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Sustainable biogas conversion: A solution to hog waste pollution and environmental degradation in Sampson County, North Carolina

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Abstract

The hog farming industry in North Carolina is among the largest in the United States, contributing substantially to the state's economy while also imposing significant environmental and social costs. The concentration of large-scale farms in rural counties, particularly in Sampson County, results in severe externalities, including air and water pollution, declining property values, and disproportionate health impacts on low-income communities. The current manure management system, which relies on open-air lagoons and waste spraying, has led to documented cases of respiratory illness and water contamination. This research explores the feasibility of a sustainable solution through biogas energy conversion, which could mitigate odor pollution, lower energy costs, and restore property values. By integrating biogas facilities into existing infrastructure and partnering with energy providers, I propose a cost-effective model that enhances sustainability while ensuring economic viability. This paper examines the environmental, economic, and policy aspects of implementing biogas solutions, arguing that transitioning from traditional waste disposal to renewable energy can create long-term benefits for both local communities and the agricultural industry.

Keywords: Sustainable Energy Solutions; Environmental Sustainability; Renewable Energy; Public Health Impact; Agricultural Policy; Waste-to-Energy Technology

1. Introduction

North Carolina is one of the top hog-producing states in the country, with Iowa being the largest producer. The industry generates approximately $10 billion annually and supports over 40,000 jobs. Despite these economic benefits, hog farming has led to severe environmental challenges, particularly in rural areas like Sampson County, where large-scale concentrated animal feeding operations (CAFOs) dominate the landscape. The current waste management system relies on open lagoons and waste spraying, leading to significant air and water pollution. The disproportionate impact on marginalized communities in these regions raises concerns about environmental justice, public health, and economic stability. This paper explores the environmental and economic consequences of hog farming and evaluates the feasibility of implementing biogas conversion as a solution to mitigate these challenges.

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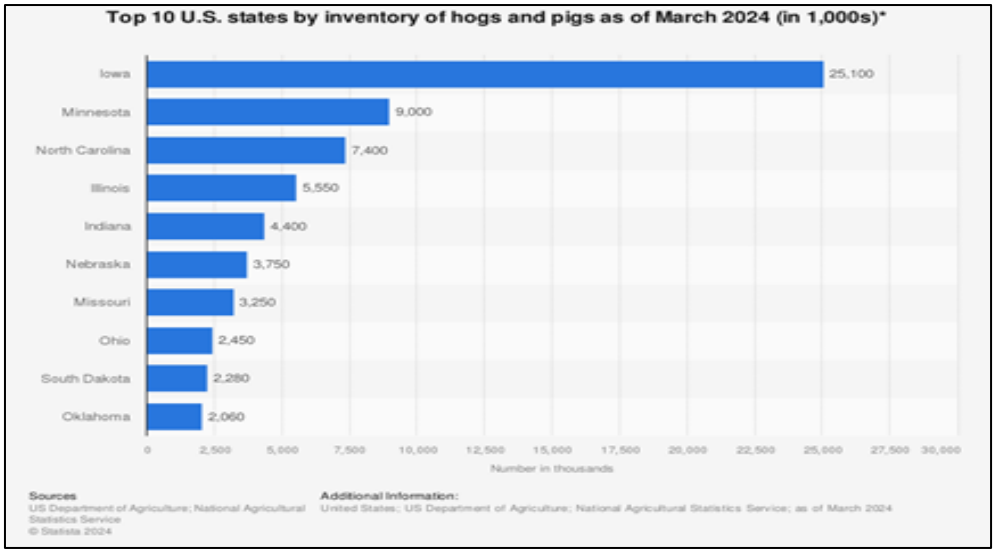

Figure 1 Graphic showing the top 10 Hogs and Pigs producing states and the number of Hogs and Pigs in each

2. Environmental and Health Impacts of Hog Farming

Hog farming in North Carolina produces millions of pounds of manure annually. The traditional method of manure management, which involves storing waste in open-air lagoons and spraying it onto fields as fertilizer, has resulted in widespread pollution. A single 220-pound pig produces approximately 11 pounds of manure daily, leading to an annual waste output of 88 million pounds in North Carolina. The decomposition of manure releases harmful gases, including ammonia, hydrogen sulfide, and methane, which contribute to respiratory illnesses such as asthma, bronchitis, and chronic lung diseases. Additionally, these pollutants degrade air quality, leading to long-term environmental damage.

Water contamination is another critical issue associated with hog farming. Rainfall events often lead to waste runoff, introducing high levels of nitrogen and phosphorus into nearby water bodies. This process contributes to algal blooms, fish kills, and the deterioration of drinking water quality. Studies have demonstrated that communities near CAFOs experience higher rates of waterborne illnesses, further exacerbating public health concerns.

Figure 2 Flood damage to manure farms, displaying massive hog waste runoff

Beyond environmental and health impacts, the presence of hog farms also diminishes property values in surrounding communities. According to a Duke University study, homes located near industrial hog farms experience devaluation by up to 30 percent. For many residents, homeownership represents their largest financial asset, and declining property values limit opportunities for wealth accumulation and economic mobility.

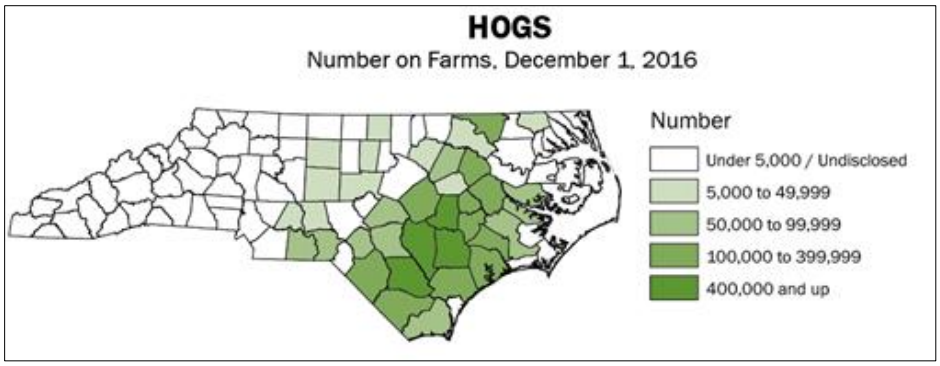

Figure 3 Graphic displaying number of hogs per NC county

3. Economic Cost of Hog Farming

The external costs of hog farming in North Carolina extend beyond health impacts. The estimated financial burden of premature deaths, healthcare expenses, and property value declines results in an aggregate external cost of approximately $11.2 billion. This estimation is based on excess mortality rates, lost income due to illness, and reductions in property value. Premature deaths in NC hog farming counties result in an estimated $1.5 billion in lost income. Additionally, the presence of hog farms reduces property values by an estimated $9.7 billion.

The financial ramifications of this industry impact not only those residing in affected areas but also the broader economic framework of the state. Diminished property values reduce tax revenues, leading to funding shortfalls for schools, infrastructure, and public services in communities already struggling with economic instability. Furthermore, the decline in home prices discourages new businesses and residents from moving into affected areas, exacerbating cycles of poverty and disinvestment.

A study conducted on communities living near CAFOs found that residents had an excess mortality rate of 93 deaths per 100,000 individuals. The cumulative income loss from these premature deaths amounts to approximately $1.5 billion. The cost of hospitalizations, treatments for chronic respiratory illnesses, and medical visits further compounds this financial burden. Given that many affected individuals lack adequate healthcare coverage, this leads to additional economic strain on state and federal health systems, diverting taxpayer dollars toward preventable medical costs.

Additionally, the loss in property values results in further economic disadvantages, limiting residents' ability to relocate or invest in alternative housing options. Many homeowners are unable to sell their homes due to plummeting property prices, forcing them to endure poor living conditions, deteriorating infrastructure, and declining quality of life. The inability to escape these conditions disproportionately affects historically marginalized groups, including Black, Latinx, and Indigenous communities, exacerbating racial wealth disparities.

Job markets in regions with high concentrations of hog farms are also adversely affected. While hog farming provides employment, the economic benefits are skewed toward large corporate entities rather than local communities. Many hog farms operate under contract farming agreements with large agribusiness corporations, leaving small farmers with limited financial autonomy and little ability to negotiate for better wages or working conditions. The low wages and physically demanding nature of hog farm labor contribute to economic precarity among workers, many of whom are from immigrant backgrounds.

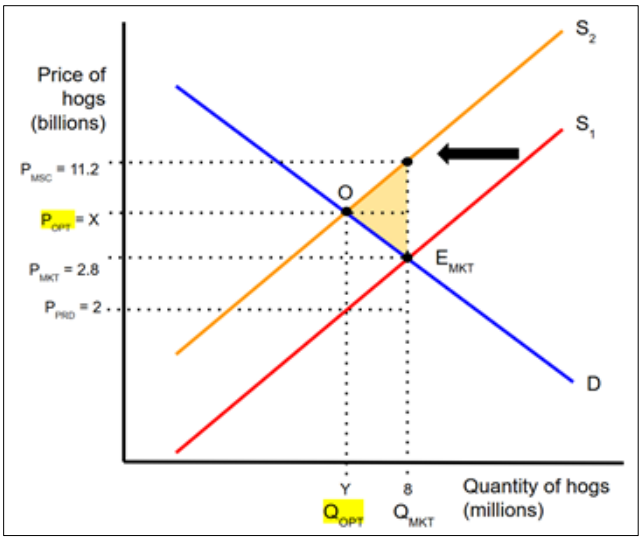

Figure 4 Graphic displaying market shift needed to reduce negative externality

Addressing these externalities is essential for fostering a more equitable and sustainable agricultural economy. Implementing solutions such as stricter waste management policies, transitioning to biogas conversion, and providing economic support to affected communities could help mitigate these costs. Policymakers must prioritize environmental justice initiatives, including financial assistance for homebuyers in affected regions, increased regulation of corporate agricultural entities, and targeted investments in alternative industries that can generate sustainable employment opportunities. Without proactive intervention, the economic cost of hog farming will continue to weigh heavily on North Carolina's residents and financial systems, perpetuating environmental and economic inequality.

4. Biogas Conversion as a Sustainable Solution

The proposed solution to mitigate the negative impacts of hog farming involves the conversion of hog waste into biogas energy. This process involves the installation of anaerobic digesters, which capture methane emissions from manure and convert them into renewable natural gas. Biogas conversion offers several environmental and economic benefits, including odor reduction, greenhouse gas mitigation, and the generation of renewable energy.

Anaerobic digestion is a natural process in which microorganisms break down organic matter in the absence of oxygen, producing biogas composed primarily of methane and carbon dioxide. The captured methane can then be refined into a cleaner, more sustainable energy source. The utilization of anaerobic digesters not only helps reduce the emission of potent greenhouse gases but also provides a sustainable method for managing hog waste, replacing environmentally harmful lagoon systems.

The implementation of biogas facilities within existing hog farms provides a dual advantage: it reduces methane emissions while creating an alternative revenue stream for farmers. By partnering with energy providers such as Duke Energy, biogas can be integrated into existing infrastructure, reducing transportation and distribution costs. This strategy aligns with North Carolina's renewable energy goals and enhances the economic viability of rural communities.

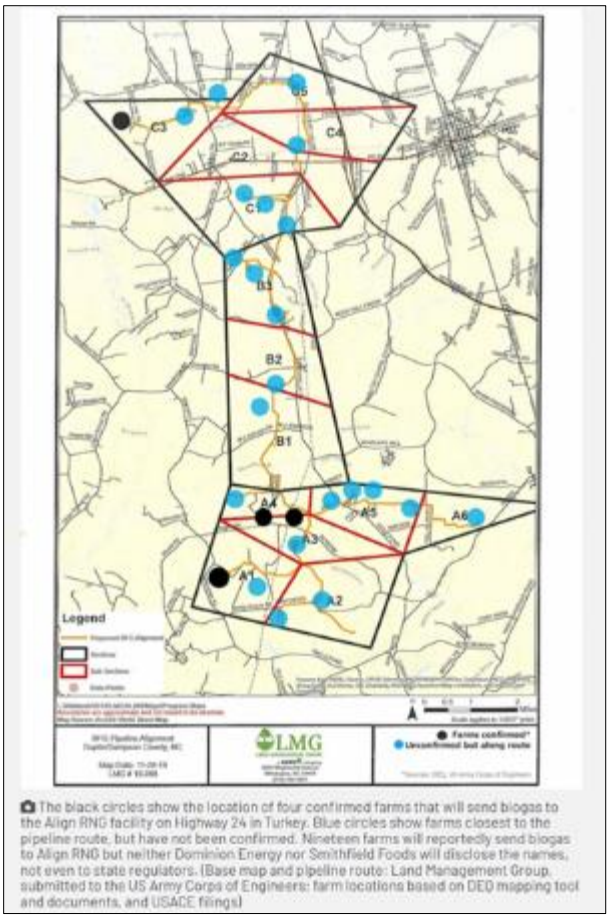

Figure 5 Graphic displaying farms in position to convert waste to biogas in the future

Additionally, biogas conversion offers economic incentives for hog farmers. The captured biogas can be sold to energy companies, creating a secondary source of income for farm owners. This financial model makes biogas conversion a more appealing and feasible investment. Furthermore, farmers can use the byproducts of anaerobic digestion, known as digestate, as nutrient-rich fertilizer, enhancing soil quality and improving crop yields.

From an environmental perspective, transitioning to biogas energy has a substantial impact on reducing odor pollution. One of the most significant complaints from residents living near hog farms is the overwhelming stench caused by manure decomposition. By processing manure in sealed digesters rather than open-air lagoons, the release of noxious gases is minimized, leading to improved air quality and enhanced community well-being.

In terms of feasibility, North Carolina has already taken steps toward biogas development. The state's Renewable Energy Portfolio Standard (REPS) mandates the integration of renewable energy sources, including biogas, into the energy grid. Various pilot programs have demonstrated the viability of biogas technology, showcasing its potential for large-scale implementation. Policy incentives such as tax credits, subsidies, and grants for farmers willing to adopt biogas technology can further accelerate the transition.

However, challenges remain in the widespread adoption of biogas technology. Initial costs for anaerobic digesters and infrastructure upgrades can be substantial. Construction and maintenance costs vary depending on farm size, manure output, and transportation logistics. To make biogas conversion more accessible, state and federal governments must continue to provide financial assistance and regulatory support.

Despite these challenges, the long-term benefits of biogas conversion outweigh the drawbacks. By addressing environmental hazards, creating economic opportunities, and aligning with renewable energy mandates, biogas conversion presents a viable, forward-thinking solution for the hog farming industry. As the demand for sustainable energy sources increases, the adoption of biogas technology in North Carolina can serve as a model for other states struggling with similar agricultural externalities.

5. Policy and Regulatory Considerations

The successful implementation of biogas conversion requires compliance with state and federal regulations. The North Carolina Department of Environmental Quality (DEQ) oversees permitting requirements for biogas facilities. As part of the 2021 Farm Act, new general permits were established to regulate anaerobic digesters on hog farms. These permits include provisions for waste management plans, air quality monitoring, and environmental impact assessments. These regulations ensure that the transition to biogas energy maintains strict environmental standards and does not inadvertently create new sources of pollution or inefficiencies.

Figure 6 Graphic displaying hog farm concentrations in NC Counties

To facilitate the transition to biogas, policymakers must provide financial incentives, such as tax credits and grants, to offset the initial capital investment required for digesters. The high upfront costs of anaerobic digestion technology and biogas infrastructure can be a barrier for many farmers. By offering targeted subsidies, low-interest loans, and tax incentives, the state and federal governments can help lower financial risks and encourage widespread adoption.

Additionally, strengthening community engagement efforts can enhance public support and ensure that the benefits of biogas projects are equitably distributed. Transparency in project planning and community input in decision-making are crucial to gaining acceptance. Local leaders, farmers, and residents must be actively involved in discussions about how biogas facilities will impact their communities, including potential economic benefits and any environmental concerns. Public awareness campaigns, town hall meetings, and stakeholder partnerships can further facilitate smoother transitions.

Moreover, regulatory frameworks must ensure that biogas conversion remains both an environmentally and economically sustainable solution. Permitting processes should be streamlined to encourage investment while maintaining rigorous environmental safeguards. Provisions must also be in place to regulate the fair pricing of biogas and its integration into the existing energy grid, ensuring that energy providers purchase biogas at competitive rates. Collaboration between the public and private sectors will be essential in creating policies that balance the interests of agricultural producers, energy companies, and affected communities.

An important policy consideration is ensuring that smaller, independent farmers have access to the same biogas conversion opportunities as large agribusinesses. Without specific regulatory protections, major corporate farming operations may monopolize the benefits of biogas conversion, leaving smaller farms struggling to compete. Programs should be developed to promote equal access to biogas technologies and financial support mechanisms, including cooperatives where small farmers can pool resources for shared infrastructure.

Finally, future policy development should focus on expanding research and innovation in biogas technology. State and federal agencies, in partnership with universities and private industry, should invest in research initiatives aimed at improving the efficiency of anaerobic digestion, reducing costs, and finding new applications for biogas byproducts such as biofertilizers. Incentivizing ongoing technological advancements will ensure that biogas remains a viable, scalable solution for the long-term sustainability of North Carolina's hog farming industry.

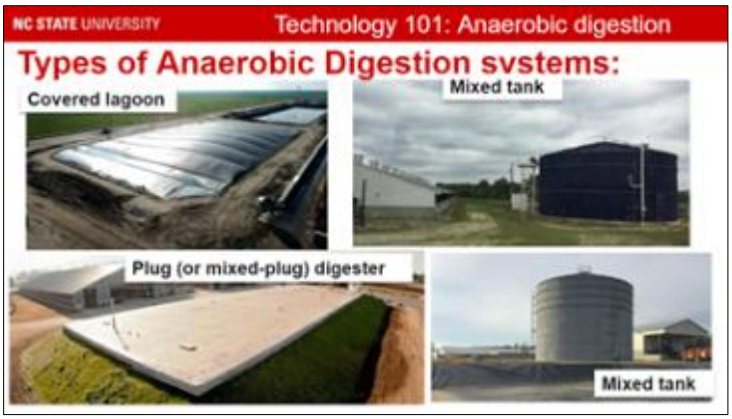

Figure 7 Graphic displaying different methods used for Anaerobic digestion

6. Cost Analysis and Feasibility

Despite the upfront costs associated with biogas infrastructure, long-term financial benefits make it a viable solution. The primary cost components include:

Infrastructure development: Estimated between $1 million and $5 million, depending on scale. This includes the construction of anaerobic digesters, piping, and storage systems required to handle methane capture and processing efficiently.

Permit and regulatory compliance: Estimated between $10,000 and $50,000. Compliance costs cover the legal requirements for environmental assessments, waste management plans, and integration into the energy grid.

Community engagement initiatives: Estimated between $10,000 and $25,000. Outreach programs, education campaigns, and public meetings ensure that local communities understand the project's benefits and potential concerns.

Annual maintenance and operation: Estimated between $100,000 and $200,000. This includes routine monitoring, equipment repairs, labor costs, and ongoing regulatory reporting to ensure system efficiency and compliance.

By leveraging existing infrastructure and securing partnerships with energy providers, the overall costs can be reduced. Integrating biogas facilities into Duke Energy's grid, for example, can reduce transportation and distribution expenses while ensuring a stable market for the produced gas. Cooperative financing models, where multiple farms share the costs of biogas conversion and distribution, can further improve economic viability.

While initial investment costs may appear prohibitive, financial incentives and long-term returns make biogas conversion an attractive alternative to traditional waste management. Federal and state grants, tax credits, and private-sector partnerships can help offset capital expenditures. Carbon credit programs may also provide revenue opportunities, as farms that reduce methane emissions can sell carbon offsets to industries looking to meet sustainability goals.

Additionally, cost savings arise from reduced environmental cleanup expenses. The elimination of open-air waste lagoons minimizes the risk of contamination-related lawsuits and regulatory fines, which have historically cost the industry millions of dollars. Health-related savings should also be considered, as reducing air and water pollution translates to lower medical costs for nearby residents, decreased absenteeism in schools and workplaces, and overall improved public health outcomes.

Figure 8 Hog waste runoff entering ocean in NC

An analysis of similar projects implemented in other agricultural regions, such as California and Denmark, indicates that biogas conversion pays for itself within a 10- to 15-year period. As technology advances and economies of scale improve, operational costs are expected to decline further, making widespread adoption more feasible.

The estimated monthly energy cost for residents would remain within the range of $110-$130, ensuring affordability while promoting sustainability. In some cases, residents may even see lower utility bills due to the increased availability of locally produced renewable energy. Future cost reductions could also arise from improvements in methane capture efficiency and advancements in biogas processing technology.

Overall, while the upfront expenses for biogas conversion may seem substantial, the long-term economic and environmental benefits far outweigh the costs. Investing in biogas technology will not only create a more sustainable and economically resilient hog farming industry but will also serve as a blueprint for other agricultural regions facing similar environmental challenges

7. Conclusion

Transitioning from traditional hog waste management to biogas conversion represents a critical step in addressing the environmental, economic, and public health challenges associated with hog farming in North Carolina. By capturing methane emissions and integrating renewable energy solutions, biogas conversion can mitigate odor pollution, reduce health risks, and restore property values. This research highlights the importance of policy intervention, community engagement, and strategic partnerships in implementing sustainable waste management practices. With proper investment and regulatory support, Sampson County can serve as a model for the future of environmentally responsible agriculture.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Academy, K. (2020). Khan academy annual report 2020: Adoption trends in schools [Accessed January 2025].

[2] Anderson, R., & Kumar, R. (2021). AI in education: The role of personalization in driving learning outcomes. Artificial Intelligence in Education, 25(1), 89–105.

[3] Brown, E., & Miller, J. (2020). Policy innovation and market equity in the edtech sector. Journal of Policy and Innovation, 17(3), 215–230.

[4] Chen, M., & Zhao, K. (2022). The role of government subsidies in shaping edtech market competition. Journal of Policy and Technology, 18(4), 305–325.

[5] Environmental Racism in Hog Farming. (2024). Vox.

[6] Hog Inventory. (2024). USDA Agricultural Statistics.
[7] How turning hog waste into biogas does more harm than good. (2022). Energy News.
[8] Medical Journal Article on Health Consequences of Hog Farming. (2024). NC Medical Journal.
[9] NC Agriculture Statistics. (2024). USDA Agricultural Statistics.
[10] NCpedia article on Hog Farming. (2024). NCpedia.
[11] Research article on if hog farms cause disease in NC neighborhoods. (2024). NIH National Library of Medicine.
[12] Research Study that proved Smithfield controls 90% of Hog farming in NC. (2024). NC Global Economy.
[13] Example of this being done in California. (2024). California Department of Food and Agriculture.
[14] Data on Job Production and Economic Output. (2024). John Locke Foundation.
[15] Census data showing how many people live close to CAFOs. (2024). Environmental Working Group.
[16] High Costs and Interconnection Obstacles for Swine Gas-to-Electricity in Sampson County. (2024). NC Newsline.
[17] Land and Economic Devaluation Due to Hog Farming. (2024). University of Wisconsin Press.