Worcester Community Project Center

Assessing Dairy Farm Waste Technologies in New England: *Supplementary Materials*

DATE: DECEMBER 16, 2021

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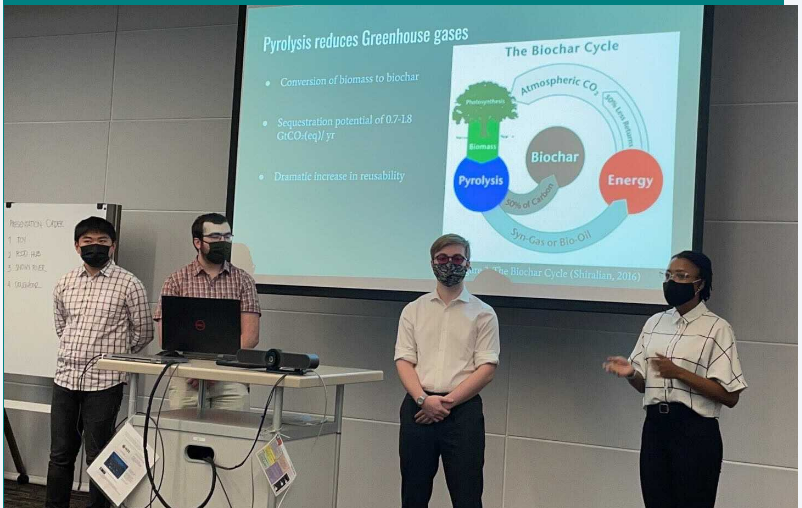

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Snowy River Innovation

Snowy River Innovation

Haoyu Fu, Cabot Priestner, Marissa Desir, and Mathieu Michaud (left to right)

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Appendix A: Informed Consent and Preamble

To accomplish our project, we conducted numerous interviews either in person or online via email or video calls. Any communication began with some version of this informed consent preamble.

Hello, we are a group of undergraduate students from Worcester Polytechnic Institute researching technologies at dairy farms in New England for our project. We are working with a sponsor from Australia and he would like to learn more about current technologies in farms in New England assessing the state of sustainability and waste management. Your involvement is purely voluntary and you can withdraw at any point. If you do participate, your identity can be made confidential if you would prefer. At the end of our findings, you can contact the team or our advisors, Corey Dehner and Elizabeth Lingo, for a copy of the final report. Feel free to email us at: gr-snowyriverb21@wpi.edu, cdehner@wpi.edu, and ellingo@wpi.edu.

Appendix B: Snowy River Innovation Sponsor Description

Snowy River Innovation is an Australia-based company that is working towards developing and increasing sustainability in rural Australia. Peter Young is the director and he oversees many projects under the general theme of helping the environment. His team includes three other directors, Geoff Andrews, Steve Ingrouille, and John Macdonald all of whom are leaders in the fields of renewable energy. They include utilizing emerging technologies and commercialization. Developing rural regions to be more environmentally friendly is very important to reduce emissions globally. Often, rural regions are left to scramble for economic stability as well as technological advancements, but SRI wishes to assist these regions. SRI has pursued efforts in the areas of commercialization, corporate advisory and ecapital, sustainability, energy, and embedded generation. These have led to the ideas and projects based on clean and renewable energy as well as developing new technology to assist in the upkeep and development of rural Australia. SRI is building framework solutions for these issues. With agriculture as such a large industry finding improvements to reduce emissions is very important (Snowy River Innovations).

Snowy River Innovation provides a multitude of programs and activities. From developing industry-focused energy and waste solutions to renewable energy generation, the company provides many options and opportunities to influence the use of energy. One of the company's major programs is devoted to innovation and commercialization. Through this, innovation insights and services assist other businesses to commercialize their sustainability project. The purpose is to customize the most relevant strategies and utilize them to guide businesses to success. The services provided through this program include collaborative research, financial modeling and review, designing funding solution strategies for the project, and many more. Alongside the services, the program has priority project areas, which comprise rural and regional energy efficiency, community energy projects, etc. Another program provided by Snowy River Innovation is the expansion of renewable energy, in short, this means improving and finding new ways to recycle energy. Through this program, cost-effective and practical methods are implemented to integrate renewable energy and technologies into a company's infrastructure. This is applied to systems for energy production or energy storage mode, which can suit on-grid or off-grid applications (Snowy River Innovations).

Snowy River Innovation is employing multiple routes to help rural Australia be more sustainable. SRI has directed its research and efforts into sustainable technology, as well as energy. Technologically, SRI has started creating an industry that is in direct contact with the rural region to assist them in drawing in money and creating a source of sustainable income. With these advancements, they can start the construction of other forms of benefits for the region to support them with energy. The methods that are being pursued all stem from clean, and renewable energy sources including solar arrays, and hydro plants. However, they have also started looking into the renewable sources that are produced as a byproduct of living organisms: biomass energy.

A topic that SRI has recently taken interest in is the waste produced on dairy farms. Dairy farms produce a ton of waste, one farm can produce as much as 40,000 metric tons of greenhouse gasses in one year. (Simpson). SRI is concerned about this new field due to the environmental impacts and positives that it brings, not only does it produce clean energy, but it reduces the pollutants that are being released into our atmosphere. SRI is interested in this to reduce emissions and to repurpose what would normally be waste, cow manure, and use it as a resource to produce clean energy.

SRI has excellent Australian rural research connections particularly in the state of Victoria with Ellinbank SmartFarm. The SmartFarm has an ambitious target in reducing methane emissions, generating electricity through a range of alternate options including solar, wind, and bio-digestion, and improving fertilizer and manure management practices. The previous research connections between SRI and Ellinbank SmartFarm provided benefits to the Australian dairy industry by enhancing measuring, managing, and utilizing the homegrown feedbase, improvements in the health, welfare, and lifetime performance of cows, and sustainable increment in annual milk production per cow.

Appendix C: Mechanical Process of Aerobic Digestion

In order for this reaction to occur, there is some equipment that is necessary. Firstly air or oxygen must be added as the sludge is mixed to produce the best results, it is common for square and rectangular tanks to use surface aerators or diffusers, but cylindrical tanks often need an eductor tube for deeper aeration. Additionally, sludge recirculation pumps, pipes, mixers, and scum collection baffles are important (Shammas and Wang, 2007). When designing a system for an aerobic digester there are a number of considerations that must be taken into account. Beginning with temperature, during the reaction lower temps will slow the process, it is common for tanks to be insulated or maybe even heated in order to achieve a faster reaction to speed up the process. In most cases, the goal is to keep the sludge in the tank around 50℃ for the best results. Secondly, the amount of oxygen required to oxidize the sludge must be considered, in general roughly 1.98 lbs of oxygen is required to oxidize 1 lb of cell mass (Shammas and Wang, 2007). The amount of oxygen needed varies with the ratios of the contents of the sludge. Next, the mixing should be considered; the length of time that the sludge spends in the tank getting mixed in order to be most efficient is an important factor that cannot be ignored.

There are a few different variations of aerobic digesters that are different based on the temperature of the reaction or whether normal air or pure oxygen is used to boost the reaction. A Conventional Semibatch Operation is the oldest method of an aerobic digester, Solids get pumped from the clarifiers to the tank, after the tank is full it takes roughly 2-3 weeks before the solids are fully stabilized. Next, the Conventional Continuous Operation is similar to the previous method, but the aerator operates at a fixed amount of sludge, the thickened solids get removed over time as they are fully processed. This process is reliable, but the processing time varies greatly depending on temperature. Autothermal Thermophilic Aerobic Digestion (ATAD) is a newer process, it uses air as its main source of oxygen in order to aerate the mixture. As the name suggests it is autothermal, meaning all the heat needed is provided from the reaction happening inside the tank, to achieve this the tank is insulated from the outside air. For this process, the sludge is thickened after it proceeds through the clarifiers to aid the reaction. Some of the benefits over the traditional methods include the more complete destruction of the pathogens in the mixture. The high temperatures also decrease the amount of oxygen needed because it prevents nitrification from occurring. Finally, ATAD with oxygen uses pure oxygen rather than air to aerate the mixture in the ATAD process. Similar to the previous process as it is autothermal there is no need for outside heat sources, and the increased heat speeds up the reaction. Compared to ATAD with air, the heat losses are minimal with the pure oxygen process as there is much less in terms of exhaust gasses pulling heat from the reaction. The downside of this process comes in the cost of supplying oxygen, this makes this method much more expensive than the rest (Shammas and Wang, 2007). It is clear that each of these methods come with their own advantages and disadvantages and whichever system is chosen will be highly situational based on the location and resources available.

Appendix D: Example Email

Dear (Farm/Organization/Designated Contact Person),

Hi, we are a group of undergraduate students from Worcester Polytechnic Institute researching technologies at dairy farms in New England for our project. We are working with a sponsor from Australia and he would like to learn more about current technologies in farms in New England. We would love to hear stories of your farm to learn more about the dairy industry, and if possible, come visit your farm and take a tour. Your involvement is voluntary and you can withdraw when you wish.

Please tell us what day/time works best for you before December 4th. We will follow up with a phone call tomorrow.

In mid-December, we will be presenting our findings and submitting a report, and if you would like to be anonymous that can be arranged. We would be delighted to have you attend our virtual presentation and view the report. We look forward to hearing from you.

Best Regards
Marissa Desir, Haoyu Fu, Mathieu Michaud, & Cabot Priestner
Worcester Polytechnic Institute

Appendix E: Example Interview Script

Hi, our names are ___, and we are undergraduate students from WPI working on a project about Addressing the Issue of Dairy Farm Emissions with an organization called Snowy River Innovation. It's nice to meet you, how are you…

Questions:

- We were amazed to read about your history. Can you tell us more about your organization?
- Before using (technology), how were you managing the waste products of the animals?
- So we read about problems with this technology, were there any other factors that influenced you to invest in an aerobic digester?
- How did you come across this technology as a solution?
    - Did you look into any other technologies?
    - Why this system over the other solutions that you looked at?
    - Did someone recommend this? (Who)
- Through our research we found that you are beginning with a smaller scale system to work out the bugs, can you tell us about the struggles with installing it or any issues that you have run across?
    - Can you give us a general look into your process (the major steps)?
    - How much waste is required to run the system efficiently?
        - What other kinds of waste do you process with the machine (food etc.)
- After the product comes through the machine what do you do with it? Are there any secondary processes
- In what ways, if at all, has implementing this technology changed your facilities
    - Any indirect benefits?
- Would you recommend this to other farms? (why/why not)
- Is there anything else that you think we might find helpful or useful that you want to talk about?
- Ask if they are interested in seeing the final report

Thank you for your time! One last thing, do you mind if we mention the name of the organization in our report or do you wish to stay anonymous.

Appendix F: Comparative Matrix

	Vanguard Renewables						Independent	Harp Renewables
	Jordan Dairy: Rutland, MA	Jordan Dairy: Spencer, MA	Barstow Longview: Hadley, MA	Goodrich Farm: Salisbury, VT	Crescent Farm: Haverhill, MA	Bar-Way Farm: Deerfield, MA	New England Biochar: Eastham, MA	Cincinnati Zoo
Technology	Anaerobic (puts cold organics into digester), 500,000-gallon capacity,	Anaerobic, 600,000-gallon capacity, 160,000-gallon hydrolyzer	Anaerobic (heats up food/organic waste before digester, two digesters)	Anaerobic (largest digester in the northeast), 1.32 million-gallon digester, hydrolyzer, phosphorus management system	Anaerobic, 660,000-gallon capacity, 160,000-gallon hydrolyzer, 3M gallon effluent storage tank	Anaerobic, 660,000-capacity	Pyrolysis	Aerobic Digester
Input	9,120 tons cow manure annually, 20,000 tons organics annually	4,400 tons cow manure annually, 38,300 tons organics annually	9,215 tons cow manure, 24,000 ton organics	3,650 tons cow manure annually, 975,000 tons organics annually	3,650 ton of cow manure annually, 36,500 ton organics annually	9,125 ton of cow manure annually, 36,500 ton of food waste annually	3 cubic yard every other day	2 million pounds of manure/year
Output	Powers 500 kW engine, more than 5,000 MWh of renewable energy/year, offsets 20,000 lbs. of CO2 emission daily	8,410 MWh of renewable energy/year from 1 MW engine, displacement of 5,500 lbs. of CO2 emissions daily	Liquid organic fertilizer, 7000 MWh of renewable energy, offsets nearly 20000 tons of CO2 annually	180,000 Mcf of RNG annually	offsets 1,000 tons of CO2 emissions annually, 7,700 MWh of renewable energy/year from a 1 MW engine, reduces phosphorus and nitrogen loading on farms	7,700 MWh of renewable energy/ year, offsets 5,500 lb. of CO2 emission daily	1 cubic yard every other day	Solid Organic Fertilizer (amount unknown, ask in interview)
Farm Stats	950 acres of corn and hay	950 acres of corn and hay	450 acres	1750 acres of hay, 650 acres of corn	650 acres (produce, pumpkins, gourds, hay, corn)	600 acres	N/A	74 acres
Livestock Stats	800 cows (300 milked daily), 700 Hybrid Double Breasted White turkeys	800 cows (300 milked daily),	550 cows, 15,000 lbs. of milk daily, cow feed has potatoes, hay, alfalfa, corn, soy (cranberry pulp before COVID)	900 milking cows	dairy cows, goats, sheep, ducks, rabbits	500 cows (250 cows milked daily), 1,700 gallons of milk daily	N/A	N/A
Sustainability Efforts	provide energy via net metering credits to area businesses (Polar Beverages, Wachusett Brewing Company), burn excess methane	receives organic waste from food manufacturers and provides energy via net metering credits to area businesses (Tree House Brewing Co, Whole Foods Market)	Incorporating leftover food from stores into cow feedstock, reduction of tilling, water recycling, rhyperior buffer, majority of electricity goes out to the community	provides RNG to Middlebury College, reducing phosphorus in watershed area	provides energy via metering credits to the City Haverhill schools and public facilities	receives organic waste from food manufacturers and provides renewable energy via net metering credits to businesses (New England Naturals, Gorton's)	Shipping systems to national and international locations	"Greenest Zoo in America" Almost entirely off the energy grid because of solar panels Storm water management/water recycling On track to be net zero carbon by 2025

	Vanguard Renewables						Independent	Harp Renewables
Benefits	Liquid organic fertilizer to increase crop yields, reduced energy cost, odor reduction, reduction of chemical fertilizer use, enhance nutrient management plan, heat reuse, animal bedding, income diversification	Liquid organic fertilizer to increase crop yields, reduced energy cost, odor reduction, reduction of chemical fertilizer use, enhance nutrient management plan, heat reuse, animal bedding, income diversification	Income diversification liquid organic fertilizer, heat, hot water, reduction of chemical fertilizers, reduction of energy cost, odor reduction, increase corn and hay crop yields, enhanced nutrient management plan, dairy community	liquid organic fertilizer, increase in crop yield, reduction of chemical fertilizer use, animal bedding, phosphorus reduction to protect sensitive watershed area, reduced GHG emissions, income diversification	odor reduction, liquid organic fertilizer, increase in crop yield, reduction in chemical fertilizer use, adhere to nutrient management plan, displace traditional fuels for heating needs on farm	liquid organic fertilizer, increase in crop yields, reduced energy cost, odor reduction, reduction in chemical fertilizer use, enhance nutrient management plan, heat reuse, annual hosting lease payment	Energy for heating and electricity, biochar for compost, increased soil fertility	Reduces the large amount of waste that the zoo has, instead of filling landfills they are making fertilizer that can be used by the community, reduction in GHGs released, 80% of zoo's waste is organic and can run through the digester
Forms of Income	Selling turkeys, selling blueberry bushes, sale of food/ bakery items	N/A	Storefront bakery, beef, milk (Cabot Creamery Cooperative)	selling phosphorus to farms	N/A	sell straw, gourds, hay, manure, and compost	selling biochar and biochar mixes, selling pyrolysis systems	Selling fertilizer to locals, general zoo things, admissions, food and gift shops
Challenges	Keeping digester happy, moving cows every 3 days	N/A	Unfair payment	N/A	N/A	N/A	air pollution, energy waste, temperature control, feedstock	N/A
Motivation/ Drivers	N/A	N/A	Overproduction of milk, milk price increase, laws/ regulations need to be changed, had to change to keep up, diversify income	Needed to do innovative environmental practices, diversify income	N/A	N/A	bring nutrients to sandy soil of Cape Cod, make best possible biochar, harvest all the available energy from the process to offset fossil fuels, make the process safe and smoke free, make the process profitable on a farm or community scale	Needed to find a way to reduce the manure coming from the zoo, very sustainability minded organization
How did they hear about the technology	Worked with a previous company to install the device	Worked with a previous company to install the device	Heard of it because Jordan was adding it to their farm	N/A	NA	N/A	Was looking for a way to improve the soil, found a book on indigenous people in south America using charcoal as fertilizer and looked into it	N/A