Evaluating Biogas as an Option to Heat an Urban Greenhouse

Marc Christiansen (PH), Natalie Marquardt (ME),
Katie Picchione (ME/Society, Technology, and Policy), Thomas Sullivan (ECE)

Advisors: Professor Geoffrey Pfeifer (Philosophy) and Professor Derren Rosbach (Environmental Science)

Abstract

In Worcester, MA, a group of urban farmers in a community called "The Shop" built a greenhouse to grow fresh produce year round. However, the greenhouse becomes too cold during winter months to sustain plant growth. Having experience with composting, The Shop is interested in pursuing biogas–methane produced from anaerobic digestion of organic waste–as a means to heat the greenhouse. This project uses data from case studies and other sources to calculate the amount of energy needed to heat the greenhouse and the expected energy yield from different obtainable substrates. Results verify that biogas is a viable way to heat the greenhouse at The Shop.

Background

- Urban farming is the growing of local produce in cities.
- Amanda Barker, director of the urban farming project at The Shop, hopes to heat the greenhouse this coming winter.
- In winter, the greenhouse becomes a lost source of income, which reduces the sustainability and self-sufficiency of The Shop and conflicts with their values.
- Currently, The Shop composts food waste from restaurants.
- Another potential product of food waste is biogas, methane created when organic waste decomposes in an anaerobic (oxygen free) system[15].
- Methane is also the main component of natural gas, which is a combustible fuel widely used for heating[16]. Biogas can be used in the same way[11].
- Since it is an established and well researched energy source, Ms. Barker proposed using biogas generated from the food waste they collect to heat the greenhouse.

The greenhouse at The Shop (left) and plants trying to grow in the greenhouse during the winter (right).

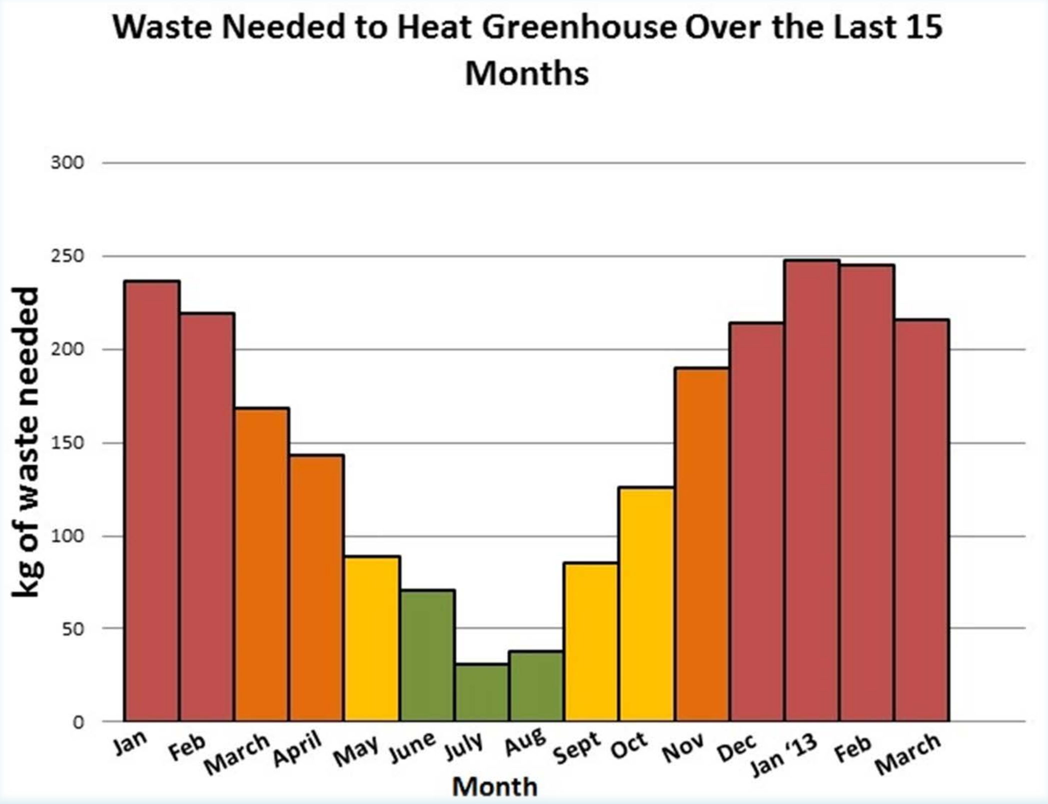
Project Goals

Can the greenhouse be heated using sustainable biogas energy?

- Suggest a sustainable way to heat the greenhouse to grow produce year round.
- Assess whether biogas produced from food waste is a viable way to heat the greenhouse.

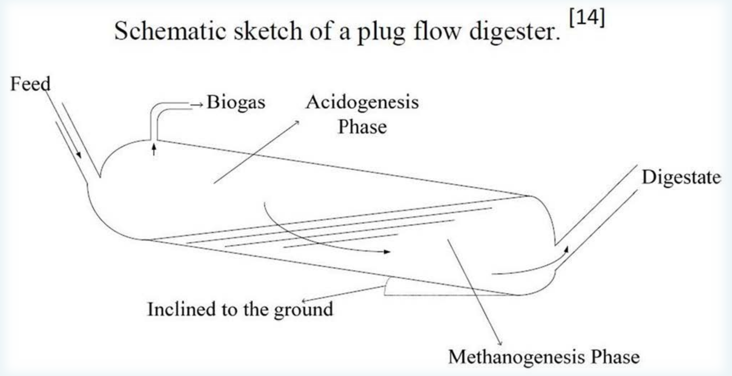
Methods/Process

- The team visited The Shop to assess the site.
- Case studies, literature research, and a visit to Jordan's Dairy (operating biogas digester) provided information about biogas systems, processes, uses, and risks[1,2,13].
- Data from several sources was used to determine the BTU yield from one kilogram of different fully digested substrates[9,10,12].
- Calculations were verified by Professor Robert Thompson (CHE).
- Greenhouse dimensions (35ft x 15ft x 8ft), a heat loss calculator, and average monthly temperature data from the past year were used to estimate the number of BTUs needed to heat the greenhouse from the external temperature to 80˚F, a viable growth and digestion temperature[19,20].
- The amount of biogas needed to meet this heat increase was calculated.
- The graph below shows the estimated amount of food waste needed to produce the necessary amount of gas at a given time of year.
- Estimates are based on the average methane yield per kilogram of fruit, vegetable, and food waste calculated from literature data [9,10,12].



Results and Recommendations

- Mixture of food, fruit, vegetable, and garden waste produces an average of 170 BTU/(kg*day).
- Amount of waste required to heat the greenhouse to 80˚F varies from ~31 kg in July to ~248 kg in January.
- Under average gas production and an expected minimum temperature of 60˚F, ~95 kg of waste collected daily from restaurants and other sources will meet the average heat requirement of 15,800 BTU/day[19].
- A plug-flow bag style digester (right) is simple, flexible, and low maintenance compared to other rigid digester systems.



- Inoculating the digester with effluent slurry from a working system will facilitate digestion[14].
- The digester should in an environment kept at 80˚F-120˚F [15].
- An insulating cover used to "tuck the greenhouse in" at night will reduce heat loss.
- A methane-burning water boiler and radiator system can distribute heat in the greenhouse and isolate combustion of the gas from its source to prevent flashback fires.

Conclusion

Based on research, biogas yield estimates, and estimated heat requirements, it is clear that biogas is a viable way to heat the greenhouse at The Shop. 100kg of waste per day is obtainable from local restaurants and colleges in Worcester. There are commercially available, relatively inexpensive digesters that can process this amount of waste. The limiting factor will be space at The Shop. If The Shop does decide to implement a biogas digester, it will be a pioneer for other urban farmers.

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