Comments on the Climate Impacts of RNG
Submitted by Michigan Food for All and the Earth Partners
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I. Introduction

MFAEP is a network of organization and citizen activists who advocate the transformation of the industrialization of the food system into a food system that provides healthy and nutritious food for all while protecting and nurturing the well-being of local communities, ecology, environment, and all life. We call for the Michigan Public Service Commission (MPSC) to not recommend biogas as a feasible renewable energy resource for Michigan.

These comments address the climate and environmental impacts of the use of biogas digesters for Concentrated Animal Feeding Operations (CAFOs).

II. Background

Over the past few decades, corporate consolidation has forced U.S. hog and dairy production to shift from traditional, independent pasture-based operations to highly concentrated and industrialized operations, which rely on the industrial model of least cost production and externalization of human, ecologic, and environmental costs to maximize profits. Unlike pasture-based operations, where animals can graze and forage on pasture, industrial hog and dairy operations confine animals in large, specialized facilities for every stage of production. Further, industrial hog and dairy operations use liquefied manure management systems, such as lagoons (flush systems) or slurry/liquid tanks (scrape systems), to collect and store massive amounts of manure from production facilities until disposal on nearby agricultural fields. Industrial hog and dairy operations stock more animals per acre than traditional pasture-based operations because they rely on confined production facilities and liquefied manure management systems.

A. Industrial dairy expansion

According to the U.S. Department of Agriculture (USDA), the structure of dairy farming has changed dramatically in the last three decades, with production shifting away from small, pasture-based farms to larger and more industrialized operations.[1] In fact, over 60 % of U.S. dairy production takes place on industrialized operations with more than 500 cows, and several farms now have milking herds of well over 10,000 cows.[2] As USDA explains, industrial dairy operations rely on animal confinement, purchased feed, liquefied manure management, and other highly polluting practices and technologies to maximize profits.[3]

The number of licensed Michigan dairy farms dropped 18% from 2,647 in 2007 to 2,158 by 2017, with all losses occurring in herd sizes under 199 head. The herd size mid-point in 1987 was 80 cows. In 2017, the midpoint in 2017 was 1,300. The dairy herd inventory increased 28.4% from 344,233 to 442,032 over same time period.[4]

The decline in dairy farms has coincided with increased consolidation in ownership on a national scale, including mergers between the nation's largest dairy cooperatives and milk processors.[5] Moreover, major grocery retailers, such as Walmart and Kroger, have built their own dairies and processing plants to cut costs, forcing smaller dairy farmers to find new buyers and lower their prices.

B. Industrial hog expansion
Similarly, the expansion of the industrial model of production has significantly changed the structure of the U.S. hog industry. According to USDA, hog farms were traditionally small, independently owned farrow-to-finish operations that performed all phases of production, from breeding to slaughtering. Traditional hog farms also typically fed their hogs crops grown onsite and then sold their hogs at local markets. Over the last three decades, however, corporate interests have forced U.S. hog production to shift away from farrow-to-finish operations to larger and more industrialized operations. In fact, 73 % of U.S. hog production takes place on industrial operations with 5,000 or more hogs.[6]

Michigan is the 13th largest pork producing state in the nation. 2,000 Michigan pig farmers raise more than 1.18 million hogs a year. In Michigan, 100 hog CAFOs have 627,734 hogs, an average of more than 6,000 per CAFO.[7] These 100 CAFOs have over half the Michigan pigs while representing only 2% of the Michigan pig farmers.[8]

Industrial hog producers produce hogs under contract for large conglomerates or corporate organizations known as integrators, and these integrators put significant financial pressure on producers to externalize the true costs of industrial hog production. Therefore, confinement facilities and the expansion of the corporate-driven model of production have enabled hog integrators to maximize industrial hog production at the expense of local communities, the environment, and public health.

III. Biogas digesters will increase CAFO methane emissions
EPA has expressly acknowledged that the expansion of dairy cows and hogs in confinement facilities with liquefied manure management systems has caused methane emissions from this sector to increase significantly in recent decades.[9] In the most recent inventory of U.S. GHG emissions, EPA noted that the "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."[10] Consequently, as animal production becomes increasingly more industrialized and concentrated, methane emissions will also increase, leading to adverse climate change impacts.

A. Enteric emissions
Ruminant digestion causes enteric fermentation or cow burps. CAFO methane emissions from enteric fermentation increases as herd size increases and feed digestibility decreases. CAFO cows emit more burps than pasture-based cows. The confined large number of cows have high input diets that include non-forage feed like corn silage, food that ruminant animals do not digest well.

The expansion of dairy CAFOs and purchased feed is largely responsible for causing enteric emissions from dairy cows to increase by 10.7% (or 4.2 mmt CO2 eq.) in the last three decades.[11]

The decrease in feed quality and increase in productivity associated with the expansion of industrial hog facilities have caused enteric emissions from hogs to increase by 40% (0.8% mmt CO2 eq.) over the same period.[12]

B. Manure management

Manure management industrial dairy and hog operations are the two largest sources of methane emissions. The shift to CAFOs that began in the 1990s increased the use of liquid manure management systems, which release more methane than dry (chicken CAFOs) and pasture-based systems. Manure from pasture-based and dry lot CAFO systems decomposes aerobically and produces little or no methane.

Manure handled in liquid-based systems (lagoons or pits) decompose anaerobically and produce large volumes of methane. Methane emissions also increase when producers use long-term storage systems, such as lagoons, which can collect and hold liquefied manure for 10-15 years.

Methane emissions from dairy and hog CAFOs manure management systems have increased 98.8% between 1990 and 2018: 120% increase from dairy and 43% from hog operations.[13]

C. Methane emissions from industrial hog and dairy operations have a substantial impact on climate change

Summary of Contributions of Industrial Dairy & Hog Operations to Total U.S. GHG & Methane Emissions in 2018 (MMT CO_2 Eq.)[14]

Enteric Fermentation	**29.1**	**16%** of total U.S. methane emissions from *all enteric fermentation processes*
Industrial Dairy	26.4	
Industrial Hog	2.7	
Manure Management	**54.5**	**88%** of total U.S. methane emissions from *all manure management processes*
Industrial Dairy	32.3	
Industrial Hog	22.2	
Total CH_4 Emissions from Industrial Dairy & Hog Operations	**83.6**	**Contribution to Total U.S. Methane Emissions** **33%** of total U.S. methane emissions from *agricultural sector* **13%** of total U.S. methane emissions from *all sectors* **Contribution to Total U.S. GHG emissions** **14%** of total U.S. GHG emissions from *agricultural sector* **1.3%** of total U.S. GHG emissions from *all sectors*

1. Contributions to total GHG levels

Industrial dairy and hog operations contribute to rising levels of total U.S. GHG emissions. Specifically, methane emissions from these operations account for 14% of total US agricultural GHG emissions, 1.3% of total US emissions. From EPA's US GHG inventory, which recent studies significantly underestimate emissions from both enteric fermentation and manure management.[15] However, CAFOs contribute 13% of US methane from all sectors.

While total GHG emissions from other sectors of the economy are decreasing due to federal regulatory efforts, total GHG emissions from the agricultural sector are increasing because EPA has failed to implement methane emission standards for industrial hog and dairy operations.

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2. Notable short-term climate change impacts

Within a 100-year timeframe, methane has a global warming potential that is 28-36 times that of CO_2. However, within a 20-year timeframe, methane has a global warming potential that is 72 to 87 times greater than CO_2.[16] The 20-year timeframe holds significance when the science and policy consensus call for reductions in the near term, meaning near term methane reductions especially benefit stabilization goals. Reducing methane emissions is critical for preventing irreversible climate change. IPCC warns that if we do not decrease global temperatures significantly in the near future, there is a "very high" risk of "severe and widespread impacts on unique and threatened systems."[17] Methane emissions from industrial hog and dairy operations pose unique threats to public health and welfare by contributing to overall GHG levels and imposing a far greater threat than carbon dioxide.

3. Eutrophication of western Lake Erie methane increases methane emissions.

The Michigan Department of Environment, Great Lakes, and Energy (EGLE) does not currently have the regulatory tools it needs to curb the runoff of CAFO manure applied to fields, which results in large amounts of phosphorus and nitrogen entering the waters of Michigan and causing their eutrophication. State efforts to encourage CAFO operators and other livestock farmers to voluntarily use best practices has not been sufficient, as stated in EGLE's *Michigan Adaptive Management Plan to Reduce Phosphorus Loading into Lake Erie.*

Stronger spring storms in the western Lake Erie watershed spurred by the warming climate will likely cause more agricultural runoff and more frequent algae blooms. More blossoms would, in turn, lead to more methane production, contributing to further climate change unless the State of Michigan provides ELGLE with more regulatory tools.

Biogas digesters increase the harmful soil and water impacts of nutrient loading and runoff by increasing the concentration of industrial dairy and hog operations in rural communities, and the amount of liquefied manure applied to nearby fields.[18]

4. CAFO biogas increases the number of CAFOs and expands existing ones and will increase methane emissions.

It is important to recall (see table on page 4 of these comments) that for CAFO dairy cows, half of the methane it emits is enteric. Thus, an additional cow added to a CAFO would cancel the climate benefits of capturing the manure biogas from a CAFO cow in the baseline size herd. For pigs, the enteric emissions of eight additional CAFO pigs would cancel the benefits from the collecting the biogas from a pig's manure in the baseline size herd.

Biogas increases methane emissions from enteric fermentation as it incentivizes producers to increase the number of animals in confinement with low-quality diets. State and federal incentives that promote the new revenue stream of carbon credits will encourage livestock operators to install methane biodigesters. That is already occurring. [19]

The government actually increases methane emissions by incentivizing industrial hog and dairy operations to increase herd size to maximize methane production and cover the substantial cost of building and maintaining biogas infrastructure:

> [R]ather than avoiding methane generation altogether, [digesters] can actually create incentives to generate methane from manure. The more methane that is produced then converted to electricity or biogas, the higher the revenue for the digester operator . . . Especially in light of the [significant] financial strains that digester investment can bring about, this is a potential perverse incentive . . . ."[20]

Thus, biogas is not an effective emission reductions strategy because it encourages industrial operations to produce more manure as a biogas feedstock, which results in more emissions of methane, other GHGs, and air pollutants in the atmosphere.

Clearly, if the State of Michigan does not cap the number of animals in a CAFO to the number that the CAFO had upon installing a biodigester with state support, the state would then knowingly increase Michigan methane emissions.

5. CAFO biogas increases leakages throughout delivery to end use system.

Methane leaks from biogas systems, pipelines, and end use further negate the climate benefits of methane capture and destruction and must be factored into the MPSC RNG Study analysis.[21]

When fossil gas leaks before it reaches the end user, it enters the atmosphere as methane. Therefore, methane leakage from production, transportation, storage, and distribution infrastructure will offset any emissions diverted by replacing oil and coal with biogas derived from liquefied manure. Likewise, the construction and maintenance of biogas infrastructure produce significant GHG emissions, which further offsets any purported benefits to fuel-switching.

Methane losses from biogas plants are problematic, since they contribute to global warming and thus reduce the environmental benefits of biogas production. Methane losses from agricultural biogas plants averaged 2.4% of methane collected in a recent study. [22] For any industry to be emitting a significant volume of methane would be a concern; but, for a renewable sector, whose entire premise is based on being green, this is catastrophic.

D. Nitrous oxide CAFO emissions and global warming impacts

Nitrous oxide (N_2O) is the third most important GHG for the enhanced greenhouse effect after carbon dioxide (CO_2) and methane (CH_4). Although there is a relatively small amount of N_2O in the atmosphere, its lifetime is long, about 120 years, which makes it very important for the total amount of global greenhouse gases. N_2O has nearly 300 times the global warming potential of carbon dioxide.[23]

Agricultural emissions of N_2O in the U.S. account for nearly 80 percent of the total human emissions of this gas—including 74 percent from cultivated soils and 5 percent from manure management.[24] And while emissions from manure may not be as significant as from soil, disposing of large amounts of manure is challenging. On some large livestock operations, farmers inject the manure into soil using a shallow disk injector in hopes it will not run off into waterways, but that practice only increases nitrous oxide emissions.

Although previous research suggested that emissions occur only during the growing season because microbes are not active during winter, climate change causes soils to warm up and thaw more frequently, activating the microbes and leading to winter N_2O emissions.

It is important to know that a CAFO biodigester does not reduce the level of nitrogen in the manure. Once the digestate is removed from the biodigester, the operator routinely applies it on a field.

IV. Other true cost of CAFOs and biodigesters

A. Degradation of air quality

Both confinement facilities and liquefied manure storage systems emit significant amounts of ammonia, hydrogen sulfide, particulate matter, and other odorous and harmful air pollutants, which degrade local and regional air quality. These sources also emit methane, nitrous oxide, and carbon dioxide, which contribute to rising GHG emissions and climate change impacts. The Michigan Department of Environmental Quality developed a comprehensive inventory of chemicals associated with air emissions from CAFOs.[25]

Industrial dairy and hog operations significantly degrade local air quality because they densely confine thousands of animals in large and highly specialized facilities for each stage of production and generate massive amounts of waste. These confinement facilities are a significant source of harmful air pollutants and odors, such as ammonia, hydrogen sulfide, and particulate matter, which adversely affect local communities. Another significant source of air pollution is liquefied manure storage, which hold millions of gallons of manure and wastewater for long periods until operators can dispose of it onto nearby fields as fertilizer or irrigation water.

B. Adverse impacts on the environmental quality of near-by neighbors

The air emissions of CAFOs degrade local air quality and threaten the health and well-being of local residents. When operations eventually dispose of liquefied manure or wastewater onto nearby agricultural fields, nutrients, pathogens, antibiotic residues, and other harmful pollutants in the manure can spread to nearby properties and water sources, threatening the health and well-being of local residents, other livestock and contaminating crops.

When there is an infrastructure failure or heavy rain storm, manure lagoons can spill decades' worth of accumulated waste onto local properties, causing crop destruction, soil degradation, water contamination, disease, and other adverse impacts. Moreover, disposing of liquefied manure and wastewater onto nearby agricultural fields can threaten crops, aquatic life, livestock, and human health by increasing manure nutrients and harmful pathogens in the environment. These risks disproportionately affect local farmers and residents.

C. Adverse impacts on rural communities

Surrounding communities will also continue to suffer disproportionate economic and physical harm due to odors, pathogens, and other intolerable nuisance conditions caused by liquefied manure management and land application of the biogas digestate.

By incentivizing industrial dairy and hog operations to increase herd size and manure production, biogas threatens to exacerbate existing social and environmental inequities in communities with a high concentration of industrial hog and dairy operations.[26]

While industrialized livestock operations increase in size and have higher gross sales, independent farmers and communities experience lower family income, higher poverty rates, higher crime rates, lower retail sales, lower housing quality, and lower wages for farmworkers relative to rural communities that do not have CAFOs.[27]

D. Adverse environmental justice impacts

Biogas production entrenches a highly polluting model of dairy and hog production with disparate impacts on frontline and vulnerable communities. Biogas production increasingly relies on the revenue from "offsets" or pollution trading scheme credits sold to entities that continue to emit GHGs and co-pollutants (e.g. gas utilities), which results in continued or increased pollution in often majority Black, Latino, or other urban communities. When pollution trading provides revenues for biogas operators, then communities on both sides of the transaction can suffer.

E. Incentivizing CAFO biogas will delay electrification

Corporate conglomerates and fossil gas utilities, and their allied industrial hog and dairy operations, proclaim biogas as a cleaner and more environmentally friendly source of energy than fossil fuel gas, and as the solution to reducing emissions and fighting climate change.[28] These claims are not only false, but they are deliberately intended to safeguard the role of fossil gas in the transition from dirty fossil fuels (e.g., oil, coal, and fossil gas) to clean zero-emission sources of energy (e.g., solar and wind). As stated by a dairy executive on record with the *Guardian*, however, biogas is not a realistic replacement for fossil gas because it is "'way too expensive' to use in homes or businesses" and "doesn't make all that much sense from an environmental standpoint."[29]

F. CAFO biogas increases dependence on dirty fossil fuels

So-called Renewable Natural Gas (RNG) will increase reliance on dirty energy, delay the transition to clean renewable energy, and hinder ongoing efforts to meet emission reduction targets. Because biogas can only displace a small fraction (2-5% of current fossil gas usage),[30] biogas increases reliance on dirty fossil fuels and undermines long-term climate goals.

As one recent study in California concluded, one of the most effective and cost-efficient strategies for reducing GHG emissions by 80 % by 2050 is "building electrification, which reduces the use of gas in buildings," not biomethane.[31] Moreover, several states and cities across the United States have already started to phase out fossil fuel-based fossil gas, such as San Francisco and Boston.

The limited amount of so-called biogas inherently means that fossil gas use will continue to hinder the transition to zero carbon energy. When operators upgrade biogas to biomethane, they can inject it into fossil gas pipelines because it has the same composition as fossil gas. As a result, there are no additional benefits to combusting biomethane mixed with fossil gas. When the mixed gas is combusted as fuel, it enters the atmosphere as carbon dioxide, another greenhouse gas. Thus, the use of biomethane will perpetuate GHG emissions from fossil gas combustion.

Emissions reductions, not fuel substitution, must occur to meet GHG emissions reduction targets.

G. CAFO biogas requires substantial investment in stranded assets.

So-called RNG is not economically viable. CAFO owners and operators need a tremendous amount of capital to develop, operate, and maintain anaerobic digesters. Typically, CAFOs need approximately $2 to $6 million to build an anaerobic digester, depending on the volume of manure the digester will process and other factors (e.g., location).[32] Because it is nearly impossible for most CAFOs to generate enough revenue to cover upfront capital costs, operators must rely heavily on grants and public funds.[33] These investment costs do not include the upfront cost of constructing or connecting to a pipeline, which requires additional public funding or financing from utility rate-making.

This infrastructure is not only expensive to construct, but also expensive to maintain and operate.[34] Moreover, the revenue potential is limited because the expected lifetime of a digester system is only 10 years, excluding the individual components, which often require more frequent maintenance and replacement (e.g., pumps).[35]

In the climate and energy scenarios to meet IPCC reduction goals, these capital investments will become stranded assets when the economy shifts to non-combustion building and transportation solutions.

MPSC should not base its performance standard on CAFO operators paying out-of-pocket or obtaining public funding for false solutions that perpetuate resource-intensive industrial animal agriculture systems, increase climate change risks, and require substantial infrastructure investments with significant risk.

CONCLUSION

Biogas conflicts with the goals of climate mitigation because it requires continued use of fossil fuels, delays the transition to zero-carbon electricity, increases methane emissions, and contributes to rising GHGs and other adverse impacts. Therefore, any standard that promotes biogas will waste significant time and resources and stymie ongoing efforts to achieve emission reduction targets and other environmental benefits with electrification, clean renewable energy, and other effective climate mitigation strategies.

Finally, MFAEP wants to remind the MPSC that the CAFO manure problem and associated methane emissions can easily be solved by the State of Michigan banning the use of liquefied manure systems. The CAFO industry created the problem through its efforts to minimize production costs by externalizing the costs of its waste and adverse impacts onto the public and environment. The time has come for the State of Michigan to reconsider the costs and benefits the CAFO industry has upon the state's people, ecology, and climate.

MFAEP urges the MPSC to reject CAFO biogas as renewable energy resource.

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[1] J. MACDONALD, ET AL., USDA, ECON. RES. REP. 205, CHANGING STRUCTURE, FINANCIAL RISKS, & GOV'T POLICY FOR THE U.S. DAIRY INDUSTRY 7–13, 18 (2016) [hereinafter USDA, U.S. DAIRY REPORT].

[2] USDA, 2017 CENSUS OF AGRICULTURE: UNITED STATES, 23 tbl.17 (2019).

[3] USDA, U.S. DAIRY REPORT, supra note 52, at 13–14, 16

[4] USDA Report: U.S. Dairy Farm Numbers Continue to Decline, USDA Market Intel, (February 26, 2021.)

[5] See, e.g., Press Release: Dean Foods Completes Sale of Assets to Dairy Farmers of America (May 1, 2020) (announcing merger between DFA, largest dairy cooperative in the country, with Dean Foods, largest milk processor in the county).

[6] USDA, 2017 CENSUS, supra note 53, at 24 tbl.21; see also USDA, CHANGES IN THE U.S. SWINE INDUSTRY, supra note, at 12 tbl.A.2.c.

[7] A Watershed Moment: Michigan CAFO Mapping Report: https://www.sierraclub.org/michigan/michigan-cafo-mapping-report.

[8] Michigan Pork Facts, https://www.MichiganGrown.org.

[9] EPA, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS & SINKS: 1990-2018, at 5-12 (2020) explaining that "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") [hereinafter U.S. GHG INVENTORY]; see also id. at 5-11 (noting that the "majority of [the 66 % increase in methane emissions from 1990 to 2018] is due to swine and dairy cow manure . . . [and] an increase in animal populations").

[10] EPA, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS & SINKS: 1990-2018, at 5-11; see also id. at 5-12 tbl.5-7 (demonstrating that methane emissions from dairy cattle and swine have increased by 120 % and 46 %, respectively, since 1990).

[11] EPA, U.S. GHG INVENTORY, supra note 50, at 5-4 tbl.5-3; 2-19.

[12] Id. at 5-4 tbl.5-3.

[13] Id. at 5-12 tbl.5-7; see also J. Wightman, et al., supra note, at 269-70 (although total number of cows in New York has deceased since 1992, methane emissions has increased dramatically due to "the shift toward anaerobic manure storage systems"

[14] Great Lakes Environmental Law Center, et al, Petition before the US EPA to list industrial dairy and hog operations as source categories under Section 111(b)(1)(A) of the Clean Air Act (April 6, 2021.

[15] See, e.g., J. Owen, et al., Greenhouse Gas Emissions from Dairy Manure Management: A Review of Field-based Studies, 21 GLOBAL CHANGE BIO. 550 (2015) (suggesting that "current greenhouse gas emission factors generally underestimate emissions from dairy manure"); A. Leytem, et al., Methane Emissions from Dairy Lagoons in the Western United States, 100 J. DAIRY SCI. 6803 (2017) ("The [EPA] method underestimated CH4 emissions [from an anaerobic lagoon] by 48%."); H. Baldé, et al., Measured Versus Modeled Methane Emissions From Separated Liquid Dairy Manure Show Large Model Underestimates, 230 AGRIC. ECOSYSTEMS & ENVIRONMENT 261 (2016) ("Comparisons between measured and modeled CH4 emissions showed that both the IPCC methane conversion factor (0.17) for cool climates (10 °C or less), and the USEPA model, underestimated annual emissions by up to 60%."); M. Borhan, et al., Greenhouse Gas Emissions from Ground Level Area Sources in Dairy & Cattle Feedyard Operations, 2 ATMOSPHERE 303 (2011) (finding that an industrial dairy's aggregate CH4 emission rate was significantly higher than EPA's estimated rate).

[16] EPA, U.S. GHG INVENTORY, supra note 50, A-504 tbl.A-252; IPCC, AR5 REPORT, supra note 42, at 87 tbl.1 ("The choice of time horizon markedly affects the weighting especially of short-lived climate forcing agents, such as methane."); EPA, Understanding Global Warming Potential (last accessed Mar. 31, 2021), https://www.epa.gov/ghgemissions/understanding-global-warming-potentials (noting that because CH4 "has a short lifetime, the 100-year GWP of 28–36 is much less than the 20-year GWP of 84–87")

[17] IPCC, AR5 REPORT, supra note 42, at 63. In a recent, alarm-raising special report, IPCC identified the urgent need to limit global warming to 1.5°C by dramatically reducing emissions. IPCC, GLOBAL WARMING OF 1.5°C, at 4–11 (2019). To achieve this goal, IPCC calls for a 35 % reduction in methane emissions by 2050 (from 2010 levels). Id. at 12.

[18] See, e.g., M. Lauer, et al., supra note 351 ("[A]naerobic digestion cannot prevent the negative impact of nitrogen contamination imposed by concentrated livestock farming on water systems . . . ."); CARB, EVALUATION OF DAIRY MANURE MANAGEMENT PRACTICES FOR GHG EMISSIONS MITIGATION IN CALIFORNIA 70-71 (2016); see also C. Liu,

et al., Temporal Effects of Repeated Application of Biogas Slurry on Soil Antibiotic Resistance Genes & Their Potential Bacterial Hosts, 258 ENVTL. POLLUTION 113652 (2020).

[19] Lisa Held, Are biogas subsidies benefiting the largest industrial animal farms? Civil Eats (September 2021.)
[20] M. Lauer et al., Making Money from Waste: The Economic Viability of Producing Biogas & Biomethane in the Idaho Dairy Industry, 222 APPLIED ENERGY 621 (2018) ("At least, 3000 cows per farm are needed for an economically feasible use of dairy manure for the production of biogas."); Z. Debruyn, et al., Increased Dairy Farm Methane Concentrations Linked to Anaerobic Digester in a Five-Year Study, 49 J. ENVTL. QUAL. 509 (2020) (methane emissions from biogas facility increased over time due "an increased use of food waste feedstocks"), Nine Iowa dairies get digester permits since new law, seven plan expansion, (Iowa) Gazette. (December 3, 2021.)
[21] E. Grubert, At Scale, Renewable Natural Gas Systems Could Be Climate Intensive: The Influence of Methane Feedstock & Leakage Rates, 15 ENVTL. RES. LETTERS 084041 (2020).
[22] C. Scheutz and A. Fredenslund, Total methane emission rates and losses from 23 biogas plants, Waste Management, Vol. 7 (September 2019.)
[23] Gosia Wozniacka, The Greenhouse Gas No One's Talking About: Nitrous Oxide on Farms, Explained. Civil Eats (September 2019.)

[24] Ibid.
[25] Concentrated Animal Feedlot Operations (CAFOs) Chemicals Associated with Air Emissions, prepared by the CAFO subcommittee of the Michigan Department of Environmental Quality (MDEQ) Toxics Steering Committee (TSC), May 10, 2006.
[26] J. Lenhardt, et al., Environmental Injustice in the Spatial Distribution of CAFOs in Ohio, 6 ENVLT. JUSTICE 133 (2013) ("[B]lack and Hispanic populations, as well as households with relatively low incomes, are disproportionately exposed to CAFOs [in Ohio.]")
[27] Impact of Industrial Farm Animal Production on Rural Communities, A Report of the Pew Commission in Industrial Farm Animal Production (2007.)
[28] See, e.g., SOUTHERN CAL. GAS CO., Biogas & Renewable Energy (last accessed Mar. 11, 2020), https://www.socalgas.com/smart-energy/renewable-gas/biogas-and-renewable-natural-gas; DUKE ENERGY CORP., Biogas: An Alternative Energy Source with a Bright Future (last accessed Mar. 11, 2020), https://www.duke-energy.com/our-company/environment/renewable-energy/biopower.
[29] See, e.g., S. Cagle, U.S. Gas Utility Funds 'Front' Consumer Group To Fight Natural Gas Bans, THE GUARDIAN (Jul. 26, 2019), https://www.theguardian.com/us-news/2019/jul/26/us-natural-gas-ban-socalgas-berkeley.
[30] A Pipedream or Climate Solution? Natural Resource Defense Council, (June 2020), p. 5.
[31] CEC, Natural gas distribution in California's low-carbon future: tech. Options, customer costs & pub. Health benefits iii (2019)
[32] In 2019, the average cost for a publicly funded dairy digester project in California was $5.4 million. CAL. DEP'T OF FOOD & AGRIC. (CDFA), 2019 DAIRY DIGESTER RES. & DEV. PROGRAM: APPLICATIONS.
[33] California offers dairies up to $3 million per project, so long as the applicant contributes at least 50 % of total project cost in matching funds, which can come from private investors or another government funding program. CDFA, 2019 DAIRY DIGESTER RES. & DEV. PROGRAM: REQUEST FOR APPLICATIONS 6 (Dec. 8, 2018)
[34] H. Lee & D. Sumner, Dependence on Policy Revenue Poses Risks for Investments in Dairy Digesters, 72 CAL. AGRIC. 226 (2018).
[35] PENN STATE UNIV. EXTENSION, Agric. Anaerobic Digesters: Design & Operation (Dec. 2016), https://extension.psu.edu/agricultural-anaerobic-digesters-design-and-operation.