Eco-E Proposal – Digestics

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Background

Inadequate management of organic waste, including manure from livestock farms, leads to a complexity of environmental harms including green house gas emissions, water pollution, and air pollution. Manure left sitting in open-air lagoons or holding tanks ends up in largely anoxic environments resulting in methane production and off-gassing. The EPA estimates methane to have a global warming potential over 100 years that is 28 to 36 times greater than that of carbon dioxide [1]. The EPA estimates that 10% of all U.S. methane emissions in 2018 originated from manure management [2]. Manure applied to agricultural fields beyond capacity or escaping from lagoons or holding tanks can wash away into rivers, lakes, and oceans, resulting in eutrophication and disruption of aquatic ecosystems. In addition, raw untreated manure carries pathogens that pose a risk to farm workers and surrounding communities.

Anaerobic digester technology provides a solution for capturing these waste streams and converting them into valuable byproducts: biogas for energy and digestate for use as an organic soil amendment. U.S. AgSTAR estimates that in 2019 digesters reduced GHG emissions from U.S. livestock farms by 3.85 million metric tons of CO_2 equivalent in direct methane reductions (Figure 1) [3]. The EPA estimates total 2019 U.S. manure management methane emissions were 62.4 million metric tons of CO_2 equivalent [4].

Biogas from digester operations provides a renewable energy source, reducing our reliance on oil and natural gas that needs to be extracted from the earth. Synthetic fertilizers often release nutrients into soils more rapidly than crops can assimilate them, creating the potential for runoff and eutrophication in aquatic ecosystems. Land application of these fertilizers is a major contributor of GHG emissions [5]. The production of synthetic fertilizers requires the use of mined phosphate rock, of limited global supply [6], and the energy intensive Haber-Bosch process for fixing nitrogen, a major GHG emitter as well [7]. Use of digestate as an organic soil amendment decreases our reliance on these fertilizers.

Eco-E Opportunity

Our research has indicated a need for digester technology in the dairy industry. Dairy farms produce significant amounts of manure, and farms often do not have enough agricultural fields on their property for manure application.[1] Manure held on site takes up space and can lead to regulatory issues. Despite challenges transporting dairy manure due to the high water content, this manure is typically at a solids content that is ideal for many digesters: 9%-12%.[2] There is a drive to implement digester technology for the environmental benefits. Dairy Management Inc. (DMI) set a goal to bring the dairy industry to net zero emissions by 2050 through its Net Zero Initiative. Curt Gooch, VP of Environmental Research at DMI doesn't see a path to net zero emissions for the industry without the use of digester technology.

Anaerobic digesters used in organic waste management are traditionally large structures that need large waste streams for operation. These systems require large capital investments, representing significant financial risk for waste producing operations.[3] While digesters can lower waste management costs, provide revenues, and shelter operations from regulations, many farmers are unable to do the research required to reliably invest in a successful project. Biogas companies are investing in and developing biogas projects with large industrial dairies, taking the financial risk and management of operations out of these dairies' hands, allowing them to focus on their business while capturing value from their waste streams. Smaller dairy operations are left out of the market addressed by most biogas companies.[4]

One approach for managing waste streams from smaller operations with digesters is to build centralized systems that are positioned to source waste from surrounding operations. This approach can work, but these systems are highly reliant on geography, and often require high transportation costs to truck in waste. This is particularly problematic in dairy, which produces manure with high water content.[5]

Experts in the space don't see many viable options for outfitting smaller operations.[6] They are largely unaware of the small-scale digester options available, and they feel that segment of the market cannot

[1] Supporting evidence documented in 5 interviews
[2] Supporting evidence documented in 3 interviews
[3] Supporting evidence documented in 9 interviews
[4] Supporting evidence documented in 5 interviews
[5] Supporting evidence documented in 7 interviews
[6] Supporting Evidence documented in 4 interviews

attract biogas companies for investment and development. Steve Hanson, VP of Farmer Activation at DMI and a dairy farmer himself, told us that the organization does not have any solution for dairies with herds under 3,000 head of cattle. For dairies at 3,000 head of cattle and above, DMI is focused on the Varcor system from Sedron Technologies, which costs $6,000,000. When we spoke to Steve, he had just finished visiting a number of farms that supply milk to Nestlé, the largest at about 2,200 head of cattle and most at about 400-500 head of cattle. Starbucks is another major brand that is supplied by relatively small farms. Nestlé and Starbucks have both joined DMI in pledging to bring their carbon emissions to net zero by 2050 and are both actively looking for solutions at the dairy level [8, 9].

We spoke to two digester companies that are targeting dairies in the 3000-6000 head of cattle range, SustainRNG and Environmental Products and Technologies Corporation. Both companies believe that the sub-3000 head of cattle market would not provide returns to justify development with these farms.

We analyzed the distribution of small-scale dairies, defined as dairies with 500-2,500 head of cattle, across the U.S. California provides a large market of these small-scale dairy farms, with about 700 of these farms in the state (Figure 2) [10]. AgSTAR's livestock anaerobic digester database lists only 13 dairies in this approximate size range as utilizing anaerobic digesters for manure management in the state [11], indicating a potentially large market opportunity.

Small-scale, on-site digesters can address small dairies' waste management needs with reduced transportation costs relative to centralized digesters. Modular digesters are available on the market that can operate off relatively smaller waste streams, bring waste management on site to reduce transportation costs, and can be moved if necessary. Through our interviews with dairy industry experts so far, we hypothesize that dairy farmers can best be served through modular digester contracting, full financing and maintenance of these systems, with contracts to bring these systems on site.

We spoke to two modular digester companies that provide a similar model when they can for customers who want it: Impact Bioenergy, based in Seattle, and SEAB Energy, a London based company with U.S. distribution. Impact Bioenergy, focused on food waste digestion, does find project financing to be a major challenge when customers cannot finance the project themselves. At the time of our conversation with CEO Sandra Sassow, SEAB Energy had not done any projects with dairies but was in talks with a dairy at around 2,000 head of cattle. Their Muckbuster system is a good candidate for small-scale digester projects with dairies, and while they are exploring servicing dairies themselves, we believe they cannot make a large dent in the small-scale dairy market through full financing and management on their own.

Objective and Research Questions

While anaerobic digester technology shows great promise, barriers exist to its mass adoption. This project is driven by the belief that anaerobic digester technology must play a role in moving our society towards a more sustainable, circular economy, where nothing is wasted. We will uncover opportunities to play a part in the ecosystem of digester technology, in order to remove barriers to adoption. This philosophy provides the project with wide guardrails, guiding its purpose as the need to pivot arises.

The following research questions will direct the project in the assessment of the opportunity for and development of a business model for implementing modular digester contracting in the dairy industry.

What lessons and best practices can be learned from digester operations on large dairy farms and applied to small-scale projects?

A digester operation needs to assume full liability for dairy manure it handles, and mishaps in handling it can result in fines or business closures. This presented a challenge for the Eco-E Project: Organic Matters in fundraising efforts in 2016. While it is possible to charge companies for food waste management, operations that manage manure for dairies are typically required to lease land from the dairy and pay the dairy for their manure.[7] The current manure management method employed on a dairy farm is an important consideration. Scraper and vacuum systems keep solids content where it needs to be for digestion. Wash or flume systems dilute dairy manure too much for use with most available digester technology.[8] Vacuum systems may be the easiest to implement on a farm, regardless of the currently employed system.[9] Our research with digester companies and dairy digester case studies will reveal additional insights from large-scale projects that can be applied to small-scale projects.

[7] Supporting evidence documented in 5 interviews
[8] Supporting evidence documented in 2 interviews
[9] Supporting evidence documented in 1 interview

Is it possible for a business to successfully serve small-scale dairies with on-site modular digester technology?
Modular digesters need to be seamlessly integrated into farm operations and managed completely; the dairy farmer cannot be tasked with operating a digester on site.[10] It can be a challenge to manage distributed modular digesters on dairy farms, as the farm clients might be spread out and would require staff to attend to each digester most days. Customer interviews with dairy farmers will give us insight into their needs and operations. Further research into available technology is needed to align farmers with the systems best suited for their operations or to identify an opportunity for additional technology development to fill a gap where the space is lacking.

What kind of business model innovations could make the economics work for digesters servicing small-scale dairies?
The OrganicMatters team found that the payback periods they could offer to investors made it difficult to raise funds. We anticipate financing to be a major challenge to achieving the goals of the project. A case study from SEAB Energy estimates a 5-year payback period for one of its systems at a commercial bakery. The company estimates that payback periods for its Flexibuster digester to be about 2-6 years with grant money [12]. These are long payback periods for attracting venture capital. Research into funding options available for projects with relatively long payback periods will be required.

Digesters can capture value through the reduction in waste management costs as well as the use or sale of biogas and digestate. Many digester operations aim to convert biogas to natural gas and sell it to energy companies by injecting it into natural gas pipelines, but this process is complex and expensive.[11] Small-scale operations may get more value from biogas used as an energy source on site. Digestate, typically with high water content, is best used close to where it is produced unless it is processed or dried. It can take some time to develop new markets for digestate. Some digester operations initially give it to farmers for free, so they can get accustomed to using it instead of typical fertilizers with a different consistency.[12] We will require markets for digestate near partner dairies or we will need to develop them in a reasonable time frame. We will research carbon markets that provide additional revenue from biogas such as the Renewable Fuel Standard (RFS) and the Low Carbon Fuel Standard (LCFS) in California.

Available Data

The following sources may provide valuable data for this project:
USDA National Agricultural Statistics Service, Agricultural Census (Database) – Provides information on farm sizes by livestock count for dairy and other agricultural sectors at the state and county level.
USDA National Resources Conservation Service and Economic Research Service Report - Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients (2000) (Text) [13]– This report contains information that can be used to estimate manure production including nutrient content for livestock operations based on number and type of livestock.
U.S. EPS AgSTAR (Text, Database) – The AgSTAR website contains a Livestock Anaerobic Digester Database with current operating digesters and locations, a digester vendor directory, and numerous reports useful for learning about digesters, planning digester operations, financing, and economics.
Digester Case Studies and Reports (Text) – Case studies for large scale and modular digester projects will be useful for understanding the potential of different projects. AgSTAR has 90 project profiles and case studies on their site. Impact Bioenergy provided a report on feedstock input and energy generation for their digester at Fremont Brewing in Seattle, and we believe we can obtain similar reports elsewhere.

Possible Approaches

A business model for modular digester contracting could be developed through analysis of digester case studies, key stakeholder interviews, an analysis of energy and fertilizer prices as well as processing and transportation costs for digestate in target areas for project development. Key stakeholders would include dairy farmers and farmers who use various types of fertilizer as soil amendments that could be customers for digestate. We will also continue to interview digester companies and operators for best practices in operations, capturing byproduct value, and developing digestate markets. We have information that can be used to estimate manure nutrient production based on livestock type and count, and this can be used to estimate biogas and digestate production at various sites.

[10] Supporting evidence documented in 4 interviews
[11] Supporting evidence documented in 6 interviews
[12] Supporting evidence documented in 3 interviews

Citations

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[2] US EPA, O. (2015, December 23). *Overview of Greenhouse Gases* [Overviews and Factsheets]. US EPA. https://www.epa.gov/ghgemissions/overview-greenhouse-gases

[3] US EPA, O. (2014, December 16). *AgSTAR Data and Trends* [Data and Tools]. US EPA. https://www.epa.gov/agstar/agstar-data-and-trends

[4] *DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019* (p. ES-7). (n.d.). United States Environmental Protection Agency. https://www.epa.gov/ghgemissions/draft-inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019

[5] Razon, L. F. (2012). *Life cycle energy and greenhouse gas profile of a process for the production of ammonium sulfate from nitrogen-fixing photosynthetic cyanobacteria*. *107*, 339–346.

[6] Cordell, D., & White, S. (2011). *Peak Phosphorus: Clarifying the Key Issues of a Vigorous Debate about Long-Term Phosphorus Security*. *3*, 2027–2049.

[7] Razon, L. F. (2012). *Life cycle energy and greenhouse gas profile of a process for the production of ammonium sulfate from nitrogen-fixing photosynthetic cyanobacteria*. *107*, 339–346.

[8] *Our road to net zero*. (n.d.). Nestlé Global. Retrieved February 3, 2021, from https://www.nestle.com/csv/global-initiatives/zero-environmental-impact/climate-change-net-zero-roadmap

[9] *Starbucks furthers commitment to sustainability goals by joining Transform to Net Zero*. (n.d.). Retrieved February 3, 2021, from https://stories.starbucks.com/stories/2020/starbucks-furthers-commitment-to-sustainability-goals-by-joining-transform-to-net-zero/

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[11] *Livestock Anaerobic Digester Database*. (2020). United States Environmental Protection Agency, AgSTAR. https://www.epa.gov/agstar/livestock-anaerobic-digester-database

[12] atelierstudios. (n.d.). Using Flexibuster™ in a Commercial Bakery. *SEAB Energy*. Retrieved February 6, 2021, from https://seabenergy.com/case-studies/using-flexibuster-in-a-commerical-bakery/

[13] Kellogg, R. L., Lander, C. H., Moffitt, D. C., & Gollehon, N. (2000). *Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States*. United States Department of Agriculture, Natural Resources Conservation Service and Economic Research Service. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/rca/?&cid=nrcs143_014126

Relevant Interviews

Dairy industry and manure management expert interviews:

- Alex Silvester, Former Intern, Dairy Management Inc., 12/1/20
- Anthony Luna, Current MESM and Eco-E Student, Team BioQuest/Rubbish, 12/1/20
- John Schauff, Director of Government Services and Training, Spartan Chemical, 12/1/20
- Eric Hassel, Manager of Sustainability Measurement and Reporting, The Innovation Center for U.S. Dairy (Part of Dairy Management Inc.), 12/7/20
- Curt Gooch, VP of Environmental Research, Dairy Management Inc., 12/17/20
- Tom Myers, COO and Board Member, Pure Bioscience, Dairy Industry Innovator, 1/9/21
- Steve Hanson, VP of Farmer Activation, Dairy Management Inc. (also a dairy farmer), 1/18/21
- Jake Levine, Former MESM and Eco-E Student, Team OrganicMatters, 1/25/21
- Katie Hames, Proprietor of El Chorro Ranch, 1/25/21
- Melissa A., Supervisor, Federal Correctional Institution Lompoc Dairy, 2/9/21

Fresh produce and food waste expert interviews:

- Minos Athanassiadis, Founder and Managing Director, Fresh Link Group, 11/30/20
- Nikki Cossio, Founder and CEO, Measure to Improve (Former Director of Sustainability at Gills Onions), 12/5/20

Digester experts and digester company interviews:

- Sara Pace, Postdoctoral Researcher, UC Davis, 1/14/20
- Chad Lipton, Former Digester Operator, Montrose Environmental in Sacramento and a Digester Operation in Rhode Island, 1/20/21
- Sandra Sassow, CEO, SEAB Energy, 1/22/21
- William Skinner, Director of Operations and Maintenance Management, Hitachi Zosen Inova, 1/22/21
- George Criner, PhD Addociate Dean of Instruction, College of Natural Sciences, Forestry, and Agriculture, The University of Maine (Assessed economic viability of an early anaerobic digester project on the campus), 1/22/21
- Michael Shore, CEO, SustainRNG, 1/25/21
- Michael Smith, Director of Legal and Business Development, Impact Bioenergy, 1/26/21
- Connor Keenan, former Financial Analyst for Anaerobic Digester pilot project at a hog farm in North Carolina, 1/26/21
- Jeremy Bunch, Digester Operator, UC Davis, 1/28/21
- Marvin Mears, CEO, Environmental Products & Technologies Corporation, 2/1/21
- Eric Hough, Former Project Manager, Cambrian Innovation, 2/4/21

Figures

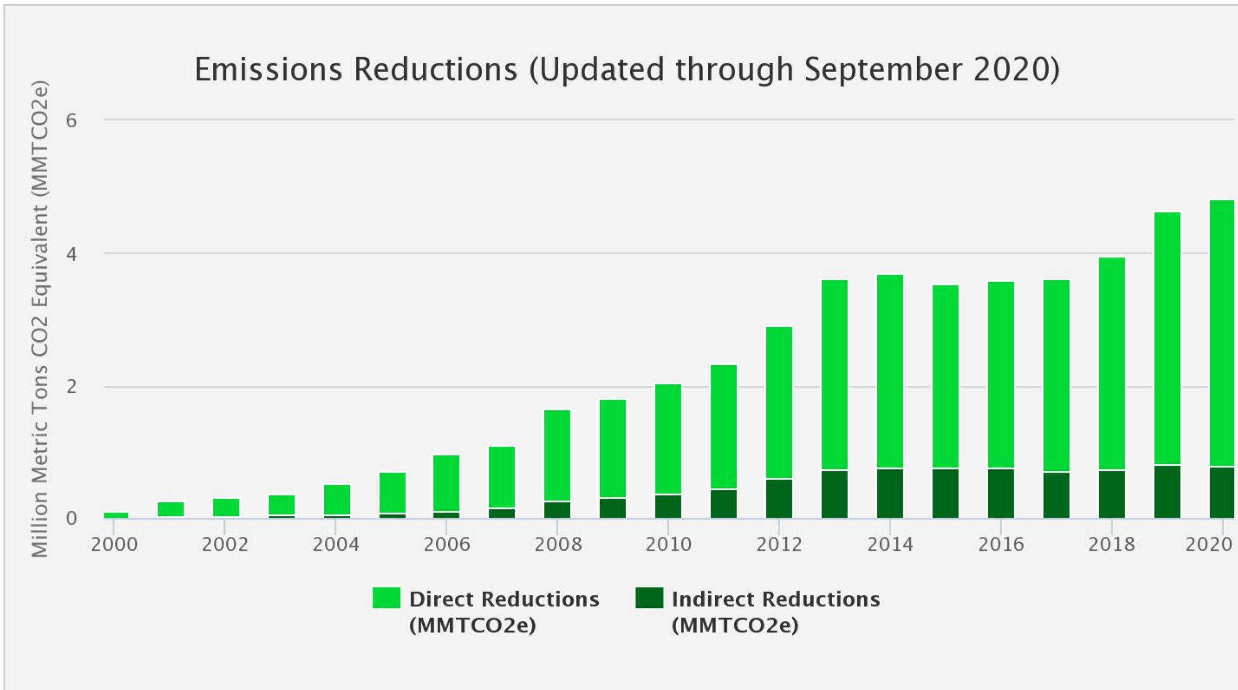

Figure 1: Direct and indirect GHG emission reductions from anaerobic digesters on livestock farms in the U.S. since 2000. Source: U.S. EPA AgSTAR (https://www.epa.gov/agstar/agstar-data-and-trends#envben)

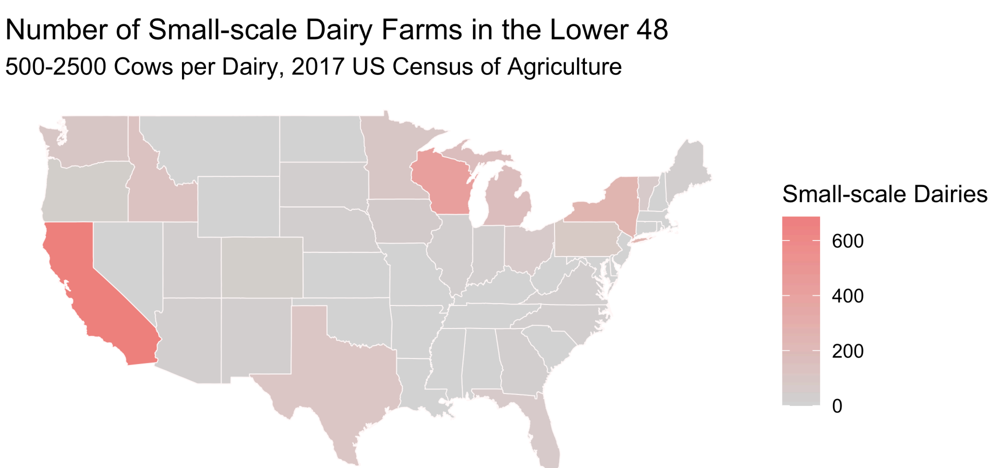

Figure 2: Source: US Department of Agriculture, 2017 Census of Agriculture; Mapped by Sophia D Arabadjis, PhD Student UCSB, 1/27/2021