and approval of antibiotics used on animals that are meant for human consumption. The conditions of the FDA's safety assessment for food animals are as follows: no risks to humans from an animal antibiotic, assessment of food safety, study to ensure that there is no increased risk of antibiotic resistant bacteria in food, and assessments of efficacy and quality of manufacturing.[135] An administrative guidance document, Guidance for Industry #152--published

[127] Neubauer, R. (n.d.). *Something Smells: Hog Farming Waste Management in North Carolina*. Retrieved from http://studentorgs.law.unc.edu/documents/elp/2016/r_neubauer.pdf

[128] North Carolina Department of Labor. (2015). *Occupational Safety and Health Standards for Agriculture*. Retrieved from http://www.nclabor.com/osha/etta/indguide/ig108.pdf.

[129] Ibid.

[130] Ibid.

[131] Ibid.

[132] Berry, Cherie. NC Department of Labor. *Agricultural Safety and Health Guide: Advice for agricultural workers in North Carolina.* Available at: http://cdm16062.contentdm.oclc.org/cdm/ref/collection/p249901coll22/id/77075.

[133] Kirkhorn, S., Schenker, M. B., & Joseph, I. S. (2001, March). Human health effects of agriculture: physical diseases and illnesses. In *Agricultural Safety and Health Conference: Using Past and Present to Map Future Actions*.

[134] McEwen, S. A., & Fedorka-Cray, P. J. (2002). Antimicrobial use and resistance in animals. *Clinical Infectious Diseases*, *34*(Supplement 3), S93-S106.

[135] FDA Approval." *Animal Health Institute*. N.p., n.d. Web. 17 Feb. 2017. <http://www.ahi.org/issues-advocacy/animal-antibiotics/fda-approval/>.

by the FDA in October 2003-- sets out human-centered safety conditions for the use of antimicrobial drugs on animals.[136] Although guidance documents are nonbinding and lack the legal authority of law or regulation, they do provide a consistent reference for the agency's interpretation of regulations. This document suggests that the FDA would discourage the use of an antibiotic that is important for humans on livestock, apart from in very specific situations and with veterinary oversight. The FDA has strict requirements for pre-market approval of drugs, including antibiotics proposed for use on animals,[137] but has very little authority or oversight of the usage of these drugs once they enter the marketplace. In 1977, the FDA began to prohibit some use of antibiotics in agriculture; however, pro-industry resolutions in Congress have largely halted such efforts.[138]

Despite its limited enforcement capacity in the post-market stage, the FDA maintains a database of information on the prevalence of antibiotic-resistant bacteria in the U.S. food supply. In 1996, the Food and Drug Administration partnered with the Centers for Disease Control (CDC) and the U.S. Department of Agriculture (USDA) to track the presence of antibiotic-resistant bacteria in commercially-available meat through the National Antimicrobial Resistance Monitoring System (NARMS), as part of a larger effort to improve food safety in the United States.[139] Given that the focus of NARMS is primarily food safety at the consumer and retail level, the data is less useful for determining what antibiotics might be used on a given CAFO or by a given firm.

Although there are limited protections for whistleblowers reporting on food processing plants regulated by the FDA (such as seafood packing plants, juice manufacturing facilities, dairies, and any number of food products covered by the FDA), meat and poultry plants are overseen by the USDA, where such protections are not available. Furthermore, the advent of "ag-gag" laws passed by state governments--including North Carolina--more explicitly limits protections for potential whistleblowers employed by CAFOs, slaughterhouses and in meat-packing facilities.[140]

United States Department of Agriculture

The United States Department of Agriculture (USDA) is the executive agency in charge of agriculture, forestry, nutrition, and rural welfare in the US. It works on these issues through two main channels: promoting nutritional education and assistance to citizens of the US, which is

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[136] Food and Drug Administration. (2003). Evaluating the Safety of Antimicrobial New Animal Drugs with Regard to Their Microbiological Effects on Bacteria of Human Health Concern.

[137] US Food and Drug Administration. (2014). From an Idea to the Marketplace: The Journey of an Animal Drug through the Approval Process. *June. Department of Health and Human Services. http://www. fda. gov/AnimalVeterinary/ResourcesforYou/AnimalHealthLiteracy/ucm219207. htm*.

[138] Paarlberg, R., & Paarlberg, R. L. (2013). *Food politics: What everyone needs to know*. Oxford University Press.

[139] Ibid.

[140] Lacy, S. (2013). Hard to Watch: How Ag-Gag Laws Demonstrate the Need for Federal Meat and Poultry Industry Whistleblower Protections. *Admin. L. Rev.*, *65*, 127.

about 80% of its budget, and through increasing agricultural production and marketing.[141] While the purpose of the USDA is not to directly safeguard and improve the health of the rural agricultural population, it does run a small number of programs that relate to improving the health and welfare of rural communities. First, the White House Rural Council Initiative, which is run by the Department of Health and Human Services (HHS) and USDA, aims to link rural residents with health resources through investments in rural health. For example, the Initiative works to recruit more physicians and health-related information technology to rural areas of the US.[142] Such an initiative thus applies to the agricultural sector and its employees because of the placement of farms in rural areas.

Aside from this initiative, USDA's health actions are focused more heavily on the broad consumer base of all US agricultural products. This includes the Animal and Plant Health Inspection Service (APHIS) and the Food Safety and Inspection Service (FSIS). APHIS' purpose is to "safeguard the health, welfare and value of American agriculture and natural resources,"[143] while FSIS intends to ensure that "the nation's commercial supply of meat, poultry, and egg products is safe, wholesome, and correctly labeled and packaged."[144] FSIS achieves a safe food supply through in-person inspection services for processors, education for proper food handling for consumers, and labeling. While labeling requirements under FSIS work to ensure the safety of consumers, there are no provisions in place to protect people whose health is affected by the production process itself.[145]

North Carolina State Policies

The NC Department of Environmental Quality (DEQ) enforces statutes that govern state regulations on permitting and siting of animal waste systems and CAFOs. State regulations are intended to protect water quality, provide technical assistance to farmers, and encourage innovation in waste management systems.

DEQ requires inspections of permitted animal waste management system facilities at least once per year, and provides guidelines for animal waste management plans to be completed before a swine farm can receive a permit.[146] These plans must include: potential sources of odors and

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[141] USDA. (n.d.). *USDA Mission Areas*. Retrieved from https://www.usda.gov/wps/portal/usda/usdahome?navid=USDA_MISSION_AREAS

[142] Exec. Order No. 13575, 76 Fed. Reg. 34841 (June 14, 2011).

[143] USDA. (n.d.). *Animal and Plant Health Inspection Service*. Retrieved from https://www.usda.gov/wps/portal/usda/usdahome?contentid=APHIS_Agency_Splash.xml.

[144] Ibid.

[145]Ibid.

[146] *See* N.C. Gen. Stat. § 143-215.10C(b) (2007) (Animal Waste Management Systems permitted under State General Permit must be "designed, constructed, and operated so that the animal operation served by the[AWMS] does not cause pollution in the waters of the State except as may result because of rainfall from a storm event more severe than the 25-year, 24-hour storm.").

insects, and plans to minimize these sources; a plan to appropriately dispose of mortalities; plans regarding best use of riparian buffers around perennial streams; periodic testing of waste used as a nutrient source for crops; provisions to ensure a balance between nutrient value of waste and nutrient requirements of crops; plans to report dates and amount of waste applied to crops; and plans for emergency management detailing operating procedures that minimize environmental and health risks. [147]

Immediate, emergency reporting is required by the state in the following situations: direct discharge of animal waste into waters of the state; deterioration or failure to maintain adequate storage capacity in a lagoon; discharges that bypass a lagoon system; spraying animal waste in excess of regulations or in an area that will runoff into waters of the state. If more than 1000 gallons of animal waste are released into public waters, the owner of the waste management system must release a press statement to the county to warn them of the discharge. [148]

Currently, North Carolina has placed a moratorium on construction or expansion of swine lagoons.[149] However, permits are acceptable if the system will meet or exceed the following requirements: eliminate waste discharge from seepage, runoff, or direct outflow; substantially eliminate emission of ammonia, odor beyond the property line, disease transmitting vectors and pathogens; and eliminate nutrient or metal contamination of soil and groundwater.[150]

In addition, a swine house or lagoon must be located 1500 feet from an occupied residence and 2500 feet from a school, hospital, church, national or state park, or child care center. It must also be 500 feet from any property boundary, a well supplying water to a public system, or any other well not under control of the swine farm. However, a swine house or lagoon can be closer to a property boundary if the owner of the property gives written permission. Additionally, the outer perimeter of crops with waste application must be 75 feet from any property boundary with an occupied residence or stream/river that is not an irrigation ditch. Finally, anyone who owns property affected by violations can bring civil action against the swine farm and can seek injunctive relief, an order enforcing the requirements, and payment of damages caused by the violation.[151]

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[147] North Carolina Department of Environmental Quality." *NC DEQ*. N.p., n.d. Web. 17 Feb. 2017. <https://deq.nc.gov/about/divisions/water-resources/water-resources-rules/animal-feeding-operations-rules-statutes>

[148] Animal Feeding Operations: Rules and Statutes. (n.d.). Retrieved from https://deq.nc.gov/about/divisions/water-resources/water-resources-rules/animal-feeding-operations-rules-statutes

[149] N.C. Gen. Stat. § 143-215.10I(b) (2007).

[150] Animal Feeding Operations: Rules and Statutes. (n.d.). Retrieved from https://deq.nc.gov/about/divisions/water-resources/water-resources-rules/animal-feeding-operations-rules-statutes

[151] Animal Feeding Operations: Rules and Statutes. (n.d.). Retrieved from https://deq.nc.gov/about/divisions/water-resources/water-resources-rules/animal-feeding-operations-rules-statutes

V. Animal Waste Management Technologies

Currently, animal waste management technologies that produce electricity as a byproduct are gaining the most momentum relative to other technological options. For example, Duke Energy and Carbon Cycle Energy are designing a system that will collect biogas from swine waste and use a pipeline to deliver it to a Duke Energy power plant.[152] TerraStar Energy, a waste-to-energy integrator, is about to construct its first of potentially 30 facilities in North Carolina that will haul waste from farms, and either gasify or anaerobically digest the waste to produce energy. Additionally, Smithfield Foods, Inc. has suggested new waste-to-energy projects to come.[153], [154]

WASTE-TO-ENERGY: Lloyd Ray Farms

An example of waste-to-energy technology is seen at Loyd Ray Farms, a CAFO with over 8,600 hogs. Loyd Ray Farms partnered with the Duke University's Carbon Offsets Initiative, Google, and Duke Energy to develop an innovative waste management system that reduces environmental impacts, generates renewable energy, and produces carbon offsets.[155] The key technologies employed are an anaerobic digester and an aeration basin. The waste is flushed out from under the barns into the anaerobic digester. The anaerobic digester is a clay basin fortified with bentonite and topped with a polyethylene cover.[156] The cover prevents oxygen from entering the digester, creating anaerobic conditions. Under these conditions, microbes break down organic matter and release biogas which is captured by the cover of the digester. The biogas is then conditioned and sent to a microturbine, which generates electricity used for on-farm operations.[157] Any excess methane is flared off. The burning methane is converted into carbon dioxide, a much less potent greenhouse gas. The waste in the anaerobic digester is then transferred into an aeration basin, where it undergoes nitrification and denitrification. This converts the ammonia into nitrogen gas to be released into the atmosphere, reducing the overall nitrogen content of the waste. Then the wastewater is cycled back to flush out the barns. Excess water is stored in the former lagoon until it is used to irrigate crops.

Other technologies have also been developed to manage swine waste. Many of these technologies were studied pursuant to the Missouri-Premium Standard Farms consent agreement.

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[152] Hilburn, R. L. (2016, May 18). *CoastLine: Hog Waste Management Alternatives*. Retrieved from http://whqr.org/post/coastline-hog-waste-management-alternatives#stream/0.
[153] Ibid.
[154] Note: Smithfield also has broader initiative to reduce greenhouse gas emissions.
[155] Adair, C. W., Xu, J., Elliott, J. S., Simmons, W. G., Cavanaugh, M., Vujic, T., & Deshusses, M. A. (2016). Design and Assessment of an Innovative Swine Waste to Renewable Energy System.
[156] Ibid.
[157] Ibid.

[158] The goal was to establish and install "Next Generation Technologies" on Premium Standard Farms that would reduce nutrient content, pathogens, odor, and air pollutants. One Next Generation Technology is a system that utilizes digesters and scrapers (which mechanically push the waste towards the lagoon). Scrapers were also found to be an odor-reducing technology and are now installed on Premium Standard Farms.[159] More information on scrapers is provided in Appendix A.

Similar to the Missouri-Premium Standard Foods consent agreement, the Smithfield Agreement sought to study animal waste technologies in North Carolina and establish Environmentally Superior Technologies for use on new and existing CAFOs. The technologies were reviewed for economic feasibility[160] and environmental performance. The environmental factors were based on current Swine Waste Management Performance Standards in North Carolina.[161] Accordingly, each technology system was measured for its nitrogen and phosphorous, copper and zinc, atmospheric emissions of ammonia, odor, and disease transmitting vectors and airborne pathogens. The study concluded that an Environmentally Superior Technology would be "Super Soils" Generation 1 in combination with "Orbit" High Solids Anaerobic Digestion, "BEST" fluidized bed combustion of solids, "RE-CYCLE" gasification of solids, or "Super Soils" solids compost.[162] Since our assessment of technologies will differ from Smithfield's criteria, those technologies as well as the other candidate technologies will be considered. Descriptions are provided in Appendix A.

Criteria for Evaluating Existing Technologies

When considering the various forms of alternative waste management technologies, it is important to develop a framework by which they can be compared. A natural product of available technologies is that there are significant differences in material and functional components, legal requirements, costs, and practicality. Likewise, in different regions and among different constituent buyers, certain technologies may be more suitable than others. This section seeks to identify some of the factors that could differentiate certain technologies from one

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[158]Nowlin, M. B. (2012). Sustainable Production of Swine: Putting Lipstick on a Pig. *Vt. L. Rev.*, *37*, 1079.
[159] Ibid.
[160] The stakeholders involved in the Smithfield Agreement negotiated what constituted "economic feasibility." The agreed upon metric was a projected ten year annualized cost of retrofitting a lagoon system with the technology (including capital, operation, and maintenance) per 1000 units of steady state live weight for each category of farm system. This includes taking account of revenue produced from the system's byproducts. The baseline was set at $87 - the cost of constructing a lagoon and sprayfield system in NC in 2004. Williams, C. M. (2016). Presentation at Duke Environmental Health Scholars Program Fall Forum: Technology Options for Capturing Greenhouse Gases and Destroying Pathogens in the AFO/CAFO Waste Stream [Powerpoint Slides].
[161] Swine Waste Management System Performance Standards. 15A N.C. Admin. Code 02T.1307. (2009).
[162] Williams,C. M. (2016). Presentation at Duke Environmental Health Scholars Program Fall Forum: Technology Options for Capturing Greenhouse Gases and Destroying Pathogens in the AFO/CAFO Waste Stream [Powerpoint Slides].

another. Moreover, these factors, by virtue of their diversity, may be used to evaluate technologies according to the specific interests of all relevant groups.

Producer Preferences

When comparing potential replacement technologies, it is necessary to evaluate them based on criteria that incorporate producer interest. As evidenced by previous discussions on the Smithfield Agreement, lagoon and sprayfield systems are the predominant model for swine waste management.[163] Given the prevalence of lagoons, new technologies and other CAFO alternatives would need to include significant benefits to producers or provide some other incentive in order to become the norm.[164] We also consider other criteria, including the amount of training required to implement a technology, the time required before a system is operational, the amount of knowledge available to farmers, and the widespread viability of a technology.

Cost Effectiveness & Economic Feasibility

Technologies have varying purchase costs, installation costs, and maintenance costs, which provide points of contrast. Moreover, certain federal programs such as the Public Utilities Regulatory Policies Act (PURPA), state level initiatives such as NC's Standard Offer Contracts provisions, and private initiatives such as carbon offsets can help offset direct costs, and their application to certain technologies is essential to evaluating cost-effectiveness. However, initiatives such as cost-sharing among farmers and other interested parties, economic returns on efficient and revenue-creating technologies (such as those that produce energy), and grants to fund part or all of a project present other opportunities to encourage the adoption of alternative technology. For instance, the Loyd Ray farms project capitalizes on the usefulness of the energy produced by WTE technologies in order to both decrease energy needs on the farm as well as provide carbon offset credit to Duke University and other organizations, thereby generating funding that makes the technology affordable. Cost effectiveness and economic feasibility could be the most inhibitive factor, because without sufficient incentive initial costs can overwhelm an individual farmer.

Environmental & Public Health Impacts

The environmental and health components of alternative technologies are some of their largest strengths, as they have the opportunity to provide significant environmental benefits and public health improvements to communities surrounding CAFOs. As stated previously, hog operations cause to air pollution, water pollution, GHG emissions, weather-related safety issues, and public health concerns. Systems that reduce these factors include those that collect and destroy GHGs, protect the waste system from overflow, promote the health of pigs, and limit odorous gases released to neighboring communities.

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[163] Ibid.

[164] Ibid. (Economic viability is understood in comparison to the lagoon model.)

Fundamental to this question of comparison is the assessment of risks with implementing new technology systems. For an industry made of companies and farmers used to a standard operation scheme, alterations can provide a difficult risk to shoulder. First and foremost, the technology in and of itself can be a risk. It may fail based on weather conditions, worn out materials, or other reasons. This possibility must be evaluated and any technology recommendation should be accompanied by recommendations as to how to mitigate these risks. Moreover, new technology can be a risk in that producers may not necessarily recover the money spent implementing and maintaining the technology, cutting into farmers' profits and ultimately threatening the technology in the long run. From these two risks, a trend emerges: farmers themselves often take on most of the burden associated with new technology, rather than the corporations to whom they owe contracts. Likewise, it is important to provide security via legal protections, capital support, large scale standardization, incentivized adoption of technology across the industry, or other means to ensure their protection. Without this security, farmers will remain resistant to new technology.

VI. Existing Technology Policies

Energy Policy Act

The Energy Policy Act was created in 2005 with the objective of increasing the popularity of energy efficient policies in the United States through tax incentives for the public.[165] The Act increased awareness of renewable energy sources, decreased in the use of automobiles and motor fuels, and increased overall education on the different types of climate change technology within the production industry. [166] The Energy Policy Act created market incentives for domestic energy production that spurred a surge in wind, solar, and natural gas energy sources.[167] The policy also incentivized certain types of animal feed and sought ways to reduce the ethanol produced by animal waste as part of its mission to improve the environmental climate.[168]

A year later, the impacts of the act were significant. By the end of 2006, "7 billion pounds of CO_2 emissions [were] avoided by new wind power production." Furthermore, a total of 27 new ethanol plants were generated, increasing the number of "gallons of annual ethanol production" to 1.4 billion gallons.[169] On the other hand, the Energy Policy Act is often critiqued for creating

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165 US EPA. (n.d.). *Summary of the Energy Policy Act*. Retrieved from https://www.epa.gov/laws-regulations/summary-energy-policy-act.
166 Ibid.
167 Ibid.
168 Ibid
169 Ibid

the unconventional oil and gas development industry (hydraulic fracturing).[170] However, the Energy Policy Act did create incentives for investment in alternative energy resources in addition to popularizing these methods.[171]

Renewable Portfolio Standards (Renewable Energy Portfolio Standards in NC)
A Renewable Energy Portfolio Standard (RPS), referred to as a Renewable Energy and Energy Efficiency Portfolio Standard (REPS) in North Carolina, is a state-mandated policy that requires utility companies to source a certain percentage of the electricity they supply from renewable energy sources.[172] Renewable Energy Certificates (RECs) are created for each megawatt-hour equivalent generated by sources classified as Renewable Energy Facilities (REF).[173] An electric energy supplier may choose to generate, or simply purchase, electricity from an REF, in order to comply with the state's REPS. Credits may also be purchased from qualifying in-state and out-of-state facilities.[174] States other than North Carolina have different clean energy standards, enforcement mechanisms, and qualifying energy sources.[175]

North Carolina's Renewable Energy and Energy Efficiency Portfolio Standard (REPS) was established in 2007, under Session Law 2007-397 (Senate Bill 3).[176] Investor-owned utilities, operating within the state, are required to source 12.5% of 2020 retail electricity sales, from qualifying renewable energy sources, by 2021; electric cooperatives and municipal utility companies are required to obtain RECs for 10% of all energy sales.[177] The policy also mandates technology-specific targets of 0.2% solar energy by 2018, 0.2% biomass energy from swine waste by 2019, and 900,000 MWh (or equivalent) from biomass energy from poultry waste by 2014.[178]

The North Carolina Utilities Commission released an annual report regarding the state's REPS in October of 2016, which stated that all electric power suppliers appeared to meet both the 2012-2015 REPS requirement and the technology-specific set-aside requirements for solar and poultry biomass sources.[179] While most electric power suppliers are on track to meet the 2016

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[170] Phillips, S. (2011). Burning Question: What would life be like without the Halliburton Loophole?. *State Impact*, 05-12.
[171] US EPA. (n.d.). *Summary of the Energy Policy Act*. Retrieved from https://www.epa.gov/laws-regulations/summary-energy-policy-act.
[172]Solar Energy Industries Association. (n.d.). *Renewable Energy Standards*. Retrieved from http://www.seia.org/policy/renewable-energy-deployment/renewable-energy-standards.
[173] Ibid.
[174] Ibid.
[175] Ibid.
[176]North Carolina Utilities Commission. (2008). Renewable energy and energy efficiency portfolio standard.
[177] Ibid.
[178] North Carolina Public Utilities Commission. (2012). Annual Report Regarding Renewable Energy and Energy Efficiency Portfolio Standard in North Carolina.".
[179] Ibid.

general REPS requirements, they are not expected to meet the swine waste set-aside requirements.[180] As a result, the North Carolina Utilities Commission has issued a moratorium on the implementation of the 2015 swine waste set-aside requirements, as it has done every year since 2012.[181] Upon further review by the NCUC, swine waste set-aside requirements were reduced to 0.07% for 2017-2018, 0.14% for 2019-2021, and 0.20% for 2022.[182]

Carbon Offsets

Carbon offsets refer to the reduction of one unit of CO_2-equivalent of greenhouse gases emitted in one place in order to compensate for emission of that unit in another place. Offsets projects must be real (an actual reduction in offsets relative to the baseline), permanent (not reversible), additional (the reduction would not have been made absent the intervention), verifiable, and enforceable. Carbon offsets initiatives allow governments and other institutions to achieve greenhouse gas emissions reduction goals and even achieve carbon neutrality.[183] Carbon offsets initiatives can thus serve as a funding mechanism for projects like the installation of waste-to-energy technology at livestock operations. These initiatives can serve as partial funding for waste management technologies.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a program administered by the USDA's Natural Resources Conservation Service (NRCS) that provides financial and technical assistance to producers seeking to implement conservation practices on their agricultural land. Financial assistance is provided through cost-sharing or incentive payments. All farmers are considered on a first come, first serve basis, but selections are made based on predetermined priorities and ranked criteria established by local Soil and Water Conservation Districts.[184] These priorities can range from projects that reduce nonpoint source pollution to habitat conservation. Soil and Water Conservation Districts select priorities based on local issues of concern and in response to initiatives promoted in the Farm Bill.

Currently, there are existing initiatives that would favor projects that implement animal waste technology. There is a National EQIP Initiative that "[p]rovides financial assistance to implement approved conservation practices in annually designated regions to address significant agricultural air quality resource concerns such as greenhouse gas emissions, air borne particles,

[180] Ibid.
[181] Ibid.
[182] American Biogas Council. (2015, August 7). *Biogas State Profile: North Carolina*. Retrieved from https://www.americanbiogascouncil.org/State%20Profiles/ABCBiogasStateProfile_NC.pdf.
[183] Goodward, J., & Kelly, A. (2010). *Bottom line on Offsets*. The World Resources Institute, 10 G Street, NE Suite 800 Washington, D. C. 20002 USA.
[184] USDA. (n.d.). *Environmental Quality Incentives Program | NRCS North Carolina*. Retrieved February 17, 2017, from https://www.nrcs.usda.gov/wps/portal/nrcs/main/nc/programs/financial/eqip/.

and other air pollutants."[185] In North Carolina, this translates into prioritizing anaerobic digesters, closure of abandoned waste impoundments, waste facility covers, and waste management systems. Waste-to-energy technologies might also receive support as a part of the on-farm energy initiative, which helps fund energy audits and implementation of some energy efficiency practices. While at the local level, priorities include projects addressing water quality and soil erosion at CAFOs.[186]

The NRCS also provides technical support by prescribing Conservation Practice Standards, with which producers must comply to receive EQIP cost-share funds. Each field office has a technical guide, which provides information tailored to its specific geographic location on a wide array of practices. Many of the Conservation Practice Standards guide waste management in terms of amendments for the treatment of agricultural waste, anaerobic digesters, compost facilities, and more.[187]

USDA Repowering Biofuels Initiative

The USDA is charged with organizing the Repowering Assistance Program. This program works to promote renewable energy use by providing funding for biorefineries to install renewable biomass systems for heat and power for their facilities. There are, however, some caveats. Applications are accepted only from July 25 - October 24 of each year, providing a small window to apply. Furthermore, funding is limited to 50% of the project costs and there is a maximum award amount updated every year in the annual federal register notice. In 2016, the maximum funding is $500,000. Therefore, in cases where fund seekers need more than 50% funding or if 50% funding is greater than the maximum allowed contribution, this program may not be ideal. Lastly, the USDA's match is limited to the costs of construction. The agency will not fund any type of system maintenance once the system is in place.[188]

Public Utilities Regulatory Policy Act

The Public Utilities Regulatory Policy Act, in part, seeks to provide incentives that encourage renewable energy development across the country. Several different mechanisms to reach this goal exist in the act. First, Standard Offer Contracts are agreements between individual energy producers and larger industry powers, such as Duke Energy. These contracts allow for facilities that produce up to 5 MW to sell this energy directly to the grid.[189] Furthermore, in North

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[185] Ibid.
[186] Ibid.
[187] USDA. (n.d.). *Conservation Practices | NRCS*. Retrieved February 17, 2017, from https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849.
[188] USDA. (n.d.). *Repowering Assistance Program | USDA Rural Development*. Retrieved from https://www.rd.usda.gov/programs-services/repowering-assistance-program.
[189] Duke Energy (2015). NC Standard Option Toolkit. Retrieved from https://wwwint.progress-energy.com/carolinas/business/renewable-energy/sell/nc-sell-all-toolkit.page.

Carolina renewable energy producers may enter into Power Purchase Agreement (PPA) with Duke Energy to sell the energy they produce, either at a Standard Option price or at a Negotiated PPA. In order to qualify for the Standard Option, a facility must produce under 5 MW, be a designated Qualifying Facility (a status delineated by PURPA), and be fueled by renewable sources (animal waste is included).[190] Facilities that produce up to 80 MW of renewable energy can meet the designation of a Qualifying Facility, pending the certification process. Additionally, facilities that produce under 1 MW can be self-certified as a qualifying facility.

Current Waste-to-Energy Projects in North Carolina

Despite the many policies discussed above that touch on waste-to-energy projects, these projects are not yet well established in North Carolina. But North Carolina holds a lot of potential for future waste-to-energy projects. NC is ranked third in the nation for methane production from biogas sources by the American Biogas Council.[191] Estimates on the number of swine farms suitable for biogas projects range from 529[192] to 939[193] to 1,179[194]. The expected energy yielded from the projects ranges from 766[195] to 1,121[196] thousand MWh annually.

Some biogas projects are already underway in North Carolina. As of September 30, 2016, there were 16 swine (and 15 poultry) biomass renewable energy facilities registered with the North Carolina Utilities Commission. Four Duke Energy plants have also registered as renewable energy facilities to begin generating electricity with biogas from swine/poultry sources.[197]

VII. Solutions

Analysing the problems of animal waste management leads to several categories of potential solutions. These include: mandating or encouraging producers to implement new technologies; incentivising producers to manage waste more efficiently; updating and clarifying regulation on waste management practices; and increasing consumer pressure on the industry through eco-labeling, public education campaigns, and other means. In weighing these solutions, it is

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[190] Duke Energy (2015). Sell Renewable Energy. Retrieved from https://wwwint.progress-energy.com/carolinas/business/renewable-energy/sell/index.page?.

[191] American Biogas Council. (2015, August 7). *Biogas State Profile: North Carolina*. Retrieved from https://www.americanbiogascouncil.org/State%20Profiles/ABCBiogasStateProfile_NC.pdf.

[192] Ibid.

[193] EPA. (2011, Nov.) Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities at Table 3. https://www.epa.gov/sites/production/files/2014-12/documents/biogas_recovery_systems_screenres.pdf.

[194] Wicker, M. (n.d.). *Swine Farm Anaerobic Digester Bio-Gas Renewable Energy Project*. Retrieved from https://c.ymcdn.com/sites/www.ncsafewater.org/resource/collection/4251BFF9-9A46-46DD-A1C4-8A83FC72727F/ST_Mon_AM_0950_Wicker.pdf.

[195] Ibid.

[196] EPA. (2011, Nov.) Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities at Table 3. https://www.epa.gov/sites/production/files/2014-12/documents/biogas_recovery_systems_screenres.pdf.

[197] NCUC, Docket E-7 Sub 1086, Docket E-7 Sub 1087, NCUC, Docket E-2 Sub 1098, Docket E-2 Sub 1099. Available at: http://starw1.ncuc.net/NCUC/portal/ncuc/page/Dockets/portal.aspx.

helpful to take a comparative approach, analysing which solutions have been effective and ineffective when applied to similar issues in the past, and in different regions. This project will compare the efficacy of strategies in Brazil, China, the Netherlands, South Africa, and New Zealand and Australia, evaluating both the status quo, and economic, social, and environmental policy impacts in these countries.

The criteria for potential solutions consists of evaluating economic and technological feasibility, then weighing risks versus benefits. It is necessary to understand not only which waste-to-energy technologies currently exist, but also which ones are the most efficient and cost-effective. Effective implementation is also crucial. Questions include whether government should be involved, or whether action by private organisations and nonprofit groups is sufficient. If government action is deemed necessary, the extent of involvement must be determined, in addition to whether intervention be state or federal. Another major issue of implementation is whether to pursue a negative policy approach--imposing taxes on firms not using WTE technologies--or a more positive approach, using tax breaks and subsidies to encourage WTE technologies. Target audience must also be evaluated to decide whether to concentrate efforts on producers (firms and farmers), or consumers. This question is crucial in determining which method of implementation will be most effective.

Target Audience

Targeting a particular segment of the population with efforts and resources to affect animal waste management practices will determine which solutions are the most efficient, and how they are best implemented. If targeting industry producers, changing current regulation and incentive structures through government action would be the priority. By contrast, if targeting consumers, non-governmental mechanisms--including awareness and marketing campaigns--would likely be more effective at inducing change.

Targeting producers, and focusing on the supply side rather than the demand side, provides a smaller target group of people to influence than all consumers buying the industry's products. However, it takes a long time for the preferences of consumers to be changed and then that change needs to be followed by the producers. Rather, the solution could start at the source initially or offer a combined approach for both the consumer and the producer. Recently, Smithfield released a statement of intent to reduce emissions by 25% in the next eight years.[198] This pledge indicates Smithfield's willingness to change its poor environmental practices, something that could bode well for producer-side collaboration.

[198] Clark, J. (2016, December 30). Smithfield Pledges To Cut Emissions By 25 Percent | WUNC. Retrieved from http://wunc.org/post/smithfield-pledges-cut-emissions-25-percent.

Targeting consumers may also be an efficient way to effect change given the political constraints of increasing regulation to create changes on the production side. For example, in 2014 the meat industry spent $4.1 million on lobbying and $1.7 million on political candidates.[199] In addition, mandating certain WTE infrastructure could arguably slow the rate of technological advancement by reducing incentives for companies to compete for market-share. Furthermore, the 2015 Nielson Global Survey on Corporate Social Responsibility reported that 66% of respondents globally were willing to pay more for "socially responsible" products, suggesting that there would likely be a market for WTE-responsible products.[200] A new "eco-label" for products could be created that incorporates emissions and adoption of waste-to-energy technology, or alternatively, this information could be amalgamated into an existing label. The latter approach has been taken in Sweden, where products can only be branded "Organic" if their energy inputs are below a certain level.[201]

One consumer-based proposal to encourage the use of waste-to energy technology is an eco-label that incorporates the waste output associated with products. This concept is predicated on the success of current ethical labels such Fair Trade, which has 1.65 million farmers globally.[202] Paul Rice, CEO of Fair Trade USA, argues that strong demand for Fair Trade products is representative of a broader desire among consumers for "transparency and traceability" over "where their stuff is coming from" and "what the impact is on the environment".[203] Increasing consumer demand for transparent information about how food was produced has been shown further in recent French proposals to have compulsory origin labelling for meat and dairy products.[204] An attempt to apply increased consumer demand for information to waste-to-energy through labeling would need to address several questions. These include: whether a binary or sliding scale is more effective; whether a broad or targeted approach has more potential impact; who would fund, regulate and control the labeling process (and whether there is any scope for a system of peer-review); whether it would be led by NGOs, government or the private sector; and finally, whether the WTE would be more impactful as a standalone label or if amalgamated into a pre-existing category.

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[199] The Center for Responsive Politics. (n.d.). *Meat processing & products: Background*. Retrieved from http://www.opensecrets.org/industries/background.php?ind=G2300

[200] Nielson. (2015, October). *Consumer-Goods' Brands That Demonstrate Commitment to Sustainability Outperform Those That Don't*. Retrieved from http://www.nielsen.com/us/en/press-room/2015/consumer-goods-brands-that-demonstrate-commitment-to-sustainability-outperform.html.

[201] Czarnezki, J. J. (2011). The Future of Food Eco-Labeling: Organic, Carbon Footprint, and Environmental Life-Cycle Analysis.

[202] Fairtrade International. (n.d.). *Impact & Research*. Retrieved from https://www.fairtrade.net/impact-research.html

[203] Gunther, M. (2011, September). *Fair Trade: Even in tough times, growing fast*. Retrieved from http://www.marcgunther.com/fair-trade-even-in-tough-times-growing-fast/.

[204] Hopkinson, J. (2016, July). *French labeling decree for meat, dairy alarms food industry*. Retrieved from http://www.politico.eu/article/french-labeling-decree-for-meat-dairy-alarms-food-industry/.

Although taxation (as proposed in Denmark to reduce red meat consumption)[205] can be effective in shifting consumer preferences, consumer-led change can also be brought about independent of government intervention through NGO/private-sector campaigns, such as the Whole Foods 5-Step Animal Welfare Rating.[206] The Whole Foods system ranks meat products according to the standards of animal practices, giving consumers convenient access to reliable information and helping them to make informed choices. Consumer-based campaigns gather traction through free market competition. Once one store adopts a certain label and consumers start to recognize and select products with that label, other stores adopt the same standard in order to compete for business and maintain their market share.

Beyond the scope of labels, consumer awareness campaigns have also been effective in changing preferences. In Australia, for example, education campaigns have reduced the rate of smoking by focusing on target audiences to create persuasive and memorable messages.[207] The '5 a Day' public education campaign initiated by the California Department of Health Services in 1988 has promoted fruit and vegetable consumption.[208] The campaign slogan has become internationally-known, spreading to countries including the UK. By 1994, more than 700 industry organizations and 48 states were participating.[209] By establishing a mutually-beneficial partnership between public health and agriculture, the campaign has reached diverse sectors of the population, including children and Latino adults. In Australia, Sanitarium, a private food sales company, introduced a 'Meat Free Monday' campaign to increase sales of meat-free products.[210] The idea has since spread to countries including the UK, demonstrating that effective, widespread campaigns can be initiated by the private sector as well as government. These lessons could be applied when creating an educational campaign around waste-to-energy technology.

Information Provision

A natural conclusion to the previous sections of this paper is that before any policy can be properly implemented, a general understanding of the opportunities of alternative technologies must be shared by stakeholders in the swine industry. Such an understanding would not be built from the ground up, but would instead rely upon current intuitions and realities facing

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205 Withnall, A. Denmark ethics council calls for tax on red meat to fight 'ethical problem' of climate change. *Independent.co.uk*. https://goo.gl/YX1m0u.

206 Whole Foods Market. (n.d.). *5-Step® Animal Welfare Rating*. Retrieved from http://www.wholefoodsmarket.com/mission-values/animal-welfare/5-step-animal-welfare-ratin1.

207 Cotter, T. & Durkin, S. Examining the effectiveness of public education campaigns. *Tobaccoinaustralia.org.au*. https://goo.gl/R83cfs.

208 Foerster S.B., Kizer K.W., Disogra L.K., Bal D.G., Krieg B.F., & Bunch K.L. (1995). California's "5 a day--for better health!" campaign: an innovative population-based effort to effect large-scale dietary change. doi:pubmed.gov https://www.ncbi.nlm.nih.gov/pubmed/7632448#.

209 Ibid.

210 Ryan, R. (2005). Aussies urged to go meat-free on Monday. *B & T Weekly*, 1. Retrieved from http://proxy.lib.duke.edu/login?url=http://search.proquest.com/docview/195558976?accountid=10598.

stakeholders to make information both relatable and compatible to various groups. Such important bulwarks of this collective understanding would include awareness of the challenges posed by the current industry, the advantages and disadvantages of alternative waste technologies, and the current policies that can help farmers transition their waste management systems. Additional information can be collected and disseminated, and it can be targeted not only at the farmers themselves but also at the communities surrounding hog operations, policymakers, and larger meat corporations such as Smithfield.

When disseminating information, a key question is who the relevant stakeholders are to swine CAFOs and the potential alternative technologies. The most obvious stakeholders are the farmers who implement the technology and the manufacturers who produce the technology. However, it is apparent that there are many others who would be interested in potential alternatives for CAFOs, including community members affected by the health impacts of CAFOs; policymakers; large corporations that contract with individual farmers; consumers of CAFO products; those buying the byproducts of a certain WTE technology; and those interested in the environmental effects of CAFOs. It would be important to emphasize how these interests are incorporated when structuring informative projects released to the public, as certain areas may be more persuasive to certain groups.

Such information campaigns would include virtues of the above information, and specific applications to farmers. Ideally, this information would be easily understandable, and provide sufficient detail for farmers, policymakers, and consumers to make educated decisions as to how to proceed with regard to technology. This could take the form of a website with various tabs pertaining to each area of CAFOs and important considerations with regard to waste management systems.

While this paper has focused mainly on North Carolina, the scalability of technology across the U.S. and even national borders is an important notion to consider. In the upcoming months, certain questions still need to be answered. Our focus needs to shift to an international lens, researching various countries and their current management practices. If their practices are more successful than our own, how can we integrate it into the framework in the United States? If it is not more successful than our own, what recommendations for the mitigation of greenhouse gases with animal waste management can we offer? With an international framework, we can have more insight on current systems and possible changes. We plan to research other countries viable for technology or for even other forms of technology that could be implemented in the U.S., and research states other than North Carolina, with different technological and energy incentives.

VIII. Conclusion

In sum, animal waste management by intensive animal operations needs to change. The current system poses environmental and public health threats. Some of the public health risks are localized, burdening surrounding communities. Other risks are globalized, such as the emission of greenhouse gases. There is a wide array of policies that affect CAFO waste management practices, but none effectively address these problems. As we move forward we will evaluate alternative animal waste management systems and technologies according the criteria developed in this paper. We will also look to how producers can take advantage of the policies that do exist to make transitioning to those alternative waste management systems less burdensome. Importantly, we will seek to inform consumers, along with producers, to create a demand for change.Our next step, the comparative analysis of other countries' systems and policies relative to the United States, will provide us with insight into the questions posed above.

Appendix: Descriptions of Existing Technologies

Scrapers

Though not all of the research used to establish Next Generation Technologies is available, there is significant information on scraper systems. A Premium Standard Farms study, done in partnership with the Iowa State University, compared an automated scraping system with tip-tank flushing systems for use at swine barns with shallow pits. Flushing systems use water (or lagoon effluent) to flush the waste out from underneath the barns, usually to a collection tank that is then pumped into a lagoon. A tip-tank system flushes the pits automatically once the tank is filled to a certain volume. The scrapers also operate automatically, mechanically scraping the waste underneath the barns to a drainage pipe, which leads to the lagoon.[211] Compared to deep pit systems, scraping systems greatly reduce ammonia, odor, hydrogen sulfide, and greenhouse gases. Retrofitting deep pit farms for scrapers requires modifying the pits, however, which is very expensive.[212]

Anaerobic Digester with Aeration Basin

Loyd Ray Farms uses a waste management system that reduces environmental impacts, generates renewable energy, and produces carbon offsets.[213] The key technologies employed are

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[211] Strobel, B. et al. (2009). Daily Cleaning Options for Sloped Manure Pits in Swine Finishing. *Agricultural and Biosystems Engineering Conference Proceedings and Presentations.* Paper 103. http://lib.dr.iastate.edu/abe_eng_conf/103.

[212] Maurer, D. et al. (2016). Summary of Performance Data for Technologies to Control Gaseous, Odor, and Particulate Emissions from Livestock Operations: Air Management Practices Assessment Tools (AMPAT). Data in Brief, 2016, vol.7, 1413-1429. http://www.agronext.iastate.edu/ampat/storagehandling/uf/homepage.html.

[213] Adair, C.W. et al. (2016).Design and Assessment of an Innovative Swine Waste to Renewable Energy System. *American Society of Agricultural and Biological Engineers* 59(5) 1-10. DOI: 10.13031/trans.59.11731.

an anaerobic digester and an aeration basin. The waste is flushed out from under the barns into the anaerobic digester. The anaerobic digester is a clay basin fortified with bentonite and topped with a polyethylene cover.[214] The cover prevents oxygen from entering the digester, creating anaerobic conditions. Under these conditions microbes break down organic matter and release biogas, which is captured by the cover of the digester. The biogas is then conditioned and sent to a microturbine, which generates electricity used for on-farm operations.[215] Any excess methane is flared off. By burning the methane, it is converted into carbon dioxide, a much less potent greenhouse gas. The waste in the anaerobic digester is then transferred into an aeration basin where it undergoes nitrification and denitrification. This converts the ammonia into nitrogen gas which can be released into the atmosphere, reducing the overall nitrogen content of the waste. Then the wastewater is cycled back to flush out the barns. Excess water is stored in the former lagoon until it is used to irrigate crops.

“Orbit” High Solids Anaerobic Digestion (HSAD)

This technology works like a typical mesophilic anaerobic digester. The unique feature of the HSAD technology is that it uses thermophilic anaerobic digestion and bacteria that can adapt to 54.40 degrees Celsius. This allows digestion of waste with higher solid concentrations of 35-40%. Under these conditions, anaerobic microbes engage in synergistic interactions that enable them to be more effective. Notably, this was performed off-site using “SuperSoils” waste that was already treated to minimize its nutrient content.[216]

“BEST” Fluidized Bed Combustion of Solids

Two versions of the “BEST” waste management system were studied. Both employ technology to separate solid waste with dry matter content of 30% or higher from the liquid waste flushed from barns. This reduces the organic content of the liquid waste that must undergo further treatment, and provides manure solids that can be used in other ways. This study used fluidized bed combustion tests to determine the energy value and emissions of the solids, and tested the resulting ash for value as a fertilizer.

The first version uses a screw-press separator (FAN® Separator (USA), Inc.) followed by tangential flow gravity-settling tanks (TFS system) (QED Occtech of Australia).[217] This was used

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[214] Ibid.
[215] Ibid.
[216] Bull, L. S., Cook M. (2004). Environmentally Superior Technology ORBIT/”HSAD” On-Campus Report. Retrieved from http://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/phase1/A.7ORBIT%20final.pdf.
[217] Westerman, P., Ogejo, J. A., (2004). Biomass Energy Sustainable Technology Performance Verification (Solids/Liquids Separation). Retrieved from http://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/phase1/A.2BEST%20final%20pw.pdf.

at a farm with five barns that were each flushed 2-4 times a day, housing 3,320 pigs. The flushed manure flows to a collection pit, and then flows to an above-ground tank where it is pumped to a screw press separator. The separator uses a screen to separate out the solids that are dropped into a bag for testing. The liquid gravity flows to an above-ground tank where it is pumped into the TFS system.[218]

The second version uses a screen and hydraulic press separator[219] followed by the TFS system. This was used on a farm with two barns that are flushed daily, and have 2,448 pigs at steady state. The flushed waste collects in an underground tank and is pumped to the Filtramat system. First, separated solids migrate down sloping concave screens into a hopper. Next the solids are fed into a chamber to be pressed by a hydraulic screw press. Then the pressed solids are dropped onto a conveyor, and dropped into a bag. Liquid waste gravity flows to the TFS system.[220]

The TFS system uses tangential flow to concentrate the solids in the center and gravity to settle the solids at the bottom of the cone shaped tank. It also uses small amounts of fresh water to wash down the solids. From there the settled solids are pumped to a different tank for sludge thickening. Then the sludge is pumped back to the screw-press separator/hydraulic press. The remaining liquid gravity flows to the stabilization and treatment ponds where it is eventually recycled to flush the barns.[221]

<u>“RE-CYCLE” Gasification of Solids</u>

This system uses belt manure removal to separate the solids from the liquid waste. The solids are then burnt in a low-oxygen environment to release gases like methane, carbon monoxide, and hydrogen. The gases are collected and used to make fuel-grade ethanol. The resulting ash contains minerals, suggesting it may be used as a fertilizer or as a feed supplement for the pigs. Any pathogens would have been destroyed during gasification due to the high temperature.
The study was done at North Carolina State University. The liquid waste receives treatment in a sequencing batch reactor.[222]

<u>“Super Soils” Processing System</u>

Since the start of the Smithfield Agreement study, the Super Soils technology has been improved upon twice. The latest version is called Terra Blue, and is described in the next section.

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[218] Ibid.

[219] Filtramat TM separator made by Denitral of France and marketed in North America by Environgain of Quebec, Canada.

[220] Williams, M., Boyd, L. D. G., Miller, M. D., & Westerman, P. W. (2004). BIOMASS ENERGY SUSTAINABLE TECHNOLOGY PERFORMANCE VERIFICATION (SOLIDS/LIQUIDS SEPARATION).

[221] Ibid.

[222]Koger, J. B., van Kempen, T., & Wossink, G. A. (2003). Belt manure removal and gasification system to convert dry manure thermally to a combustible gas stream for liquid fuel recovery. *Animal and Poultry Waste Management Center. North Carolina State University, Raleigh, North Carolina*.

The "Super Soils" system was used at a farm with 4,000 hogs. It begins by separating the solid waste from the liquid waste using a flocculating agent. The solids are taken offsite, composted, used in a fertilizer blend, bagged, and sold for off farm use. The liquid waste receives further treatment. Nitrogen is removed from the waste as it circulates between one tank with aerobic activity that denitrifies the waste and another tank with nitrifying bacteria that nitrifies the waste. Most of the treated liquid waste is then stored until it is used to recharge the pits underneath the barns. But some of the liquid waste is treated for soluble phosphorous removal.

"Terra Blue" System

This system used solid-liquid separation, biological nitrogen removal, and disinfection and phosphorus removal unit processes to treat swine waste. It was implemented on a farrow-to-finish operation with 1,200 sows and 12,960 hogs. The sows were housed in barns that are flushed multiple times a day. The other barns used a pit recharge system to remove the waste once a week.

The waste from the flushed barns flows to a decanting tank that concentrates the solids. Then the waste flows into a homogenization tank where it is mixed with waste from the recharge pit system. Next the waste is pumped into a tank where it is injected with polymer flocculants and the solids are separated from the liquid waste via a rotary press. The dewatered solids, biological sludge, and phosphorus sludge are removed and taken off site for use in fertilizers. The liquid waste cycles between a denitrification tank and a biological module containing high performance nitrification bacteria (HPNS), which removes nitrogen from the waste. Then the waste goes through a clarification treatment, and is stored to flush or recharge the pits under the barns. Some of the wastewater goes on to be treated with lime, which separated the phosphorous from the waste and disinfects the effluent. The phosphorus treated water is stored in a former lagoon and used for crop irrigation. The phosphorous precipitate is looped back to the solid separation unit and leaves the farm with the manure solids.[223]

"AgriClean" Mesophilic Digester and "AgriJet" Flush System

The AgriClean technology system was employed at a farm with 12 barns and 11,520 hogs. Seven of the barns were flushed using gravity flow, and five were flushed using water pressure from the AgriJet system. Each day the barns were flushed, sending the waste to an underground tank where it is pumped to a fixed-film mesophilic digester. The AgriClean Digester sends the captured methane to be flared off – where it is burned and converted to carbon dioxide. The undigested and settled solids in the digester are pumped first to a settling tank, and then to a

[223] Vanotti, M., Hunt, P., Rice, M., Kunz, A., & Loughrin, J. (2013). Evaluation of generation 3 treatment technology for swine waste-A North Carolina's Clean Water Management Trust Fund project. Final Environmental Performance Report for the Director, NCSU Animal and Poultry Waste Management Center. 50 pp.

screw press separator for additional solid removal. The removed solids are land applied. The remaining liquid is brought to a lagoon.[224]

Innovative Sustainable Systems Utilizing Economical Solutions, "ISSUES"

The first ISSUES technology is the RENEW System, which uses a mesophilic digester, a microturbine generator, aeration and a wastewater filtering, and disinfection systems. The waste flows from an underground tank to the digester. The digester produces biogas to fuel the microtubrine, generating electricity. From there, the waste flows to a polishing storage basin, then to an aerobic digester where it undergoes nitrification. Some of the waste returns to the polishing basin and is either recycled to flush the barns or land applied. But some of the waste flows to a sand carbon filters and reverse osmosis filtration system. Then it is disinfected using ozonation and ultraviolet light, and used as drinking water for the pigs.

The second technology is a patented permeable lagoon ("Bio-Cap ML"). The waste flows from the barns to the covered anaerobic lagoon, which reduces ammonia emissions and odor. Next the waste flows to an aerated nitrification pond, and then to a denitrification/irrigation storage pond until it is used to flush the barns or applied to land.

The third technology is an aerobic blanket. Instead of covering the lagoon with a permeable cover, it covers it with a layer of aerated water. Like the permeable cover, the aerated layer reduces ammonia emissions and odor.[225]

"Environmental Technologies" Closed Loop Technology

The closed loop technology system was employed at a farm with 3,700 hogs. The waste is flushed to an equalization tank, where it is pumped onto an inclined-screen separator. The separated solids are land applied or used in compost. The liquid waste is injected with a polymer flocculant and sanitizer/disinfectant, and then pumped into a settling tank. The flocculated solids settle to the bottom. The liquid waste is reused as flush water. Any excess liquid undergoes filtration, aeration, and is blended with well water to meet a solids content concentration level that meets the human drinking water standard. This serves as drinking water for the hogs.[226]

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[224]NC State Animal and Poultry Waste Management Center. (n.d.). *AgriClean Technology*. Retrieved from https://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/technologies/phase3-agriclean.pdf.
[225] Bull, L. (2004). ISSUES Innovative Sustainable Systems Utilizing Economical Solutions. Retrieved from http://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/technologies/phase2-issues.pdf.
[226] (2004). Closed Loop Technology. http://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/technologies/phase3-closed%20loop.pdf.

Integrated Bioresource Recovery System

The bioresource recovery system integrates anaerobic digestion, biofilter nitrification, and greenhouse tomato production to manage hog waste. The study was done at Barham Farm that has 4,000 hogs.

The waste first flows from pits underneath the barns to an ambient-temperature in-ground anaerobic digester with an impermeable cover. The digester produces methane which fuels a generator producing electricity for the farm. Heat from the generator is also captured and used for on-farm use. The digester and methane recovery and utilization system were constructed under the U.S. Environmental Protection Agency AgSTAR Program prior to the Smithfield Agreement study. Then the waste flows to a lagoon. Some of the effluent then goes through nitfrication biofilters, which convert the ammonia into nitrate and produce nitrified water. The nitrified water is used to recharge the pits underneath the barn every eight days, which otherwise would have wastewater denitrifying into odorless nitrogen gas. The remaining lagoon effluent is used to fertilize plants and vegetables grown in on-site greenhouses via an automated irrigation system. Excess lagoon effluent is land-applied.[227]

Manure Solids Conversion to Insect Biomass

This Manure Solids Conversion system uses black soldier fly larvae to digest swine manure. The waste is placed concrete pits that have edges sloped at 45-degree angles. At the top of the pit, there is a gutter with an attached bucket. The larvae are put in with the waste, and will digest the manure until they become prepupae. At that life stage, they will crawl up the slopes, fall into the gutter, and then fall into the bucket. The digestion process cuts the amount of manure in half. The residue is dry, has a lower nutrient content, is less odorous, and is 42 percent protein and 35 percent fat. The residue could be used to feed swine, poultry and fish.[228]

Sequence Batch Reactor

The Sequence Batch Reactor was used on a farm with 10,800 hogs, but the technology was designed to treat waste from 2,700 animals. The barns are flushed repeatedly throughout the day, and the waste is collected in a tank. Once a day the tank is pumped to the sequencing batch reactor.

The Sequence Batch Reactor is an open-top concrete tank with aerators and mixers, that cycles the waste through aerated conditions and anoxic conditions. Under aerated conditions, microbes convert the ammonia in the waste to nitrate. Under anoxic conditions, the nitrate is converted to

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[227] Cheng, J. J., Peet, M. M., & Willits, D. H. (2005, October). Ambient temperature anaerobic digester and greenhouse for swine waste treatment and bioresource recovery at Barham Farm. In *ANIMAL WASTE MANAGEMENT SYMPOSIUM.*

[228] Sheppard, C. et al. (2004). Manure Solids Conversion to Insect Biomass (Black Soldier Fly Project). Retrieved from http://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/technologies/phase-2-soldier-fly.pdf.

nitrogen gas and released into the air. Microbes concentrate phosphorus into their microbial cell mass throughout that process. The waste is then pumped into a lagoon. Notably, the solid wastes have a high phosphorous content, and the liquid wastes have a low nutrient content. This suggests it would pair well with a solid/liquid separation in place of using a lagoon.[229]

Solids Separation/Constructed Wetlands System

The Solids Separation and Constructed Wetland System was used on a farm with 3,520 hogs. First the waste is flushed from the barns and screened for solids. The solids are used off-farm. Next the waste flows through 8 acres of constructed wetlands, where microbes in the root-zone of plants convert ammonia into nitrogen gas. From there, the waste flows to an irrigation pond.[230]

Ekokan Up-flow Biofilter

The Ekokan LLC waste treatment system was used on a farm with 16,000 hogs, but only treats waste from 4,000 hogs housed in five barns. First the waste goes through a screening process that removes large solids, and then the liquid waste flows to an equalization tank. Next the liquid waste flows up through four biofilters, which are supplied with air via blowers at the bottom. The biofilters contain a substrate for a biofilm of bacteria that biologically degrade organics, odor, and convert ammonia into nitrate. The effluent then gravity flows to a storage tank where it is rerouted back to the solid separation basin or used to recharge the barn pits.[231]

Solids Separation/Reciprocating Wetland

The Solids Separation and Reciprocating Wetland system is used on a farm with 1,600 hogs. It uses earthen, synthetically lined wetland basins to remove nitrogen from the waste. The basins are filled with gravel, which serve as substrates for microbes. The waste flows from the barns to a settling tank that removes solids. The liquid waste continues on, to be pumped back and forth between the wetland basins. As the waste fills one basin, anaerobic conditions take hold and denitrification occurs. As the waste is pumped out of the basin, aerobic conditions take hold and nitrification occurs. After six days, the liquid waste is recycled to flush the barns, and excess is applied to land.[232]

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[229] Classen, J., Liehr S. (2004). Sequencing Batch Reactor. Retrieved from http://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/technologies/phase2-batch-reactor.pdf.

[230] Humenik, F. J., Classen, J., Liehr, S., & Baird, C. (2003, October). Solids separation/constructed wetland system. In *Virtual Farm Tours. Animal Waste Management Workshop. October* (pp. 16-17)

[231] Westerman, P., Ogejo, J. A., (2004). Ekokan Up-flow Biofilter. Retrieved from http://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/technologies/phase1-upflow-biofiltration-ekokan.pdf.

[232] Rice, M. (2004). Solids Separation-Reciprocating Wetland. Retreived from https://www.bae.ncsu.edu/topic/waste-mgmt-center/smithfield-project/technologies/phase1-reciprocating-wetland.pdf.