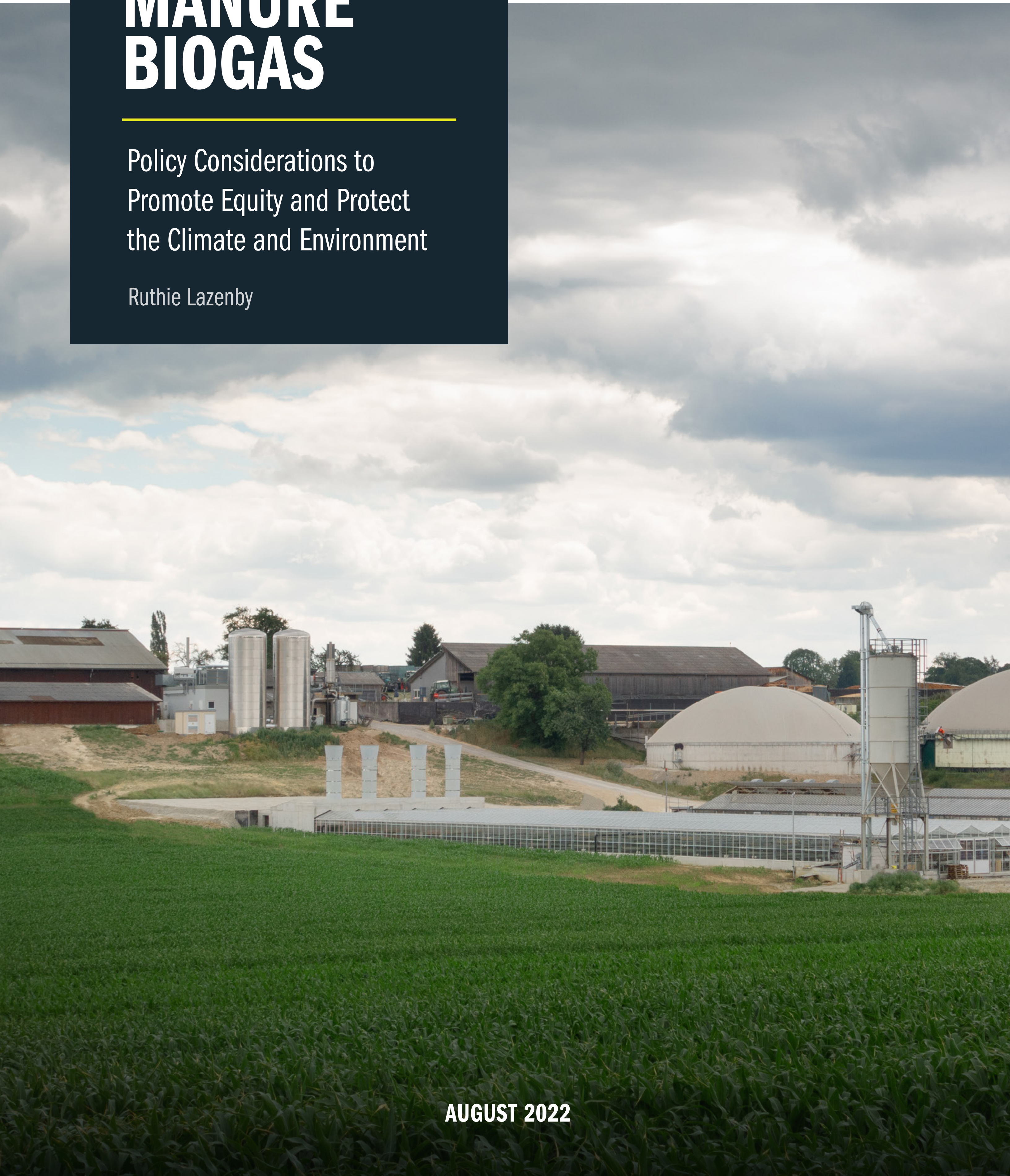
VERMONT LAW & GRADUATE SCHOOL | CENTER FOR AGRICULTURE & FOOD SYSTEMS

RETHINKING MANURE BIOGAS

Policy Considerations to Promote Equity and Protect the Climate and Environment

Ruthie Lazenby



AUGUST 2022

AUTHORS & ACKNOWLEDGMENTS

This report was produced by the Center for Agriculture and Food Systems at Vermont Law and Graduate School. The author of this report is **Ruthie Lazenby** (she/her), LLM Fellow and Staff Attorney at the Environmental Justice Clinic at Vermont Law and Graduate School.

This report was made possible with support from the National Agricultural Library, Agricultural Research Service, US Department of Agriculture. The report benefited from significant writing, input, and editing support from several members of the Center for Agriculture and Food Systems at Vermont Law and Graduate School, including **Laurie J. Beyranevand**, Director and Professor of Law; **Lihlani Nelson**, Associate Director and Research Fellow; **Claire Child**, Assistant Director and Research Fellow; **Whitney Shields**, Project Manager; and **Molly McDonough**, Environmental Communications Specialist.

About the Center for Agriculture and Food Systems

Vermont Law and Graduate School's Center for Agriculture and Food Systems (CAFS) uses law and policy to build a more sustainable and just food system. In partnership with local, regional, national, and international partners, CAFS addresses food system challenges related to food justice, food security, farmland access, animal welfare, worker protections, the environment, and public health, among others. CAFS works closely with its partners to provide legal services that respond to their needs and develop resources that empower the communities they serve. Through CAFS' Food and Agriculture Clinic and Research Assistant program, students work directly on projects alongside partners nationwide, engaging in innovative work that spans the food system. Please visit www.vermontlaw.edu/cafs to learn more.

Cover photo source: Photo 139746937 © Robert Schneider | Dreamstime.com

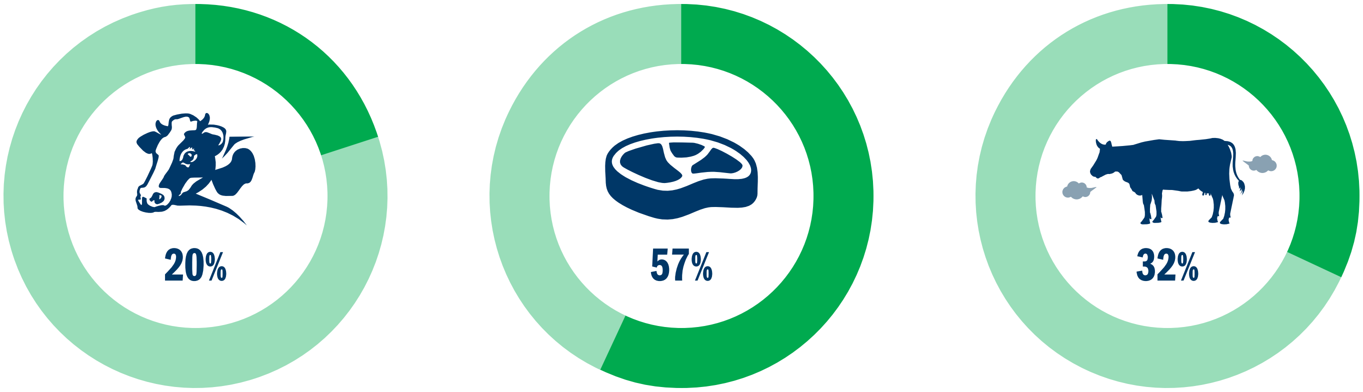
TABLE OF CONTENTS

INTRODUCTION

THE WORLD IS ON TRACK TO EXCEED A 2° C INCREASE DURING THE 21ST CENTURY, an outcome scientists have described as catastrophic.[1] Direct impacts on the food and agriculture sectors will be far-reaching.[2] Already, climate-related impacts to farming include "observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones."[3] These changes impact both crop and livestock production. Experts predict that further warming will continue to dramatically affect the "global water cycle and its variability, global monsoon precipitation and the severity of wet and dry events."[4]

In regions like eastern North Carolina, home to the United States' top two pork producing counties,[5] producers will experience more regular hurricanes of greater magnitude.[6] California's Central Valley, which provides cropland for over 250 different crops[7] and houses 80 percent of the state's milk cows,[8] already relies on the second most over-pumped aquifer in the nation while facing substantially drier conditions as a result of climate change.[9] These impacts will disproportionately harm vulnerable populations[10] in addition to historically marginalized farmers, who will be the first to lose their livelihoods.[11] Climate change will force agriculture to adapt—either now, through innovation to mitigate increased warming, or later, as regional climates become incompatible with existing models of food production.[12]

It is clear that the food and agriculture sector will bear significant impacts from climate change, but this sector is also a major contributor of greenhouse gas (GHG) emissions. Animal agriculture, in particular, is responsible for approximately 20 percent of global GHG emissions and 57 percent of food related emissions.[13] Animal agriculture's primary contributions to climate change result from methane and nitrous oxide emissions. Methane has a global warming potential 28 to 36 times that of carbon dioxide on a 100-year timescale and nitrous oxide has a global warming potential 265 to 298 times that that of carbon dioxide on a 100-year timescale.[14] Moreover, while emissions from the energy sector have decreased as a result of emission reduction policies, GHG emissions from agriculture have increased over recent decades with this trend projected to continue.[15] Consequently, addressing emissions from agriculture is increasingly critical.



Percent of global greenhouse gas emissions caused by animal agriculture

Percent of global food-based emissions caused by animal agriculture

Percent of global methane emissions caused by livestock manure and enteric fermentation

Source: Food in the Anthropocene: the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems, THE LANCET

One approach to reducing atmospheric GHGs from livestock involves capturing emissions from manure through the use of anaerobic digesters.[16] Proponents of this approach herald it as a win-win. Manure biogas systems reduce GHG emissions by capturing GHGs that would otherwise be emitted and can displace the use of fossil fuels. Additionally, this new fuel source (biogas) creates a new revenue stream from a former waste product. In a 2017 press release announcing federal funding to help farmers construct biogas systems, the United States Department of Agriculture (USDA) articulated the conventional wisdom of the emissions reduction claim, stating:

> "Anaerobic digesters actually provide two-fold greenhouse gas reduction. First, they capture methane that otherwise would be emitted from the manure into the atmosphere. . . . Second, by utilizing the trapped biogas as a renewable energy source, digesters displace the need for additional fossil fuels."[17]
>
> **– LAURA MELLING**

While these claims sound promising, they omit important nuance. **Animal agriculture generates emissions throughout the operation—from land conversion to enteric fermentation (the emissions generated from ruminant burps), to transportation.** It is imperative that policymakers and others recognize that manure biogas systems reduce emissions from only one part of this system—manure management. At the same time, manure biogas systems rely on the ongoing production of large quantities of livestock manure—the source of manure management emissions—to function. Espousing these systems to the exclusion of other emissions mitigation measures can foreclose the potential to make important modifications throughout the livestock life cycle. Ultimately, this reinforces current conventional models of livestock production at the expense of farmers using more sustainable production models.

Currently, policymakers are dedicating increasing amounts of public funding and attention to manure biogas as compared to other policy interventions that can reduce livestock emissions. Recently, the American Biogas Council suggested that the US could support at least another 13,740 potential new biogas systems, including 8,300 on farms, in addition to 4,000

What is Methane?

"Methane is produced as part of normal digestive processes in animals. During digestion, microbes resident in an animal's digestive system ferment food consumed by the animal. This microbial fermentation process, referred to as enteric fermentation, produces CH4 as a byproduct, which can be exhaled or eructated by the animal. The amount of CH4 produced and emitted by an individual animal depends primarily upon the animal's digestive system, and the amount and type of feed it consumes."

Source: Inventory of US Greenhouse Gas Emissions and Sinks (1990-2020), Environmental Protection Agency

What is Enteric Fermentation?

"Enteric fermentation is fermentation that takes place in the digestive systems of animals. In particular, ruminant animals (cattle, buffalo, sheep, goats, and camels) have a large "fore-stomach," or rumen, within which microbial fermentation breaks down food into soluble products that can be utilized by the animal."

Source: AP-42: Compilation of Air Emissions Factors, Environmental Protection Agency

What are Biosolids?

"Biosolids are a product of the wastewater treatment process. During wastewater treatment the liquids are separated from the solids. Those solids are then treated physically and chemically to produce a semisolid, nutrient-rich product known as biosolids. The terms 'biosolids' and 'sewage sludge' are often used interchangeably."

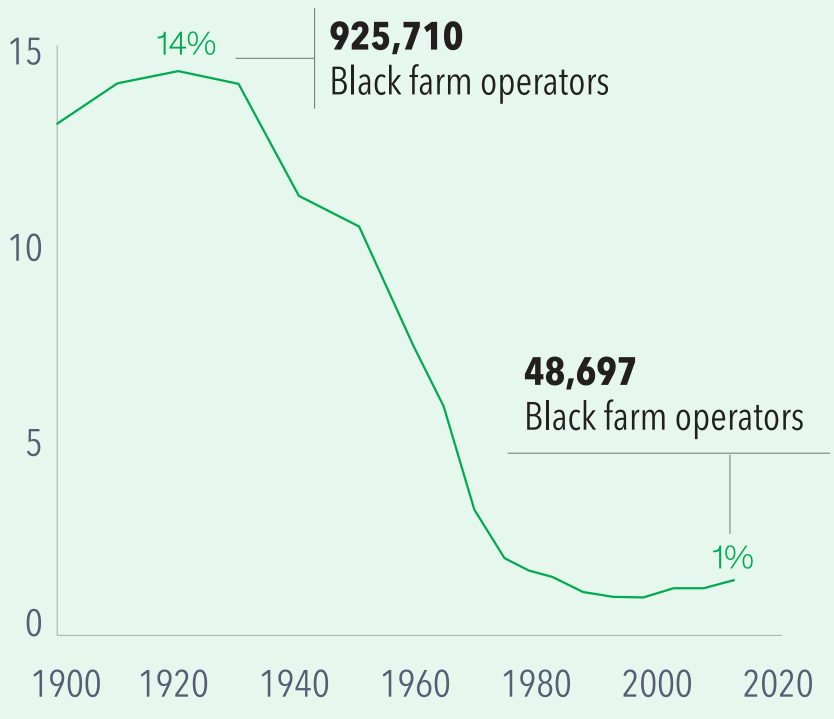
Source: Environmental Protection Agency

for wastewater, 1,000 for food scraps, and 440 for landfills.[18] Biogas systems are expensive to construct and operate. They require substantial investment into long-lasting, durable infrastructure such as pipeline interconnections and facilities upgrades. As more public and private resources are dedicated to this infrastructure, the incentives to continuing using these systems will increase.

To date, many discussions on the benefits of manure biogas fail to account for the concerning and negative implications associated with widespread adoption of manure biogas systems. For example, the climate implications resulting from the need for these systems to engage in long-term production of massive quantities of livestock manure (or other biosolids) to recoup the fixed upfront costs of installation and continued revenue generation is rarely addressed. To illustrate this point, the public programs subsidizing production and sale of biomethane from these operations provide incentives for the ongoing production of the core input—livestock manure—even as climate scientists warn that greater reductions from animal agriculture are necessary.[19] Promoting widespread investment in and adoption of manure biogas systems will inevitably impact livestock agriculture for years, if not decades, into the future, creating potential barriers for more substantial and systemic climate mitigation measures for the sector.

Moreover, because manure digesters are typically feasible only for industrial-scale livestock operations, the largest confined animal feeding operations will reap the financial and public relations benefits that accompany the installation of digesters. This is not a new trend: today and historically, large-scale commercial operations have benefited from the lion's share of federal funding for agriculture. Due to decades of discriminatory lending by USDA,[20] the majority of these operations are owned by white farmers.[21] Racism and discriminatory lending by the federal government over the past century has resulted in a dramatic loss of Black-owned land and farms across the board (one recent analysis calculated this dispossession to total $326 billion).[22] This disparity is even more pronounced for larger agricultural operations.[23] However, in some parts of the country, the substantial environmental impacts generated by these larger agricultural operations disproportionately harm Black, Indigenous, and communities of color.[24]

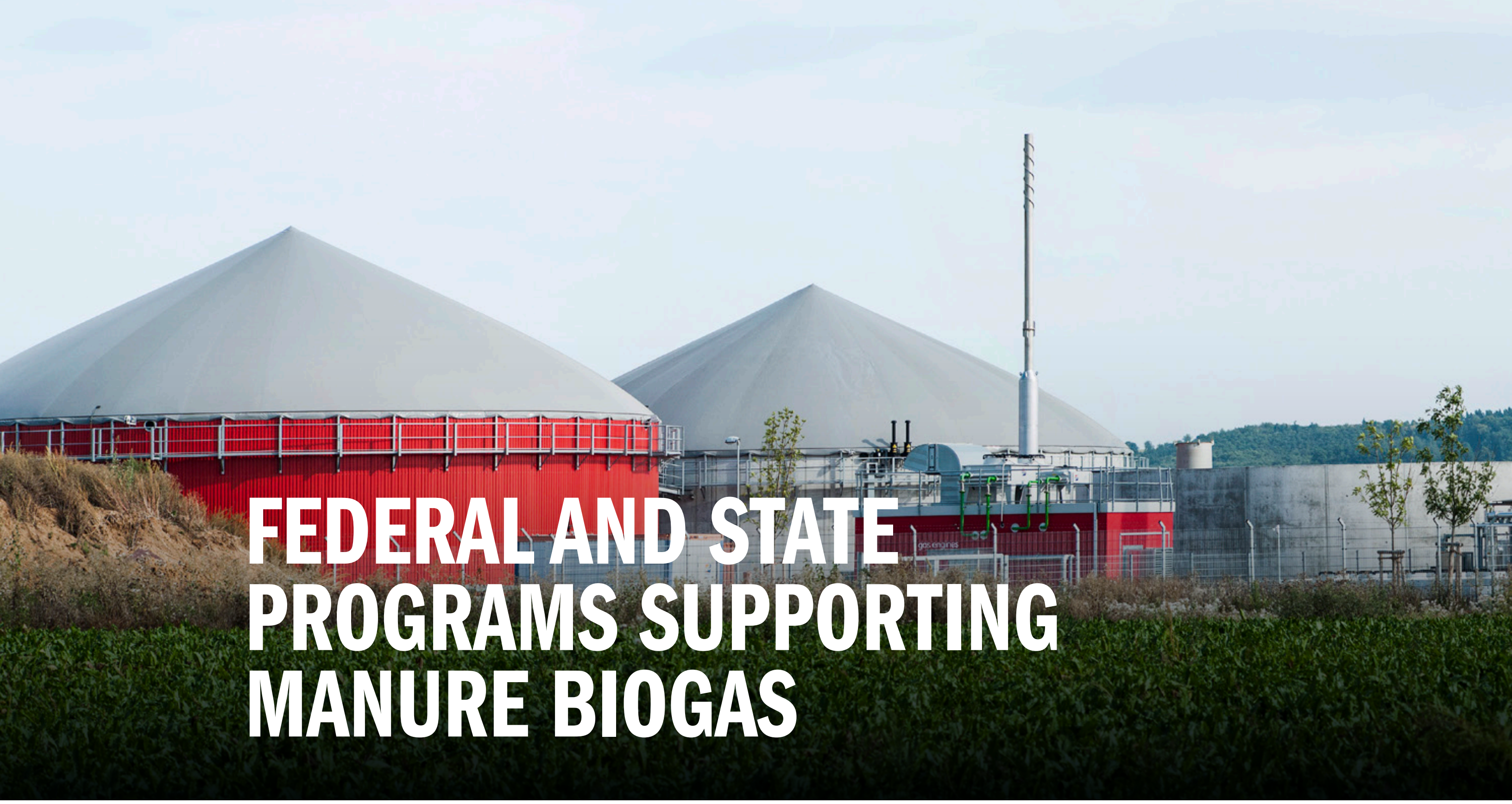
The share of Black farmers has declined significantly over the last century. Today just 1.4 percent of farmers identify as Black.



Source: Black farmers in the US: The opportunity for addressing racial disparities in farming, McKinsey & Company

Anaerobic digesters, in contrast to alternative mitigation measures, are an appealing means to reduce livestock emissions in industrial animal agriculture because they require no change to the structure of conventional livestock operations and manure management. On the contrary, these systems function by ensuring the continuity of both the existing system and its beneficiaries. This fails to consider and plan for the systemic changes needed in conventional operations and manure management due to the current, near, and long-term impacts of climate change.[25] Consequently, policymakers should immediately begin to proactively plan for the future by assessing the full range of suitable mitigation measures and supporting those that will provide for long-term sustainability and climate mitigation. As part of this process, policymakers must also critically evaluate the environmental justice impacts to neighboring communities and equity implications of elevating biogas systems over other mitigation measures.

This report analyzes and evaluates the extensive adoption and support of manure anaerobic digesters with a specific focus on the resulting equity implications, a goal explicitly aligned with two executive orders issued by the Biden Administration—Executive Order 14008: Tackling the Climate Crisis at Home and Abroad[26] and Executive Order 13985: Advancing Racial Equity and Support for Underserved Communities Through the Federal Government.[27] The report begins by surveying existing funding opportunities for manure biogas systems and the fuels they produce. It then addresses the direct environmental impacts of installing and operating these systems, including a brief discussion about the methodology used to account for life cycle emissions. The next section evaluates alternative methods to reduce livestock emissions, indirect environmental impacts of adopting manure biogas as the primary means to reduce GHG emissions from livestock operations, and the equity impacts. The report concludes with a set of recommendations for policymakers and regulators as they consider the role this technology should play in shifting livestock agriculture toward a more equitable, just, and climate-smart model.



FEDERAL AND STATE PROGRAMS SUPPORTING MANURE BIOGAS

THE BIDEN ADMINISTRATION HAS CONSISTENTLY EMPHASIZED ITS COMMITMENT TO CLIMATE-SMART AGRICULTURE and tasked a number of federal agencies with collecting input from stakeholders and developing plans to address the climate crisis.[28] USDA was directed to submit a report to the administration laying out an "agricultural and forestry strategy."[29] In USDA's 90-Day Progress Report on Climate-Smart Agriculture and Forestry,[30] the agency embraced the president's "focus on developing a climate-smart agriculture and forestry strategy that employs proven conservation practices," announced plans to reduce methane from livestock,[31] and significantly funded research efforts targeted at these reductions.[32] With this new momentum, policy attention and interest in manure biogas has never been greater due to the perception that it provides an easy solution to reduce atmospheric emissions without requiring significant changes to the conventional industrial livestock model. This section surveys many of the existing and overlapping funding sources and incentive programs for manure biogas.

Grants & Loans Covering Start-Up Costs

Direct financial support for anaerobic digester systems is available to livestock facilities in the form of grants and loans. At the federal level, the Rural Energy for America Program (REAP) provides guaranteed loan financing and grant funding for the construction of biogas systems.[33] Federal funds for biogas systems can also be obtained through USDA's conservation programs—the Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), and the newer Conservation Loan Program (CLP).[34] While these conservation and energy programs are the most important sources of federal funds for manure biogas, many other programs support the development of the industry. The 2018 Farm Bill's Energy Title alone includes the Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program;[35] the Bioenergy Program for Advanced Biofuels;[36] Biomass Research and Development Program;[37] the Biodiesel Fuel Education Program;[38] and the Carbon Utilization and Biogas Education Program.[39]

USDA encourages livestock operations to "stack" multiple programs. In 2015, USDA stated:

> To coordinate and maximize the potential assistance programs, Rural Development (RD) and Natural Resources Conservation Service (NRCS) met and developed a working partnership to deliver USDA services to producers interested in getting an anaerobic digester for their farming operation.... When "stacking," both RD and NRCS funding mechanisms can be used to assist in funding a project but each has limitations; for instance, the $450,000 cap on EQIP encompasses financial assistance for any practice that the producer wants to implement during the life of the Farm Bill.[40]

The report encourages the 50-50 use of EQIP and REAP funds and provides a detailed breakdown of estimated costs, where the two programs cover the total $1,778,950 required to construct the digester system.

Some states provide a similar suite of programs to fund the installation of manure biogas systems. In California, for example, the Dairy Digester Research & Development Program (DDRDP) provides funding for the installation of dairy digesters.[41] There are many smaller programs that offer grants, such as the Minnesota Department of Agriculture's Methane Digester Loan Program.[42]

The federal 1603 program, "Payments for Specified Energy Property in Lieu of Tax Credits,"[43] provides grants to reimburse businesses for a portion of the cost of installing certain energy projects, including anaerobic digesters on farms.[44] The 1603 program's creation as part of the American Recovery and Reinvestment Act in 2009 was "motivated by difficult economic conditions and the perceived lack of tax-equity capacity to support renewable energy projects" eligible for the tax credits discussed below.[45] While most 1603 funding has gone to wind and solar projects,[46] the program has provided funding for at least 98 projects designated "biomass (open loop, livestock)" for a total of $119,133,949.00 or an average of $1,215,652.54 per operation.[47]

1603 PROGRAM:
Payments for Specified Energy Property in Lieu of Tax Credits

98+
Biomass projects funded

$119,133,949
Total funding for biomass

$1,215,652
Average funding per operation

Private investment is also available to livestock operations seeking funding to install digester systems. As public programs to subsidize manure biogas production proliferate, the industry has become increasingly appealing to private investors. A March 2021 report by Stifel Equity Research laid out the prospects for manure biogas as follows:

> We are bullish on the fundamentals of renewable natural gas (RNG) as it is positive for the environment (net negative carbon form of energy post-combustion), it is economic today (10-60 percent project IRRs), and offers immense growth potential (IEA projects an 18x increase in supply by 2040).[48]

The report noted that the current optimistic forecast for investors is closely linked to the enormous policy supports for this technology:[49]

> The combination of policy ([CA] Senate Bill 1383, requiring reductions in short-lived climate pollutants) and regulatory incentives (both federal and state) have driven the recent inflection in RNG growth. In our view, producers are not in the business of producing RNG; they are in the business of monetizing RNG's environmental attributes through various federal and state programs.[50]

Subsidies & Other Programs That Enhance Revenue from Biogas Sales

In addition to funding sources intended to help livestock operators cover the fixed costs of biogas system construction, state and federal programs subsidize the revenue from biogas production on an ongoing basis.

The Federal Renewable Fuel Standard (RFS), which requires transportation fuels sold in the United States to contain a minimum amount of renewable fuel (a "Renewable Volume Obligation"), is a key source of potential revenue for manure biogas operations. The RFS is a market-based program intended to reduce overall emissions from transportation fuels in the United States. It is structured like a cap-and-trade program, but rather than cap net GHG emissions, the RFS mandates a quota for the amount of renewable fuel that must be incorporated into conventional transportation fuels.

EPA measures the emissions impact of each eligible renewable fuel through the evaluation of fuel "pathways."[51] The pathway for each renewable fuel describes the inputs and processes required, as well as the life cycle GHGs.[52] Renewable fuel producers then apply to EPA for the specific pathways to which their fuel product corresponds. Once approved, these fuel producers can generate renewable identification numbers (RINs), which allow EPA to track and monitor these fuels.[53] Renewable fuels and their corresponding RINs can be sold to producers of conventional fuels so they can meet the quota required by the RFS. Biogas from manure digesters can be used to generate advanced biofuel RINs, coded D5 in the RFS regulation.[54] (77,000 British thermal units are equal to one gallon equivalent or one RIN.[55]) RINs are explicitly allowed to be layered on top of other analogous credits, such as those from California's Low Carbon Fuel Standard.[56]

Meeting the Federal Renewable Fuel Standard (RFS)

EPA measures the emissions impact of renewable fuels by evaluating their fuel "pathway," or the processes required to produce them. Biogas from manure digesters can be used to generate advanced biofuel renewable identification numbers (RINs).

Renewable fuel producers apply to EPA for their product's specific pathway.

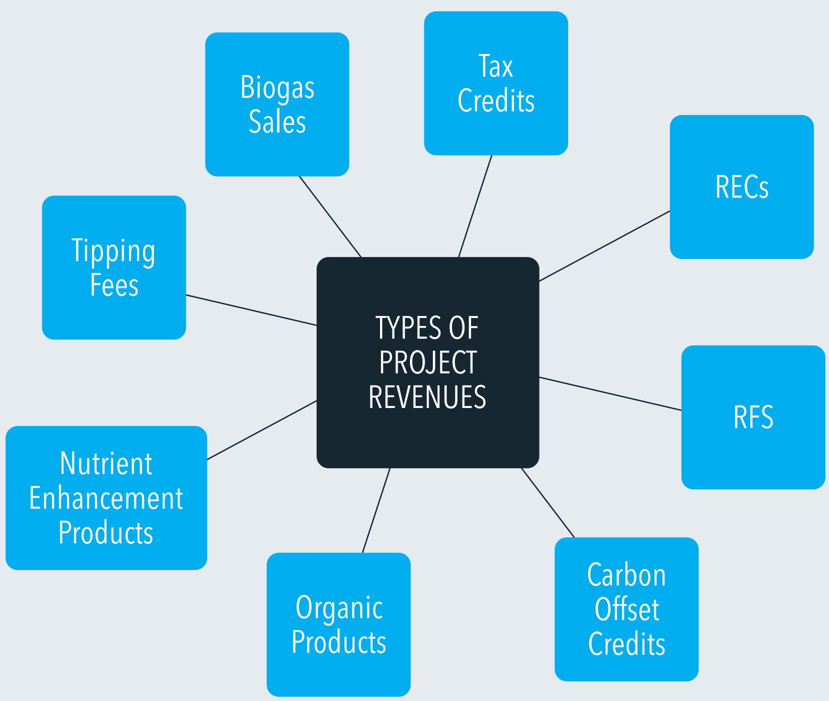
Approved fuel producers generate RINs so EPA can track and monitor their fuels.

RINs can be sold to conventional fuel producers, allowing them to meet the Renewable Fuel Standard.

The federal Advanced Biofuel Payment Program also subsidizes biogas revenue. The program provides quarterly payments "for the actual quantity of eligible advanced biofuel produced during that quarter" to biofuel producers, including refined biogas from farms.[57] Entities that produce and sell biofuels, as defined in 7 CFR § 4288.102, can apply to participate in the program.[58] This program was granted $322,000,000 in mandatory funding between 2009 and 2023, in addition to $80,000,000 of discretionary funding authorized to be appropriated for the program between 2019 and 2023.[59]

In addition to direct payments, the federal government provides tax credits through the Electricity Production Credit and the Investment Tax Credit. Both corporate tax credits reduce energy producers' tax burdens, but while the Electricity Production Credit compensates producers on a per kilowatt-hour basis for renewable energy (including "open-loop biomass"), the Investment Tax Credit reimburses a set percentage of installation costs.[60] Importantly, taxpayers must choose either the Electricity Production Credit or the Investment Tax Credit—they cannot apply for both.

TYPES OF PROJECT REVENUES



[61]

Source: AgSTAR Project Development Handbook, Environmental Protection Agency

At the state level, the Biofuels Investment Tax Credit also allowed companies in Florida to recoup "75% of all capital, operation, maintenance, and research and development costs incurred in connection with an investment in the production, storage, and distribution of biodiesel (B10-B100), ethanol (E10-E100), or other renewable fuel" through 2016.[62] Additionally, industry groups tout California's Low Carbon Fuel Standard (LCFS) as a boon to the biogas industry's profitability.[63] The program creates a tradeable market for credits and deficits, which are allocated to transportation fuel producers based on the carbon intensity of the fuels they produce. Low carbon intensity fuels receive credits, while high carbon intensity fuels receive deficits. Like the federal RFS, California's LCFS program currently designates manure biogas as a negative emissions fuel and, consequently, awards profitable credits for its production.[64] This revenue is allocated to producers on an ongoing basis in proportion to the quantity of fuel they produce. Biogas producers that participate in the LCFS are also explicitly allowed to participate in California's cap-and-trade program, as well as the federal RFS. Like the stacking of USDA and DOE funds described above, layering multiple credits is explicitly described as a benefit.

Ultimately, however, the layering of credits from multiple market-based programs can undermine the additionality of emissions reductions claimed by those programs. Additionality is a term of art used to evaluate whether the policy intervention in question is in fact the cause of a given real-world behavior change. A behavior is not additional if it would have happened with or without the policy intervention. Compensating or crediting nonadditional behaviors, like the production of manure biogas, risks over-incentivizing them and even increasing rather than decreasing overall emissions. While California's LCFS is the most well-developed credit trading program for transportation fuels, other states are developing similarly structured programs, including Oregon's Clean Fuels Initiative program.

Finally, some states are creating reliable markets for these fuels as a source of "renewable energy" through utilities. Where renewable fuels standards like the programs described above focus on transportation fuels, renewable portfolio standards or renewable electricity standards focus on the use of renewable energy sources for electricity generation. These programs typically mandate that a certain amount of energy be derived from renewable sources and define what constitutes renewable sources for the purposes of the program. Much like the RINs in the federal renewable fuel standard, many renewable portfolio standards at the state level implement trading programs using renewable electricity certificates (RECs). State programs vary, but they usually include manure biogas as a renewable energy source.[65]

Considered collectively, these funds represent potential windfalls for operations well suited to the installation of manure biogas systems. But, smaller, less established operations, or operations that use dry manure management systems or grazing systems are unlikely to benefit from these funds, even though their models may be more climate smart overall in accord with the Biden Administration's stated goals and objectives.

More Information on Funding for Manure Biogas

- *Federal and State Laws and Incentives*, Alternative Fuels Data Center, https://afdc.energy.gov/laws/search
- U.S. Env't Protection Agency, AgStar Handbook, https://www.epa.gov/sites/default/files/2014-12/documents/agstar-handbook.pdf#page=81
- Cal. Dep't of Food and Agriculture, *Dairy Digester Research and Development Program Report of Funded Projects (2015-2019)* (April 2020), https://www.cdfa.ca.gov/oefi/ddrdp/docs/DDRDP_Report_April2020.pdf
- Cal. Public Utilities Comm'n., *Bioenergy Feed-In Tariff Program* (SB 1122), https://www.cpuc.ca.gov/SB_1122/

ANAEROBIC DIGESTERS CAN IMPOSE NEW ENVIRONMENTAL HARMS

TO PRODUCE BIOGAS FROM MANURE, farming operations must install an anaerobic digester, typically by capping or covering an existing manure lagoon to create an oxygen-free environment in which bacteria can break down organic matter. Biogas is a byproduct of this process. These systems offer some climate benefits (namely capturing methane and converting it to carbon dioxide during combustion) but their installation and use can also add new environmental harms. Such harms depend on a range of factors, including:

- the scale of the operations;
- the geography of the site;
- existing cumulative impacts to air and water;
- the end use of the biomethane; and
- the management of digestate (a byproduct of anaerobic digestion).

Through the process of anaerobic digestion, animal manure undergoes chemical changes that result in the production of a mix of gases, solid digestate, and liquid effluent. Biogas can be combusted to generate electricity on-site or exported as electricity and sold to the grid or at wholesale rates. The gases can be further "upgraded" to biomethane, which has a range of potential uses. Biomethane can be used on-site, injected into a pipeline, or used as a transportation fuel (when compressed to produce compressed natural gas).[66]

Through the process of anaerobic digestion, animal manure undergoes chemical changes that result in the production of a mix of gases, solid digestate, and liquid effluent.

Photo source: 20120717-OSEC-RBN-8338 by US Department of Agriculture is licensed under CC BY 2.0.

Anaerobic System Design & Technology

There are several process steps that can be used alone or in combination to treat and manage manure. This diagram illustrates the elements of a biogas recovery system.

Source: Anaerobic System Design and Technology, Environmental Protection Agency

Organic Waste Collection System
collects waste in a way that is compatible with biogas recovery

Organic Waste Handling System
stores and pretreats organic waste(s)

Anaerobic Digester
a system in which anaerobic digestion can occur to produce biogas and other useful coproducts

Coproducts
Separation, Treatment, and Storage

Solid Coproducts
include fiber-based products, fertilizer, compost, soil amendments, bedding

Liquid Coproducts
include fertilizer, flush water, concentrated fertilizer

Biogas Handling System
collects and treats biogas

Biogas
Processing, Transport, and Use

Electricity and Heat
biogas can be used to produce electricity and heat

Transportation Fuel
when processed and refined, biogas can be used as a compressed natural gas and vehicle fuel

Flare Excess
destroys excess gas and backs up primary gas use device

Biogas Systems Primarily Benefit Large Operations Using Liquid Manure Management Systems

Two of EPA's screening questions to evaluate a livestock facility's potential for anaerobic digester systems ask whether the operation is "large" and whether it uses a liquid manure management system.[67] To be financially viable, biogas recovery systems typically require manure from at least 2,000 hogs or at least 500 cows.[68] According to EPA, manure biogas projects are "most likely to succeed where manure is collected as a liquid, slurry, or semi-solid and stored in open pits, ponds, or lagoons" because liquid manure can be easily flushed into lagoons.[69] Dry manure management is more common on pasture-based operations, where there is no easy manure collection system. Industrial scale operations and liquid manure management tend to go hand-in-hand because very large facilities often cannot dispose of all of their manure safely through land application without exceeding the amount of nutrients the land can take up. Additionally, liquefaction makes manure management less costly where livestock is confined.[70] A major downside to the liquefaction of manure, however, is that it generates more GHG emissions, since the anaerobic conditions in manure lagoons produce additional methane.[71] A 2022 EPA report explains:

To be financially viable, biogas recovery systems typically require manure from at least 2,000 hogs or at least 500 cows.

> When livestock manure is stored or treated in systems that promote anaerobic conditions (e.g., as a liquid/slurry in lagoons, ponds, tanks, or pits), the decomposition of the volatile solids component in the manure tends to produce CH4 (methane). When manure is handled as a solid (e.g., in stacks or drylots) or deposited on pasture, range, or paddock lands, it tends to decompose aerobically and produce CO2 and little or no CH4.[72]

The same report tied growth in industrial animal agriculture operations that liquefy manure to the broader increase in manure-related methane and nitrous oxide emissions since 1990.[73] EPA concluded:

> In many cases, manure management systems with the most substantial methane emissions are those associated with confined animal management operations where manure is handled in liquid-based systems… The shift toward larger dairy cattle and swine facilities since 1990 has translated into an increasing use of liquid manure management systems, which have higher potential CH4 emissions than dry systems.[74]

Biogas Systems Require New Infrastructure

Depending on the desired end use of the refined biomethane produced by anaerobic digestion and subsequent refining, operations require a range of additional infrastructure. New infrastructure can introduce additional truck traffic or pipeline interconnections and result in significant wear to common infrastructure such as roads. Depending on how the biogas is to be used, on-site gas treatment systems may be necessary to process the gas accordingly. Temporary storage systems for biogas may also be required and excess biogas may need to be flared, or burned off, in some cases.

Biogas Systems Produce New Co-Pollutants & Exacerbate Existing Co-Pollutants

Anaerobic digestion creates a byproduct called digestate, which can be used as animal bedding or as fertilizer. Digestate is chemically different from the original manure. Digestate contains "more soluble plant nutrients due to mineralization and has less degradable biomass than the original substrate resulting in changes in GHG and NH3 emissions."[75] The method of storage and treatment of digestate can significantly impact the total GHG emissions from the biogas system, as well as co-pollutants like volatile organic compounds (VOCs) and hydrogen sulfide.

A 2017 study seeking to provide clarity on the emissions impact of anaerobic digestion (versus solid-liquid separation versus a combination of the two methods) found that anaerobic digestion alone resulted in an 81 percent increase in ammonia emissions during storage.[76] The authors concluded that anaerobic digestion could "significantly increase NH3 emissions from manure storage if manure covers are not implemented."[77] While ammonia is not a greenhouse gas, it

creates serious public health harms and degrades air quality.[78] The study also found that the nitrous oxide from digested separated solids "was much higher than separated solids without digestion," canceling out net GHG reductions.[79] This indicates that the simple adoption of manure biogas systems is not enough to ensure a net reduction in emissions from a given operation.

One study at a swine biogas facility in China took digestate to a research facility, stored it under controlled conditions, and then measured resulting emissions. The study identified 49 VOCs, 22 of which have been described as hazardous air pollutants by EPA. Of these 22 hazardous VOCs, "11 of these had relatively high concentrations . . . 8 were identified to be or likely to be carcinogenic, and 14 were identified to be harmful to other human organs or systems."[80] While most studies on VOCs from manure focus on the odor-causing compounds, the "proportion of hazardous air pollutants (32.77 percent) was shown to be considerably higher than that of odorous pollutants (5.15 percent)."[81]

Another study looked at manure under anaerobic conditions from two different dairy farms in Japan and found that hydrogen sulfide emissions vary considerably based on the mixing speed and frequency of disturbance of the stored manure as well as the manure's total solid content, temperature, and pH. For example, when stored at 18 degrees Celsius (64 degrees Fahrenheit), there was a sudden increase in the concentration of hydrogen sulfide (H_2S).[82] Additionally, "[the highest H_2S emissions were achieved at the fastest speed and longest duration of manure mixing."[83] Given that exposure to hydrogen sulfide is extremely dangerous and has been linked to death, the storage and treatment of manure and digestate is critical.[84]

New Impacts Must Be Evaluated in Analyses of Biogas Systems

These new impacts must be incorporated into analyses intended to evaluate the potential benefits of manure biogas systems. Unfortunately, such analyses often omit key considerations regarding co-pollutants, new infrastructure, and the environmental justice and equity implications associated with manure biogas systems. As stated above, the conventionally cited environmental benefit of manure biogas systems is a net reduction in atmospheric GHG emissions. Policy support for biogas systems rests on this reduction and as a result, life cycle analyses of manure biogas systems typically focus their impact evaluation on GHG emissions specifically and do not always address harms from co-pollutants or new infrastructure.

The metric typically used to quantify the environmental sustainability of a product or service is life cycle analysis (LCA). The goal of LCA is to provide a comprehensive view of environmental impacts to help decision-makers identify the effect of a given good or service. LCAs estimate

To properly account for the full life cycle emissions, any manure biogas LCA should include the storage and disposal of digestate, as well as the emissions generated in the production of manure, that is, the emissions resulting from raising the livestock in question.

the cumulative environmental impacts resulting from all stages of a product, process, or service through the life cycle, from raw material acquisition, manufacturing, use/reuse/maintenance, to recycling/waste management.[85] Programs like the Federal Renewable Fuel Standard and California's Low Carbon Fuel Standard, described above in part II, rely on life cycle assessments to determine the life cycle GHG emissions of participant fuels, including those derived from manure biogas systems. Both EPA and the California Air Resources Board use versions of the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) life cycle analysis model which is designed for transportation fuels.[86]

System boundaries mark the beginning and end of the process or life cycle in question. Consequently, the boundaries and assumptions used in the LCA model are critical. For example, an LCA that excluded emissions related to digestate would not fully account for life cycle emissions of manure biogas. To properly account for the full life cycle emissions, any manure biogas LCA should include the storage and disposal of digestate, as well as the emissions generated in the production of manure, that is, the emissions resulting from raising the livestock in question.

When produced at an industrial scale, animal manure can create severe environmental harms and adverse impacts to public health. The impacts of manure include water contamination, air pollution, and foul odor (which can degrade quality of life for neighboring communities and decrease property values), in addition to GHG emissions. Manure biogas systems capture some of the emissions from livestock facilities, but fail to address the co-pollutants associated with manure production while also producing new co-pollutants from the processing and storage of the resulting digestate, as discussed above. Multiple toxic pollutants, including VOCs, ammonia, endotoxins, particulate matter, and bioaerosols are linked to large-scale industrial confined animal feeding operations.[87] To the extent that anaerobic digestion technology maintains or even expands the model of concentrated industrial animal agriculture, it can perpetuate and even increase resulting public health harms.

In many parts of the country, these impacts disproportionately harm Black, Indigenous, and low-income communities. Multiple disparity analyses (and resulting civil rights complaints submitted to regulators) have challenged states' approaches to the regulation of industrial animal agriculture. One recent complaint filed with EPA's External Civil Rights Compliance

> "These harms disproportionately affect Black and Latinx people living near the Hog Operations, and it is these communities who will suffer most if pollution from the Hog Operations worsens, as is expected with the Permits. Decades of research–including research reviewed by this office–demonstrate how the lagoon and sprayfield waste management system authorized by the Permits pollute rivers, streams, and air quality throughout eastern North Carolina. Despite this, and despite evidence indicating the increased risk of pollution and adverse health impacts to nearby residents from the increases to harmful hog waste pollutants resulting from biogas production, DEQ issued the Permits without addressing these harms. This is unacceptable and a violation of federal law." – SELC complaint to EPA, 2021
>
> **Source:** Southern Environmental Law Center

Office under Title VI of the Civil Rights Act alleged that North Carolina's new general permit for manure biogas exacerbated existing discriminatory impacts of the livestock industry in the state.[88] The complaint alleges that the North Carolina Department of Environmental Quality's new general permit for biogas systems on confined animal feeding operations "authorizes not only the continued use of the discriminatory lagoon and sprayfield system, but also the use of anerobic digesters and uncovered 'secondary' lagoons, which will exacerbate the underlying system's impacts on communities of color."[89] This complaint follows another civil rights complaint addressing the discriminatory harms of the hog industry in North Carolina, to which EPA responded with a letter expressing "deep concern."[90]

Typical Pollutants Found in Air Surrounding CAFOs

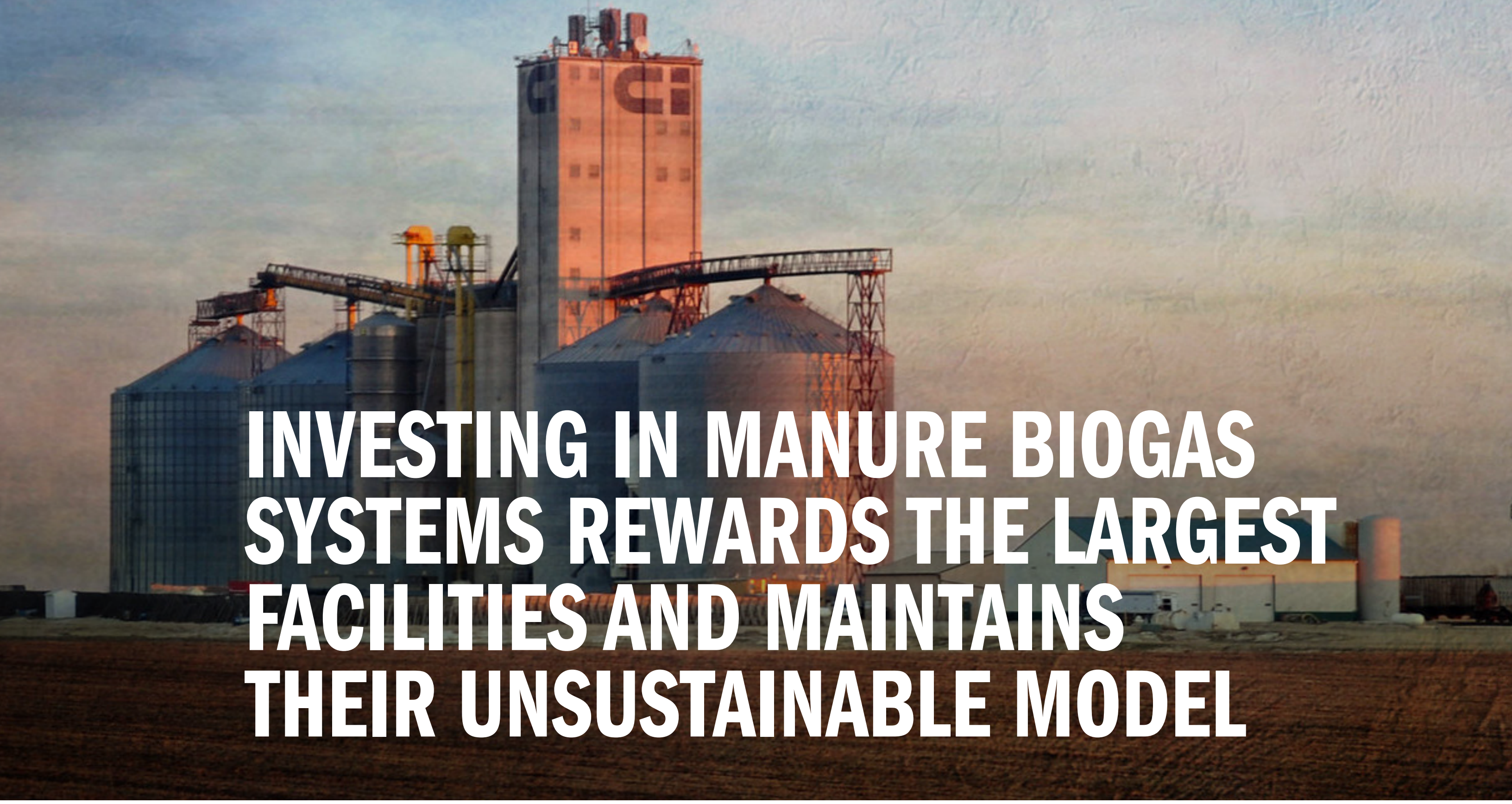
CAFO EMISSIONS	SOURCE	TRAITS	HEALTH RISKS
Ammonia	Formed when microbes decompose undigested organic nitrogen compounds in manure	Colorless, sharp pungent odor	Respiratory irritant, chemical burns to the respiratory tract, skin, and eyes, severe cough, chronic lung disease
Hydrogen Sulfide	Anaerobic bacterial decomposition of protein and other sulfur containing organic matter	Odor of rotten eggs	Inflammation of the moist membranes of eye and respiratory tract, olfactory neuron loss, death
Methane	Microbial degradation of organic matter under anaerobic conditions	Colorless, odorless, highly flammable	No health risks. Is a greenhouse gas and contributes to climate change
Particulate Matter	Feed, bedding materials, dry manure, unpaved soil surfaces, animal dander, poultry feathers	Comprised of fecal matter, feed materials, pollen, bacteria, fungi, skin cells, silicates	Chronic bronchitis, chronic respiratory symptoms, declines in lung function, organic dust toxic syndrome

Source: Understanding Concentrated Animal Feeding Operations and Their Impact on Communities

More Information on the Impacts of Manure Biogas

- Michael A. Holly, Rebecca A. Larson, J. Mark Powell, Matthew D. Ruark, & Horacio Aguirre Villegas, *Greenhouse Gas and Ammonia Emissions from Digested and Separated Dairy Manure During Storage and After Land Application*, Agriculture, Ecosystems and Env't 239 410–419 (2017), http://dx.doi.org/10.1016/j.agee.2017.02.007
- Valerio Paolini, Francesco Petracchini, Marco Segreto, Laura Tomasetti, Nour Naja, & Angelo Cecinato, *Environmental Impact of Biogas: A Short Review of Current Knowledge*, 53 J. Env't Sci. Health Pt. A 899-906 (2018), https://doi.org/10.1080/10934529.2018.1459076
- C. Alan Rotz, *Modeling Greenhouse Gas Emissions from Dairy Farms,* 101 J. Dairy Sci. 6675-6690 (2018), https://www.sciencedirect.com/science/article/pii/S002203021731069X
- F. Montes, R. Meinen, C. Dell, A. Rotz, A. N. Hristov, J. Oh, et al., *SPECIAL TOPICS-Mitigation of Methane and Nitrous Oxide Emissions From Animal Operations: II. A Review of Manure Management Mitigation Options*, J. Anim. Sci. 91 5070–5094 (2013), https://doi.org/10.2527/jas.2013-6584
- Emily Grubert, *At Scale, Renewable Natural Gas Systems Could Be Climate Intensive: The Influence of Methane Feedstock and Leakage Rates*, Env't Research Letters 15 084041, 5 (August 2020), https://doi.org/10.1088/1748-9326/ab9335
- Hannah Rigby, *A Critical Review of Nitrogen Mineralization in Biosolids-Amended Soil, the Associated Fertilizer Value for Crop Production and Potential for Emissions to the Environment*, 541 Sci. of the Total Env't 1310, 1310 (Jan. 2016), https://www.sciencedirect.com/science/article/abs/pii/S0048969715305921

Photo source: Anaerobic Digester Fenville, MI by eXtension Farm Energy Community of Practice is licensed under CC BY-NC 2.0.



INVESTING IN MANURE BIOGAS SYSTEMS REWARDS THE LARGEST FACILITIES AND MAINTAINS THEIR UNSUSTAINABLE MODEL

THE SHEER NUMBER OF PROGRAMS designed to support the installation and operation of manure biogas systems on livestock operations presents two important questions. First, are these programs necessary to obtain the intended climate benefits of biogas systems and to what extent do they contribute to an overall emissions reduction? Second, what are the opportunity costs of the intense focus on this one method of reducing livestock emissions, given the range of alternatives? The fact that alternatives exist, coupled with the requirement that manure production continue at staggering rates to ensure the productivity of manure biogas systems calls into question whether it is prudent to focus policy efforts on a single solution.

Biogas Systems May Not Reduce Overall Emissions

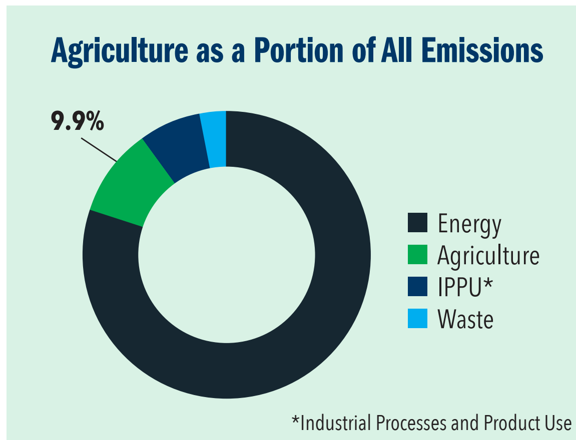
Anaerobic digesters are designed to capture (and monetize) methane and other gases that would otherwise be emitted into the air from manure lagoons. However, *capturing* emissions does not avoid or reduce emissions at the source. Reducing emissions at the source would entail significant changes in livestock production systems. Digester systems are sometimes described as stopgap measures—a means to reduce emissions quickly in the absence of developing or implementing alternative measures. However, climate science demonstrates that significant reductions at the source are required in the next decade. Investing in expensive durable infrastructure that requires ongoing manure production at current rates without emissions reductions fails to meet this imperative.

Because manure biogas systems capture rather than reduce emissions, these systems **require the ongoing generation of GHG emissions** to be financially viable. The digester's function is to capture the emissions, so the system breaks down if emissions are reduced at the source. Producers must continue to generate manure at scale for the facilities to remain financially sustainable. The large upfront investment in these systems then fixes the current numbers and concentration of livestock at facilities where they are installed, despite the range of harms

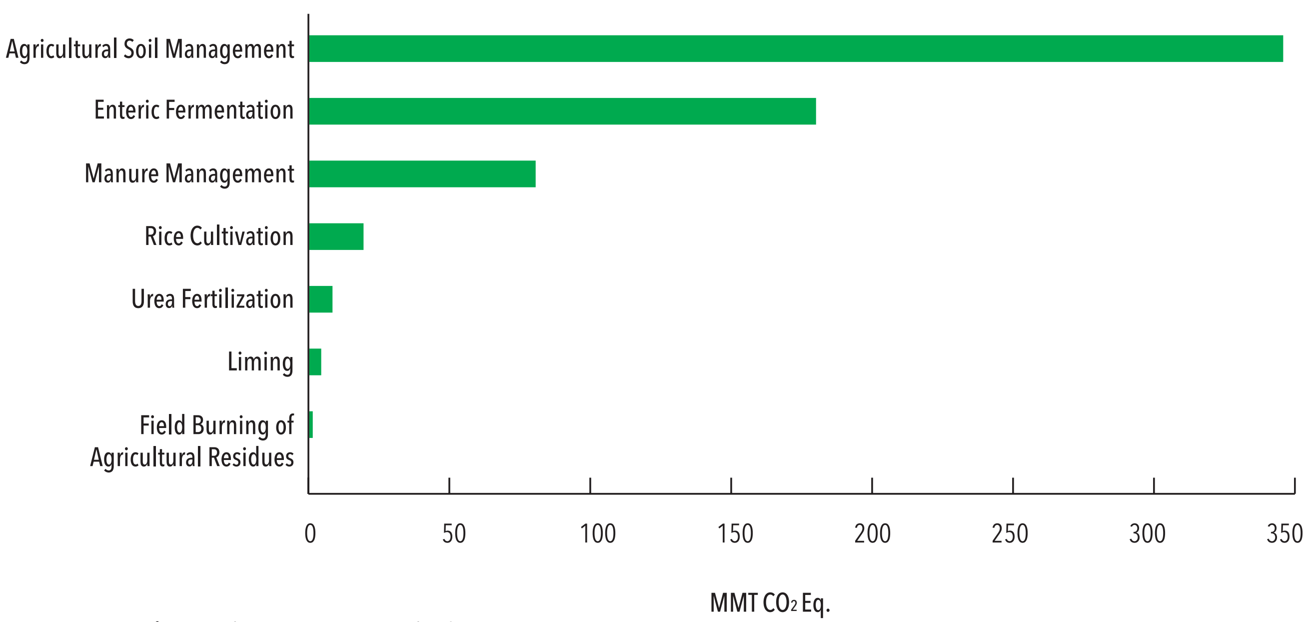
Photo source: Ag Partners, Hartley, Iowa by TumblingRun is licensed under CC BY-NC-ND 2.0.

generated by such concentrated operations. Simultaneously, the new subsidized revenue streams support the ongoing generation of manure at scale. This outcome is sharply at odds with the prescriptions of climate scientists and the Biden Administration's stated climate goals.

Additionally, while anaerobic digesters capture manure methane from lagoons, they do not capture greenhouse gas emissions before or after this point. The emissions from manure management that can be targeted by digesters make up 9.2 percent of total methane emissions from anthropogenic activities, while emissions from enteric fermentation, which remain untouched by digester systems, make up 26.9 percent.[91] In contrast, other interventions in the industrial animal agriculture system, including alternative methods of manure management and changes to animals' diet, address emissions throughout or at various points in the process of raising livestock. Importantly, a significant portion of livestock GHG emissions result from the decision to liquefy manure.[92] Some manure management emissions can be avoided by using dry manure management systems, as many farmers do. Capturing GHG emissions should be a last resort option after other alternatives have been pursued to avoid

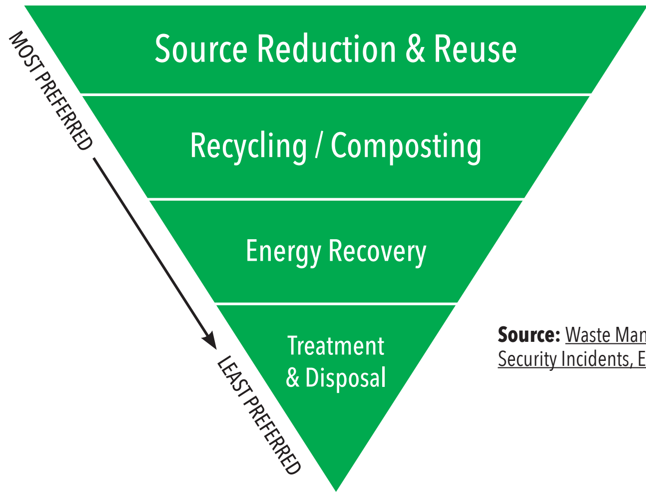


2020 Agriculture Sector Greenhouse Gas Emission Sources



Source: Inventory of US Greenhouse Gas Emissions and Sinks (1990-2020), Environmental Protection Agency

Waste Management Hierarchy



Source: Waste Management Hierarchy and Homeland Security Incidents, Environmental Protection Agency

or reduce emissions. This tracks with other federal policy efforts and priorities, as reduction is the management method at the top of EPA's waste management hierarchy for decision-making (organized from least to most detrimental to human and animal health and the environment).[93]

Alternative measures to reduce methane emissions from animal agriculture are available and feasible. Manure management systems generally include processes for the collection, transfer, storage, and sometimes treatment and end-use of manure.[94] Alternatives are available at each point along the way. At the initial collection stage, operations can opt for dry-scrape systems, rather than the flush systems typically used for lagoons. Dry scrape systems use mechanical scrapers to move manure into holding pits.

Livestock operations can also be designed as pasture-based, rather than confinement. On pasture-based operations, manure is typically left on pasture and produces minimal methane.[95] Pasture-based operations that rely primarily on grazing for animals' nutrition can also avoid emissions associated with the production and transportation of the feed used on confinement operations[96] and can potentially provide carbon sequestration benefits if grasslands and grazing are properly managed.[97] At the storage stage, operations can employ solid-liquid separation rather than flushing all liquefied manure directly into a lagoon. Once liquids have been separated out, manure solids can be composted.[98] A technical report prepared for the California Air Resources Board concluded that, in addition to manure biogas system installation:

> Methane emissions from lagoon storage systems can be decreased by reducing the amount or modifying anaerobic storage (i.e. solids separation and diversion from lagoon, modifying dominant flush collection to manure scraping with drying/composting or other lagoon diversion, etc.), aerating the lagoon (to reduce or eliminate anaerobic conditions).[99]

These are viable methods of manure management that would avoid, rather than simply capture, at least some emissions associated with open-air lagoons of liquid manure.[100] Many livestock operations already employ these lower-emissions practices. Unfortunately for them, however, smaller operations, pasture-based operations, or operations that have a more sustainable business model of dry manure management will not benefit from the significant public funds currently being channeled to biogas-eligible facilities. This sets a perverse precedent of neglecting historically good actors while rewarding the worst polluters in the livestock industry with new revenue and fodder for positive public relations.

Tied to the claim that biogas systems reduce emissions is the argument that the use of manure systems displaces the use of fossil fuels. An empirical analysis of this claim is beyond the scope of this report. However, regulators and policymakers should carefully consider the climate value of replacing fossil fuels with the combustion of biomethane, especially for the magnitude of public funds invested in this displacement. Renewability does not necessarily mean that a fuel is sustainable or climate friendly.[101]

Biogas Systems May Not Generate Revenue & "Design Out Waste"

Another important consideration is whether manure biogas systems really generate revenue and "design out" waste. This reflects a broader trend in policy prescriptions, sometimes referred to as the "circular economy," that seeks to "design out" waste from various industrial life cycles.[102] Proponents of the circular economy use the phrase "designing out" manure or any other waste product to mean that the waste is made profitable through other industrial processes. Unlocking new profits from waste,[103] however, does not necessarily entail any changes to the processes of waste generation or to any environmental or public health harms that arise from these processes.

In the case of manure biogas systems, manure is still produced, liquefied, and transported to manure lagoons—it must be for the biogas system to function. Anaerobic digestion does not make the manure vanish, it produces digestate. As discussed above, digestate has industrial uses, as fertilizer, for example, but also carries many of the same potential environmental harms as manure. Therefore, while it is correct to say that manure biogas systems access the potential economic value of manure as a fuel source, the waste does not disappear and can continue to cause environmental and public health harms, before, during, and after (as digestate) the process of anaerobic digestion.

While it is correct to say that manure biogas systems access the potential economic value of manure as a fuel source, the waste does not disappear and can continue to cause environmental and public health harms, before, during, and after (as digestate) the process of anaerobic digestion.

The massive quantities of manure produced at industrial scale livestock facilities can and do cause serious environmental, quality of life, and public health harms to neighboring communities. These harms do not cease to exist upon the addition of an anaerobic digester. In fact, while proponents of biogas systems sometimes argue that capping lagoons can address these issues, impacted environmental justice communities around the country have organized against the proliferation of biogas because it is viewed as maintaining and supporting a harmful system.[104]

Beyond the Baseline: Evaluating Mitigation Measures Against Policy Alternatives

The climate benefits associated with greater public resources devoted to expanding manure biogas production can only be evaluated relative to other available policy options. Such policy options cannot be limited to a business-as-usual scenario, which the scientific community has made clear is untenable. Regulators currently consider the displacement of fossil fuels when evaluating the benefits associated with these systems, but they must also consider the alternative emissions reduction strategies that are displaced now and into the future upon investment in large-scale manure biogas systems.

Unfortunately, conventional win-win claims break down when framed in the broader context of policy mechanisms available to address emissions from livestock. This is attributable to the many alternative approaches to reducing emissions from livestock facilities, some of which could reduce emissions throughout the life cycle, instead of those emitted only from

manure lagoons. The Biden Administration's plan to reduce methane names several of these alternatives, including installing "solid separators that reduce methane-producing slurries; providing conservation assistance for transitions to alternative manure management systems, such as deep pits, composting, transitions to pasture, or other practices that have a lower greenhouse gas profile."[105] Despite the administration's support of reducing methane-producing slurries on paper, funding for manure biogas systems that require methane-producing slurries to function continues to dwarf alternatives.

While it is unreasonable to expect a single policy mechanism or technology to solve all problems, there are viable alternative manure management practices and policy mechanisms to decrease emissions as well as co-pollutants in a more equitable manner. Currently, however, these programs are not being funded at nearly the same rate as manure biogas. In California, for example, the Alternative Manure Management Program (AAMP) has been funded at roughly half the rate of the Dairy Digester Research & Development Program (DDRDP) in recent years.[106]

In addition to a broad evaluation of each of these alternative mechanisms and potential policy mechanisms to promote them, it is essential to note the reason policy incentives are strictly necessary in this case—industrial livestock operations have historically been essentially exempt from any regulation of GHG emissions. It is, in fact, only this absence of regulation that makes the calculation of emissions reductions from the addition of digesters so high. The primary alternative policy mechanism should be to treat industrial livestock operations like every other industry in the country and regulate the emissions they externalize to the detriment of the public—the primary funders of manure biogas systems. Regulators should actively support farmers that engage in climate-friendly practices less likely to harm neighboring communities.

In the United States, livestock agriculture has dramatically shifted toward "large scale industrialized production systems."[107] As a result, livestock operations are producing more manure in centralized regions.[108] The storage, transportation, and land application[109] of this waste poses serious environmental risks, in addition to the GHG emissions from other parts of the livestock life cycle. Methane emissions from livestock manure are significant, but experts note that the trade-offs associated with manure management options, including the use of biodigesters, are not well studied and have not been proven to be "climate smarter."[110]

While it is unreasonable to expect a single policy mechanism or technology to solve all problems, there are viable alternative manure management practices and policy mechanisms to decrease emissions and co-pollutants in a more equitable manner.

POLICY RECOMMENDATIONS AND CONCLUSION

LIVESTOCK OPERATIONS' IMPACT ON CLIMATE CHANGE presents an opportunity for a real win-win: the US can develop policies that reduce GHG emissions from these facilities—as is required in order to mitigate the substantial impact of livestock agriculture on the climate—while simultaneously reducing the additional environmental harms many such facilities externalize into local communities. In many cases, have a discriminatory impact on the basis of race. These prerogatives are well aligned with the Biden Administration's Climate Smart Agriculture policy, Executive Order 14008, and Executive Order 13985.[111] Specifically, policymakers should consider the following:

- **USDA must ensure that recipients of its funding are in compliance with Title VI of the Civil Rights Act of 1964.** This includes ensuring that state agencies that receive USDA funding and implement programs supporting manure biogas are developing such policies in a manner that does not disproportionately benefit white operators or disproportionately harm nearby communities on the basis of race, national origin, or color.

- **Evaluate USDA's programs** to ensure that they do not have a disproportionate impact on the basis of race, national origin, or other protected class.

- **Properly account for the full climate impacts of manure biogas** and ensure that emissions life cycle analyses consider the full range of upstream and downstream emissions in the manure biogas life cycle.

- **Move beyond business-as-usual as a point of comparison** for manure biogas, which does not ensure a viable climate-smart future. The point of comparison should be the range of policy alternatives to biogas promotion, including the regulation of methane from agricultural operations.

- **Properly account for the full impacts of policies supporting manure biogas,** including environmental, public health, and quality of life impacts from co-pollutants caused by manure.

- **Ensure a just transition** for all, including for livestock farmers. Policy should ensure that farmers and farmworkers can make viable livelihoods while transitioning to more sustainable models.

- **Evaluate the efficacy of overlapping programs** to ensure that public funds for manure biogas are effectively promoting new emissions reductions.

Endnotes

1 *Why Did the IPCC Choose 2° C As the Goal for Limiting Global Warming*, MIT Climate Portal (June 22, 2021), https://climate.mit.edu/ask-mit/why-did-ipcc-choose-2deg-c-goal-limiting-global-warming/.

2 *See generally* U.S. Climate Change Science Program, The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States (May 2008), https://www.usda.gov/sites/default/files/documents/CCSPFinalReport.pdf.

3 IPCC, *Sixth Assessment Report Headline Statement from the Summary for Policymakers* at A.3 (August 9, 2021).

4 *Id.* at B.3.

5 Jennifer Shike, *Residents in Top Pork-Producing Counties Reveal Their Perspective on Ag*, Farm Journal's Pork (January 12, 2022), https://www.porkbusiness.com/news/industry/nc-residents-top-pork-producing-counties-reveal-their-perspective-ag.

6 Kendra Pierre-Louis, *Lagoons of Pig Waste Are Overflowing After Florence. Yes, That's as Nasty as It Sounds*, N.Y. Times (September 19, 2018), https://www.nytimes.com/2018/09/19/climate/florence-hog-farms.html; James Bruggers, *After Back-to-Back Hurricanes, North Carolina Reconsiders Climate Change*, Inside Climate News (December 27, 2018), https://insideclimatenews.org/news/27122018/hurricane-damage-north-carolina-climate-change-2018-year-review-florence-michael-matthew/.

7 *California's Central Valley*, U.S. Geol. Survey, https://ca.water.usgs.gov/projects/central-valley/about-central-valley.html.

8 *California is the Leading Farm State*, Cal. Legislative Analyst's Office (December 4, 2014), https://lao.ca.gov/LAOEconTax/Article/Detail/13#:~:text=Over%2080%20percent%20of%20California's,surpassed%20Wisconsin%20in%20milk%20production.

9 The Central Valley is predicted to be "substantially drier (10 to 15 percent) during the mid-late 21st century." *Conjunctive Use in Response to Potential Climate Changes in the Central Valley, California*, USGS, https://ca.water.usgs.gov/projects/central-valley/climate.html; Bettina Boxall, *Overpumping of Central Valley Groundwater Creating a Crisis, Experts Say*, L.A. Times (March 18, 2015), https://www.latimes.com/local/california/la-me-groundwater-20150318-story.html.

10 *See generally* U.S. EPA, Climate Change and Social Vulnerability in the United States, https://www.epa.gov/system/files/documents/2021-09/climate-vulnerability_september-2021_508.pdf. Leah Campbell, *North Carolina Hurricanes Linked to Increases in Gastrointestinal Illnesses in Marginalized Communities*, Inside Climate News (March 7, 2022), https://insideclimatenews.org/news/07032022/north-carolina-hurricanes-gastrointestinal-illnesses/.

11 Huanjia Zhang, *For Black Farmers, Climate Change Magnifies Existing Inequality*, ScienceLine (January 19, 2021), https://scienceline.org/2021/01/for-black-farmers-climate-change-magnifies-existing-inequality/. Internationally, "the negative impacts [of climate change] on [farmer] income are hitting the poorest countries and farmers most due to both higher exposure to climate risks as well as lower adaptation capacity." Food and Agriculture Organization of the United Nationals, Climate Change and Food Security: Risks and Responses (2015) at 21, https://www.fao.org/3/i5188e/I5188E.pdf.

12 Sabri Ben-Achour, *Farmers Need to Adapt Crops to Climate Change to Stay Profitable, Experts Say*, Marketplace (October 20, 2020), https://www.marketplace.org/2020/10/20/many-farmers-need-swap-crops-stay-profitable-climate-change-continues/.

13 Walter Willett, MD *et al*., *Food in the Anthropocene: the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems,* The Lancet (January 16, 2019), https://doi.org/10.1016/S0140-6736(18)31788-4; Gidon Eshel *et al*., *Land, Irrigation Water, Greenhouse Gas, and Reactive Nitrogen Burdens of Meat, Eggs, and Dairy Production in the United States*, PNAS (July 21, 2014), https://www.pnas.org/doi/10.1073/pnas.1402183111; Henry Fountain, *Cutting Greenhouse Gases From Food Production Is Urgent, Scientists Say*, N.Y. Times (October 26, 2021), https://www.nytimes.com/2020/11/05/climate/climate-change-food-production.html; Andrea Thompson, *Here's How Much Food Contributes to Climate Change*, Scientific American (September 13, 2021), https://www.scientificamerican.com/article/heres-how-much-food-contributes-to-climate-change/. It has recently been argued that estimates of methane emissions from U.S. livestock operations have routinely been underestimated. *See* Matthew N. Hayek and Scot M. Miller, *Underestimates of Methane from Intensively Raised Animals Could Undermine Goals of Sustainable Development,* Env't Res. Lett. *16 (June 4, 2021),* https://iopscience.iop.org/article/10.1088/1748-9326/ac02ef.

14 Understanding Global Warming Potential, U.S. Env't Protection Agency, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

15 *Burps in Merps: Addressing Agricultural Methane Emissions in the U.S. Methane Emission Reduction Plan (MERAP),* https://storymaps.arcgis.com/stories/be03fd94bbfb4586bf7ccf5627aa4afb. Not only are overall emissions from agriculture increasing, but per head emissions from enteric fermentation are also increasing. U.S. Greenhouse Gas Inventory Agriculture at 5-5, U.S. Env't Protection Agency, https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-5-agriculture.pdf. .

16 *See, e.g.,* Sustainia, *Win-Win Scheme Turns Pig Waste into Power*, Global Opportunity Explore (March 14, 2019), https://goexplorer.org/win-win-scheme-turns-pig-waste-into-power/; *Using Methane from Waste Streams for Energy: A Win-Win Solution*, Environmental and Energy Study Institute (March 9, 2010), https://www.eesi.org/articles/view/using-methane-from-waste-streams-for-energy-a-win-win-solution.

17 Laura Melling, *USDA Offers Funding to Help Farmers Turn Manure into Energy*, U.S. Dep't of Ag. (February 21, 2017), https://www.usda.gov/media/blog/2010/11/18/usda-offers-funding-help-farmers-turn-manure-energy.

18 American Biogas Council, *How to Maximize USDA Funds Webinar* (January 30, 2020), *available at* https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiG3YaUrtz1AhXmIEQIHbk7B0cQFnoECAMQAQ&url=https%3A%2F%2Famericanbiogascouncil.org%2Fwp-content%2Fuploads%2F2020%2F01%2FHow-to-Maximize-USDA-Grant-Dollars-from-REAP.pdf&usg=AOvVaw3u_9Ola0x9SiHDF3spSqC1.

19 Michael Clark *et al., Global Food System Emissions Could Preclude Achieving the 1.5 and 2 C Climate Change Targets,* 370 Science 6517 (November 6, 2020), https://www.science.org/doi/10.1126/science.aba7357.

20 Ximena Bustillo, *'Rampant Issues': Black Farmers Are Still Left Out at USDA*, Politico (July 5, 2021), https://www.politico.com/news/2021/07/05/black-farmers-left-out-usda-497876; Nathan Rosenberg and Bryce Wilson Stucki, *How USDA Distorted Data to Conceal Decades of Discrimination Against Black Farmers*, The Counter (June 26, 2019), https://thecounter.org/usda-black-farmers-discrimination-tom-vilsack-reparations-civil-rights/.

21 *Who Is the American Farmer?,* USA Facts, https://usafacts.org/articles/farmer-demographics/ (95.4% of American farmers are white).

22 Dania Francis, Darrick Hamilton, Thomas Mitchell, Nathan Rosenberg, and Bryce Wilson Stucki, *How the Government Helped White Farmers Steal Black Farmland*, The New Republic (May 5, 2020), https://newrepublic.com/article/166276/black-farm-land-lost-20th-century-billions.

23 Today the average size of farms owned by Black farmers is 132 acres, as compared to 441 acres for white farmers. 15% of Black farmers own farms larger than 180 acres, as compared to 32% of white farmers. *2017 Agricultural Census,* U.S. Dep't. of Ag., https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Race,_Ethnicity_and_Gender_Profiles/cpd99000.pdf.

24 *See, e.g.* Ji-Young Son *et al.*, *Distribution of Environmental Justice Metric for Exposure to CAFOs in North Carolina*, USA, Env't Research 195 (April 2021), https://doi.org/10.1016/j.envres.2021.110862.

25 For example, heat stress due to climate change has already significantly impacted dairy production in the United States and is expected to further contribute to economic losses for that sector. More broadly, the "U.S. Global Change Research Program (USGCRP) recognizes that increased heat stress will increase livestock production costs, lower feed efficiency, and compromise livestock health." *Climate Change, Heat Stress, and US Dairy Production,* U.S. Dep't. of Ag. Econ. Research Serv. at 1-2 (2014), https://www.ers.usda.gov/webdocs/publications/45279/49164_err175.pdf?v=2463.8.

26 Exec. Order No. 14008, Tackling the Climate Crisis at Home and Abroad, 86 Fed. Reg. 7619 (2021).

27 Exec. Order 13985, Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, 86 Fed. Reg. 7009 (2021).

28 *See generally* Exec. Order No. 14008, Tackling the Climate Crisis at Home and Abroad, 86 Fed. Reg. 7619 (2021).

29 *See generally* Exec. Order No. 14008, Tackling the Climate Crisis at Home and Abroad, 86 Fed. Reg. 7619 (2021).

30 U.S. Dep't of Ag., Climate-Smart Agriculture and Forestry St5rategy: 90-Day Progress Report (May 2021), https://www.agri-pulse.com/ext/resources/pdfs/Embargoed-climate-smart-ag-forestry-strategy-90-day-progress-report.pdf.

31 Lisa Friedman, *Biden Administration Moves to Limit Methane, a Potent Greenhouse Gas*, N.Y. Times (November 2, 2021), https://www.nytimes.com/2021/11/02/climate/biden-methane-climate.html.

32 Jared Strong, *USDA Pledges $1B for 'Climate Smart' Ag Products*, Missouri independent (February 7, 2022), https://missouriindependent.com/briefs/usda-pledges-1b-for-climate-smart-ag-products/.

33 *Rural Energy for America Program Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants*, U.S. Dep't of Ag. Rural Development, https://www.rd.usda.gov/programs-services/energy-programs/rural-energy-america-program-renewable-energy-systems-energy-efficiency-improvement-guaranteed-loans.

34 *Conservation Programs*, U.S. Dep't of Ag. Rural Development, https://www.fsa.usda.gov/programs-and-services/conservation-programs/index.

35 7 U.S.C.A. § 8103 ("The purpose of this section is to assist in the development of new and emerging technologies for the development of advanced biofuels, renewable chemicals, and biobased product manufacturing…")

36 7 U.S.C.A. § 8105 ("The Secretary shall make payments to eligible producers to support and ensure an expanding production of advanced biofuel.")

37 7 U.S.C.A. § 8108.

38 7 U.S.C.A. § 8106 "…make competitive grants to eligible entities to educate governmental and private entities that operate vehicle fleets, other interested entities (as determined by the Secretary), and the public about the benefits of biodiesel fuel use.")

39 7 U.S.C.A. § 8115. This program provides grants to educate agricultural producers and other stakeholders about the collection of organic waste from multiple sources to be used in a single biogas system.

40 *Biogas Opportunities Roadmap Progress Report*, U.S. Dep't of Ag., Env't Protection Agency & Dep't of Energy (December 2015) at 2, https://www.energy.gov/sites/prod/files/2015/12/f27/biogas_opportunites_roadmap_progress_report_0.pdf.

41 *Dairy Digester Research & Development Program*, Cal.

Dep't Food & Ag., https://www.cdfa.ca.gov/oefi/ddrdp/.
42 *Methane Digester Loan Program*, Minn. Dep't of Ag., https://www.mda.state.mn.us/methane-digester-loan-program.
43 Referring to Section 1603 of the 2009 American Recovery and Reinvestment Act (ARRA).
44 *1603 Program: Payments for Specified Energy Property in Lieu of Tax Credits*, U.S. Dep't of the Treasury, https://home.treasury.gov/policy-issues/financial-markets-financial-institutions-and-fiscal-service/1603-program-payments-for-specified-energy-property-in-lieu-of-tax-credits.
45 *ARRA Section 1603 Grants in Lieu of Tax Credits for Renewable Energy: Overview, Analysis, and Policy Options*, Congressional Research Service (November 9, 2011), https://www.everycrsreport.com/files/20111109_R41635_f042092b5c65021d792f0ccb79634694bd9aeea8.pdf.
46 *Id.* at 5, Figure 1.
47 *1603 Program List of Awards*, U.S. Dep't of the Treasury, *available at* https://home.treasury.gov/policy-issues/financial-markets-financial-institutions-and-fiscal-service/1603-program-payments-for-specified-energy-property-in-lieu-of-tax-credits.
48 Stifel Equity Research, Energy & Power – Biofuels: Renewable Natural Gas (March 8, 2021) at 4.
49 *See also*, *Chevron's Energy Transition Spotlight Edited Transcript,* Chevron Corp. (September 14, 2021), *available at* https://chevroncorp.gcs-web.com/static-files/f9d402c6-22e2-4c00-ad45-3a61fde9ff73 ("For roughly half a billion dollars committed to date, we're building an RNG business expected to produce about 10,000 million BTUs per day in less than five years, with expected double-digit returns and an average carbon intensity feedstock score of around negative 250 under California's Low Carbon Fuel Standard.")
50 Stifel Equity Research, Energy & Power – Biofuels: Renewable Natural Gas (March 8, 2021) at 5.
51 For general information on fuel pathways, *see What is a Fuel Pathway?,* U.S. Env't Protection Agency, https://www.epa.gov/renewable-fuel-standard-program/what-fuel-pathway.
52 40 C.F.R. § 80 subpart M. EPA also provides a list of fuel pathways online at *Approved Pathways for Renewable Fuel*, U.S. Env't Prot. Agency, https://www.epa.gov/renewable-fuel-standard-program/approved-pathways-renewable-fuel.
53 *Renewable Identification Numbers*, Alternative Fuels Data Center, U.S. Dep't of Energy, https://afdc.energy.gov/laws/RIN.html.
54 40 C.F.R. § 80.1426; *Renewable Fuel Standard*, Alternative Fuels Data Center, U.S. Dep't of Energy, https://afdc.energy.gov/laws/RFS; *Approved Pathways for Renewable Fuel*, U.S. Env't Protection Agency, https://www.epa.gov/renewable-fuel-standard-program/approved-pathways-renewable-fuel.
55 U.S. Env't Protection Agency, *Information About Renewable Fuel Standard for Landfill Gas Energy Project,* https://www.epa.gov/lmop/information-about-renewable-fuel-standard-landfill-gas-energy-projects.
56 "The federal RFS and state LCFS incentives are additive, meaning both incentives can be earned for a specific project." *Renewable Natural Gas from Agricultural-Based AD/Biogas Systems*, U.S. Env't Protection Agency, https://www.epa.gov/agstar/renewable-natural-gas-agricultural-based-adbiogas-systems.
57 *Advanced Biofuel Payment Program*, U.S. Dep't of Ag. Rural Development, https://www.rd.usda.gov/programs-services/energy-programs/advanced-biofuel-payment-program.
58 7 C.F.R Part 4288, Advanced Biofuel Payment Program Final Rule, *available at* https://www.rd.usda.gov/sites/default/files/AdvancedBiofuel_9005_FinalRule122719.pdf; *Advanced Biofuel Payment Program in California,* U.S. Dep't of Ag. Rural Development, https://www.rd.usda.gov/programs-services/energy-programs/advanced-biofuel-payment-program/ca.
59 7 U.S.C. § 8105(g).
60 *Renewable Electricity Production Tax Credit Information*, U.S. Env't Protection Agency, https://www.epa.gov/lmop/renewable-electricity-production-tax-credit-information; *Form 8835*, Dep't of the Treasury Internal Revenue Service, *available at* https://www.irs.gov/pub/irs-pdf/f8835.pdf.
61 U.S. Env't Protection Agency, AgStar, Project Development Handbook: A Handbook for Developing Anaerobic Digestion/Biogas Systems on Farms in the United States 3rd Edition, *available at* https://www.epa.gov/sites/default/files/2014-12/documents/agstar-handbook.pdf#page=81.
62 *Biofuels Investment Tax*, Alternative Fuels Data Center, U.S. Dep't. of Energy, https://afdc.energy.gov/laws/6074.
63 Cal. Code of Regs Tit. 17 § 95480.
64 *See* Jessica Fu, *Is California Giving Its Methane Digesters Too Much Credit?,* Grist (May 19, 2022), https://grist.org/accountability/california-methane-digesters-low-carbon-fuel-standard/; Evan Halper, *California Set Off a Biofuel Boom—But Can It Manage the Fallout?,* L.A. Times (March 24, 2022), https://www.latimes.com/politics/story/2022-03-24/california-set-off-a-biofuel-boom-but-can-it-manage-the-fallout.
65 *State Renewable Portfolio Standards and Goals*, National Conference of State Legislatures, https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx.
66 U.S. Env't Protection Agency, AgStar, Project Development Handbook: A Handbook for Developing Anaerobic Digestion/Biogas Systems on Farms in the United States 3rd Edition at 6.3.2., *available at* https://www.epa.gov/sites/default/files/2014-12/documents/agstar-handbook.pdf#page=81.
67 *Is Anaerobic Digestion Right for Your Farm*, U.S. Env't Protection Agency, Ag Star, https://www.epa.gov/agstar/anaerobic-digestion-right-your-farm#q2.

68 *Id.*
69 U.S. Env't Protection Agency, AgStar, Market Opportunities for Biogas Recovery Systems at US Livestock Facilities (June 2018), *available at* https://www.epa.gov/sites/default/files/2018-06/documents/epa430r18006agstarmarketreport2018.pdf.
70 Horacio A. Aguirre-Villegas, Rebecca A. Larson, and Mahmoud A. Sharara, *Anaerobic Digestion, Solid-Liquid Separation, and Drying of Dairy Manure: Measuring Constituents and Modeling Emission*, Sci. of the Total Env't 696 (December 2019), https://www.sciencedirect.com/science/article/pii/S0048969719340367.
71 S.O. Peterson et al., *Manure Management for Greenhouse Gas Mitigation*, Animal 7 at 2 (2013), https://doi.org/10.1017/S1751731113000736 ("CH4 emissions may occur from all manure environments, but is mainly associated with liquid or compacted manure.")
72 U.S. Env't Protection Agency, U.S. Greenhouse Gas Inventory Agriculture at 5-11, https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-5-agriculture.pdf.
73 Ben Lilliston, *EPA Data Confirms Role of Factory Farms in Rising Agriculture Emissions*, Inst. for Ag. and Trade Policy, https://www.iatp.org/new-epa-data-confirms-role-factory-farms-rising-agriculture-emissions.
74 U.S. Env't Protection Agency, U.S. Greenhouse Gas Inventory Agriculture at 5-12, https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-5-agriculture.pdf.
75 Holly, et al., *Greenhouse gas and ammonia emissions from digested and separated dairy manure during storage and after land disposal*, AG., Ecosystems and Env't 239 at 411 (2017), https://doi.org/10.1016/j.agee.2017.02.007.
76 *Id.* at 413. This increase was attributed to the "mineralization of organic N through the digestion process which increased NH4 + NH3 concentrations in manure."
77 *Id.* at 418.
78 *See* Ma, R., Li, K., Guo, Y. *et al. Mitigation potential of global ammonia emissions and related health impacts in the trade network*, Nat Commun 12 at 6308 (2021), https://doi.org/10.1038/s41467-021-25854-3 (""NH_3 emissions contribute to $PM_{2.5}$ pollution through the chemical formation of particulate ammonium sulfate and ammonium nitrate, and lead to tens of thousands of deaths annually.")
79 Holly, et al. at 418 ("…anaerobically stacking digested solids increase emissions of N20 negating abatement of total GHG.")
80 Y. Zhang et al., *Characterization of Volatile Organic Compound (VOC) Emissions from Swine Manure Biogas Digestate Storage*, Atmosphere 10(7):411 at 8 (2019). https://doi.org/10.3390/atmos10070411.
81 *Id.* at 9.
82 Fetra J. Andriamanohiarisoamanana, et al., *Effects of handling parameters on hydrogen sulfide emission from stored dairy manure*, J. of Env't Management, Vol. 154 at 112 (2015), https://doi.org/10.1016/j.jenvman.2015.02.003.
83 *Id.* at 115.
84 Wendee Nicole, *CAFOs and Environmental Justice*, Env't Health Perspectives (June 2013), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3672924/A ("As one pair of investigators explained, '[P]eople of color and the poor living in rural communities lacking the political capacity to resist are said to shoulder the adverse socio-economic, environmental, or health related effects of swine waste externalities without sharing in the economic benefits brought by industrialized pork production.'")
85 Scientific Applications International Corp., *Life Cycle Assessment: Principles and Practice*, prepared for U.S. Env't Protection Agency, *available at* https://www.epa.gov/nscep. Life cycle studies can be conducted within different scopes, including "cradle to gate" (from raw materials to factory gate), gate to gate (only focusing on the manufacturing processes), cradle to grave (from raw materials until disposal), or cradle to cradle (a specific cradle to grave assessment, in which the disposal process is actually a recycling process). Life cycle assessments which are not conducted for a full life cycle from "cradle to grave" are called partial life cycle assessments.
86 Meltem Urgun-Demirtas, *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model*, U.S. Dep't of Energy (May 16, 2019), https://www.energy.gov/eere/bioenergy/articles/greet-greenhouse-gases-regulated-emissions-and-energy-use-transportation.
87 Christine Loftus et al., *Estimated time-varying exposures to air emissions from animal feeding operations and childhood asthma*, International J. of Hygiene and Env't Health, Vol. 223: 1 (2020), https://doi.org/10.1016/j.ijheh.2019.09.003; B. Yuan et al., *Emissions of volatile organic compounds (VOCs) from concentrated animal feeding operations (CAFOs): chemical compositions and separation of source*s, Atmos. Chem. Phys. 17 (2017), https://doi.org/10.5194/acp-17-4945-2017.
88 SELC Complaint to EPA, 2021, https://www.southernenvironment.org/wp-content/uploads/2021/09/2021-09-27-Title-VI-Complaint-Index-DEQ-Biogas-Permits.pdf.
89 *Id.* at 3.
90 *Letter to Secretary Ross re: EPA File No. 11R-14-R4* (November 12, 2017), *available at* https://www.epa.gov/sites/default/files/2018-05/documents/letter_of_concern_to_william_g_ross_nc_deq_re_admin_complaint_11r-14-r4_.pdf.
91 U.S. Env't Protection Agency, U.S. Greenhouse Gas Inventory Agriculture , https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-5-agriculture.pdf.
92 U.S. Env't Protection Agency, U.S. Greenhouse Gas Inventory Agriculture , https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-5-agriculture.pdf.

93 *Waste Management Hierarchy and Homeland Security Incidents*, U.S. Env't Protection Agency, https://www.epa.gov/homeland-security-waste/waste-management-hierarchy-and-homeland-security-incidents (last updated May 31, 2018).

94 Randall James et al., *Ohio Livestock Management Guide*, Ohio State Univ. Extension at 18 (2006), *available at* https://agcrops.osu.edu/sites/agcrops/files/imce/fertility/bulletin_604.pdf.

95 U.S. Env't Protection Agency, U.S. Greenhouse Gas Inventory Agriculture , https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-chapter-5-agriculture.pdf ("When manure is handled as a solid (e.g., in stacks or drylots) or deposited on pasture, range, or paddock lands, it tends to decompose aerobically and produce $CO2$ and little or no $CH4$.")

96 Feed production can generate nitrous oxide emissions from the application of synthetic N or manure to crops, while energy use in field operations, feed transport, fertilizer manufacturing, feed blending, etc. can contribute more nitrous oxide as well as carbon dioxide and methane emissions. Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G., *Tackling Climate Change Through Livestock – A Global Assessment of Emissions and Mitigation Opportunities*, Food and Agriculture Organization of the United Nations (2013) Table 1 at 7, https://www.fao.org/3/i3437e/i3437e.pdf.

97 *Id.* at 12.

98 Randall James et al., *Ohio Livestock Management Guide*, Ohio State Univ. Extension at 31 (2006), https://agcrops.osu.edu/sites/agcrops/files/imce/fertility/bulletin_604.pdf.

99 Stephen Kaffka, Tyler Barzee, Hamed El-Mashad, Rob Williams, Steve Zicari, and Ruihong Zhang, *Evaluation of Dairy Manure Management Practices for Greenhouse Gas Emissions Mitigation in California, FINAL TECHNICAL REPORT to the State of California Air Resources Board Contract # 14�456 (*February 26, 2016), https://biomass.ucdavis.edu/wp-content/uploads/ARB-Report-Final-Draft-Transmittal-Feb-26-2016.pdf.

100 *See Alternative Manure Management Program*, Cal. Dep't Food and Ag., https://www.cdfa.ca.gov/oefi/AMMP/.

101 Renewability describes an energy source that is replenished over time. However, even renewable sources can contribute to climate change or impose environmental harms. For example, wood pellets used as biomass may technically be renewable but the . Similarly, a solar array may provide renewable energy and climate benefits but cause other environmental harms by destroying habitat. Policymakers evaluating a given energy source should be vigilant to avoid the all-too-common slippage between "renewable" and "climate-friendly" in order to properly identify the costs and benefits of a given intervention.

102 *The Circular Economy in Detail*, Ellen Macarthur Foundation, https://archive.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail.

103 An Ellen Macarthur Foundation report doesn't mince words: "The circular economy presents a multi-trillion-dollar economic opportunity… More and more companies across industries are adopting circular principles to reduce costs, increase revenues, and manage risks." Ellen MacArthur Foundation, Financing the Circular Economy, Executive Summary, *available at* https://ellenmacarthurfoundation.org/financing-the-circular-economy-capturing-the-opportunity.

104 *See, e.g.,* Phoebe Gittelson et al., *The False Promises of Biogas: Why Biogas Is an Environmental Justice Issue*, Mary Ann Liebert, Inc., https://doi.org/10.1089/env.2021.0025.

105 White House Office of Domestic Climate Policy, U.S. Methane Emission Reduction Act Plan at 11 (November 2021), https://www.whitehouse.gov/wp-content/uploads/2021/11/US-Methane-Emissions-Reduction-Action-Plan-1.pdf.

106 *See* Cal. Dep't Food and Ag., AMMP Program-Level Data of Executed and Funded Grant Projects (updated December 23, 2021), https://www.cdfa.ca.gov/oefi/AMMP/docs/AMMP_Program_Level_Data.pdf; and Cal. Dep't Food and Ag., DDRDP Program-Level Data of Executed and Funded Grant Projects (updated December 23, 2021), https://www.cdfa.ca.gov/oefi/DDRDP/docs/DDRDP_Program_Level_Data.pdf.

107 U.S. Dep't of Ag. Econ. Research Service, The Transformation of U.S. Livestock Agriculture: Scale, Efficiency, and Risks (2009), https://www.ers.usda.gov/webdocs/publications/44292/10992_eib43.pdf?v=0 (2009).

108 *Id.* at iv ("Livestock wastes are becoming more geographically concentrated in the United States, and excessive applications of the nutrients contained in manure pose risks to air and water resources.")

109 *Id.* at 29 ("Large livestock operations store substantial quantities of manure onsite. The manure is generally applied to cropland much more intensely than on smaller farms, and large volumes of manure must still be removed from the operation. High concentrations of manure—whether stored in lagoons, pits, or ponds prior to transport or application—raise the likelihood of leaching or volatilization, threatening groundwater and air quality. And farms that intensively apply manure to cropland and pasture may apply it at rates that exceed the ability of crops to absorb nutrients, with the excess nutrients transmitted to water and air resources.").

110 Leslie Lipper et al., *Climate Smart Agriculture*, Food and Ag. Org. of the United Nations at 397-398, https://link.springer.com/content/pdf/10.1007/978-3-319-61194-5.pdf.

111 Exec. Order No. 14008, Tackling the Climate Crisis at Home and Abroad, 86 Fed. Reg. 7619; Exec. Order No. 13985, Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, 86 Fed. Reg. 7009.

VERMONT
LAW & GRADUATE SCHOOL

CENTER FOR
AGRICULTURE &
FOOD SYSTEMS

VERMONT
CENTER FOR AGRICULTURE & FOOD SYSTEMS

164 Chelsea St, PO Box 96
South Royalton, VT 05068
(802) 831-1000
vermontlaw.edu/cafs