Feasibility Of Large-Scale On-Site Algae Production For Dairy Farms To Mitigate Methane Emissions

Ella Weldy, Julia George, Nathan Blumer, Philip Hekeler, Razieh Analouei, Andrea Ferro, Shane Rogers, Stefan Grimberg

Clarkson University, Potsdam, NY

Dr. Stefan Grimberg | sgrimber@clarkson.edu | 315-268-6490

Problem Statement

- Methane is a greenhouse gas 25 times more potent than carbon dioxide. Methane from cows is the 3rd largest source (30%) of methane emitted in the US.
- Adding just 0.1% bromoform-containing algae to cow feed can reduce their methane emissions by 88% [1].
- Growing microalgae as a dairy cow supplement on site reduces transportation emissions and increases the farms' self-sufficiency.

We propose a closed-loop system for growing microalgae on dairy farms where cow manure generates energy and nutrients via an anaerobic digester to support the algae photobioreactors.

Approach

For the P3 project, we split the closed loop system into three areas, each providing key parameters to support the proposed solution to the problem statement.

Anaerobic Digester Modeling:

Inputs include;

- Farm size, location, climate

Outputs include;

- Size, biogas production, heating energy requirement, net energy produced

Algae Bioreactor Modeling:

Inputs include;

- Inclusion rate, biomass density, growth rates, bioreactor size

Outputs include:

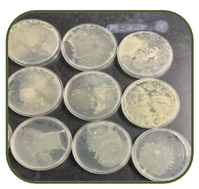
- # of bioreactors, volume of water, energy consumption, biogas requirements, digester effluent requirements

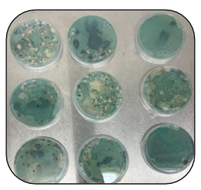
Water Recycling Feasibility Experiments:

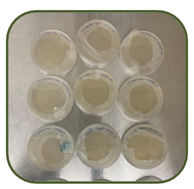
- 3 disinfection methods tested for treating digester effluent: UV, Chlorination, Pasteurization
- Petri dishes were inoculated post treatment to determine sterility
- Results show effectiveness of UV treatment

Experimental Results

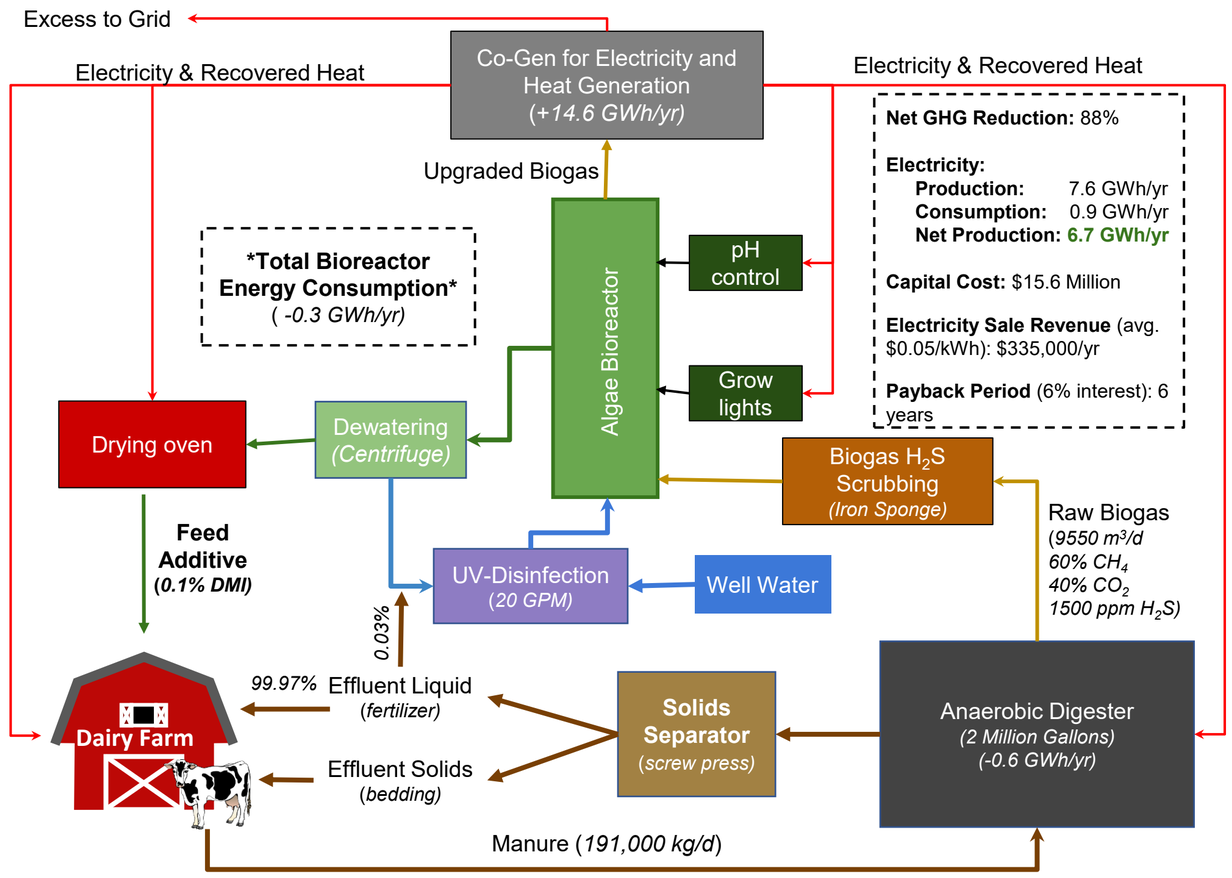
Chlorination	Pasteurization	Ultraviolet
• Chlorine dose: 0.2 mg/L - 8 mg/L • **NOT** effective at killing bacteria	• Temperatures: 60℃, 70℃, 80℃ • Residence Time: 20, 30, and 40 min • **NOT** effective at killing bacteria	• Flow rates: 0.025 GPM-0.5 GPM • **Effective at** killing bacteria







Anaerobic Digester + Algae Production Process



Digester		
Variable	*Value*	*Units*
Farm Size	3000	Cows
Raw Energy	20	GWh/yr
Co-Gen Efficiency	31	%
Electricity Produced	7.6	GWh/yr
Heat Recovered	7.0	GWh/yr
Bioreactor		
Reactor volume	1350	L
Target biomass	20	gDW/L
Required bioreactors	20	units
Harvest	4000	L/d

People, Prosperity, Planet

This system offers multifaceted benefits, spanning across people, the environment, and economic viability.

- **People:** Mitigating global warming can positively impact people by preserving habitats, reducing the spread of novel pathogens, and minimizing extreme weather events.
- **Prosperity:** Implementing algae-based methane reduction can be financially lucrative for farmers, ensuring profitability and the continuity of family farms. This stability benefits local communities and economies, sustaining jobs throughout the supply chain and supporting businesses in the area.
- **Planet:** Ruminants like cows contribute significantly to methane emissions, with approximately 99±12 Tg CH4 yr-1 [2]. Reducing this by 88% would markedly decrease GHG emissions and the environmental footprint of dairy farms.

References

[1] De Bhowmick, G. & Hayes, M. (2023) Potential of seaweeds to mitigate production of greenhouse gases during production of ruminant proteins. *Global Challenges*, *7*(5), 2200145.

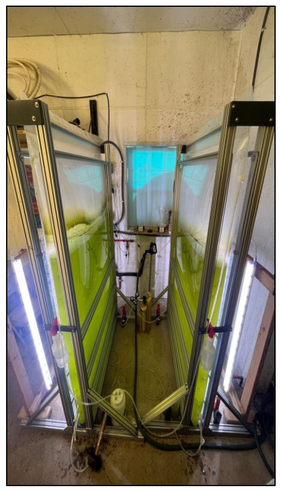
[2] Saunois et al. (2020). The global methane budget 2000–2017. *Earth System Science Data*,12, 1561–1623.

Future Work

We currently have a working pilot plant with an anaerobic digester and, two small algae bioreactors.

Our future work includes:

- Scaling up the pilot plant for complete energy and mass balance assessment needed for economic feasibility evaluation.
- Integrating UV disinfection of digester effluent and water recycling for algae production
- Creating a Life Cycle Assessment for the system
- Working with local farmers to understand and lower implementation barriers.



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