

# ANAEROBIC DIGESTION AT WESTERN WASHINGTON UNIVERSITY

*Determining the feasibility of an anaerobic digestion to mitigate dining hall food waste.*



**Sienna Taylor**

06.01.2023

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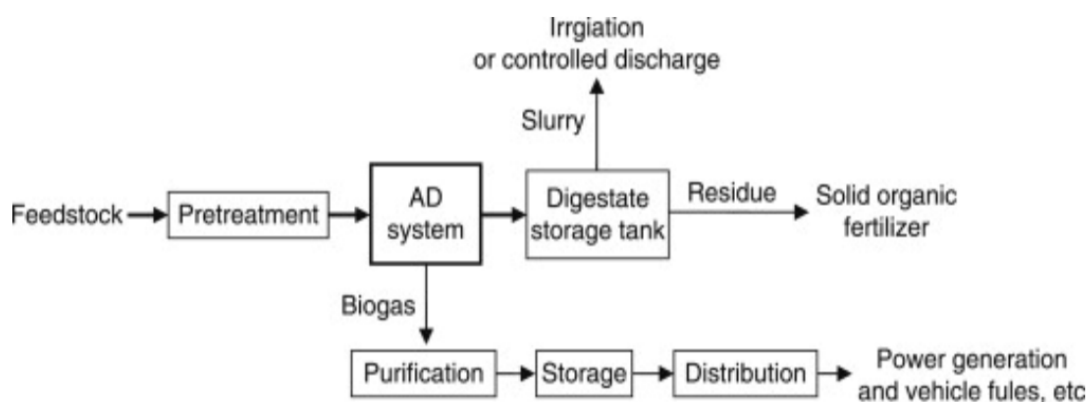
<sup>1</sup> "Snapshot," accessed May 18, 2023, <https://foodwastealliance.org/>.

## TABLE OF CONTENTS

1. INTRODUCTION
2. BACKGROUND
3. METHODS
4. RECOMMENDATIONS AND CONTINUITY PLAN
  - a. Option A – The HORSE AD
  - b. Option B – Dining Services
  - c. Option C – Vander Haak Dairy Farm Partnership
  - d. Option D – SSC Composting
  - e. Continuity
5. OPTIMIZING THE BYPRODUCTS THROUGH ANALYSIS OF FEEDSTOCK
6. RECOMMENDED METHODOLOGY FOR A FOOD CHARACTERIZATION STUDY
7. LONG-TERM FUNDING
8. LESSONS LEARNED
9. STAKEHOLDERS AND CONTACTS
10. REFERENCES
11. APPENDIX
  - a. On-Campus Anaerobic Digester
  - b. Anaerobic Digester Study
  - c. SEJF Grant Application 2022
  - d. Anaerobic Digestion at Western Washington University
  - e. Keep Calm, Digest On – A report of anaerobic digestion at Western Washington University
  - f. Impact Bioenergy Q&A
  - g. SEJF Abstract Application 2023
  - h. Evidence Tables
  - i. Edge Analytical Quote
  - j. Exact Scientific Services Quote and Email Correspondence
  - k. Exact Scientific Services General Chain of Custody for Vander Haak Dairy Farm

## INTRODUCTION

Anaerobic digestion (AD) is the process by which organic matter (such as food waste, manure, paper products, etc.) are broken down by bacteria in a contained system lacking oxygen. The decomposition in this environment produces the byproducts of digestate, which can be used as a liquid fertilizer, and biogas, which can be used in place of natural gas. The goal of anaerobic digestion at WWU is to create a closed-loop waste system to process the pre-consumer and post-consumer organic food waste from the dining halls and use the resulting byproducts. Anaerobic digestion at WWU has been an ongoing effort with multiple student-led studies that began prior to the COVID-19 pandemic.



*Anaerobic digestion occurs on a range of different scales. A larger agricultural system can be described by the graphic above.<sup>2</sup>*

This report is intended to provide a detailed legacy of the continued effort to bring anaerobic digestion to WWU. What began as a quarter-long project has turned into a two-plus year effort, and it is important to document and consolidate the information gathered up until this point. Reading through the documents in the APPENDIX section prior to the body of this paper is highly recommended in order to understand the foundation of this research and the path that has led to the recommendations produced in this paper. This paper should serve as a living document and should be updated and added to as new information is gathered.

## BACKGROUND

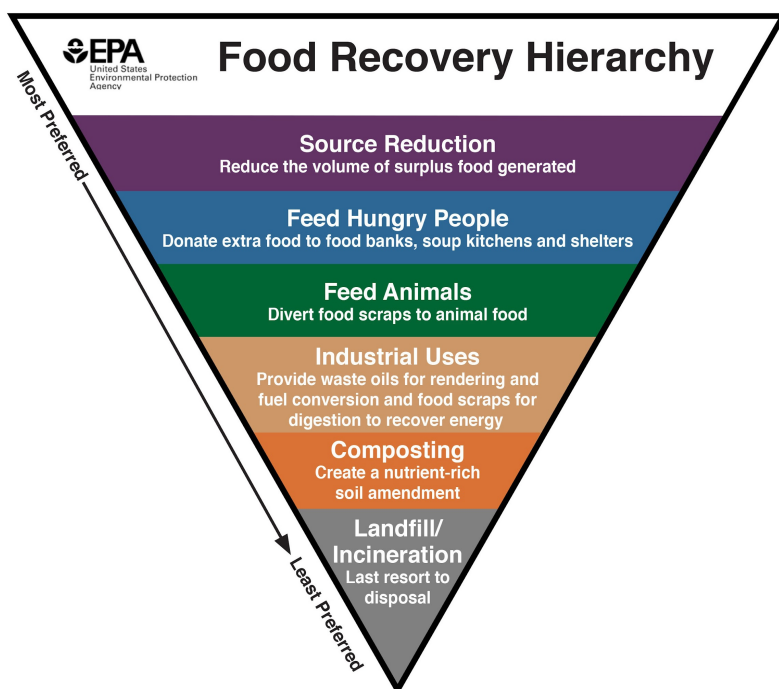
One-third of all food produced in the U.S. is wasted or lost through the supply chain every year. That

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<sup>2</sup> X. Liu, Z. Yan, and Z. -B. Yue, "3.10 - Biogas," in *Comprehensive Biotechnology (Second Edition)*, ed. Murray Moo-Young (Burlington: Academic Press, 2011), 99–114, <https://doi.org/10.1016/B978-0-08-088504-9.00165-3>.

results in 38 million tons of discarded food, 76.3% ending up in landfills<sup>3</sup> accounting for ten percent of global greenhouse gas emissions.<sup>4</sup> As universities across the globe are setting ambitious climate and sustainability goals, it is critical to evaluate and mitigate food waste to meet emissions and zero-waste targets.

Western Washington University houses three main dining halls: Viking Commons, Ridgeway, and the Fairhaven Commons which aim to feed around 4,200 on-campus and off-campus residents.<sup>5</sup> Altogether, the dining halls produce around 30,000 pounds of food waste per week (see *Keep Calm, Digest On* in the APPENDIX). Western Washington University recognizes the impact of food waste and contracts with Sanitary Services Company to bring all food waste collected from campus-wide bins and the pre- and post-consumer waste from the dining halls to a commercial composting facility called Green Earth Technologies in Lynden, WA.



EPA Food Recovery Hierarchy<sup>6</sup>

The Food Recovery Hierarchy defined by the EPA illustrates the most to least preferred methods of dealing with food waste. Total consumption of food by way of human or animal are the most preferred

<sup>3</sup> Fuqing Xu et al., "Anaerobic Digestion of Food Waste - Challenges and Opportunities," *Bioresource Technology* 247 (2018): 1047–58, <https://doi.org/10.1016/j.biortech.2017.09.020>.

<sup>4</sup> Lilian Gikandi, "10% of All Greenhouse Gas Emissions Come from Food We Throw in the Bin," WWF, accessed May 18, 2023, <https://updates.panda.org/driven-to-waste-report>.

<sup>5</sup> "About Us | On-Campus Housing," accessed May 18, 2023, <https://housing.wvu.edu/get-started/mission>.

<sup>6</sup> OLEM US EPA, "Food Recovery Hierarchy," Overviews and Factsheets, August 12, 2015, <https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy>.



options. Efforts such as recovery, donation, diversion, etc., are important to investigate at the university level, however, there will always be some volume of unavoidable pre- and post-consumer waste. Industrial Uses, like anaerobic digestion, are preferred over composting due to the maximum recovered energy from the usable byproducts. Researching the feasibility of anaerobic digestion seeks to put WWU one step higher on the pyramid and one step closer to a sustainable, closed-loop campus. This study only focuses on the unavoidable food waste, but it is in the best interest of the University to practice a combination of reduction, donation, and diversion. Additional food waste mitigation studies along other parts of the waste stream are encouraged.

The prospect of implementing an anaerobic digester at WWU has been considered by multiple groups of students. The first documented effort was from a project team in a Business and Sustainability class who submitted a grant application to the Sustainability, Equity, and Justice Fund (SEJF) and presented on a prospective prefabricated biodigester in fall of 2021. The grant application and presentation are attached in the APPENDIX. In the spring quarter of 2022, a student group took on the first documented feasibility study of anaerobic digestion in the Campus Sustainability Planning Studio class taught by instructor Jill McIntyre-Witt, and supported by Amanda Cambre, Director of Sustainability Integration. The following fall, another group of three students continued the feasibility study with a narrowed scope of examining the HORSE AD—a prefabricated anaerobic digester from a company in Auburn, WA called Impact Bioenergy (Impact Biogenery is now Chomp and will be referred to as such throughout the rest of the paper). Coincidentally, the fall 2022 project team in the Planning Studio class chose to research the same prefabricated biodigester from Chomp that the Business and Sustainability class wrote a grant to purchase. Had this been known, the project team in the fall 2022 might have steered another direction or focused on details not yet addressed. The purpose of including all the associated presentations, papers, and grant applications into one document in the APPENDIX section is to create a cohesive legacy to prevent similar unnecessary overlap in the future.

The HORSE AD from Chomp varies in size from around 160 square feet to 500 feet and can process around 80,000lbs of food waste per year (see SEJF Abstract in the APPENDIX). The project team identified the Fairhaven dining hall as the feedstock for the digester due to its medium size, the space in the back parking lot, proximity to the Outback Farm (where the liquid digestate could partially be used), and connection to interdisciplinary work at the Fairhaven College (see *Keep Calm, Digest On* in the APPENDIX).



The HORSE AD from Chomp<sup>7</sup>

This group of students in the fall 2022 Campus Sustainability Planning Studio championed a more thorough investigation looking into a cost-benefit analysis of the HORSE AD, determining a preferred site location, and meeting regularly with the CEO of Chomp, Jan Allen, to determine the logistics needed for purchase and implementation. The intention behind purchasing a prefabricated digester from Chomp was the prospect of a self-sustaining system by profiting off the byproduct of liquid digestate and reducing University spending by mitigating the need for weekly pick-ups from Sanitary Services Company (see *Keep Calm, Digest On* in the APPENDIX).

Two team members, Clara Copley and Sienna Taylor, decided to continue the investigation as their senior capstone projects in winter and spring quarter 2023. After conducting a literature review into the biochemical process of anaerobic digestion and coordinating with Chomp, Clara submitted a 14-page SEJF grant abstract in March 2023 to begin the process of applying for the SEJF (see SEJF Abstract in the APPENDIX). The grant abstract requested around \$300,000 for the upfront purchase of the HORSE AD, retrofitting and any construction costs, and for the first year of operation which likely would include a part-time paid student position. The grant abstract was only the preliminary phase of the whole grant process and must receive approval from the SEJF committee through a vote. If the abstract was approved by the committee, the students could continue to write the whole grant application. The grant abstract did not pass the SEJF committee vote in early April 2023. Committee members felt the energy and economic savings of the HORSE were minimal and therefore not compelling enough to justify implementation without more research and a thorough continuity plan. Thus Sienna continued the research with the production of this paper as the next phase. Details on the process are outlined in the METHODS section.

It should be noted that the HORSE may not be the best option for the university based on limited energy and economic savings. The HORSE or smaller digester may make more sense from an educational

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<sup>7</sup> “Commercial Anaerobic Digester Solutions by Chomp,” accessed May 18, 2023, <https://www.chomp.energy/solutions>.

standpoint, but new prospective avenues such as including the responsibility of anaerobic digestion into with the new Dining Services contract that will be produced and signed in 2023, partnership with the Vander Haak Dairy Farm, and a better evaluation of the current composting system, will be further discussed in the RECOMMENDATIONS AND CONTINUITY PLAN section below. The following options have been categorized as “on-campus, partially closed-loop system” and “off-campus outsourcing food waste.” The Continuity portion illustrates the recommended next steps that each option would necessitate.

The recommended next step in research was to conduct a food characterization study by testing samples of the feedstock from the dining halls to determine key levels of nutrients that might affect the production of the byproducts. The first step in the food characterization study includes an analysis of the literature review to determine the preferred quality, quantity, and content of the feedstock which can be found in the OPTIMIZING THE BYPRODUCTS section. The next portion of the food characterization study is to conduct lab tests of the actual feedstock coming from the Fairhaven dining hall. This report includes the RECOMMENDED METHODOLOGY FOR A FOOD CHARACTERIZATION STUDY which outlines the needed next steps.

Additionally, this paper examines different avenues of long-term funding to continually operate the digester. The LONG-TERM FUNDING section includes details on profiting from the digestate, potential sources of state and federal funding, SEJF grant, maintenance within the WWU Operating Budget, receiving carbon credits from potential offset emissions, and the overall educational value of anaerobic digestion. The STAKEHOLDERS AND CONTACTS section lists and briefly identifies the various stakeholders that have had some level of involvement in this project in an effort to contribute to the legacy theme of this paper and provide quick reference for future research. The LESSONS LEARNED section should serve as an orienteering compass for future work and research, especially as it relates to stakeholder engagement and University decision making.

## METHODS

The information provided in this report came from a combination of academic research (articles, journals, other web sources), interviews, and personal communication with stakeholders from within and outside the University (see the STAKEHOLDERS AND CONTACTS section). Clara Copley produced a literature review of peer reviewed research around anaerobic digestion in winter 2022 (see Literature Review in the APPENDIX) which helped to inform the OPTIMIZING OF BYPRODUCTS THROUGH ANALYSIS OF FEEDSTOCK and RECOMMENDED METHODOLOGY FOR A FOOD CHARACTERIZATION STUDY sections. The RECOMMENDATIONS AND CONTINUITY PLAN section was an accumulation of insights gleaned through interviews with faculty and staff on campus, and with specific companies like Chomp and

Regenis. Methods of obtaining information included phone calls, in-person meetings, and site visits. Often, communication with individuals required persistence as several emails, phone calls, and introduction via a common connection was necessary to make initial contact. Keeping track of different individual communication styles was key. Some stakeholders responded quickly to email, while others could only be reached by serendipitously catching them in their office, and others were entirely unresponsive. Much information gathered for this project was dependent on the responsiveness and level of engagement from necessary contacts, thus making it hard to meet the initial deliverables outlined. Ultimately, this project required intuitive social and communication skills and a spectrum of stakeholder engagement. Independent Study advisors, Lindsey MacDonald and Zander Albertson, were met with on a weekly basis to maintain progress and consistency.

This whole project has required immense flexibility and adaptability. At the beginning of spring quarter 2023, the project team was under the assumption that the SEJF grant abstract would pass and the main deliverable in the spring quarter would be the full SEJF application for the HORSE AD. When the grant abstract did not pass committee, the deliverables and recommendations significantly pivoted. Although this seemed like a setback, stepping away from the HORSE AD unearthed new possibilities of anaerobic digestion and food waste at Western.

## RECOMMENDATIONS AND CONTINUITY PLAN

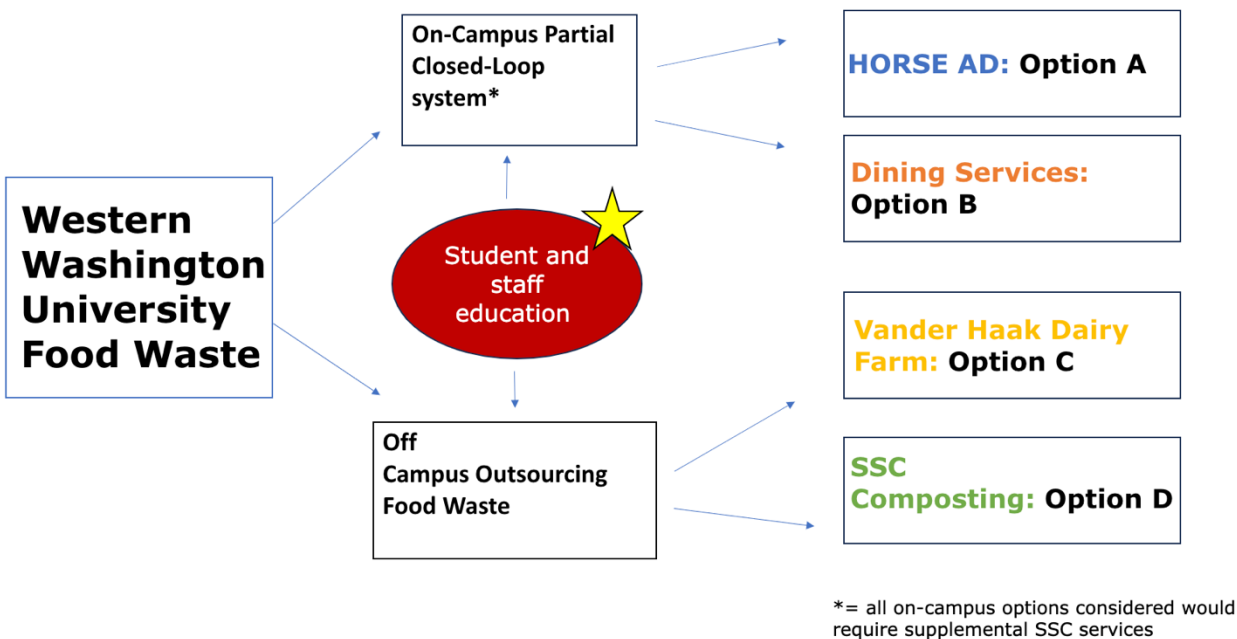
The initial anaerobic digestion option examined was the purchase of the HORSE AD from Chomp, but further research has determined other routes should not be limited to that. These include: forming a partnership with the Vander Haak Dairy farm, writing anaerobic digestion into the new dining hall contract, or continuing to operate the current SSC composting operations. From an environmental and economic lens, and without serious academic or research interest, anaerobic digestion may not be the best method to process food waste at Western.

The purpose of organizing these options into on-campus partial closed-loop system and off campus outsourcing food waste is to delineate between associated transportation emissions and other overall differences. Additionally, it is critical to educate students and staff about the food waste and waste stream at Western. Reducing food waste accumulation from the source is the top priority, and any of the considered methods should only serve to process the unavoidable waste. If Western pursues a form of anaerobic digestion, the “reduce first” mindset must be prioritized and spread throughout campus; anaerobic digestion does not ameliorate the problem of wasteful behavior and practices.

It is important to note that the closed-loop options are only considered partial because Sanitary Services Company will still need to pick up the compost from the bins throughout campus that are unconnected to the dining hall. All methods of AD in this study only account for the dining hall waste stream. The

commercial composting service at WWU accepts compostable materials such as biodegradable plastic that would not be accepted into an anaerobic digester. However, the dining hall does not provide those products and the waste stream is controlled entirely by kitchen staff so their ability to sort the food waste as it comes into the kitchen is preferred.

The options below illustrate the recommended avenues for continued research, and the final section describes preliminary instrumental next steps. It is also important to note that the order of these steps is a recommendation but will likely be adjusted to meet current needs and new information.



## Option A: On-Campus, partially closed-loop system: **HORSE AD**

The HORSE AD from Chomp was the solution investigated by the fall 2022 project team. More can be read in the feasibility study titled, Keep Calm and Digest on and in the grant abstract application in the APPENDIX. The HORSE is a prefabricated, smaller system designed to fit near the dining hall or other waste-producing facility. The HORSE has the potential to create academic interest as an on-campus option and could provide cost-savings through production of the digestate (either applying directly to grounds at Western or selling for profit). A smaller-single system of this capacity would likely have minimal environmental and economic benefit but could serve as a pilot project for additional HORSES implemented throughout campus, or to eventually build a bigger campus-wide solution. It is estimated to cost \$300,000 for purchasing and for the first year of operation. If run successfully, it could become a self-sustaining system thereafter.

The implementation of the HORSE requires additional inquiry around academic and research interest, an identified student-run position, and a thorough cost-benefit analysis that evaluates carbon reduction and cost savings through input of the pre- and post-consumer waste from the Fairhaven Dining hall (the initial proposed location). A detailed use plan for the digestate must also be produced. It is unclear whether the best use of the digestate will be for on-campus landscaping, or whether it is best to develop a partnership with a local farm. On-campus use of digestate could reduce university spending since WWU spends about \$3,000 per year on organic and synthetic fertilizer (see SEJF Abstract in the APPENDIX). The University uses around 950 lbs. of fertilizer per year and the HORSE AD 40 is estimated to produce around 1,822 lbs. annually, so there would be a surplus to sell to a farm regardless. Additionally, it provides a natural alternative to the synthetic fertilizer because it contains slow-release nutrients and mitigates the possibility of excess nutrients leached into the ground (see SEJF Abstract in the APPENDIX).

The HORSE AD from Chomp was initially identified to be located behind the Fairhaven Commons in the parking lot near the loading dock (see more info about the site in the SEJF Abstract and Keep Calm, Digest On in the APPENDIX). Prior to the re-submission of the grant abstract, the site needs pre-approval from Capital Planning and Development. Amanda Cambre has suggested obtaining pre-approval from Forest Payne, Project Manager and University Planner. Forest was contacted via email in April 2023, but will not be able to give pre-approval until there is a well-established contingency plan. Prior to pre-approval it is critical to perform a food characterization study, bench model testing and establish a long-term use plan, including partnerships with faculty on campus who may have curriculum or research interests in anaerobic digestion.

It is important to note that while the parking lot and loading dock behind Fairhaven was initially identified as the best location, that could change based on new information uncovered by this step. It is also possible that another use of that space may be identified before pre-approval is achieved and might require identifying a new location or changing orientation.

A food characterization study including lab testing and bench model construction are critical next steps to demonstrate the process of anaerobic digestion on campus and estimate the potential volume of byproducts after evaluating the nutrient levels of the food waste. After the above steps are completed, the SEJF grant application can be revisited. The SEJF committee has amended the application process and no longer requires an abstract to be submitted prior to the full grant application.

If the HORSE AD or another AD from Chomp is deemed the right fit, it is time to loop CEO, Jan Allen, and Michael Smith, Director of Legal and Business Development, back into the conversation. They both have been instrumental in providing information for this project and working alongside us to move the project forward. Continued funding of the AD—for the short term start up until it becomes profitable or self-reliant—could possibly come from the University Operating Budget. More information can be found

in the LONG-TERM FUNDING section.

## **Option B: On-Campus, partially closed-loop system: New Dining Services Contract**

In fall of 2023, there will be a new dining services contract starting at Western. The provider and operating changes have not been announced as of the production of this paper, but it does create a possible intersection to weave anaerobic digestion into the responsibility of the new contract. This option is relatively new and thus requires further investigation. The physical infrastructure would likely be similar to the HORSE where individual digesters are constructed behind each dining hall. Dining Services could choose to purchase the HORSE(s) or other prefabricated digesters or build their own, but the maintenance, operation, and funding would largely, if not entirely, come from their budget.

Western has identified sustainability goals around reduction of food waste so as a new contract is produced, it could be a perfect time to explicitly include those in the new term. The WWU Sustainability Action Plan states: “The plan establishes the goal of carbon neutrality by 2035, reductions in water consumption and drive-alone rates to campus and adopting zero-waste operations in dining halls.”<sup>8</sup> AD would substantially help the dining halls achieve zero-waste operation and could potentially help reach carbon neutrality as articulated above. Dining Services at WWU are actively looking for ways to mitigate their waste to comply with the University goals. It is possible that a partnership with Dining Services could provide funding, staffing, and other necessary logistics for operation and could be beneficial in helping the dining halls achieve zero-waste.

Like the HORSE AD, on-campus anaerobic digestion in any capacity provides an opportunity for research and academic partnership and an educational value. Additionally, the economic and environmental benefits are similar to HORSE such as a self-sustaining system, potential profit, and cost-reduction, but if Dining Services has the means to apply AD on a larger scale, these benefits would be much greater.

A food characterization study with lab testing and bench model construction and other logistics such as siting, funding, staffing, etc. would all be next steps like what is described in Section A. The main differencing being that it would not fall on the sole shoulders of students but could be a more combined student-staff effort.

## **Option C: Outsourcing Food Waste Off Campus: Partnership with the Vander Haak Dairy Farm**

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<sup>8</sup> “Carbon-Neutral WWU by 2035 | Window | Western Washington University,” accessed May 18, 2023, <https://window.wvu.edu/carbon-neutral-wwu-2035>.



Sending the food waste from the dining halls to the Vander Haak Dairy farm could be a very promising route. What was not made apparent until more recently is the connection to anaerobic digestion in the Puget Sound region, particularly, in conjunction with dairy farming. The Vander Haak Dairy Farm has received national recognition and a US Dairy Sustainability Award<sup>9</sup> for their self-sustaining, closed-loop system, and recognition from the EPA and World Wildlife Fund. Their feedstock consists of both manure from dairy cows and food waste from 15-20 commercial kitchens such as bakeries and meat processing plants.<sup>10</sup> The Vander Haak Dairy Farm diverts 18 million pounds of food waste each year which amounts to about 400,000 pounds of carbon dioxide.<sup>11</sup>

There are two dairy farms in Lynden, WA that have on-site anaerobic digesters to process manure and other feedstock. They use the digestate on the farm and send the electricity generated from the biogas to the electricity grid.<sup>12</sup> The digester at the Vander Haak Dairy farm was designed, constructed, and continues to be maintained by an anaerobic digestion consulting company in Ferndale called Regenis.<sup>13</sup> They specialize in digestion on dairy farms with either manure as the main feedstock or a co-digestion process with the certain types of food waste, but also offer a variety of consulting services in many different industries and states. Sienna and Clara visited the Vander Haak Dairy Farm in May 2023 and toured the AD facilities with Eric Powell, a representative from Regenis. The feedstock that they accept from external facilities include a range of grains and leftover breads from bakeries, waste from chickens, blood and meat processing waste, artificial crab, spent brewers' grain, grease trap waste, and more. According to Regenis, the Vander Haak Dairy Farm pioneered this diverse co-digestion process because they saw potential to boost biogas production, as a combination of manure and food waste is ideal for high methane yield (see OPTIMIZING BYPRODUCTS THROUGH ANALYSIS OF FEEDSTOCK section), and because they could profit from charging a tipping fee. Businesses are incentivized to send their waste to the dairy farm because the tipping fee is less than conventional landfill or composting facilities. The farm charges about \$0.12 per gallon or \$30 per ton not including trucking costs.

Co-digestion of manure and other organic matter like food waste has the potential to increase methane and digestate yield if the feedstock is very consistent, lacks harmful contamination, and contains optimal nutrients. Before accepting feedstock from a business, the Vander Haak Dairy Farm requires that feedstock be tested in a lab for elements such as heavy metals, nitrogen, phosphorus, pH, and others (similar to what has been suggested for testing Western's feedstock) must be analyzed. If the feedstock is deemed uncontaminated, and relatively consistent in material, the dairy farm will service regular pickups to the business or commercial kitchen. Contamination is important to prevent because the dairy

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<sup>9</sup> "Vander Haak Dairy," accessed May 18, 2023, <https://www.usdairy.com/getmedia/6f32c653-1507-4956-a3fe-ab8d41eeeac9/vander%20haak%20casestudy%20sust4012%20r2.pdf.pdf.aspx>.

<sup>10</sup> Eric Powell, Correspondence with Regenis, n.d.

<sup>11</sup> "Vander Haak Dairy."

<sup>12</sup> Powell, Correspondence with Regenis.

<sup>13</sup> "Turn Manure Into Money with Anaerobic Digesters," Regenis, accessed May 20, 2023, <https://regenis.net/>.

farm feeds any food waste they can to the dairy cows prior to being put into the digester. There is a dual economical and ethical incentive as companies pay a lower fee to have their food waste hauled away (as opposed to landfill or composting services), and contribute to a sustainable, closed-loop system. Additionally, the dairy farm currently accepts only pre-consumer food waste since post-consumer waste has a higher probability of being contaminated and requires additional permitting from the Washington State Department of Agriculture (WSDA).

Due to the consistency of manure input, digestion on dairy farms is constantly in operation 24 hours of the day, 7 days a week, and 365 days a year. Dairy cows are fed a consistent diet on a regular basis and produce a large amount of manure. The consistency of this system produces a large, stable microbiome community. Anaerobic digesters that only process food waste deal with the variability of the input and may require additional supplementation of nutrients when activity is low (such as operating a digester at the dining halls when school is not in session).

The tipping fee the farm charges varies depending on the nutrients that the incoming feedstock provides.<sup>14</sup> For instance, if the food waste from a facility is high in nitrogen, the farm might have to alter their distribution of the liquid effluent onto their adjacent fields to prevent leaching and this inconvenience could result in a higher tipping fee. If the feedstock contains a key nutrient that the current system may be lacking, the tipping fee might be less. Conducting lab testing of the feedstock would provide the farm with this information and help calculate the rate. Regenis reiterated, however, that the rate would still be lower than the normal landfill or composting services.

A new option for processing food waste at Western could be to redirect food waste from the dining halls to the Vander Haak Dairy farm. According to Regenis, the dairy farm has the capacity to easily process the food waste produced by the dining halls, which is calculated to be around 30,000 pounds per week including both pre-and post-consumer (see Keep Calm, Digest On in the APPENDIX). Sending the post-consumer waste to the dairy farm would require additional steps to ensure that there is no contamination with items that cannot be processed, and the dairy farm would have to obtain a post-consumer permit. For the immediate future, it is likely that only the pre-consumer waste could be sent to the farm based on permitting restrictions. A better calculation of pre- versus post-consumer waste that is produced by the dining halls is needed to understand if there would be an environmental and economic benefit to doing so.

If the farm can only accept the pre-consumer, Sanitary Services Company would still have to pick-up the post-consumer waste along with the compost produced from the bins distributed around campus unconnected to the dining hall. The economic and environmental consequences of this dual operation would also need to be evaluated. The Vander Haak Dairy farm is located about 17 miles north of WWU

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<sup>14</sup> Powell, Correspondence with Regenis.

and offers waste pickup services. Due to the similar proximity to Green Earth Technologies, where compost is currently being sent, the transportation related emissions would not vary greatly from the current system.

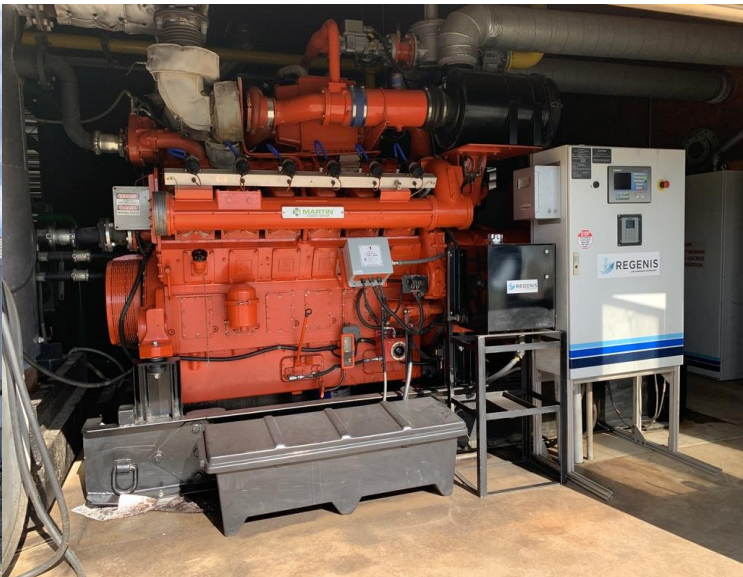
Additionally, a portion of the dining hall food waste sent to the Vander Haak Dairy Farm would potentially be fed to the cows rather than going into the digester. Reducing food waste by feeding animals is ranked even higher on the EPA food recovery hierarchy and thus, has an additional environmental benefit. The grease collected from the dining halls could also be sent to the digester at the dairy farm instead of the current service through Bayside Services that collects the grease on a semi-annual basis.

Connecting with the Vander Haak Dairy Farm provides an opportunity to build a new relationship with Western Washington University and the agricultural sector of Whatcom County. Western does not have an agricultural department of its own but agriculture, and particularly dairy farming, are major industries in Whatcom County. Bridging this gap is important for a variety of social, political, and generational values. It could also spark new research interest among existing departments on campus.

A food characterization study involving lab testing is also required for this option. Bench model construction may not be necessary but is not discouraged either. A further evaluation of the levels of pre- versus post-consumer waste are also highly encouraged to understand exactly what percentage could be diverted to the dairy farm rather than the compost.

It is recommended to hire Regenis or another third-party professional consulting service to determine the exact carbon reduction and analysis compared to compost, and possible cost savings. It would be beneficial to have this study for all recommended anaerobic digestion options, whether that be on-site or external processing to fully understand the potential benefit to the current composting operation. Involving a professional consulting company to evaluate the environmental and economic impact has proven to be impactful to informing University Leadership. For instance, transitioning away from the natural gas-powered steam plant on campus has been a significant consideration over the past decade but action was only taken after two professional consulting firms were hired to do a feasibility study. Applying the same principle to anaerobic digestion would necessitate a paid professionals opposed to the sole effort of student calculations.

Since the Vander Haak Dairy Farm operates a large-scale digester that is in close proximity to the University and has the potential to be more economical than Sanitary Services Company (due to lower tipping fee), it is recommended that this option be explored further and to prioritize communication and relationship building with Regenis and the dairy farm.





*Images of digestion process at Vander Haak Dairy Farm in order from left to right: the input tank where food waste feedstock is dropped off, the dry digestate used to make cattle bedding, the lagoon where manure is siphoned to before pumped into the digester, the underground tank that cycles the material into the digester, the generator that turns the biogas into electricity, the anaerobic digester.*

## **Option D: Outsourcing Food Waste Off Campus: Current SSC Composting**

Sanitary Services Company is the current service that Western contracts with to send food waste and compost to a commercial composting facility in Lynden WA called Green Earth Technologies. This option is considered the “business as usual,” since it does not alter the current system. Given the parameters at Western such as size, location, and lack of agricultural connection it is very possible that composting is superior to AD. All the AD options investigated so far would necessitate supplemental services from SSC, so the marginal benefit of the alternatives may be lower than expected. Some evaluations have credited composting as superior due to “...its intrinsic robustness and scalability,” and makes more sense in smaller-scale or low-tech institutions.<sup>15</sup> It is worth acknowledging that Western already does divert food waste and compostable materials from the landfill which receives higher accreditation by the EPA food recovery hierarchy.

## **Continuity**

**Food characterization and bench model:** The options illustrated above have their own recommended next steps, however there are a few common research components that are critical to the longevity of each option. Before any of the options are pursued in greater detail, it is recommended to conduct a food characterization study that involves collecting and testing samples of the food waste from the dining halls and building a bench model to better demonstrate the process of anaerobic digestion.

Qualitative and quantitative data collection using samples from the dining hall(s) is necessary to understand the nutrient levels of the feedstock (see OPTIMIZATION OF BYPRODUCTS THROUGH ANALYSIS OF FEEDSTOCK). This is particularly applicable to the on-campus options so the feedstock and health of the digester can be tweaked or adjusted based on the components of the input. The Vander Haak Dairy Farm also requires lab testing before they accept any feedstock from an external source. Embrey Bronstad at Washington State University (WSU) has been instrumental in developing a potential methodology for sample collection. Edge Analytical and Exact Scientific Services have provided quotes for the suggested panel, both of which are included in the APPENDIX. The RECOMMENDED METHODOLOGY FOR A FOOD CHARACTERIZATION STUDY illustrates this step in greater detail. The lab

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<sup>15</sup> “Choosing between Composting and Anaerobic Digestion: Soil, Fuel or Both?,” accessed May 18, 2023, [https://zerowasteurope.eu/wp-content/uploads/2019/11/zero\\_waste\\_europe\\_ZWIA\\_policy\\_paper\\_composting\\_and\\_anaerobic\\_digestion\\_en.pdf](https://zerowasteurope.eu/wp-content/uploads/2019/11/zero_waste_europe_ZWIA_policy_paper_composting_and_anaerobic_digestion_en.pdf)

results of the nutrient panel would need to be evaluated to determine the potential yield of biogas and digestate from the system. Interpretation is necessary whether Western implements their own digester or sends their feedstock to an external source like the Vander Haak Dairy Farm.

The food characterization study should also include a calculation of the levels of pre- versus post-consumer waste generated from the dining halls, especially as some systems, like the Vander Haak Dairy Farm, would only be able to take the pre-consumer waste.

Building a bench model AD is also recommended to demonstrate how the system works using feedstock from the dining hall. Embrey Bronsted from WSU has also offered to facilitate this process along-side lab testing. There are many different types of bench models, ranging from smaller systems that use 7-gallon jugs, all the way to larger systems that use 30–50-gallon drums. Both the food characterization study and the bench model construction would be viable projects for the Campus Sustainability Planning Studio class in fall quarter 2023.

**Educational component and research interest:** Anaerobic digestion has a large potential to overlap with various faculty, research, and curriculum at WWU. A general blurb about the project was sent out to CENV staff and faculty in May 2023, but it is recommended to contact professors in various departments to see if this might be something they could integrate into their curriculum and research. The on-campus options such as the HORSE, provide hands-on research or learning experience. If a digester is placed behind the Fairhaven Dining Hall that opens the potential for overlap with Fairhaven College and the Outback Farm.

A partnership with the Vander Haak Dairy farm could also spark interest among more faculty connected to sustainable agriculture and the closed-loop system that already exists among dairy farms that use AD. Long term research and commitment to the whole of food waste production at WWU is also critical, and potential overlap with the chemistry or energy studies departments might be able to precisely calculate the carbon footprint of the current food waste produced at WWU. Support within these departments would also help analyze the results from the food characterization study and the amount of digestate and biogas that Western is projected to produce.

On-campus anaerobic digestion is applicable to a variety of curriculum. Chomp, manufacturer of the HORSE, markets toward restaurants and smaller businesses looking to reduce their carbon footprint and often receive tax credits or benefits from doing so. Therefore, operating the HORSE, or another system designated by Dining Services on campus could serve as a case study for the Greening Business Applications (ENVS/MGMT 359), Energy Efficient and Carbon Neutral Design (ESCI/ENRG 360), or other Business and Sustainability curriculum. The Business and Sustainability department is aware of this prospect, as the very first documentation of purchasing a HORSE was proposed by a MGMT 359 class (see “Anaerobic Digester” in the APPENDIX). This project is widely interdisciplinary, so this is just one

example of intersection within curriculum and investigating further overlap is encouraged.

**Professional consulting to determine benefit of AD over composting:** The initial proposal of the HORSE AD did not evaluate the current composting system described in Option D. While the HORSE could have large educational value, the benefit of AD over composting at Western is not well understood and without current research interest, the best way to produce an accurate cost-benefit analysis would be through hiring a third-party consulting group to conduct a thorough study. Regenis, the manufacturer of the digester at the Vander Haak Dairy Farm, offers consulting services and is aware of Western's interest in such. However, there may be a conflict of interest with hiring Regenis, so an un-involved company like Peak Sustainability or similar local group may be a better route. Regenis and another consulting company could possibly co-author a study as well.

The scope of this project has expanded beyond a student-driven research project. University Leadership has shown that commitment to AD needs a more thorough economic investigation than undergraduate students alone are not equipped to handle and therefore necessitates contracting with a professional entity.

**Partnership with Kulshan Carbon Trust:** Gabe Travis from Kulshan Carbon Trust indicated support for the project during a meeting in April 2023. Gabe suggested that KCT could offer support in writing the SEJF grant application (if the HORSE or other on-campus option is pursued) or support a student internship. This proposed student position could investigate energy savings from the utilization of the effluent on campus grounds or looking into the possibility of combining AD with biochar. Gabe addressed current research around using biochar in anaerobic digestion<sup>16</sup> as using biochar in AD has the potential to increase the methane production.<sup>17</sup>

KCT prioritizes natural climate solutions, which is why looking into biochar could be an interesting overlap. They are always looking for ways to partner with the community and support natural climate solutions. If the AD system also proves to significantly reduce emissions or save energy on campus, they could potentially offer carbon credits.<sup>18</sup>

## OPTIMIZING THE BYPRODUCTS THROUGH ANALYSIS OF FEEDSTOCK

Food waste coming out of the dining hall is a combination of pre-, and post-consumer waste containing a wide variety of fats, carbohydrates, proteins, and paper products. The dining hall accepts

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<sup>16</sup> Gabe Travis, Conversation with Gabe Travis (KCT), May 28, 2023.

<sup>17</sup> Jan Mumme et al., "Use of Biochars in Anaerobic Digestion," *Bioresource Technology* 164 (July 1, 2014): 189–97, <https://doi.org/10.1016/j.biortech.2014.05.008>.

<sup>18</sup> Travis, Conversation with Gabe Travis (KCT).



biodegradable and compostable materials into their waste stream, such as paper napkins, tea bags, and other biodegradable materials all of which can be broken down in most anaerobic digesters. It is critical to test the organic waste coming from the dining hall to calculate the potential biogas and digestate yield.

The type of anaerobic digestion examined in this paper is a type of wet AD. Wet AD systems are designed to intake a high-moisture content feedstock—a “slurry” of biodegradable waste—to produce a liquid digestate which is typically less than 15% total solids.<sup>19</sup> Wet, as opposed to dry anaerobic digestion, is primarily investigated since the HORSE AD operates under these conditions as do most commercial anaerobic digestion facilities, like those found on the Vander Haak Dairy Farm in Lynden, WA.

If the total solids content of feedstock from the dining halls is too high, it will require dilution with freshwater or recirculated water. The HORSE AD is designed to dilute the feedstock, if necessary, which is why water, sewer, and other utility hookups would be necessary (See “Keep Calm and Digest On” in the APPENDIX).

A literature review performed by Clara Copley provided key insight into what type of material and components of that material yield the most favorable biogas and digestate. One study examined, showed that optimizing methane production comes from a high level of lipids in the feedstock. Methane potential of food waste is on a range between 0.3-1.1 m<sup>3</sup> CH<sub>4</sub>/kgVSadded, where a pure (or almost pure) combination lipids have the highest potential at 1.1 m<sup>3</sup> CH<sub>4</sub>/kgVSadded.<sup>20</sup> Protein and carbohydrates are the next highest. This varies based on the quality of the feedstock because sources, processes, handling methods, eating habits, culture, climate, seasons, etc., can be vastly different.

Many anaerobic digestion systems, especially those within universities, are commonly found on farms due to their greater attention, space, and research around agriculture. For instance, Michigan State University hosts an Anaerobic Digestion Research and Education Center (ADREC) with a range of digesting facilities surrounding their agricultural compound.<sup>21</sup> Anaerobic digestion at Western Washington University poses many questions around spatial capacity, resources, or research and continuing education interests. In terms of the feedstock, WWU also lack the input of manure which is a common input material based on its stability, frequency, and quantity. Manure stays constant compared to a food waste stream. It may seem like a critical component to a digester, but according to several

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<sup>19</sup> “What Is Wet Anaerobic Digestion?,” QUBE Renewables Ltd, June 20, 2018, <https://www.qubernewables.co.uk/new-blog/what-is-wet-anaerobic-digestion>.

<sup>20</sup> Xu et al., “Anaerobic Digestion of Food Waste - Challenges and Opportunities.”

<sup>21</sup> “Anaerobic Digestion Research and Education Center (ADREC),” accessed May 20, 2023, <https://www.egr.msu.edu/bae/adrec/>.

studies, food waste has more methane potential than animal manure<sup>22</sup> and the EPA even suggests a co-digestion process, like the Vander Haak Dairy Farm, where manure is used in combination with food waste such as oils and grease (high lipid content) to increase the nutrients of the effluent.<sup>23</sup>

Residential and restaurant anaerobic digestion has high-methane yield because of high lipid content and balanced nutrient composition.<sup>24</sup> It can therefore be deduced that a commercial facility dealing primarily with food waste (easily biodegradable carbohydrates) has a high potential for methane yield, compared to a farm, even though that's where most university level anaerobic digestion currently occurs.

The optimal combination of manure with other feedstock for co-digestion is likely one of the reasons the Vander Haak Dairy Farm in Lynden, WA uses the manure from their dairy cows in tandem with food waste from 15-20 other external sources. Their feedstock is about 60% manure and 40% food waste.<sup>25</sup>

It is in the University's best interest to understand the characteristics of the feedstock from the dining halls so there is knowledge and potential to troubleshoot or fix the digester if the output is not optimal.<sup>26</sup> Knowing the characteristics of the input will help us determine the quality of the output and where the effluent should be used (i.e., in landscaping or edible agriculture). Embrey Bronstad, at the Washington State University Center for Sustaining Agriculture and Natural Resources recommended that samples of the food waste be taken and tested in a lab for the following components:

COD: Chemical Oxygen Demand

TOC: Total Organic Carbon

TN: Total Nitrogen

TKN: Total kjeldahl nitrogen (measures organic nitrogen + ammonia nitrogen)

TS: Total solids

VS: Volatile solids

pH: Potential Hydrogen

These elements are necessary for the on-campus AD options and additional testing may be required for the Vander Haak Dairy Farm (see the Substrate Evaluation in the APPENDIX). The following section

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<sup>22</sup> Xu et al., "Anaerobic Digestion of Food Waste - Challenges and Opportunities."

<sup>23</sup> OAR US EPA, "Is Anaerobic Digestion Right for Your Farm?," Overviews and Factsheets, December 22, 2014, <https://www.epa.gov/agstar/anaerobic-digestion-right-your-farm>.

<sup>24</sup> Xu et al., "Anaerobic Digestion of Food Waste - Challenges and Opportunities."

<sup>25</sup> Powell, Correspondence with Regenis.

<sup>26</sup> Embrey Bronstad, Correspondence with Embrey Bronstad, n.d.

outlines the suggested protocol for obtaining samples to test these nutrients and evaluating the results determine the potential quality and quantity of the byproducts.

## RECOMMENDED METHODOLOGY FOR A FOOD CHARACTERIZATION STUDY:

A food characterization study should be conducted to collect quantitative data, as described in the section above, and qualitative data to get a better understanding of 1) the types of food waste commonly produced and their associated nutrient levels 2) the volume of pre- versus post-consumer waste collected. Since Vander Haak Dairy Farm would only be able to process the pre-consumer waste at this time, it is critical to know exactly how much of the waste produced is pre-consumer. Whereas the on-campus options would likely be able to process both pre- and post-consumer waste. The steps below outline the recommended protocol for lab testing. Practicing with sample collection is highly recommended before formal samples are taken.

Western does not currently have the instruments (such as a Hach spectrophotometer) needed to test for the recommended elements above. Therefore, the best way to obtain the necessary measurements is to collect samples from the dining hall and send them to a nearby lab. Two regional labs have sent quotes for the panel above, Exact Scientific Services in Ferndale, and Edge Analytical Labs in Burlington. Both quotes will be included in the APPENDIX for reference. Lab testing at this stage would provide information for both the on-campus partially closed-loop options, and the off-campus option of sending food waste to the Vander Haak Dairy Farm. The dairy farm has worked with Exact Scientific Services in the past so they would likely have the best protocol for testing the solid samples we need. Prior to lab testing, the project group would need to apply for a small grant through the SEJF. The lab testing should be under the \$5,000 threshold for small grant funding.

The sample collection and lab testing will be conducted in the Campus Sustainability Planning Studio fall 2023 class with facilitation from Alyssa Tsukada and the Scientific Technical Services department. The team from Scientific Technical Services will be instrumental in developing a methodology as well as analyzing the results once they are returned. Together, students from the Planning Studio and the Scientific Technical Services will devise a more thorough methodology, but it will likely operate around these parameters:

- Consistent data collection including same time, place, sample weight, and volume.
- Representative sample of the whole days' worth of food waste. This might look like "coring" the waste collected in the bin and collecting multiple samples from the same bucket.
- Taking note of what was served on the menu that day to compare it to the sample received and taking photos of the samples spread out on a solid background for the

visual, qualitative analysis.

- Making sure the samples are delivered to the lab in the same day or preparing a method to store samples in the correct fridge.
- Sending the samples to Exact Scientific Services in the same consistency as they would be delivered to the dairy farm. Likely whole in Ziploc bags and the lab can perform the slurrying if necessary.

It is also recommended to investigate the options of testing the kitchen grease that also gets collected in receptacles outside of the kitchen. Currently, WWU contracts with Bayside Services for grease removal semi-annually. Read more about cost and operations in the SEJF Abstract in the APPENDIX.

## LONG-TERM FUNDING

Long-term funding of anaerobic digestion looks particularly at the option of purchasing a prefabricated anaerobic digester from Chomp as discussed in Section A, or to supplement operations within dining services as discussed in Section B. In March of 2022, Clara submitted a grant abstract for the Sustainability, Equity, and Justice Fund (SEJF) to obtain over \$300,000 for the purchase and first year operation of the digester. The SEJF committee did not approve the abstract as they felt more research was necessary in the areas addressed in this paper and one of those being a long-term funding source. Detailed below are the funding methods that were investigated to operate a digester more generally, whether that is one purchased from another company or built on campus. These methods are not mutually exclusive and are thought to be used in conjunction with one another.

**The sale or use of digestate (fertilizer).** The anaerobic digester is designed to be able to support itself by the sale or use of the digestate byproduct. The current market rate for the digestate is still not well defined but two examples within the region can help assess the potential monetary and social capital associated. The Vashon Bioenergy Farm is a commercial digesting facility on Vashon Island that partners with a tofu factory to turn their organic food waste into fertilizer that they sell for around \$2 per gallon.<sup>27</sup> Although the Vander Haak Dairy Farm does not sell their digestate, they use the digestate right on property. The dry effluent is used in place of sawdust for bedding for the cattle and the liquid effluent is distributed as fertilizer on the field.

Both larger systems illustrate the effectiveness of anaerobic digestion in the Puget Sound area. Although the initial proposed system at Western is smaller, the system has the potential to expand given the social, political, and environmental benefit. The application of the digestate on campus grounds might

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<sup>27</sup> “Community Supported Biocycling - Biofertilizer Share/Subscription,” Vashon Bioenergy Farm, accessed May 18, 2023, <https://vashonbio.energy/products/community-supported-biocycling-biofertilizer-share-subscription>.

yield the greatest monetary benefit.

**Sustainability, Equity, and Justice Fund**. This funding source is the more direct route to purchasing the digester, with a large initial investment, but would not be a consistent long-term funding source.

**State funding**. Western Washington University submits a capital budget request to the Washington State Legislature every budget cycle (normally every two years) for a range of infrastructure and sustainability investments. The state legislature and governor determine a budget for capital investment and distribute biennium funds to state institutions based on their requests. WA State is expected to generate over \$2 billion from the Climate Commitment Act from auctions in 2023-2025. This is a huge pool of funding for climate action initiatives and in the 2023-2025 budget cycle, WWU received \$10 million to begin the transition away from the natural gas-powered steam plant on campus after a comprehensive feasibility study was conducted. Projects receiving funding from the capital budget usually range from \$1.5 to \$100 million but can also be part of a larger “umbrella” fund.<sup>28</sup> Anaerobic digestion has the potential of receiving funds under a larger sustainability infrastructure umbrella but it is unlikely it would make it onto the capital budget request as an individual project.

A conversation with Brian Ross, Director of Capital Budget and Public Works Procurement, helped to illustrate the ways Western receives funding from the state capital budget and whether an anaerobic digester could make it onto the the biennium capital request or long term (10 year) capital plan. Brian and others in Capital Planning meet with the WA State Office of Financial Management on a regular basis to talk about what the state is looking for in terms of advancements and its priorities, like sustainability and decarbonization.<sup>29</sup> Understanding the political landscape and the priorities of the state help Western identify key projects to include in the capital request, which usually turns out to be \$70 million in total—\$60 million of that coming from state issued bonds.<sup>30</sup>

Funding for the purchase, operation, or construction of an anaerobic digester on campus would not likely make it onto the budget request due to its small size and limited life cycle. Brian articulated that the state usually only issues bonds to permanently established structures (those with lifespans greater than 30 years) and focuses on academic or academic support facilities, which does not usually include residences or dining facilities.<sup>31</sup> Without strong research and academic ties, the digester is more related to an accessory feature not prioritized by the long-term or biennium capital requirements.

In April 2023, the WA legislature added an amendment to an energy bill requiring college campuses in

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<sup>28</sup> Nora Selander, Conversation with Nora Selander, Zoom, May 25, 2023.

<sup>29</sup> Brian Ross, Interview with Brian Ross, May 3, 2023.

<sup>30</sup> Ross.

<sup>31</sup> Ross.

WA to begin their transition away from fossil fuels.<sup>32</sup> Representative Alex Ramel, a WWU alumni, championed HB 1390 and used Western as a model for this bill for showing serious initiative to transition away from the natural gas-powered steam plant. The bill requires universities to submit decarbonization plans to the Department of Commerce by June 2024, and a final draft by June 2025.<sup>33</sup> The bill is focused around decarbonization within heating and cooling systems, so digestion has the potential to be included in Western's plan by providing renewable natural gas heating for buildings in conjunction with the new geothermal heating system proposed.<sup>34</sup>

Both the Climate Commitment Act and the House Bill 1390 demonstrate the push toward renewable energy projects and decarbonization in Washington State and anaerobic digestion follows the guidelines outlined in the legislation. However, since it is not yet a mainstream practice on medium-sized, non-agricultural campuses, Western has the potential to be a model for this niche and possibly champion future sustainability legislation.

**WWU Operating Funds.** To obtain long-term operating funds, the most likely avenue would be directly from the University's operating budget. This budget allocates funds for smaller-scale renewal, upkeep projects that extend the lifespan of assets, and is approved by the University Board of Trustees on an annual basis.<sup>35</sup> The University sets strategic goals and priorities for funding, like the state. The digester could potentially fall into this category but faculty backing and a strong research or academic benefit to the University would have to be shown, i.e., a high educational value. An abstract (found on the WWU Operating Budget page) would need to be submitted to obtain funds from this avenue. However, although this path is possible, it is not likely due to the recent university budget deficit and a lack of funding. It is advised to run the digester from the get-go as a self-sustaining system rather than seek external funds.

**Federal funding.** The federal Inflation Reduction Act (IRA) of 2022 contains \$500 billion of additional spending, much of that going toward renewable and clean energy infrastructure. It is unclear as of late spring 2023, exactly how federal funding from the IRA will trickle down to the university level, but the IRA supports clean energy primarily through tax credits and since public universities are tax exempt institutions, they do not have the ability to directly apply for these credits. However, consulting firms like Baker Lilly are currently working with universities to potentially acquire the revenue from smaller

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<sup>32</sup> "1390-S2.PL.Pdf," accessed May 18, 2023, <https://lawfilesex.leg.wa.gov/biennium/2023-24/Pdf/Bills/House%20Passed%20Legislature/1390-S2.PL.pdf?q=20230418085101>.

<sup>33</sup> "Cushing - SENATE COMMITTEE ON WAYS & MEANS.Pdf," accessed May 18, 2023, <https://lawfilesex.leg.wa.gov/biennium/2023-24/Pdf/Bill%20Reports/Senate/1390-S2%20SBR%20APS%2023.pdf?q=20230418085101>.

<sup>34</sup> "Final WWU Heating Feasibility Study Report\_2.Pdf," accessed May 20, 2023, [https://cpd.wwwu.edu/files/2022-07/Final%20WWU%20Heating%20Feasibility%20Study%20Report\\_2.pdf](https://cpd.wwwu.edu/files/2022-07/Final%20WWU%20Heating%20Feasibility%20Study%20Report_2.pdf).

<sup>35</sup> "WWU Operating Budget | Strategy, Management & Budget | Western Washington University," accessed May 18, 2023, <https://bfp.wwwu.edu/www-budget>.

avenues.<sup>36</sup> For example, a private contractor who builds or installs retrofits for energy efficiency within public buildings could qualify for the “Tax Deductions for Energy Efficiency” and that could reduce their quote to the University.<sup>37</sup>

**Carbon credits and a “natural climate solution:”** Gabe Travis from Kulshan Carbon Trust (KCT) was consulted about the possible connection between university level anaerobic digestion and the services at KCT. If the associated reduction of emissions through anaerobic digestion are substantial, KCT could potentially offer carbon credits to the University.<sup>38</sup> This avenue necessitates much more thorough energy savings research.

## LESSONS LEARNED

Anaerobic digestion at Western Washington University has proven to be difficult to implement for a variety of reasons. While it may be possible, there is no perfect solution. Flexibility and patience must be practiced while continuing this project, especially while communicating with various stakeholders. This study has proven to be much more interdisciplinary than anticipated which is why it is recommended that multiple groups of students who specialize in various fields take on the next steps.

When given the task of researching the “feasibility of anaerobic digestion at WWU,” the fall 2022 Campus Sustainability Planning Studio project team jumped to one solution, the HORSE AD, in order to narrow the scope of the project. Although the HORSE was beneficial as a launchpad, the project team moved ahead with this project through the perspective that AD is superior to composting. Looking back, it would have been valuable to look at the whole waste stream first and ask the question, does AD make sense given current parameters and operations? Are there large benefits to overriding or working alongside an already-functioning composting system?

Ultimately, to tailor this project to a quarter-long class or study it needs to be broken down into very small pieces. When the SEJF abstract for the HORSE did not pass through committee in April 2023 it showed that many of the little steps were overlooked. Rather, it is important to spend time lingering in the problem to figure out what is already going on. It is recommended that the project be taken on by a team of four students or more if the Campus Sustainability Planning Studio conducts lab testing and bench model construction in fall quarter 2023. It is not recommended to take this research as a solo project.

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<sup>36</sup> Ross, Interview with Brian Ross.

<sup>37</sup> “HigherED-InflationReductionAct-Screen.Pdf,” accessed May 18, 2023, <https://secondnature.org/wp-content/uploads/HigherED-InflationReductionAct-Screen.pdf>.

<sup>38</sup> Travis, Conversation with Gabe Travis (KCT).



The lack of research interest from faculty and curriculum due to the absence of an agricultural department or college is an inherent barrier. Current anaerobic digestion systems are currently found on farms, and usually dairy or cattle farms. Universities that have anaerobic digesters also have large agricultural departments and research interests. The use of anaerobic digestion for commercial kitchens or on universities of this size and scale, without manure as one of the feedstocks, is a relatively new concept. Companies like Chomp are branching into that sector by manufacturing smaller systems that can be placed and run at smaller capacities and facilities. However, since this is such a new field, there are many institutional and infrastructural barriers. Undergraduate-level research has shown anaerobic digestion has the potential for environmental and economic savings, but if the University wants to take the best step in terms of economic, environmental, and educational benefit, the scope of this project is better designed for PHD, graduate studies, several student groups working in coordination with one another, as well as a greater top-down approach from University leadership.

Additionally, it may be necessary to loop in a professional consulting company to determine the actual cost savings and carbon reduction at various scales. For instance, implementing the HORSE on campus provides hands-on learning opportunities and potential for research, but has little environmental or economic savings. The educational benefit of a digester on campus could be the most valuable although that option is difficult to quantify now without ties to current faculty or curriculum. Sending pre-consumer food waste to the Vander Haak Dairy Farm is possible but the carbon reduction and cost savings would need to be evaluated against the current composting services. Through a purely economic and carbon reduction lens, the in-place composting system at Western may be the most sustainable option for a university of this size and scale. All options considered would be most accurately evaluated by professionals at consulting companies like Regenis or Peak Sustainability.

Although a few stakeholders within the College of the Environment and Environmental Studies department and chemistry department have been made aware of the project, none have taken a vested interest. Forming further connections to various departments on campus, particularly Chemistry, Energy Studies, Environmental Science, and Business and Sustainability is critical to the longevity of this project. All options and next steps require continued communication, collaboration, and stakeholder engagement. General practices such as professional emails, in-person meetings, and early-on engagement help to facilitate a strong connection.

## STAKEHOLDERS AND CONTACTS

1. **Amanda Cambre** – *Director of Sustainability Integration*. Co-sponsored the feasibility studies conducted in Campus Sustainability Planning Studio. [cambrea@wwu.edu](mailto:cambrea@wwu.edu)
2. **Lindsey MacDonald** – *Associate Director of Sustainability at the Sustainability Engagement*

- Institute*. Advised Clara and Sienna from winter to spring quarters 2023. [macdonl6@wwu.edu](mailto:macdonl6@wwu.edu)
3. **Zander Albertson** – *Senior Instructor in the College of the Environment*. Advised Sienna in spring quarter 2023. [albertz2@wwu.edu](mailto:albertz2@wwu.edu)
  4. **Embrey Bronstad** – *Center for Sustaining Agriculture and Natural Resources at Washington State University*. Has assisted developing a preliminary methodology for lab testing and bench model construction. Great resource for anaerobic digestion at the university level.  
[embrey.bronstad@wsu.edu](mailto:embrey.bronstad@wsu.edu)
  5. **David Patrick** – *Vice Provost for Research and Dean of the Graduate School*. Brief communication in winter and spring quarter 2023 to inquire about the lab testing instruments at Western. [dpatrick@wwu.edu](mailto:dpatrick@wwu.edu)
  6. **Jill McIntyre-Witt** – *Senior Instructor in the College of the Environment*. Instructed the Campus Sustainability Planning Studio in spring and fall 2022 and advisor for the Students for Renewable Energy Club. [macintj@wwu.edu](mailto:macintj@wwu.edu)
  7. **Nora Selander** – *Director of Government Relations*. Interviewed Nora to understand the process of applying for state funds for university projects. [selandn@wwu.edu](mailto:selandn@wwu.edu)
  8. **Brian Ross** – *Director of Capital Budget and Public Works Procurement*. Interviewed Brian to understand the Capital Budget and levels of federal and state funding. [rossb5@wwu.edu](mailto:rossb5@wwu.edu)
  9. **Forest Payne** – *Project Manager/University Planner*. Contacted to inquire about pre-approval for siting of the HORSE. [paynef2@wwu.edu](mailto:paynef2@wwu.edu)
  10. **Gabe Travis (KCT)** – *Program Coordinator at Kulshan Carbon Trust*. Offered insight into a potential collaboration between AD research on campus and KCT.  
[gabe@kulshancarbontrust.org](mailto:gabe@kulshancarbontrust.org)
  11. **Jan Allen (Chomp)** – *CEO of Chomp*. Mainly worked with Jan during fall 2022 to learn about the HORSE and its application at Western. [jan.a@impactbioenergy.com](mailto:jan.a@impactbioenergy.com)
  12. **Michael Smith (Chomp)** – *Director of Legal and Business Development at Chomp*. Worked with Clara in winter quarter 2023. [michaels@chomp.energy](mailto:michaels@chomp.energy)
  13. **Eric Powell (Regenis)** – *Business Development Director at Regenis*. Corresponded via phone interviews, email, and in-person tour of the Vander Haak Dairy Farm. Has provided valuable insight into potential collaboration between WWU and the dairy farm. [ericp@regenis.net](mailto:ericp@regenis.net)
  14. **Steve Haak (Vander Haak Dairy Farm)** – *Owner of Vander Haak Dairy Farm*. According to Regenis, Steve is the person that manages the partnership with external kitchens. No introduction has been made thus far.
  15. **Alyssa Tsukada** – *Scientific Technical Services support tech*. Will co-sponsor the Campus Sustainability Planning Studio to assist with the food characterization study in fall 2023.  
[tsukada2@wwu.edu](mailto:tsukada2@wwu.edu)
  16. **Sarina Kiesser** – *Scientific Technical Services Research Associate*. Provided insight into the food characterization study. [larivis@wwu.edu](mailto:larivis@wwu.edu)

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## APPENDIX

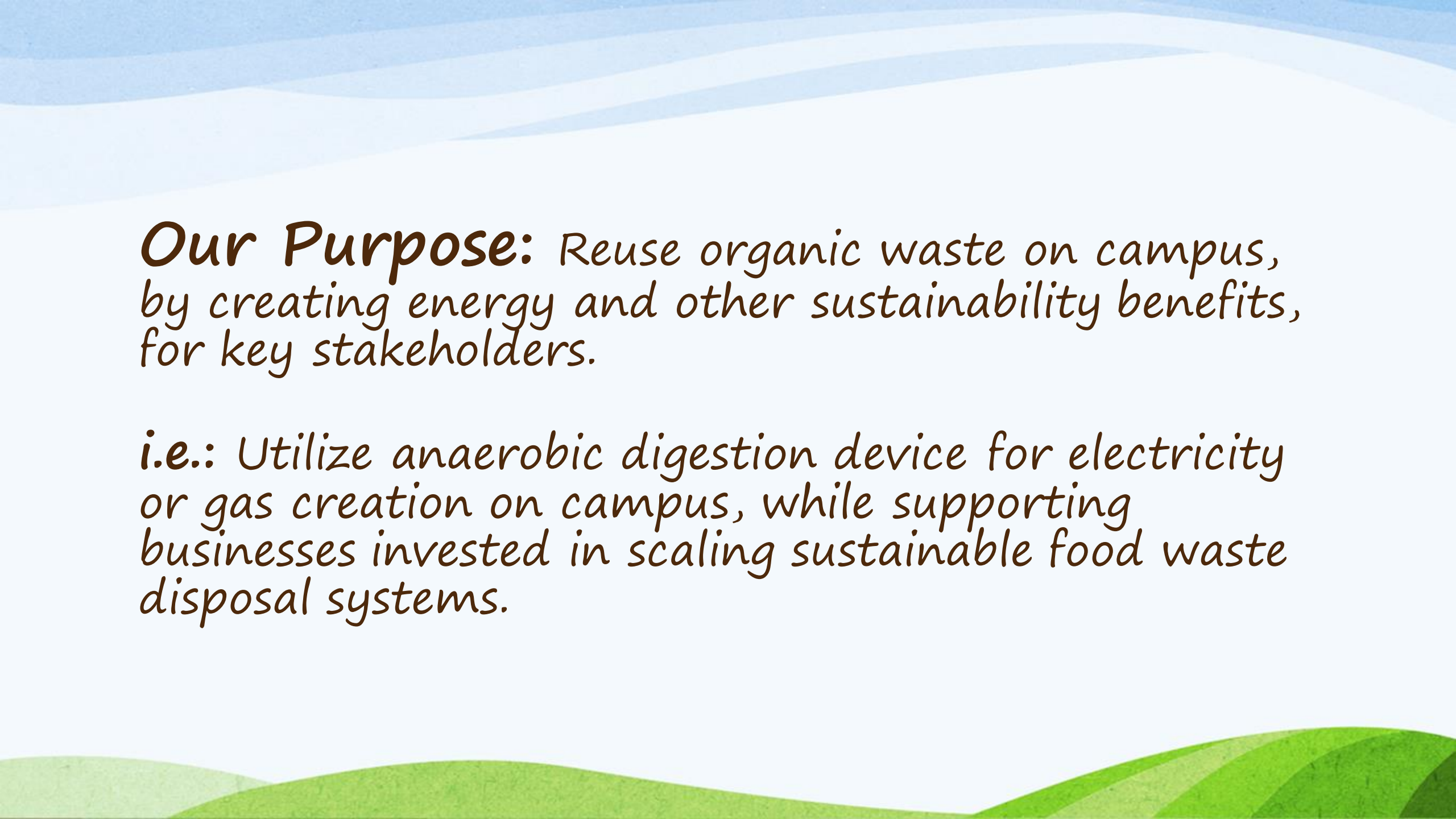
For the sake of thoroughness and easy reference, all the relevant documents are attached in the pages below in order of date they were created.

# On-Campus Anaerobic Digester

Amelia Bineham  
Cole Strickland  
Emily Busack  
Keahn White  
Tiffany Lin  
Zach Williams







**Our Purpose:** Reuse organic waste on campus, by creating energy and other sustainability benefits, for key stakeholders.

*i.e.:* Utilize anaerobic digestion device for electricity or gas creation on campus, while supporting businesses invested in scaling sustainable food waste disposal systems.

# Sustainable Development Goals

## 1. Affordable and clean energy:

- By creating a closed loop energy system on-campus we will decrease our carbon footprint
  - Process 25 Tons of Food Services waste (~17% of current hauled off by SSC)
  - Generate:
    - ~0.8KW of Electricity (with 24x7 generation @ 27.5% efficiency)
    - OR
    - Biogas 129,468 cu ft/year - Equivalent to 772 gallons of gasoline per year
    - AND
    - Probiotic Plant Food (Digestate): 5,516 gallons (Liquid) or 276 lbs (Dry)

2. **Partnership for the goals:** Engage Impact Bioenergy, partnering with their existing network and support their sustainable waste disposal objectives.

3. **Climate action:** By creating a system to reuse energy and get rid of waste in a sustainable way we are working towards a more environmentally friendly campus

4. **Responsible consumption and production**



# WWU Sustainability Action Plan

- Zero Waste
  - "Western is a zero-waste institution through leadership, operations, education, and engagement."
- Engagement
  - "Western builds, supports, and sustains equitable and mutually enhancing relationships throughout our campuses, our communities, the Salish Sea region, and the world."
- Curriculum and Research
  - "Western curricula and research support social, economic, and environmental sustainability through diverse perspectives."

# Stakeholders

Students

Custodians

The Outback

SEJF Leaders

People in charge of funds

AS

University Recruiters

Groundskeepers

Sanitary Services (SSC)

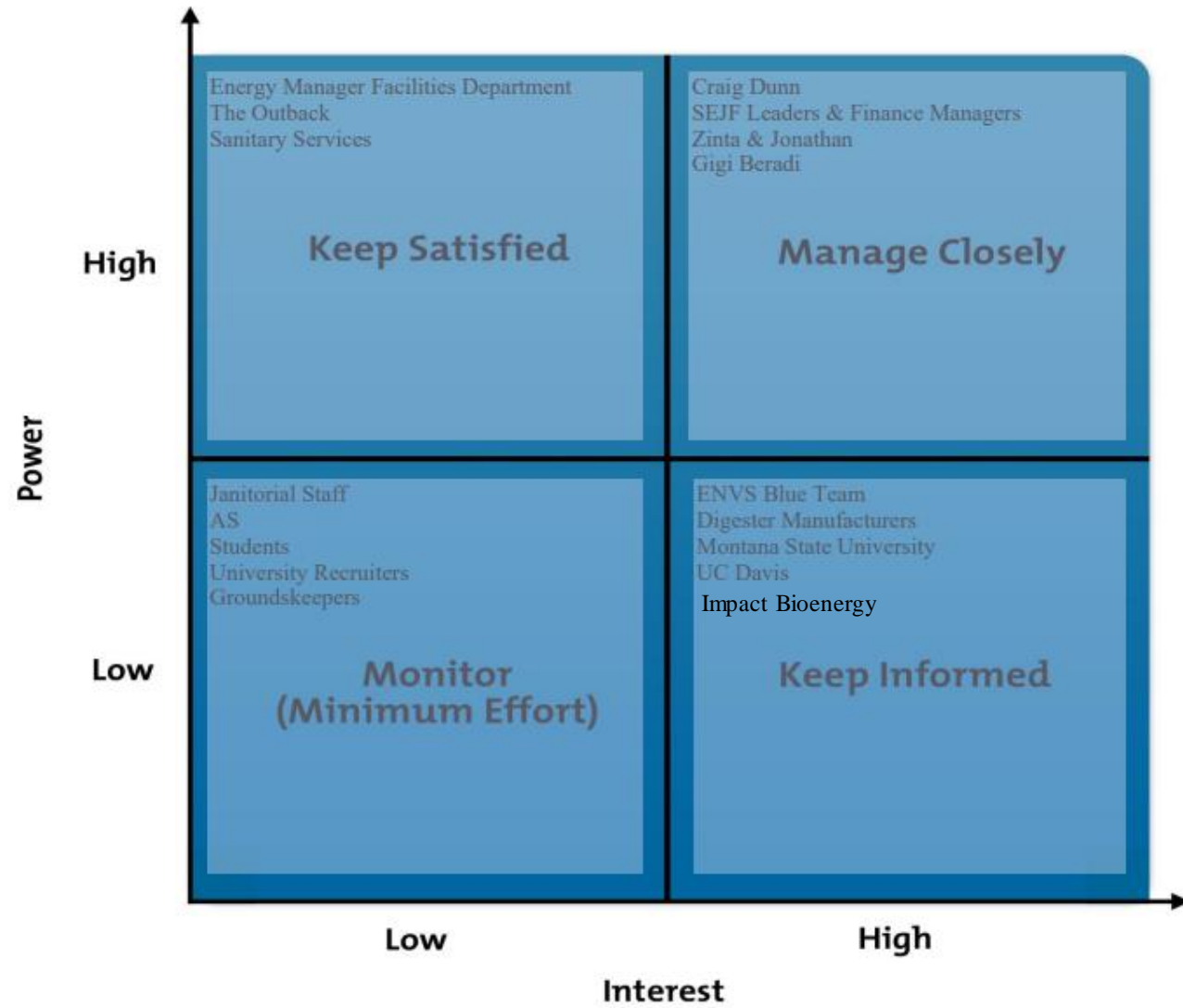
Energy Manager Facilities Dept

Project Adviser Craig Dunn

Zinta & Jonathan

Blue Team (ENVS)

Impact Bioenergy



## Stakeholder Map

# Costs

- **\$20K: Pre-Project Costs** (Engineering/Siting, Regulatory/Compliance Assessment, Etc.)
- **\$160K: Equipment** (Bioenergy HORSE)
- **\$20K: Freight** (Transportation to WWU)
- **\$20K: Hookup** (Service provided by Manufacturer)
- **\$10K: Miscellaneous** (Equipment, Parts, Temporary Labor, or Publicity)
- **TOTAL: \$230K**
- \*Additional on-going costs of ~\$2K maintenance Annually
- \*\*Additional on-going cost of Labor (Currently Unknown)

# Challenges

- Due to the number of Stakeholders and sheer scope of this project, we were unable to fully connect all the dots required to execute this project immediately.
- Our intent is to create a self-study for Winter Qtr. to carry the project forward



# Closing

- Have you considered the possibility of generating useable energy to power systems on campus?
- Would you be excited to tell your friends, family, or future Western Students that we are considering this type of technology on campus?
- Do you have any additional questions for us?

# Sources

- Craig Dunn
- Gigi Berardi
- Terri Kempton (Outback) – Pending
- Alyssa Tsukada (AS) – Pending
- Anaerobic vs. Aerobic Digesters & What Others are Doing.
- Zinta Lucans (SEJF)
- Michael Smith, Impact Bioenergy

<https://www.cornell.edu/news/powering-campus-using-food-waste>

[\(9\) The Anaerobic Digester at MSU – YouTube](#)

<https://www.epa.gov/newsreleases/epa-selects-montana-state-university-receive-299881-funding-initiate-anaerobic>

<https://www.ucdavis.edu/news/biogas-digester-turns-campus-waste-campus-energy>

[\(9\) Biogas Digester Turns Waste into Campus Energy at UC Davis – YouTube](#)

<https://www.worldbiogasassociation.org/notre-dame-adopts-anaerobic-digestion-in-response-to-students-concerns-over-food-waste/>

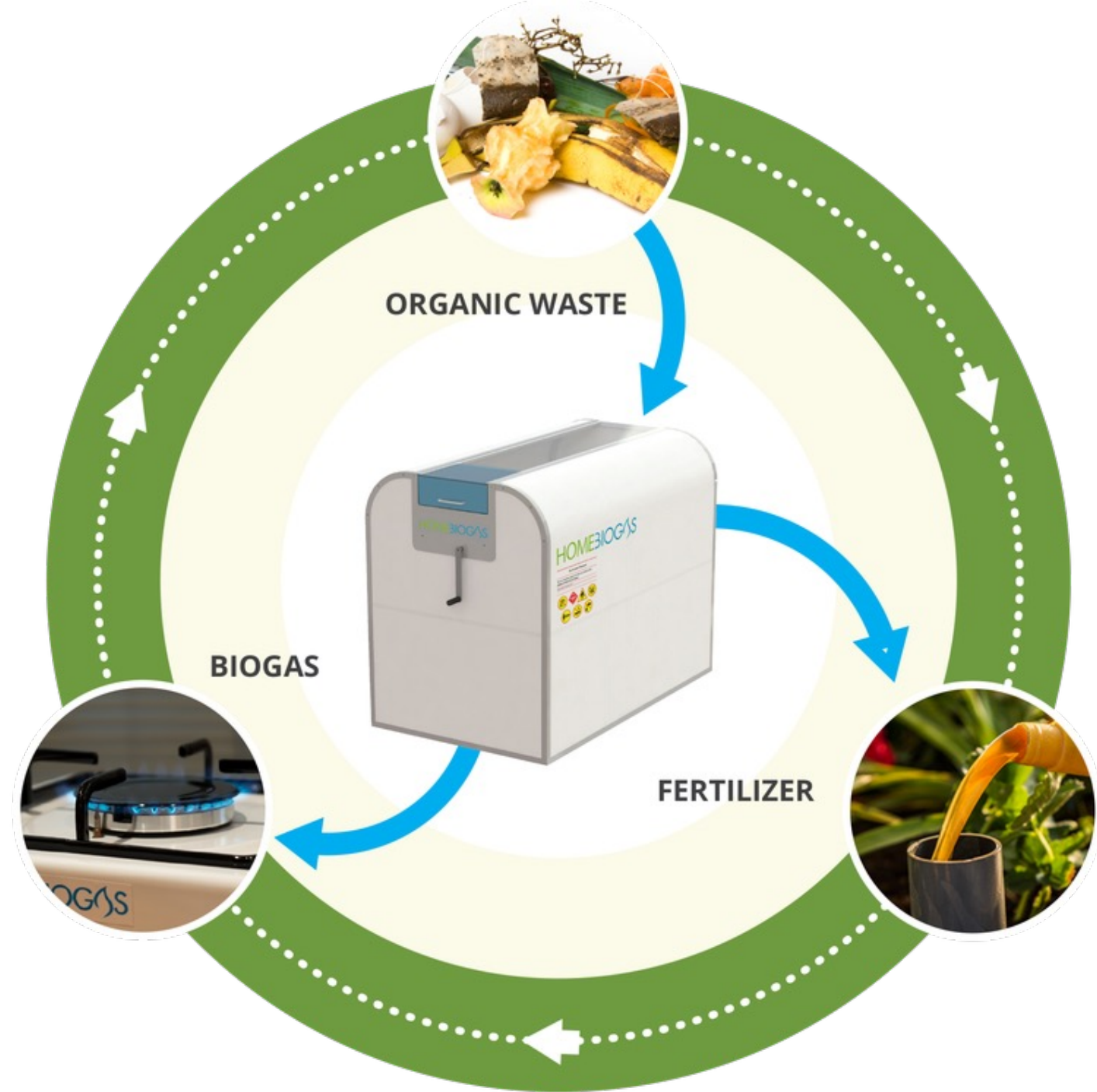
<http://www.sussex.ac.uk/broadcast/read/51557>

<https://hillelnews.com/2019/11/13/munchy-crunchy-eat-my-lunchy-welcoming-haverfords-new-aerobic-digester/>

<https://green.harvard.edu/topics/waste/composting#:~:text=In%202012%2C%20Harvard%20Campus%20Services%20pounds%20of%20sterile%20pellets>

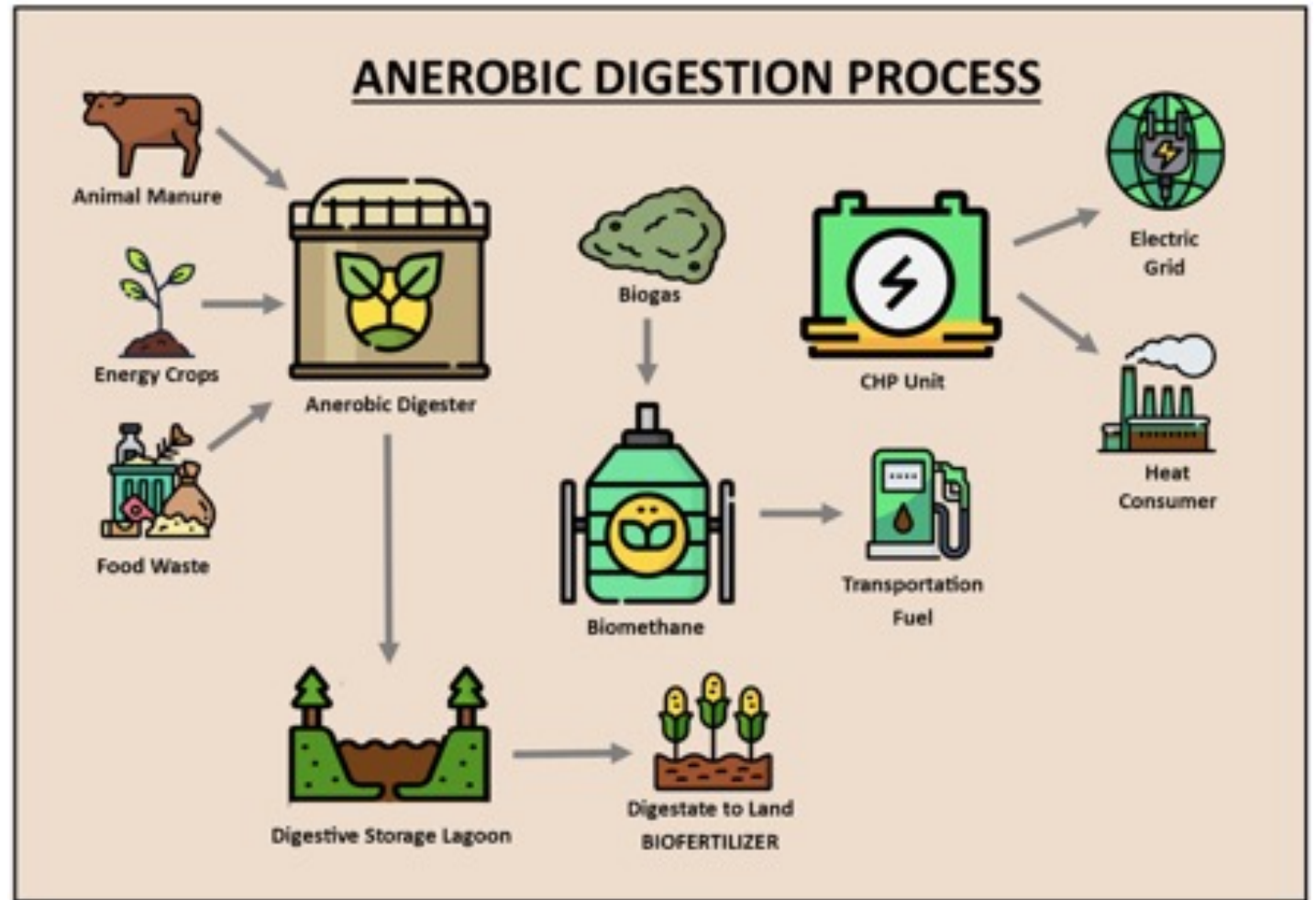
# Anaerobic Digester Study

Presented by: Cole Strickland, Zach Williams, Trevor Behrens, and Keahn White





What is an Anaerobic Digester?



# Where We Started

Purpose: Create an SEJF proposal to reuse organic waste at a larger scale on campus, while maximizing quality uses of the outputs, and benefits, to demonstrate the efficacy of energy reuse on campus, while driving partnership with sustainably focused businesses in support of Sustainable Development Goals (SDGs).



Background Research on Digesters



Impact BioEnergy



Rough Budget Estimations



#### Maximum Energy Production

**15,000 - 105,000** BTU/hour

The energy production is designed for 15,000-105,000 BTU/hour continuously.

#### Organic Input


**960 – 6,700** lbs/week

Organic feedstock input is designed for 960-6,700 lbs/week (440 – 3,050 kg/week).

#### Organic Matter Output

**100 – 730** gallons/week

Produces 100 – 730 gallons/week (400-2,800 liters/week) of liquid organic fertilizer.



# Results & Progress



- Pre-Consumer vs. Post-Consumer Waste
  - Pulper Process
  - SSC Pickup and Processing
  - Compost Output
- 
- Inconsistent Measurement of Outbound Waste
  - Highly Manual Data Retrieval



# Pre- Consumer Waste Data

## Current Fiscal Year

- 27,063 pounds

## 21-22 School Year

- 12,000 pounds

## 18-19 School Year

- 40,000 pounds



# Funding

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**Sustainability, Equity,  
& Justice Fund**



# Gaps

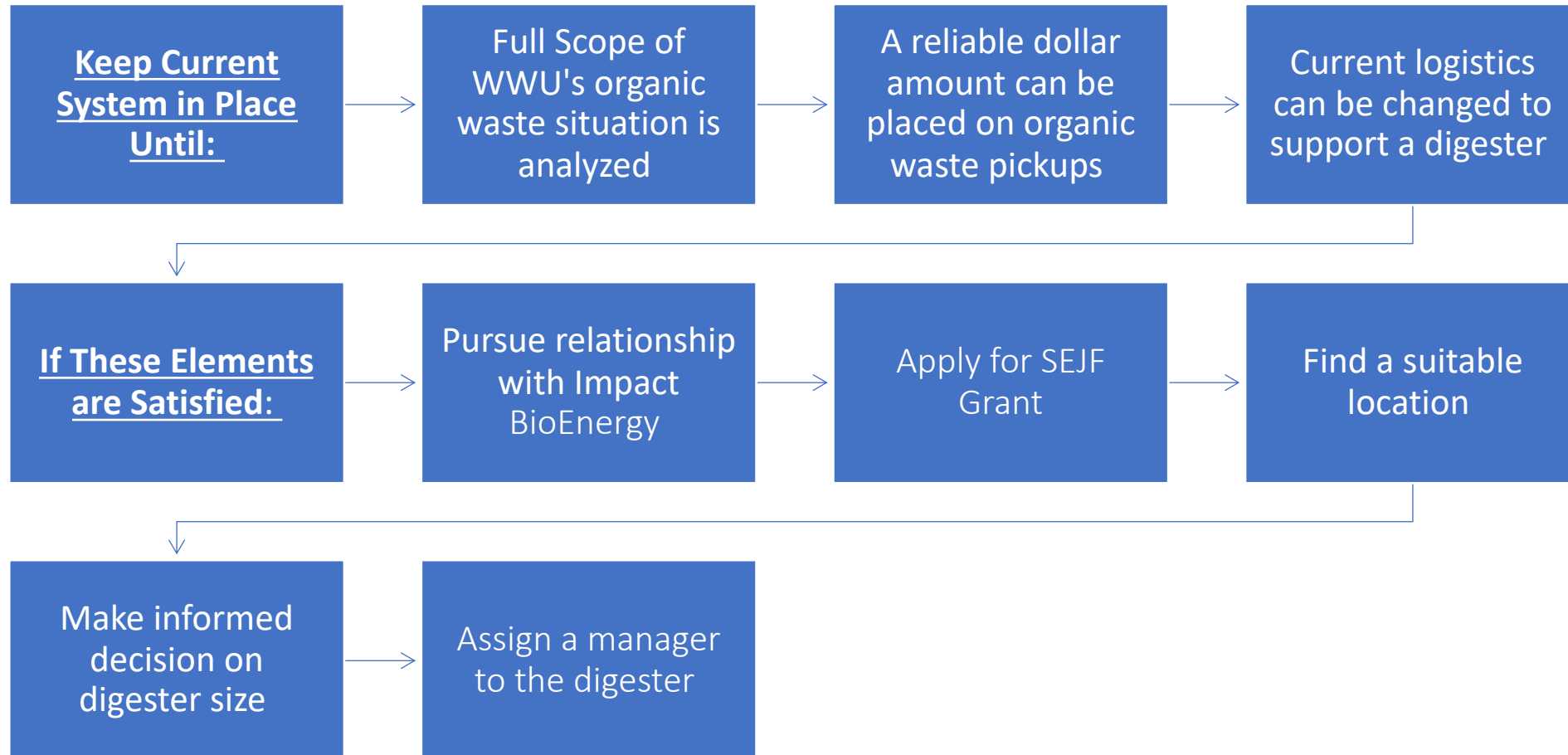
Lack of waste data

Uncoordinated Bureaucracy

Confusing SSC Billing Data



# Recommendations



# Appendix



# Sources

- [Impact Bioenergy | Distributed Food Waste to Energy Technology](#)
- [Anaerobic Digestion - KB BioEnergy](#)
- [Sanitary Service Company: Waste and Recycling Collection in Bellingham, Blaine, and Ferndale \(ssc-inc.com\)](#)
- Jan Allen, President of Impact BioEnergy
- Amanda Cambre, Facilities Management
- Steven Erbe, Aramark



# Current Costs



Line Item Type	2019	2020	2021	Grand Total
Service charge	\$186,108	\$362,253	\$329,944	\$878,305
Refuse (Cu Yd)	\$170,245	\$4,979	\$3,895	\$179,119
Other charges	\$15,701	\$11,356	\$14,077	\$41,134
Tax: City	\$23,309			\$23,309
Refuse (lbs)	\$13,620			\$13,620
Tax: County	\$9,589			\$9,589
Tax: State	\$7,703	\$108	\$101	\$7,912
Charges	\$4,113			\$4,113
Customer charge	\$2,353			\$2,353
Mileage	\$402	\$307	\$519	\$1,228
Excess weight charge	\$634			\$634
Pickup charge	\$633			\$633
Misc. fee	\$19	\$47	\$71	\$137
<b>Grand Total</b>	<b>\$434,429</b>	<b>\$379,051</b>	<b>\$348,606</b>	<b>\$1,162,086</b>

**\*\*NOT Food Waste Specific**

Facility Name	2019	2020	2021	Grand Total
Miller Hall	\$36,607	\$34,519	\$33,596	\$104,722
Fairhaven Towers	\$34,521	\$34,027	\$33,194	\$101,741
Haggard Hall	\$24,667	\$22,745	\$26,862	\$74,274
Birnam Wood	\$21,956	\$17,224	\$25,454	\$64,633
Nash Hall	\$25,029	\$21,796	\$15,490	\$62,314
Academic Instruction/West	\$20,163	\$20,112	\$21,750	\$62,025
Buchanan Towers	\$21,049	\$19,394	\$16,383	\$56,826
Mathes	\$18,016	\$15,418	\$14,616	\$48,051
Ridgeway - Beta	\$18,835	\$14,218	\$5,091	\$38,144
Ridgeway - Kappa	\$16,216	\$13,334	\$7,772	\$37,321

(WWU Campus Utilities Manager, 2022)

Budget item	Cost per Item	Quantity	Cost
Civil Engineering, Permitting, Regulatory, Compliance, and Key Stakeholder costs: i.e. General Pre-Project Plan Execution	\$20K	Rough Estimate Total	\$20K
Equipment - Impact Bioenergy "HORSE"	\$160K	1	\$160K
Freight (Transport to WWU) (Estimate per Impact Bioenergy)	\$20K	1	\$20K
Hookup (Estimate per Impact Bioenergy)	\$20K	1	\$20K
Ongoing Costs:			
Labor Option (level 1) Based off WWU current wage schedule	Hourly Rate: \$14.49-18.85	1 (Part Time 20hrs/week)	~\$15K
Labor Option (level 2) Based off WWU current wage schedule	Hourly Rate: \$15.95-\$20.75	1 (Part Time 20hrs/week)	~\$16.5K
Labor Option (level 3) Based off WWU current wage schedule	Hourly Rate: \$17.55-\$22.80	1 (Part Time 20hrs/week)	~\$18k
Labor Option (Graduate Classification) Based off WWU current wage schedule	Hourly Rate: \$18-\$22.80	1 (Full Time 40hrs/week)	~\$37.5k
Parts/Maintenance	~2k	Per Year	~2k

Benefits (Assuming the digester is running 40 weeks of the year)	\$ Amount/Year @ Minimum Capacity	\$ Amount/Year @ Maximum Capacity
Reduction in Food Waste	38,400 lbs/year	268,000 lbs/year
Energy Output (gas)	11,568 cubic feet/year @ \$7.65 per 1000 cubic feet = \$88.50	162,000 cubic feet/year @ \$7.65 per 1000 cubic feet = \$1,239.30
Energy Output (Electricity)	\$189.20 2,000 kwh @ 9.46¢/kw	\$605.44 6,400 kwh @ 9.46¢/kw
Fertilizer Production	\$20,000 @ \$40/gal (20 hrs a week)	\$40,000 @ \$40/gal (40 hrs a week)
Educational Value	Less than 10 credits/quarter  Resident Undergraduate: \$252  Non-Resident Undergraduate: \$827  Resident Graduate: \$379  Non-Resident Graduate: \$787	More than 18 credits/quarter  Resident Undergraduate: \$230  Non-Resident Undergraduate: \$804  Resident Graduate: \$356  Non-Resident Graduate: \$764
Marketing Value (Attract 1 Sustainability Student)	In State (First Year) Tuition: \$6,893 Fees: \$2,110 Housing & Meals: \$13,080 Total Direct Costs: \$22,083 Additional Expenses Books & Supplies: \$1,011 Transportation: \$1,359 Personal & Miscellaneous: \$2,481 Total Cost of Attendance: \$26,934	Out of State (First Year) Tuition: \$24,120 Fees: \$2,110 Housing & Meals: \$13,080 Total Direct Costs: \$39,310 Additional Expenses Books and Supplies: \$1,011 Transportation: \$1,359 Personal & Miscellaneous: \$2,481 Total Cost of Attendance: \$44,161
Marketing Value (Attract 1 Sustainability Graduate)	In State \$12,490/year	Out of State \$24,737/year



# TECHNOLOGY SIZING CALCULATOR

PROPRIETARY & CONFIDENTIAL

	AD25 Prefab-relocatable	AD40 Prefab-relocatable	AD100 Prefab-relocatable	AD175 Prefab-relocatable	AD185 CHP Prefab-relocatable	AD500 CHP Prefab-relocatable	AD750 CHP Prefab-relocatable	AD925 CHP Prefab-relocatable	AD1500 RNG Prefab-relocatable	
	HORSE	HORSE	HORSE	HORSE	NAUTILUS	NAUTILUS	NAUTILUS	NAUTILUS	NAUTILUS	
Wet Tons per Year	25	40	100	175	185	500	750	925	1,500	Wet Tons per Year
Frac Tanks					1	1	1	2	2	
scale factor	1.0	1.6	4.0	7.0	1.0	2.7	4.1	5.0	8.1	
Wet lbs per Day	137	219	548	959	1,014	2,740	4,110	5,068	8,219	Wet lbs per Day
Peak MMBTU/year	131	210	526	920	972	2,628	3,942	4,862	7,884	MMBTU/year
Nominal MMBTU/year	79	126	315	552	583	1,577	2,365	2,917	4,730	MMBTU/year
Peak Design Rate: highest hourly rate that might occur	15,000	24,000	60,000	105,000	111,000	300,000	450,000	555,000	900,000	BTU/hr
Nominal Rate: target average hourly rate	9,000	14,400	36,000	63,000	66,600	180,000	270,000	333,000	540,000	BTU/hr
Nominal Daily Rate:	216,000	345,600	864,000	1,512,000	1,598,400	4,320,000	6,480,000	7,992,000	12,960,000	BTU/day
CSTR size - min gallons	479	767	1,918	3,356	3,548	9,589	14,384	17,740	28,767	CSTR size - min gallons
HRT days	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	HRT days
ideal biogas storage BTU designed for 12 hours of nominal biogas generation	108,000	172,800	432,000	756,000	799,200	2,160,000	3,240,000	3,996,000	6,480,000	ideal biogas storage BTU
supplemental storage BTU same as above	108,000	172,800	432,000	756,000	799,200	2,160,000	3,240,000	3,996,000	6,480,000	supplemental storage BTU
supplemental storage ft3	153	245	613	1,072	1,134	3,064	4,596	5,668	9,191	supplemental storage ft3
supplemental storage m3	4.3	7	17	30	32	87	130	161	260	supplemental storage m3
40' ISO intermodals	0.06	0.10	0.26	0.45	0.48	1.29	1.94	2.39	3.88	40' ISO intermodals
ideal fuel rate CHP/12-7 designing for 12 hr/day generator run time each day	18,000	28,800	72,000	126,000	133,200	360,000	540,000	666,000		ideal fuel rate CHP/12-7
KWe at 30% efficiency	1.6	2.5	6.3	11	12	32	47	59		KWe at 30% efficiency
ideal fuel rate CHP/24-7 designed for 24 hr/day generator run time each day	9,000	14,400	36,000	63,000	66,600	180,000	270,000	333,000		ideal fuel rate CHP/24-7
KWe at 30% efficiency	0.8	1.3	3.2	5.5	5.9	16	24	29		KWe at 30% efficiency
liquid plant food output - gal/yr salable product	5,625	9,000	22,500	39,375	41,625	112,500	168,750	208,125	337,500	liquid plant food output - gal/yr
solid compost - tons/yr salable product	zero	zero	zero	zero	zero	zero	zero	zero	zero	solid compost - tons/yr
ideal plant food storage gallons designed for transfer every 21 days	324	518	1,295	2,265	2,395	6,473	9,709	11,974	19,418	ideal plant food storage gallons
<b>Estimated Drawdown (Carbon Offsets)</b>										
Digester Only	53	84	210	368	389	1,052	1,578	1,946	3,156	MTCO2e per Year
Digester + Indoor Farm System	208	333	833	1,458	1,541	4,165	6,248	7,705	12,495	MTCO2e per Year
liquid plant food output - gallons per week salable product	108	173	433	757	800	2,163	3,245	4,002	6,490	



## Grant Application

The SEJF grant application is for all fund requests. Please fill out the application completely, creating and utilizing additional space as appropriate. Supplementary documents may be added in the appendix at the end of the document.

Each grant team is assigned a project coordinator; this individual will collaborate with the project team and provide feedback and insight on the application. For detailed application instructions, please refer to the *SEJF Grant Application Toolkit* or ask a program representative.

Submit your completed application by emailing a scanned version (including signatures) to [Johnathan Riopelle](mailto:johnathan.riopelle@wwu.edu). Applications must be signed by your advisor, all members of the project team, and all stakeholders in order to be reviewed. Email: [johnathan.riopelle@wwu.edu](mailto:johnathan.riopelle@wwu.edu).

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Application Level: Please determine the amount of funding you will require and check the appropriate box:

- ☐ Small Grant: Up to \$5,000. Applications of this size will be reviewed by the Communications Manager and the Sustainability Institute Director. Small grants may be approved, declined, or sent to the SEJF Committee for consideration.
  - ☐ Medium Grant: Between \$5,001 and \$35,000. Applications of this size will be reviewed by the Communications Manager and the Sustainability Institute Director for alignment and completeness and then provided to the SEJF Committee. The committee will review the grant, receive your presentation, and approve or decline the funding request.
  - ☐ Large Grant: Over \$35,000. To request funding at the level, you must already have submitted and received approval of your grant abstract. Please attach your approved abstract to the end of this application. Applications of this size will be reviewed by the Communications Manager and the Sustainability Institute Director for alignment and completeness and then provided to the SEJF Committee. The committee will review the grant, receive your presentation, and approve or decline the funding request.
- 

### SECTION 1: Project Concept.

a. Project Title:

On-Campus Anaerobic Digester

b. Statement of Purpose (This is a one- to two-sentence synopsis of the project):

Reuse organic waste at a larger scale on campus, while maximizing quality uses of the outputs, and benefits, to demonstrate the efficacy of energy reuse on campus, while driving partnership with sustainably focused businesses in support of Sustainable Development Goals (SDGs).

Our intent is to utilize an anaerobic digestion system to demonstrate that it is possible to transform food waste into usable energy, in the form of electricity or gas, to power existing campus systems.

c. Describe your proposed project in detail:

Our project proposal is to buy and implement an anaerobic digester from Impact Bioenergy on WWU's campus. An anaerobic digester turns food waste and organic material into renewable energy. The waste is stored in a container that utilizes micro-biotic organisms to create biogas that can be used on campus via electricity or plugged into the existing natural gas system. This will create a more closed loop energy system on campus which will reduce Western's carbon footprint.

The Impact Bioenergy "HORSE" is the size of a shipping container, reasonably "plug and play" because it comes with a standard generator to convert the biogas into electricity or can be upgraded to utilize the biogas directly into existing gas systems on campus. We have chosen this system because it will demonstrate, on a small scale, the possibility of expanding this technology in larger applications for a relatively low project cost compared to most anaerobic digestion systems that exist today.

The lower cost, lower capacity digester will allow us to implement this technology more realistically on campus. The larger digesters require lots of capital to buy and install, therefore, the smaller scale digester makes more sense for our project. Furthermore, digesters are not very commonplace for most people, so having this smaller one installed creates an educational opportunity for students and other campus-goers. Implementing educational signage near the digester to inform those interested and create a push for more digesters. It would also be exciting for students and faculty to see that their university is implementing changes to tackle large issues such as food waste and climate change.

d. Who is the intended audience?

Any organization interested in reducing the cost of their existing operations, WWU stakeholders interested in demonstrating the efficacy of biogas production in powering existing systems, and potential Western Students currently evaluating Western's commitment to Sustainable Initiatives.

e. How many students will be directly affected?

A digester will be used among all students and faculty on campus due to the energy output that will be used. Students who eat at the dining hall will contribute to the digester by composting waste. The waste will then be turned into renewable energy by the digester which will be used on campus.

## **SECTION 2: Project Outcomes.**

a. What are the goals and desired outcomes of your project?



- To reuse organic waste at a larger scale on campus, while maximizing quality uses of the outputs (clean energy), and benefits, to key stakeholders. Our goal is to take steps towards a more closed loop energy system on campus. By implementing an anaerobic digester, we will decrease Western's carbon footprint by creating a more resilient system that removes outside sources. This project will lead to a more localized/self-sustained campus that does not contribute as much waste into the landfill. We also strive to incorporate a learning opportunity into the installation of the digester. It will inform people about how the digester works, how the energy produced is being used, and how much food waste is produced on campus.
- b. How will your project positively impact the four pillars of sustainability at Western?
- c.
1. Create economic vitality:
    - Generate profit or equivalent compensation from products like heat, electricity, or fuel generated from biogas. The anaerobic digester also acts as a demonstration of the efforts that Western is willing to put in to working towards a more sustainable campus. Partnering with impact bioenergy, which is a local company from Auburn, Washington will help stimulate the green economy and boost the market for green jobs.
  2. Promote human health:
    - Reduces the amount of chemicals and pollutants in meals from fertilizers and pesticides. The overall project reduces Western's carbon footprint which leads to mitigating climate change thus creating a healthier environment. Promoting better waste systems shows the community how waste can be utilized in a safer and healthier way. Education regarding improper waste practice is another factor that should be considered with this project.
  3. Protect local and global ecology:
    - Lowers methane emissions
    - Increases agricultural crop production
    - Assists in reforestation (improves contaminated and compacted soils)
    - Improves water retention in soil
    - Carbon sequestration
    - Reduces and minimizes wind and water erosion
    - Adds nutrients and promotes the growth of beneficial micro-organisms, worms, insects, etc.
  4. Uphold social equity:
    - Reduces the negative impacts of toxic waste upon our surrounding communities. The reduction of methane emissions from food waste reduces the impacts of climate change, which inherently affects low-income households at a higher rate. It is on a small scale, but we hope that the installation of a digester on Western's campus will promote the technology and pave the way for more digesters to be built in our community, as well as around the world.
- d. SEJF projects must align with Western's Sustainable Action Plan (SAP). Please determine how it advances one or more of the ten SAP chapters. For information on the SAP, please refer to the Canvas site, the SEJF Toolkit, or ask your program coordinator. The ten SAP chapters are:
1. Built Environment
  2. Campus & Community Engagement
  3. Curriculum and Research

4. Dining Services
5. Grounds
6. Investments
7. Procurement
8. Student Life
9. Transportation
10. Waste

Primary chapter of alignment: Waste

Explanation: The project aligns with the SAP Waste chapter because the main goal of our project is to reduce waste produced on campus and utilize its outputs. By utilizing the waste made on campus to create renewable energy, we are taking steps towards a more closed loop energy system on campus. Reducing food waste is a very complicated issue that is hard to solve, but by having a use for the outputs instead of letting them go to a landfill helps relieve some of the problem. We also hope that the educational factor of the digester set up will help inform people about how much food waste is produced at western, which will cause them to change their personal habits.

Secondary chapter of alignment: Investments

In order to successfully implement the installation of a digester at WWU, we are partnering with Impact Bioenergy, a local Washington business that is driven by sustainability. Investing in an anaerobic digester shows the commitment to sustainable waste management on campus. It also creates a system that students can learn from and educate those around them. Enhanced waste management is one step, educating others how to properly partake is another. By taking steps towards a renewable waste system it creates more opportunities for students to learn hands-on.

Third chapter of alignment: Dining Services

The anaerobic digester will receive most of its waste from the dining services. The dining services have a composting system in place, however instead of going to the city compost it will be digested here on campus and turned to renewable energy. This aligns with Western's goal to have zero-waste dining services.

- e. The United Nations has developed seventeen sustainable development goals (SDGs) to transform our world. These goals address the full spectrum of sustainability. When we work locally to transform our community, we are in league with people around the globe striving to create a more just society. The UN's seventeen SDGs are:
- |  |  |
|--|--|
| 1. No Poverty                              | 10. Reduced Inequality                     |
| 2. Zero Hunger                             | 11. Sustainable Cities and Communities     |
| 3. Good Health and Well-being              | 12. Responsible Consumption and Production |
| 4. Quality Education                       | 13. Climate Action                         |
| 5. Gender Equality                         | 14. Life Below Water                       |
| 6. Clean Water and Sanitation              | 15. Life on Land                           |
| 7. Affordable and Clean Energy             | 16. Peace and Justice Strong Institutions  |
| 8. Decent Work and Economic Growth         | 17. Partnerships to Achieve the Goal       |
| 9. Industry, Innovation and Infrastructure |  |

Please list and explain the three United Nations' Sustainable Development Goals that your project primarily addresses.

1. **Affordable and Clean Energy** - By taking steps towards a closed loop energy system on campus we are decreasing the carbon footprint and taking ownership of portions of our own waste. Renewable energy is more sustainable and affordable because it increases the resilience of the system by cutting out external factors.
  2. **Partnership for the goals** - By contracting with Impact Bioenergy we can drive partnership, joining their existing network, within the sustainable development industry. This will also enable us to demonstrate the efficacy of these types of systems, on a small scale (about 20% of WWU's current Food Services waste), in hopes of enabling larger scale projects on campus or elsewhere, while financially supporting a Washington business seeking to do good work in pursuit of a more sustainable world.
  3. **Climate action** - By creating a system to reuse energy and get rid of waste in a sustainable way we are working towards a more environmentally friendly campus, inspiring others to pursue similar projects, and demonstrating Western's commitment to real sustainable action for those considering Western on the merits of the real-life applicability of the University's programs. Specifically, the reduction of methane gas emissions is vital in the fight against climate change. The proposed digester is a small step in tackling the problem of methane gas emissions resulting from food waste, but we hope that our project will help build more traction to get more of these devices installed.
- f. How will the success of the project be measured? Describe the quantitative and/or qualitative sustainability metrics you will use to measure the success of your project. A data collection plan is required for all project, and all data must be provided to the SEJF Program upon completion of the project.

Metric	Description	How and when will you collect it?
SEJF Approval	Further development of this plan to ensure Real World steps towards implementation.	Independent Study, Winter Qtr. 2022
Successful Install of HORSE on Campus	Navigate all key stakeholder requirements to fully implement installation on campus.	Estimate Winter 2023
Waste Diverted (LBS)	Measure LBS of waste diverted as the system is used.	Can be measured by system operators Post Installation.
Electricity/Biogas Produced	Depending on alignment of key stakeholder requirements, we will measure the amount of electricity produced or the amount of gas we are able to utilize for campus facilities.	Can be measured by system itself once in operation.
Community Recognition	Measure the amount of interest generated from WWU Recruiters, journalists, researchers, or relevant industry publications.	When is TBD, because the system could get recognition while install is in process. Measured by # of promotional videos/communications created by WWU, media articles, research papers, or other accessible publicity over time.

### SECTION 3: Project Participants.

- a. Team Information: A team should consist of two to five individuals, including the team advisor.

Project Advisor Information (Faculty or Staff) Student proposals must include a staff or faculty advisor. The role of the advisor is to provide assistance and guidance to the team during the development, implementation, and post-implementation stages of the proposal process.

Project Lead: There must be at least one team lead designated for the project. This individual is expected to serve as the communication liaison for the project.

Financial Agent: The project must have a budget authority to manage funds for all purchases. Should funds require transfer, this individual will have to provide a FAST Index and Activity Code to the SEJF Manager.

Program Coordinator: A member of the SEJF team will serve as the primary contact for the program and committee.

Name	Department/School Students provide major/minor	Position: Faculty/staff/student <i>Students provide expected graduation quarter/year</i>	Western email address	Signature to verify agreement
<i>Team Advisor:</i>	Craig Dunn	Faculty	dunnc3@wwu.edu	
<i>Team Lead:</i>	Zach Williams	Student	willi469@wwu.edu	
<i>Team Member:</i>	Cole Strickland	Student	strickc6@wwu.edu	
<i>Team Member:</i>	Amelia Bineham	Student	binehaa@wwu.edu	
<i>Team Member:</i>	Keahn White	Student	whitek40@wwu.edu	
<i>Team Member:</i>	Tiffany Lin	Student	lint5@wwu.edu	
<i>Team Member:</i>	Emily Busack	Student	busacke@wwu.edu	
<i>Financial Agent:</i>	TBD			
For fund transfers  <i>FAST Index:</i>  <i>Activity Code:</i>	TBD			
<b><i>Program Coordinator:</i></b>	TBD – Would plan to enroll Johnathan Riopelle			

#### SECTION 4: Project Timeline.

- a. Describe your project's progress and promotional activity. Outline all tasks that are required to complete the projects, and all means in which you will promote the project to the campus, in the table below. Include all activities that will occur both before and after funding approval, Insert additional rows as necessary.

Action	Purpose	Initiation	Completion
<b>Abstract Creation and Approval</b>	Obtain Abstract Approval to proceed prior to further action.	Jan 2022	Jan 2022
<b>Refine elements of this proposal</b>	Refine this proposal to more succinctly sell this project to SEJF.	Jan 2022	Jan 2022
<b>Gain SEJF Approval</b>	Gain full SEJF Approval	Jan 2022	Feb 2022
<b>Enroll Stakeholders</b>	Enroll support from key stakeholders (Finance, Facilities, Food Services, Etc.)	Jan 2022	March 2022
<b>Outline Compliance/Regulatory Requirements</b>	Ensure key considerations for Legal/Environmental compliance regulation are incorporated into plan.	Jan 2022	March 2022
<b>Finalize Project/Funding</b>	Ensure all funding is secured, project is approved, and ready to move to purchasing initiation phase.	April 2022	June 2022
<b>Initiate Purchase</b>	Work with Michael Smith @ Impact Bioenergy to initiate payment (deposit) and production of our HORSE. Lead time is estimated @ 3-6 months from deposit + transportation lead time.	July 2022	August 2022
<b>Coordinate Delivery &amp; Install</b>	Coordinate with Impact Bioenergy, Campus Facilities, and Food Services for Delivery & Installation	Aug – Nov 2022	Nov 2022 (Estimate)
<b>Training and Onboarding</b>	Train and Onboard personnel in operation requirements.	Nov 2022	Dec 2022
<b>Monitor &amp; Maintain</b>	Monitor Success of Intended Outcomes and Required Maintenance.	In Perpetuity	

- b. Where will the project be located?  
TBD Depending on the final output suggested and key stakeholder alignment/buy-in. Initial ideas are 1) The Outback or 2) In a location most convenient to the largest Food Services facility on campus.
- c. Planned project completion date: December 2022
- d. Who will the project owner be upon completion? This individual, office, or department is a stakeholder—see next section. TBD Depending on stakeholder approval. Top idea: Energy Manager within the Facilities Department.

## SECTION 5: Project Stakeholders.

Does your project involve labor, include involvement, or require permission from organizations, departments, or individuals on campus? These project partners are your stakeholders. All stakeholders must provide a signature of approval for this project.

Key questions to identify your potential stakeholders:

- Who will impact or be impacted by implementation of the project?
- What financial or emotional interest do they have in the project, positive or negative?
- What information will they want, and what is the best way of communicating with them?
- What is their current opinion of your proposal? Is it based on accurate information?
- Who influences their opinions generally, and who influences their opinion of you? Do some of these influencers therefore become important stakeholders in their own right?
- Who else might be influenced by their opinion? Are these individuals also stakeholders?
- If they aren't likely to be amenable, what will win them around to support your project?
- If you are not able to win their support, how will you manage their opposition?

Stakeholder Name	University Department and Position	Involvement in Project	Stakeholder signature of approval
Craig Dunn	WWU Professor of Business and Sustainability	Advisor (High Power, High Interest)	
Jonathon	SEJF program coordinator and assistant	Approval of proposal (High Power, High Interest)	
Aramark	Dining Hall Services	Coordinate changes in how food is disposed of (Low Power, High Interest)	
Michael Smith	Director, legal and business development; Works for Impact Bioenergy	Resource and has experience with anaerobic digesters (Low Power, High Interest)	
WWU Students	Students	Student support and interest (Low Power, Low Interest)	

*If your project team is proposing a temporary or permanent facility or property modification, then a Project Owner Form must be submitted with the application. Please ask your project coordinator for this form.*

## SECTION 6: Project Budget.

- g. Provide an itemized list of the budget items required for this project. Include equipment, construction costs, publicity, labor, and any other costs. Include funding amounts from other sources that will impact project cost. The SEJF Program encourages the identification of additional funding sources to augment SEJF funds, and failure to secure such support may prevent approval of an application. List pending, approved, and denied applications

for funding from other sources, along with amounts requested from those sources.

Budget item	Cost per Item	Quantity	Cost
Civil Engineering, Permitting, Regulatory, Compliance, and Key Stakeholder costs: i.e. General Pre-Project Plan Execution	\$20K	Rough Estimate Total	\$20K
Equipment - Impact Bioenergy “HORSE”	\$160K	1	\$160K
Freight (Transport to WWU) (Estimate per Impact Bioenergy)	\$20K	1	\$20K
Hookup (Estimate per Impact Bioenergy)	\$20K	1	\$20K
Miscellaneous Post Hookup Costs: Equipment, Parts, Temporary Labor, or Publicity	\$10K	Rough Estimate Total	\$10K
Total project budget			\$230K
Additional funding source	Status		Amount
Total of all other funding sources			
Total requested funds from SEJF			

- h. If the project is implemented, will there be any ongoing replacement, operational, maintenance or renewal costs? If yes, has a source of funds been identified to cover those costs? This must be communicated to the appropriate stakeholder.

Ongoing cost	Amount/year	Responsible Stakeholder	Signature
Labor	TBD	Food Services	
Parts & Labor	TBD	Facilities Management	

## SECTION 6: Appendices.

Provide any additional documents, references, or information here. For large grants, attach the approved abstract in its entirety at the end of this document. When possible, provide documents rather than URLs.





**GRANT APPLICATION  
PROPOSAL REVIEW PROCESS**

Please set an appointment with Johnathan Riopelle, Communications Manager for the Sustainability Institute, to review your drafted proposal. Once your project proposal is complete, sign and deliver it via email to:

[johnathan.riopelle@wwu.edu](mailto:johnathan.riopelle@wwu.edu).

Completed medium and large grants applications are presented to the SEJF Committee for consideration. The Communications Manager will provide you with dates and information for your presentation once your application is complete and submitted.

**Johnathan Riopelle**  
**Communications Manager, Sustainability Institute, Western Washington University**

**Signature:** \_\_\_\_\_ **Date:** \_\_\_\_\_

*This signature confirms that the application has been accepted for SEJF committee review; it does not indicate funding approval.*

**Grace Wang**  
**Director, Sustainability Institute, Western Washington University**

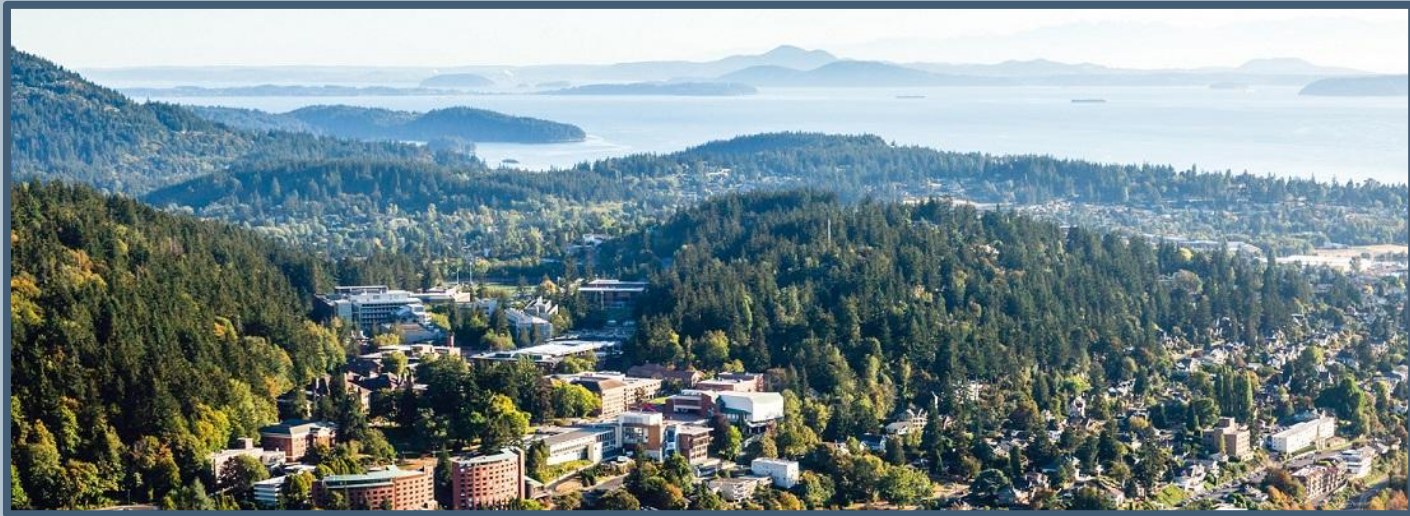
**Signature:** \_\_\_\_\_ **Date:** \_\_\_\_\_

*This signature confirms that the application has been accepted for SEJF committee review; it does not indicate funding approval.*

Comments:

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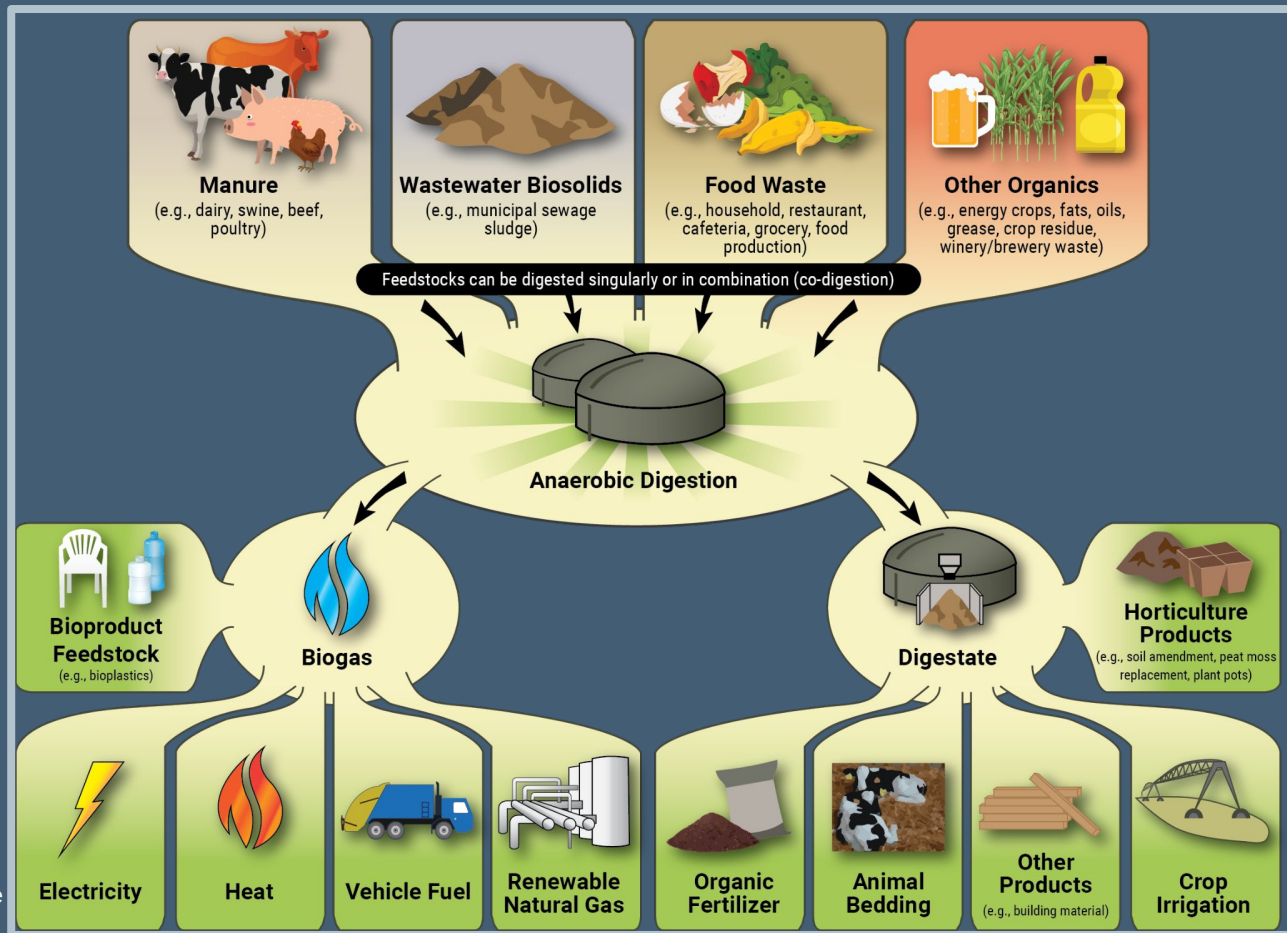
# Anaerobic Digestion at Western Washington University



WWU (aerial)

Clara Copley, Liam Flynn, Sienna Taylor  
Project Sponsor: Amanda Cambre

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Anaerobic Digestion image



Sanitary Services truck

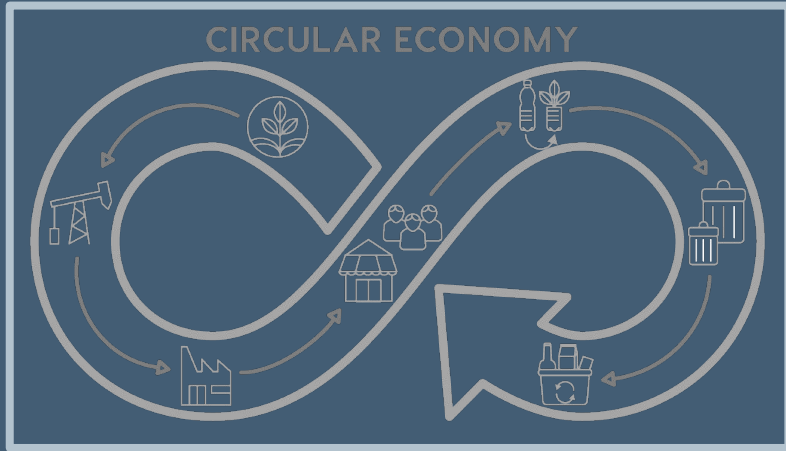


2-cubic yard receptacle behind Fairhaven Commons

The WWU Dining Halls generate more than  
30,000 lbs of food waste weekly!



# Project Goals

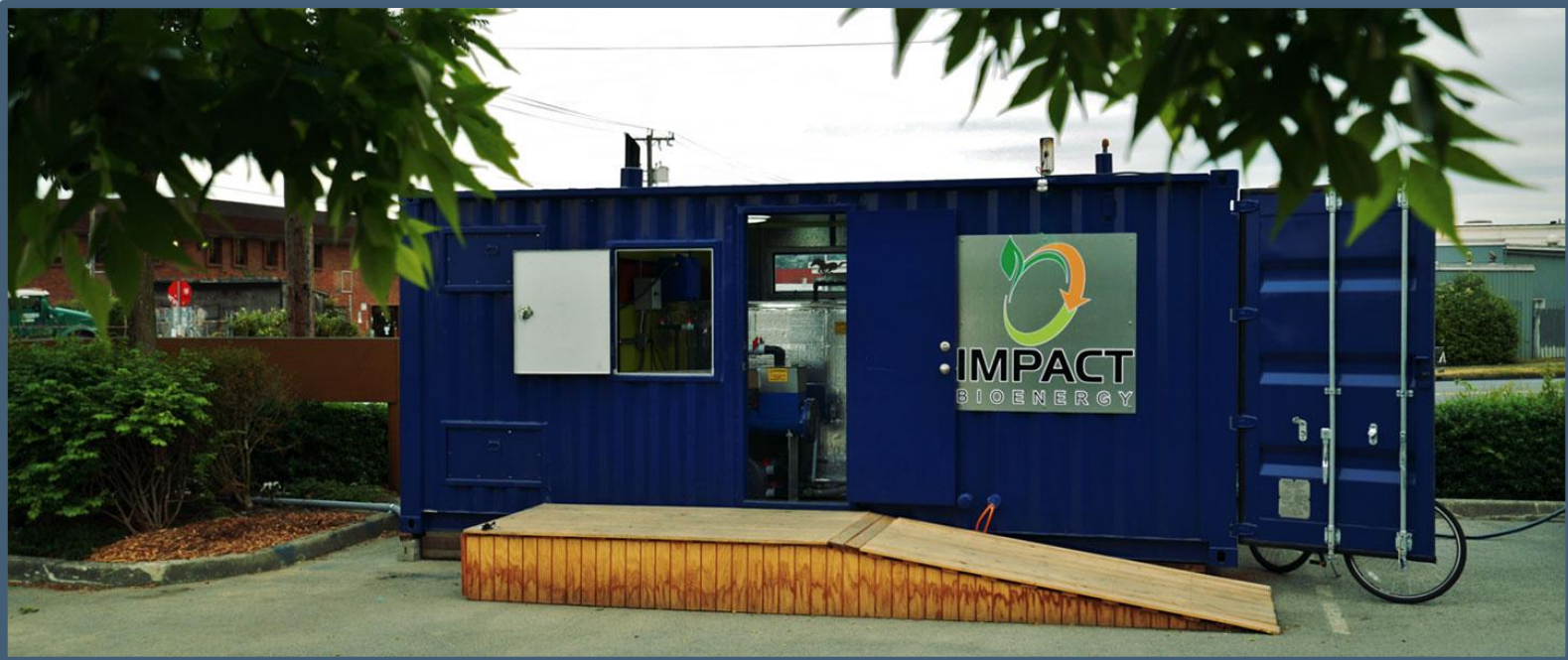


Circular economy graphic

1. Reduce costs to WWU
2. Reduce carbon footprint
3. Build University partnerships
4. Serve as an example to other Universities



Impact Bioenergy Logo



HORSE AD25

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# Methodology

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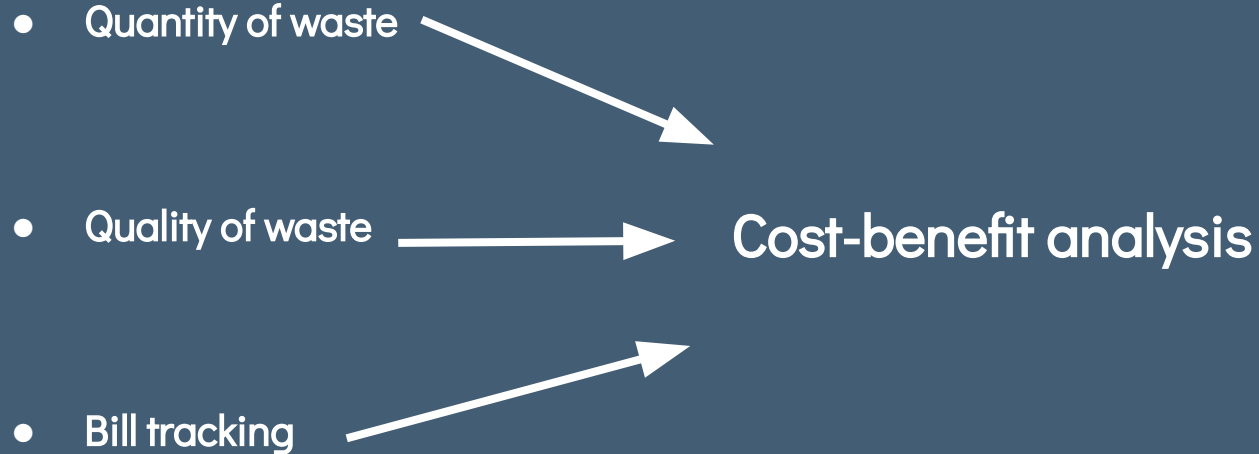


# Interviews

Name & Title	Communication
Amanda Cambre - Director of Sustainability Integration (facilities & operations)	<b>Logistical</b> and <b>locational</b> questions, aided in making <b>connections across campus</b>
Jan Allen - President, Founder, CEO of Impact BioEnergy	<b>General digester info</b> (staffing requirements, utility logistics, and emission benefits)
Dylan Lew - Carnegie Mellon alumnus	How to turn the digester into a <b>self-sustaining business</b>
Stephen Wadsworth - Aramark Resident District Manager	Explained daily dining hall <b>waste production</b> , <b>location</b> , and <b>operation feasibility</b>
Tim McLaughlin - Fairhaven Commons Director	Gave insight into <b>current</b> Fairhaven commons <b>waste removal procedures</b>

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# Inventory Assessment



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# Results

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Current motorcycle parking



Current accessible parking

# Location

Considerations:

- ❖ One accessible parking spot + partial motorcycle parking

OR

Complete relocation of motorcycle parking

- ❖ Vehicle accessibility

# Staffing Plan



32 gallon receptacle

New digester position:

- One, part-time worker
- 4-9 p.m.



2-cubic yard receptacle located at the Fairhaven Commons loading dock



64 gallon receptacle

# Utilities + Transportation

## Utilities

- Heating & Mixing
  - 240 V AC circuit & 60 amp electrical service
- Water
  - Standard garden hose
- Sewage
  - Plumbing connection
- Biogas (purely optional)

## Transportation (2 options)

- Manual process:
  - 5-gallon container
- Mechanical process:
  - 36-gallon toter

# Budget



SEJF logo

- SEJF
  - Sustainability, Equity, and Justice Fund
  - Available for student and faculties
  - Accumulation of quarterly fees
- HORSE AD25 funding
  - Initial capital investment - \$300,000
    - \$210,000 for AD
    - \$90,000 for initial operation costs
  - Annual operating costs - \$4,300 - \$21,000



---

# Cost-Benefit Analysis

## SSC Billing

- Fairhaven Commons generates ~4,200 lbs of food waste weekly
- The HORSE AD25 can digest up to 960 lbs/week
  - 22% of the total food waste
- SSC charges for pickup not amount
  - Could eliminate one pickup per week
  - \$2,500 → \$1,250

## Emissions Reductions

- WWU generates 10,000 MTCO<sub>2</sub>e/year
  - Digester can reduce emissions by 53 MTCO<sub>2</sub>e/year (0.5%)
  - Selling digestate
    - Up to 5,200 gallons/year (~\$78,000)
    - Can reduce emissions by 2,500 MTCO<sub>2</sub>e/year (25%)
-

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# Recommendations

HORSE AD25  
(buy)

HORSE AD25  
(lease)

Nautilus

Other AD

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# Conclusion

- Reduce frequency of SSC pickups
  - Offset carbon emissions through digestate production and sale
  - Production of a natural gas alternative
  - Phase II and Phase III
-

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# References

*Distributed food waste to energy technology.* Impact Bioenergy. (2022, October 25). Retrieved November 16, 2022, from <https://impactbioenergy.com/>

Environmental Protection Agency. (n.d.). EPA. Retrieved November 16, 2022, from <https://www.epa.gov/agstar/how-does-anaerobic-digestion-work#:~:text=Anaerobic%20digestion%20is%20a%20process,in%20the%20absence%20of%20oxygen.>

*Horse AD25 series.* Impact Bioenergy. (2022, October 27). Retrieved November 16, 2022, from <https://impactbioenergy.com/horse-ad25/>

*UW anaerobic digester: Food waste, Renewable Energy & Public Health (Phase 2).* UW Anaerobic Digester: Food Waste, Renewable Energy & Public Health (Phase 2) | Campus Sustainability Fund (CSF). (n.d.). Retrieved November 16, 2022, from <https://csf.uw.edu/application/uw-anaerobic-digester-food-waste-renewable-energy-public-health-phase-2#:~:text=The%20anaerobic%20digester%20would%20utilize,and%20by%20the%20UW%20Farm.>

*Volume-to-weight conversion factors - NH department of environmental ...* (n.d.). Retrieved November 16, 2022, from <https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/vol-to-weight-conversion.pdf>

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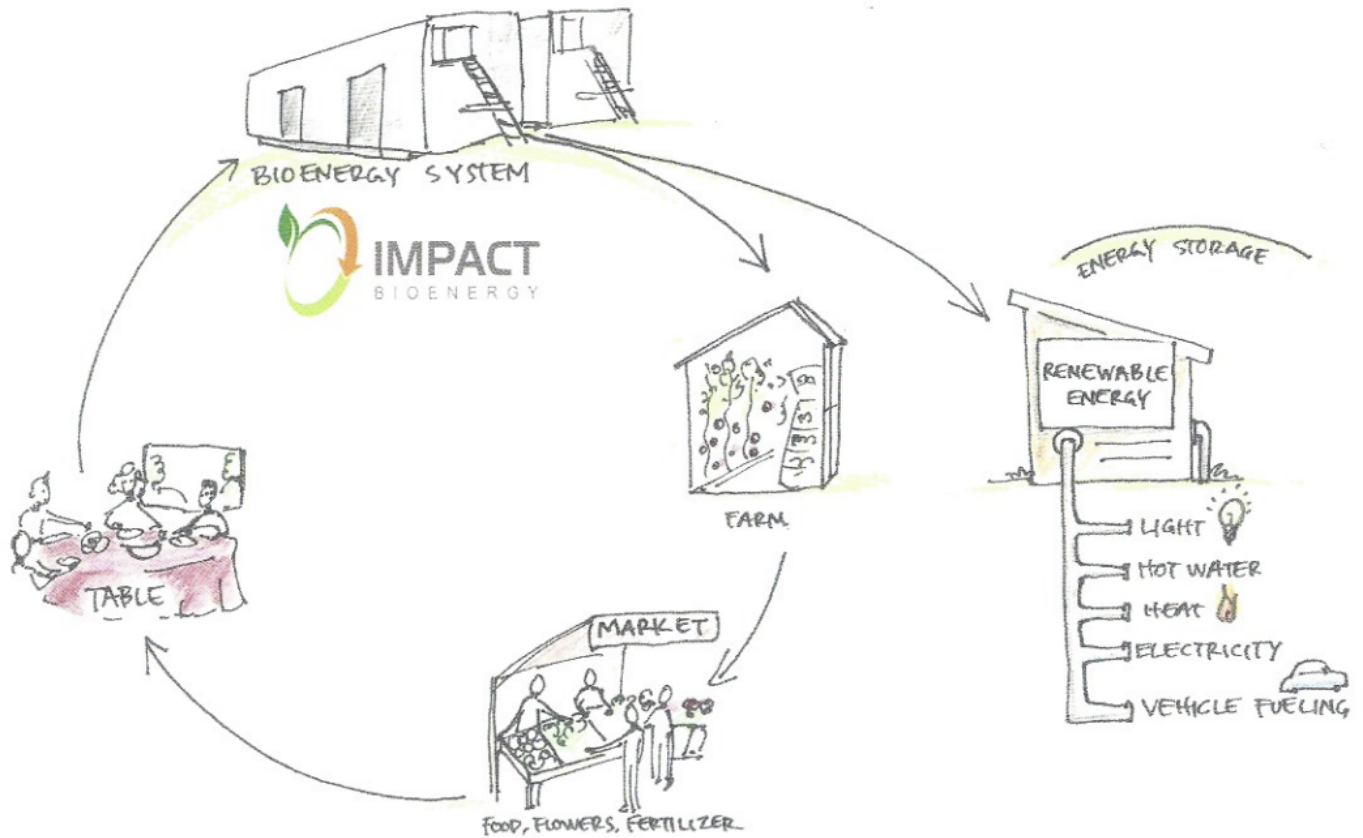
**Keep Calm, Digest On**  
**A Report of Anaerobic Digestion at Western Washington University**

Sienna Taylor, Clara Copley, Liam Flynn  
Western Washington University  
ENVS 471  
Amanda Cambre - Director of Sustainability Integration  
Dec. 8, 2022

## **Table of Contents**

1. Executive Summary .....	4
a. Problem Statement.....	4
b. Project Description .....	4
c. Summary of Recommendations.....	4
2. Introduction .....	5
a. Statement of Need .....	5
b. Project Goals .....	6
c. Background Research .....	7
3. Methodology .....	7
4. Results .....	8
a. Staffing Plan .....	8
b. Location .....	9
c. Transportation .....	10
d. Utilities .....	10
e. General operation .....	10
f. Summer operation .....	11
g. Cost-Benefit Analysis .....	11
i. Emissions Reductions .....	12
5. Recommendations .....	12
6. Monitoring and Evaluation .....	13
7. Budget .....	13
8. Conclusion .....	14
9. References .....	15
10. Appendix .....	16
a. Anaerobic Digestion feasibility study from Campus Sustainability Planning Studio Spring 2022 .....	16
b. Q&A from conversation with Jan Allen, Impact Bioenergy .....	17
c. SSC Invoice .....	17

**Figure 1**  
*Impact Bioenergy anaerobic digestion*



Note. Diagram of a circular economy from a [Impact Bioenergy](#) digester



## **Executive Summary**

### **Problem Statement**

To stay on track with the targets outlined in Western Washington University's Sustainability Action Plan, the University must begin to adopt different methods of energy generation and waste removal. Currently, the University relies on outsourcing for both heat, and waste removal. All of the buildings on campus are heated from a natural gas steam plant located behind the Ross Engineering Technology building and both food and solid waste are collected by the Sanitary Services Company (SSC).

This report investigates the possibility for implementation of an anaerobic digester which would create a closed loop system by turning food waste into usable forms of energy. Anaerobic digestion works as bacteria break down organic matter in an oxygen-free environment and produce biogas (a form of biofuel) and digestate (liquid fertilizer) as byproducts (Environmental Protection Agency, n.d.).

Biogas is mainly composed of methane (50-70%), carbon dioxide, hydrogen sulfide, water vapor, and other trace gasses. It can be used in mechanisms that natural gas is traditionally used in including heating systems, cooling systems, energy generation, etc. It can also be purified into Renewable Natural Gas (RNG) and used for things such as vehicle fuel (Environmental Protection Agency, n.d.). Digestate is made up of the leftover organic material from the digestion process (Environmental Protection Agency, n.d.). The digestate can be used as a soil conditioner/plant fertilizer that has a high value.

The ultimate objectives of this project are to save the University money by reducing the costs associated with waste removal transportation, reduce the carbon footprint of the University through alternative fuel sources and offsets associated with fertilizer production and sales, build lasting community relationships, and serve as a template for sustainability pursuits on other campuses.

### **Project Description**

The goal of this report is to provide a feasibility study and recommended operational plan consisting of suggestions for the use of a prefabricated anaerobic digester, specifically the HORSE AD25 from the company Impact Bioenergy. The recommended operational plan includes: the exact location and placement, the staffing required for operation, the hours and times of operation, the equipment and utilities required, the use of the byproducts (biogas and digestate), the input of organic matter at the specific location, and the proposed funding source.

### **Summary of Recommendations**

There are four identified recommendations for this project. Buying the HORSE AD25, leasing the Horse AD25, looking into implementation of the NAUTILUS, and looking into implementation of another, smaller anaerobic digester. The main recommendation is to buy the HORSE AD25 because through purchasing, the University or established businesses are able to profit off of the revenue generated through utilization of the byproducts, biogas and digestate. Another recommendation is to lease or lease-to-purchase the HORSE AD25 but will need to be further investigated in subsequent reports.

**Figure 2**

*The HORSE AD25*



*Note.* The smallest anaerobic digestion system from impact bioenergy.

## **Introduction**

### **Statement of Need**

Western Washington University's campus consists of three main dining halls that feed students from sixteen residence halls as well as some students that live off campus. The dining halls operate for breakfast, lunch, dinner, and late night dining services 7 days a week with closures for holiday breaks including Thanksgiving, Winter Break, Spring Break, and Summer Break. Together, the University dining halls produce roughly 30,000 lbs of organic food waste per week. This includes both pre and post-consumer waste and any material that can be commercially composted such as degradable napkins, tea bags, compostable flatware, paper products, etc. The calculation is based on an invoice provided by the Sanitary Services Company (SSC) which is the entity responsible for weekly pick ups at the separate dining hall locations (see Appendix A). SSC transports the compost to a third party commercial composting facility located in Lynden called Green Earth Technology.

Although Western diverts most of its food waste from the landfill via compost, this report investigates the option of anaerobic digestion to process the food waste more locally and potential uses for the byproducts. The scope of the paper is primarily focused on the feasibility and operations of implementing the HORSE AD25 which is an anaerobic digester produced by a company out of Auburn, WA called Impact BioEnergy. HORSE is an acronym for "High-Solids Organic-Waste Recycling System with Electrical output, and AD stands for anaerobic digester. The HORSE AD25 is roughly the size of a small shipping container and has the capacity to process 20-75 tons of food waste annually which translates into 960 weekly (*Horse AD25 Series*, n.d.).

The HORSE AD25 was chosen based on research conducted around anaerobic digestion from a previous Campus Sustainability Planning Studio (ENVS 471) class in Spring 2022. Their report (see Appendix B) looked at anaerobic digestion more generally and several options for digesters, as well as potential locations. After making initial contact with Impact Bioenergy in

Spring 2022, their suggestion for the next group of 471 students was to investigate the HORSE more thoroughly.

Upon selecting to research the operation of the HORSE AD25, the project team decided to focus on the location of the Fairhaven dining hall (also known as the Fairhaven Commons). Narrowing down the scope of anaerobic digestion and focusing on one manufacturer in one location creates the potential for a localized closed-loop system and the potential for a business plan involving various University and community partners.

### **Project Goals**

This project is broken into three phases with this report being Phase I. The goals of Phase I are to devise an operational plan associated with implementation of the HORSE AD25 with logistics illustrated in the **Results** section and recommended options for next steps located in the **Recommendations** section. Logistics addressed in Phase I include a staffing plan, a cost-benefit analysis, and location and utility requirements. Based on this information, the project team recommends several different options for anaerobic digestion (AD) at the Fairhaven Commons.

Phase II of this project will be taken on by one of the group members Clara Copley for her Senior Project. In this phase, she will focus on finding an output for the digestate produced by the AD by working with farms in the community. Once a farm partnership is established, Clara will work to develop a business plan between the farm or farm coalition and the University. The business plan may also include a path to sell fertilizer commercially, apart from a partnership between the University and a farm. This aspect of Phase II will also bolster the cost-benefit analysis.

Another aspect of Phase II is to further investigate the logistics of utilization of the second byproduct from the AD, biogas. Phase II will work through how the output of Bio-CNG will be best served for the University. Options may include using this gas to provide heat for the Fairhaven Commons or another building on campus, storing it in fuel cylinders to transport to another location, and powering a generator that can be used to charge electric vehicles.

The final deliverable for Phase II is to begin working towards funding sources for the digester. Phase I of the report more thoroughly investigated purchasing the HORSE AD25 unit, but Phase II will also look at the option to lease it. Capital investment for obtaining and owning the digester is around \$210,000 with extra capital investment for the first year of operations, rounding the initial investment to \$300,000. The capital investment for leasing is around \$35,000 (*UW Anaerobic Digestion*). A cost-benefit analysis will be conducted to identify whether leasing or buying is the right fit for the University. Whether it will be bought or leased, funding will likely, at least in part, come from the Sustainability, Equity, and Justice Fund (SEJF)—a pool of funds accumulated through quarterly student fees accessible for student and faculty sustainability projects. Clara will begin to construct and write the abstract for an SEJF grant proposal. The goal for the SEJF is to use it as a primary funding source that will finance purchasing, implementing, and the first year or so of operations for the digester. The ideal amount of funding to be sourced from the SEJF would be around \$300,000.

Phase III of this project will be pursued by another team member, Sienna Taylor. Sienna will continue the grant writing process as well as locating other potential funding sources, if necessary. She will also work on wrapping up the project and working to get the digester up and

running. This will include final operational logistics, staffing, etc. Many of her deliverables are contingent upon the completion and results from Phase II.

### **Background Research**

To begin, research was conducted regarding anaerobic digesters that had been established on college campuses in the U.S. The project team looked at case studies to gauge the feasibility of anaerobic digestion at the university level. Case studies included: University of Washington, University of California San Diego, and Carnegie Mellon. Following an interview with Chief Inventor and CEO of Impact BioEnergy Jan Allen, there was an emphasis placed on the comparison of anaerobic digestion implementation at WWU and the process followed by Carnegie Mellon. At Carnegie Mellon, a student Dylan Lew, obtained the HORSE AD25 through a school sponsored grant and now sells the digestate through a business called Ecotone.

To determine the site of potential AD implementation, it was necessary to look at the amount of food-waste generated at each of the dining halls at WWU as well as accessibility to the digester, appropriate spacing accommodations, and locale in proximity to other important functions and considerations. Given these criteria, a focus was placed on examining the feasibility of the Fairhaven Commons. The Fairhaven Commons is located in South Campus and provides dining services primarily to students in the Fairhaven Residence Hall and Buchanan Towers. It is also around 1,000 feet from the Outback Farm which may be an output for generated digestate.

Additional research was conducted to quantify the type and quality of organic material from the Fairhaven Dining Hall that will be used to feed the digester. Aspects considered were the amount of waste daily and weekly, and a comparison of pre-consumer waste and post-consumer waste and which one, or both, should be utilized. A rough estimate of the quantity of waste, and the frequency and location of compost pick up was identified through examining an invoice billed to the University by SSC. It is important to note that SSC charges are based on frequency of pick-up, not the quantity. At the Fairhaven Commons, the compost is held in 2-cubic yard receptacles and is picked up twice a week. Assuming that the 2-cubic yard receptacles are full at the time of pickup, there would be around 4,000 lbs of food waste generated and transported weekly.

### **Methodology**

The methodologies include both interviews and inventory assessments. Interviews have been conducted both on Zoom and in person, including physical site visits to the Fairhaven Commons. Communication with Amanda Cambre, the team project sponsor, involved weekly check-in emails and occasional Zoom and in-person check-ins. Since Amanda is the Director of Sustainability Integration for facilities and operations, she was able to answer many of the logistical and locational questions. Additional interviews were conducted with Jan Allen of Impact Bioenergy, Stephen Wadsworth of Aramark Dining, and Tim McLaughlin of the Fairhaven Kitchen. Jan Allen was addressed over Zoom with the project team, and Stephen and Tim were instrumental in answering questions relating to the daily dining hall waste, location of the digester, and operation.

The interview with Jan Allen, provided important information about the digester itself and information on staffing, cost, emissions reduction and benefit, utility logistics and other important information that is summarized in the **Results** section. Jan provided us with a typed Q&A document from our interview questions (see appendix C)

The inventory and benchmarking components of the methodologies include: quantity of waste, quality of waste, and bill tracking of organic waste outputs to SSC. Quantity of waste includes the amount in pounds of weekly organic waste from dining services, specifically the Fairhaven Commons. For the quality of the waste, inventory will be taken of the contaminants in the compost and how the amount of contaminants will impact the ability of the anaerobic digester to process the waste. The last category will be bill and cost tracking and analyzing. Analysis of how diversion of organic waste from SSC frees up funding for operations of the digester will be conducted to fulfill this last category.

Inventories and benchmarks were assessed to produce a cost-benefit analysis that included the current cost of food waste at the Fairhaven Dining Hall from SSC services, the cost reduction of that service with the installation of the HORSE, and the amount of food waste produced at the dining hall and the amount of food waste the HORSE can handle on a weekly basis.

## **Results**

### **Staffing Plan**

Staffing will be a collaborative effort from the Fairhaven kitchen staff and additional student(s) positions to run the digester. Kitchen staff from the Fairhaven dining hall currently transport the pre-consumer waste and post-consumer from the kitchen grinder and receptacles within the kitchen to a 2-cubic yard bin located on the loading dock that belongs to SSC and is picked up twice a week. There is a 64 gallon food waste receptacle located in the prep kitchen and a 32 gallon receptacle that captures the post-consumer waste from the built-in food pulverizer located next to the dish washing station. Both of these receptacles are emptied into the 2-cubic yard bin twice a day.

### **Figures 3, 4 & 5**

*Food receptacles at the Fairhaven Commons*



*Note.* Figure 3: the 32 gallon receptacle for post-consumer organic waste, Figure 4: the 64 gallon receptacle for pre-consumer organic

waste, Figure 5: the 2-cubic yard receptacle for combined pre and post-consumer waste

If the HORSE is located in one of the parking spaces adjacent to the loading dock, it is recommended that the student operating position assists the kitchen staff in transporting the receptacle bins to the digester. There should be very minimal extra effort from the kitchen staff, their procedure should remain extremely similar to the current process. The transport of this material to the machine requires minimal effort (walking a few extra feet out the door) compared to the current practice of dumping the organic waste receptacle into the large bin located at the loading dock.

Operating the digester requires at least one part-time attendant at the machine. The hours of operation are recommended to be between the hours of 4-9pm. The Fairhaven kitchen fills up their in-kitchen vessels and empties them twice a day, once around 4pm and again around 8-9pm. Therefore, the HORSE would be fed around evening time. Jan Allen recommends the student run position part-time with only two to four hours per week to load food waste into the machine and another two hours per week should be budgeted for cleaning, datalogging, testing the digestate for pH, etc., and equipment care.

### **Location**

The selected location for the anaerobic digester is behind the Fairhaven Commons building. The lot houses eight standard vehicle parking spaces, one for University vehicles, four accessible parking spaces, and three regular parking spaces. The HORSE AD25 requires 160 sq. ft. of space and a location that is mostly level, but with enough tilt to allow the water to drain through the floor. The HORSE weighs approximately 20,000 lbs that are supported at all four corners with the heaviest corner weighing 8,000 lbs (J. Allen, Personal Communications, Nov. 2, 2022).

### **Figure 6**

*Fairhaven Loading Dock*



*Note.* This figure displays the physical space available in the loading dock behind the Fairhaven Commons. There are several general and accessible parking spaces, and designated motorcycle parking.

Options for precise locations include relocation of an accessible parking spot from the northwest corner of the parking lot to the north end, which would reduce but not eliminate the existing motorcycle parking. Another option is for relocation of motorcycle parking from the north end of the lot to another location that is yet to be determined. It is possible to place a smaller digester on the west end of the loading dock where the current recycling receptacles are held. A smaller model and unit has not yet been identified but will be investigated in Phase II.

Other important location considerations are easy access to the digester by a vehicle. One of the byproducts of digestion, liquid plant food, needs to be emptied with a hose and a pump into a 275 gallon IBC tote on a truck (*HORSE AD25 series*, 2022). The frequency of this process will be dependent on the capacity at which the digester is running. The physical structure of the HORSE AD25 is a lockable, steel, 20' intermodal container that has the capability to last longer than 20 years (J. Allen. Personal Communication, Nov. 2, 2022).

Other possible locations will be addressed in Phase II of the project with possibilities including the AS Recycling Center lot which is located one block South of Campus.

### **Transportation**

Due to the close proximity of the HORSE system to the Fairhaven Commons, transportation of the food waste to the digester will ensure little extra work for kitchen staff. The food waste can be transported utilizing one of two suggested methods. The first involves the use of small, five-gallon, containers which can hold roughly 40 lbs. each and will have to be manually lifted in order to be emptied into the food grinder. Another method utilizes 36-gallon sized wheeled recycling carts (toters) that may weigh up to 250 lbs. and will require the use of a mechanical (motorized) lifter to be emptied (A. Cambre. Personal Communication, Nov. 14, 2022).

### **Utilities**

There are several utility requirements necessary for the HORSE AD25, including electrical, water, and sewer. A single phase 240 Volt AC circuit along with a 60 amp electrical service will be needed for food grinding, mixing, and heating processes (*HORSE AD25 series*, 2022). A standard garden hose faucet or irrigation pump is necessary for water supply for sanitation and housekeeping purposes (J. Allen. Personal Communication, Nov. 2, 2022). Additionally, a sewer connection will have to be installed to ensure proper separation of greywater (J. Allen. Personal Communication, Nov. 2, 2022). Other communication utilities or biogas transmission piping can be added upon request.

If the HORSE AD25 is placed in one of the parking spaces on the west side of the lot, the electrical hookup would likely come from an extension of the existing light pole (A. Cambre. Personal Communication, Nov. 14, 2022). Water and sewer are more uncertain but will be covered in Phase II or III.

### **General Operation**

A wide array of food waste can be fed into the food grinder, gradually. This waste is then emulsified and made into a pourable and pumpable mixture. The input material must be the proper consistency, both pourable and pumpable, in order for the plumbing system to be



capable of recirculating the digestate back to the food grinder to help liquify dry food waste. The pulp from the grinder already in place in the Fairhaven kitchen will need to be liquefied and if not, the grinder is recommended to be forgone altogether. Other materials such as plastic, glass, or metal must be removed when loading waste into the grinder.

### **Summer Operation**

During the summer months, the period of low food waste accumulation, it is recommended to continue to heat and mix the digester while maintaining a low input rate of about 50-100 lbs of food waste per week in order to keep the microbiome robust (J. Allen. Personal Communication, Nov. 2, 2022).

### **Cost-Benefit Analysis**

The cost-benefit analysis looks at the current cost to Western to pay for Sanitary Services Company (SSC) for the removal of food waste from the Fairhaven Commons and compares it to the cost reduction of the long-term use of the HORSE AD25. Since the funds for the initial purchase of the AD will likely come from the SEJF grant, that is not included as a “cost” to the University at the moment. Additionally, long-term funding is likely to come from the sale of the fertilizer so the cost of long-term funding is not included in this primary analysis. The focus is on the cost saved to Western from the reduction of SSC services and the overall emissions reduced from the HORSE AD25.

Currently, SSC bills Western around \$2,500 a year for organic waste removal only (not including other solid waste services) at the Fairhaven Commons. This is calculated based on the \$237/month rate for a 2x week pickup and occasional fuel “surcharges.” The sum is also based on an estimated reduction during summer months in which there is much less waste produced. Therefore, the amount of \$2,500 is based on a 9 month cycle, not including the summer period between Summer and Fall quarter, and includes a buffer for additional surcharges as illustrated on the SSC bill (see Appendix A, image 3).

The Fairhaven Commons produces about 4-cubic yards of organic waste per week which is calculated based on the 2x weekly pickup of the 2-cubic yard receptacles at the loading dock. Based on a standard volume-to-weight conversion factor, one cubic yard of organic food waste weighs approximately 1,070 lbs (Volume-to-weight conversion factors). Multiplying this by four, means Fairhaven Commons produces about 4,280 lbs of organic waste per week.

The HORSE AD25 system is capable of handling 960 lbs of organic waste which could theoretically reduce SSC weekly pickups from the Fairhaven Dining Hall from twice a week to just once a week, assuming the 2-cubic yard receptacles are not regularly full at the time of pickup. Even though 960 lbs is not even half of the calculated waste generated, Stephen and Tim from Aramark alluded to the the difference of the room left in the 2-cubic yard, this would save the University roughly \$1,250 per year based on the assumption that Fairhaven would reduce their SSC pickups to once a week.

a. **Emissions Reductions:**

**Figure 7**

*HORSE AD25 carbon drawdown*

<b>Estimated Drawdown (Carbon Offsets)</b>	
Digester Only	53
Digester + Indoor Farm System	208
liquid plant food output - gallons per week salable product	108
<b>Wet Tons per Year</b>	<b>25</b>
machine footprint (ft <sup>2</sup> )	160
realistic ground space (ft <sup>2</sup> )	240

Note. This chart outlines the estimated carbon drawdown from the HORSE AD25 including solely from the digester and from the production and sale of fertilizer (*HORSE AD25 series*, 2022).

The estimated carbon emissions “drawdown” from the HORSE AD25 digester would be about 53 MTCO<sub>2</sub>e per year. The University’s annual emissions are around 10,000 MTCO<sub>2</sub>e per year for scope 1 & 2 of the energy portion of Western’s emissions so the digester alone would have a minimal impact. However, the sale of the liquid fertilizer would allow funding to purchase other larger, durable, long term offsets. Not to mention the physical use of the fertilizer on Western’s green spaces and the Outback Farm.

The AD produces around 100 gallons of fertilizer per week at max capacity and if there are 52 weeks in a year, that’s about 5,200 gallons per year. If fertilizer was sold for \$15 per gallon (which would likely be the wholesale rate considering retail liquid fertilizer from anaerobic digesters sell at around \$19 per gallon on Amazon.com), the University would generate around \$78,000 per year. Amanda Cambre assisted with these calculations based on her information about current University emissions and estimated that even a smaller revenue of \$50,000 could reduce University emissions by 25%, or 2,500 MTCO<sub>2</sub>e by purchasing carbon offsets and funding further sustainability initiatives on campus (A. Cambre, Personal Communications, Nov. 10, 2022).

### **Recommendations**

The HORSE AD25 model fulfills the needs of the University laid out in the Sustainability Action Plan. However, if the expenses incurred with this bigger system does not justify its implementation, other systems have been recommended that can fulfill a more robust cost-benefit relationship. Senior leadership at the University has expressed serious interest in some form of digester “...as it would support an educational enhancement on campus, further our sustainability mission, and could potentially be self-supporting...” (A. Cambre. Personal

Communication, Dec. 2, 2022), but will need more information on staffing plan and revenue potential before committing further (details to be addressed in Phase II and III).

The first alternative recommended option involves implementing a larger HORSE model or perhaps something even bigger, such as the NAUTILUS system. Also created by Impact BioEnergy, the NAUTILUS would be large enough to suspend SSC organic food waste services at the Fairhaven Dining Hall altogether (Distributed food waste to energy technology, n.d.). However, while the initial price of this larger system is also much greater than the HORSE counterpart, it would effectively save the University roughly \$2,500 each year. The University also has the potential to profit from the sale of the digestate and use the revenue to invest further in sustainability initiatives and alternative carbon reduction measures such as air source heat pumps for buildings. Most of the carbon savings from the HORSE AD25 would likely come from offsets and alternative projects funded by the revenue of the digestate.

Furthermore, a third recommendation involves a smaller digester from an alternative company other than Impact BioEnergy which has not yet been identified but will be further investigated in Phase II. This digester would have to be smaller than 160 square feet which would allow it to fit on the loading dock behind the Fairhaven Kitchen. This option is suggested because the cost of purchase and installation of a larger system entails expensive and logistically complicated water, sewer, and electrical hookups.

Finally, the last recommended option is to lease the HORSE AD25 directly from Impact BioEnergy rather than buying it. This alternative comes from preliminary research that included observing the steps taken by the University of Washington when (UW) implementing their own anaerobic digester. Reasons given by UW as to why they chose to lease include making the project a trial rather than a permanent installment to save investment capital in case it is not a good fit with the University, and at the time of implementation, there was no entity that was willing to take over the operational costs of the digester (*UW anaerobic digester, 2017*). Furthermore, according to UW, leasing would cut implementation costs down to roughly \$35,000 and Impact BioEnergy would be liable for any continued costs of the system.

### **Monitoring and Evaluation**

Success of the project will be tracked utilizing the results from the cost-benefit analyses. If the results indicate that the anaerobic digester will be capable of producing a sufficient amount of clean energy and compost that will justify the amount of investment put into the project, success can be determined. These cost-benefit analyses will also provide insight into what staffing logistics will look like in the future and what staffing the system will need. From this, success can be determined by tracking whether the system is producing enough sustainable energy to justify part time or full time staffing and whether those positions are voluntary or paid.

### **Budget**

Due to the extent and complexity of the project, the budget is likely to be sourced from multiple input pools. To begin, initial funding is projected to come from the Sustainability,

Equity, and Justice Fund (SEJF) that is made available for student and faculty projects through collection of student fees. The funds provided from the SEJF grant are likely to be used for the acquisition of the digester, transporting it to its new home on campus, and setting it up. It is still undetermined whether or not these initial funds will be budgeted for buying or leasing the system, this will be decided by the results of further cost-benefit analyses in future phases.

Estimated capital investments for the acquisition and implementation of the HORSE AD25 model are estimated to range from \$200,000 - \$600,000. While the sole cost of the digester is \$210,000, Jan Allen recommended applying for a SEJF grant as much as \$300,000 to allow for an operational budget for its first year in use. These costs would include: a paid part-time student position to run the digester, funds to retrofit the location in order to include sewer, water, and electrical hookups, purchasing a vessel that is capable of transporting liquid fertilizer on a campus-owned vehicle, and any other additional buffer funds. For this particular system, operating costs are expected to range between \$4,300 and \$21,000 annually once the device is up and running (*HORSE AD25 series*, 2022).

The process for grant writing is unlikely to fit into the timeline for this course and therefore is not included in deliverables. However, it will be continued on through the independent study projects of two students and will be addressed in Winter Quarter, 2023. Subsequent funding, following the first year of its use, would come from the sale of liquid fertilizer, additional SEJF grants, and other potential state and local funds. The details of setting up a business model for selling the liquid fertilizer will also be included in the work of the follow-up independent study projects.

## **Conclusion**

Anaerobic digestion at Western Washington University, specifically through operation of the HORSE AD25 from Impact Bioenergy, has the potential to mitigate the University carbon footprint by creating a localized closed loop system of regenerating food waste into usable energy. The University could mitigate their cost and frequency of SSC pickups, offset carbon emissions through the production and sale of digestate, and provide an alternative to natural gas.

After completing this report it is evident that implementation of an anaerobic digester could be an important asset to the University to meet sustainability goals. It is important to continue research and further comparisons to determine if another option such as those listed in the recommendations section of this report are more viable and feasible for WWU specifically.

## **References**

*Amanda Cambre*. (2022, November 14, and December 2). Interviews, email, and other forms of personal communication.

*Distributed food waste to energy technology*. Impact Bioenergy. (2022, October 25). Retrieved November 16, 2022, from <https://impactbioenergy.com/>

Environmental Protection Agency. (n.d.). EPA. Retrieved November 16, 2022, from <https://www.epa.gov/agstar/how-does-anaerobic-digestion-work#:~:text=Anaerobic%20digestion%20is%20a%20process,in%20the%20absence%20of%20oxygen.>

*Horse AD25 series*. Impact Bioenergy. (2022, October 27). Retrieved November 16, 2022, from <https://impactbioenergy.com/horse-ad25/>

*Jan Allen*. Impact Bioenergy. (2022, November 2). Interviews, email, and other forms of personal communication.

*UW anaerobic digester: Food waste, Renewable Energy & Public Health (Phase 2)*. UW Anaerobic Digester: Food Waste, Renewable Energy & Public Health (Phase 2) | Campus Sustainability Fund (CSF). (n.d.). Retrieved November 16, 2022, from <https://csf.uw.edu/application/uw-anaerobic-digester-food-waste-renewable-energy-public-health-phase-2#:~:text=The%20anaerobic%20digester%20would%20utilize,and%20by%20the%20UW%20Farm.>

*Volume-to-weight conversion factors - NH department of environmental ...* (n.d.). Retrieved November 16, 2022, from <https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/vol-to-weight-conversion.pdf>

## Appendix:

### A. SSC Invoice

**SANITARY SERVICE COMPANY, INC.**  
21 BELLWETHER WAY STE 404  
BELLINGHAM, WA 98225  
www.ssc-inc.com

PHONE: 360-734-3490 FAX: 360-671-0239 EMAIL: SSC@SSC-INC.COM

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Award Winning FoodPulst

Billing Date: 10/4/22 Due: 10/20/22 Delinquent: 10/31/22

ACCOUNT NUMBER: 4809102 INVOICE NUMBER: 20436609 SERVICE NAME & ADDRESS: ARAMARK 516 HIGH ST STOP 9196 BELLINGHAM PREVIOUS BALANCE: \$0.00

QUANTITY	DATE	DESCRIPTION	AMOUNT
1.00	9/30/22	Site Address: WWU RIDGEWAY BELLINGHAM	
1.00	9/30/22	2 YD WEEKLY X 3	\$373.69
1.00	9/9/22	DELIVERY	\$0.00
1.00	9/28/22	REPAIR	\$0.00
1.00	9/30/22	2YD FOODWASTE WKLY X 2	\$142.56
2.00	9/30/22	CITY OF BELLINGHAM TAX - 12.99%	\$48.54
2.00	9/30/22	WHATCOM COUNTY EXCISE TAX - 3.3%	\$12.33
2.00	9/30/22	STATE REFUSE TAX - 3.6%	\$13.45
2.00	9/30/22	STATE REFUSE TAX - 3.6%	\$1.75
1.00	9/30/22	2YD RENT	\$11.00
2.00	9/30/22	FUEL SURCHARGE	\$7.69

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Please make your payment and manage your account online at [www.ssc-inc.com](http://www.ssc-inc.com)

	0-30	31-60	61-90	Over 90	Total	BALANCE DUE
Aging	\$811.01	\$0.00	\$0.00	\$0.00	\$0.00	\$811.01

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Billing Date: 10/4/22 Due: 10/20/22 Delinquent: 10/31/22

ACCOUNT NUMBER: 4100374 INVOICE NUMBER: 20437154 SERVICE NAME & ADDRESS: ARAMARK 516 HIGH ST STOP 9196 BELLINGHAM PREVIOUS BALANCE: \$1,054.85

QUANTITY	DATE	DESCRIPTION	AMOUNT
1.00	9/20/22	Site Address: ATRIUM BELLINGHAM	
1.00	9/20/22	PAYMENT - THANK YOU	(\$1,054.85)
1.00	10/4/22	SERVICE: 6 YD WEEKLY X 2 PERIOD: SEP	\$804.49
4.00	10/4/22	SERVICE: 60 FOODWASTE WEEKLY PERIOD: SEP	\$76.20
1.00	9/30/22	CITY OF BELLINGHAM TAX - 12.99%	\$104.50
1.00	9/30/22	WHATCOM COUNTY EXCISE TAX - 3.3%	\$26.55
1.00	9/30/22	STATE REFUSE TAX - 3.6%	\$28.96
1.00	9/30/22	STATE REFUSE TAX - 3.6%	\$3.76
2.00	9/30/22	FUEL SURCHARGE	\$13.13

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Please make your payment and manage your account online at [www.ssc-inc.com](http://www.ssc-inc.com)

	0-30	31-60	61-90	Over 90	Total	BALANCE DUE
Aging	\$1,057.59	\$0.00	\$0.00	\$0.00	\$0.00	\$1,057.59

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21 BELLWETHER WAY STE 404  
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Billing Date: 10/4/22 Due: 10/20/22 Delinquent: 10/31/22

ACCOUNT NUMBER: 4809101 INVOICE NUMBER: 20436290 SERVICE NAME & ADDRESS: ARAMARK 516 HIGH ST STOP 9196 BELLINGHAM PREVIOUS BALANCE: \$200.51

QUANTITY	DATE	DESCRIPTION	AMOUNT
1.00	9/20/22	Site Address: WWU FAIRHAVEN BELLINGHAM BELLINGHAM	
1.00	9/20/22	PAYMENT - THANK YOU	(\$200.51)
1.00	10/4/22	SERVICE: 2 YD WEEKLY X 3 PERIOD: SEP	\$431.18
1.00	10/4/22	SERVICE: 2YD FOODWASTE WKLY X 2 PERIOD: SEP	\$237.60
1.00	9/30/22	CITY OF BELLINGHAM TAX - 12.99%	\$56.01
1.00	9/30/22	WHATCOM COUNTY EXCISE TAX - 3.3%	\$14.23
1.00	9/30/22	STATE REFUSE TAX - 3.6%	\$15.52
1.00	9/30/22	STATE REFUSE TAX - 3.6%	\$2.02
1.00	9/30/22	2YD RENT	\$11.00
2.00	9/30/22	FUEL SURCHARGE	\$9.96

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Or visit: [ssc-inc.com](http://ssc-inc.com). Connect: Facebook/sscinc

Please make your payment and manage your account online at [www.ssc-inc.com](http://www.ssc-inc.com)

	0-30	31-60	61-90	Over 90	Total	BALANCE DUE
Aging	\$777.52	\$0.00	\$0.00	\$0.00	\$0.00	\$777.52

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Billing Date: 10/4/22 Due: 10/20/22 Delinquent: 10/31/22

ACCOUNT NUMBER: 4100687 INVOICE NUMBER: 20436089 SERVICE NAME & ADDRESS: ARAMARK 516 HIGH ST STOP 9196 BELLINGHAM PREVIOUS BALANCE: \$612.01

QUANTITY	DATE	DESCRIPTION	AMOUNT
1.00	9/20/22	Site Address: WWU VIKING UNION BELLINGHAM	
1.00	9/12/22	PAYMENT - THANK YOU	(\$612.01)
1.00	9/12/22	DELIVERY	\$0.00
3.00	9/30/22	2YD FOODWASTE WKLY X 5	\$930.60
1.00	9/12/22	CITY OF BELLINGHAM TAX - 12.99%	\$0.00
1.00	9/12/22	WHATCOM COUNTY EXCISE TAX - 3.3%	\$0.00
1.00	9/12/22	STATE REFUSE TAX - 3.6%	\$0.00
1.00	9/12/22	STATE REFUSE TAX - 3.6%	\$0.00
2.00	9/30/22	2YD RENT	\$33.00
2.00	9/30/22	FUEL SURCHARGE	\$13.87

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Please make your payment and manage your account online at [www.ssc-inc.com](http://www.ssc-inc.com)

	0-30	31-60	61-90	Over 90	Total	BALANCE DUE
Aging	\$977.47	\$0.00	\$0.00	\$0.00	\$0.00	\$977.47

- B. [Anaerobic Digestion feasibility study from Campus Sustainability Planning Studio Spring 2022](#)
- C. [Q&A from conversation with Jan Allen, Impact Bioenergy](#)



November 10, 2022

## Q&A - Western Washington University

### Answers to AD25 HORSE Digester Due Diligence

- Meeting with Impact Bioenergy and WWU project team November 2, 2022
- Attendees: Clara Copley, Sienna Taylor, Liam Flynn, Jan Allen

WWU speaking in green text. Impact Bioenergy in black text

Must be a secure location and ground space for deploying a small system - Behind Fairhaven dining hall

This location looks great. We will need these utilities:

1. 240V, single phase, 60 amp electrical service for food grinder, mixers, heaters
2. Standard water hose faucet for housekeeping
3. Sanitary sewer connection for housekeeping
4. Any communications utilities you might want (WIFI, Cellular, hardwire, etc)
5. Any biogas transmission piping you might want.)

#### • Can it sit on a slope? What kind of foundation can it sit on?

Yes, so long as you can get the food waste to the HORSE. You may need an ADA compliant access ramp. Note: the HORSE has to be installed nearly level and weighs approximately 20,000 lbs, supported at the four corners (8,000 lbs per corner at the heavy end). It needs to be tilted just enough to let the floor drain itself to the drain location. You will also have to empty the liquid plant food tank with a hose and pump - transferring liquid to a tank on a truck.

#### • How is it assembled? How permanent is the structure?

We build everything into a lockable, steel, 20' intermodal container. It will last well beyond 20 years.

#### Secure consistent supply of source, separated food waste to feed it

We have discussed this. You cannot feed more than 960 lbs per week into the machine but you can absolutely feed less, or even suspend feeding. For summer (low food waste period) we recommend you continue to heat and mix the digester and try to feed a low input rate of 50-100 lbs per week to keep the microbiome robust.

- **Separated? Do you have to collect waste in separate bins before moving it to the Digester?**

This varies for each location. Small containers (i.e. 5 gallon size) are typically used and may weigh 40 lbs each that will have to be hand- lifted to empty into the food grinder. If you use 36 gallon wheeled recycling carts (toters) they may weigh 250 lbs and you will need a mechanical (motorized) lifter to empty them.

- **Do you feed the system directly?**

Yes. The full spectrum of food waste can be fed into the food grinder gradually. It is emulsified and made into a pourable and pumpable mixture. You should remove any plastic, glass, or metal that you see when loading into the grinder.

- **Does there need to be a certain water content in the organic waste?**

Yes. It must be a pourable and pumpable mixture so we include plumbing to recirculate digestate to the food grinder to help liquify dry food waste (breads, starches, etc).

**Beneficial use plan for renewable energy which might best be at the host location**

You have some choices. Hot water heating, space heating, electricity generation, fireplace or fire pit, and BBQ or other cooking applications. One or more of these is possible. You may find it beneficial to procure a [portable power station](#) to charge at the digester and then carry the renewable energy to other locations on campus.

- **Where is biogas stored within the system and how can you access it?**

It is automatically stored in a gas-tight PVC coated membrane bladder inside the container (approximately 105,000 BTU; 175 cubic feet). Biogas accumulates overnight in the storage system so you can use it during the day.

- **How does the biogas get from the Horse to a building?**

This is site specific. If you use an off-grid generator in or next to the HORSE the biogas doesn't need to go anywhere. If you want to use it in the Fairhaven Dining Hall it would require a compressor and piping (typically underground).

**Beneficial use plan for fertilizer which is ideally also host or another market in close Proximity**

- **Where is the digestate stored in the system? How do you access it?**

It is automatically stored in a 275 gallon IBC Tote (HDPE tank) inside the container. The digester will generate approximately 105 gallons per week so you will need to empty this tank 2.5 weeks at the longest interval. You can access it by a valve on the bottom of the tank and use



gravity to fill some containers, or use a pump to transfer the digestate to a similar tank on a truck.

- **How does fertilizer get from the Horse system to a site such as the outback farm?**

By truck using a 275 gallon IBC tote on the truck.

- **Planning to apply for funding through SEJF. This would likely be more of the initial investment and TBD where continuous funds would come from. Possibly from whoever “owns” it.**

We discussed this on the call. You should strive to cover the capital cost (possibly \$220,000 as envisioned), plus sales tax, plus utility connections, plus corner supports, plus working capital. I suggested having \$100,000 of working capital to operate the project and prove out the business model. We will provide you with a detailed formal quote when you are ready for it.

- **Do you recommend capital investment or equipment lease given the scope of our Campus?**

You can consult with the WWU Administration or Facilities staff to see if they have experience and knowledge about leasing. It is possible but it would be with a third party.

- **How much is the upfront cost of both capital investment and equipment lease?**

**Organization including specific individual, “manager” who will own and care for the System**

You will have to create a budget for the items mentioned above, plus any others we aren’t aware of.

- **What hours does someone need to be present, running it?**

You should budget 2 to 4 hours per week to load food waste into the machine. Another 2 hours per week should be budgeted for cleaning, datalogging, testing the digestate for pH, etc., and equipment care.

- **Is this a position equipped for a student? Or staff?**

A student would be best. We can offer a training and testing package that includes an exam and certificate for digester operators. We can also offer an operational audit every 6 months (for example) to support and assist. You should develop some method to document the operational knowledge for the waste, digester, and digestate use.

- **What are the time requirements? Part-time? Full-time?**

Minimum 4-6 hours per week. Marketing and transporting digestate will be additional hours.

## 1. Timeline: can you go over the timeline that is indicated in the fact sheet?

### a. The planning, design, permitting

You are 50% complete on this. We could be done in a couple weeks - utilities and location and have to be finalized.

### b. Fabrication

100 calendar days. Once you give notice to proceed and make the initial payment we can begin fabrication.

### c. And delivery, start up

14 calendar days. You will need to lift and place the container (14,000 lbs without liquid)

## 2. How familiar are you with Western's campus? Have you ever toured/visited a site Before?

Somewhat. We can accomplish most tasks remotely.

## Prior Email Correspondence

Nov 9 2022: Hi Dylan. Impact has been working with WWU for several years (I think 6) to deploy a 25 ton/year HORSE on their campus. Bellingham WA is a very progressive city with many CSA farms and others that practice regenerative farming. The only missing piece for WWU has been organizational in nature. I discussed with the WWU team that each University has four stakeholders (Administration, Facilities, Faculty, Students), and of all the university projects I have worked on I mentioned that you and Ecotone have the best business model I have seen. It seems that student-led bioenergy projects fare better over the long term, based on the limited experience we have right now.

Would you mind talking to Sienna and her team so she can hear your story? Specifically how to sustain the digester operation when students age out and disappear? WWU has all the pieces they need and a little inspiration from you on revenue, expenses, selling digestate, interacting with the community – all are very relevant.

I think you will enjoy talking to each other. I would love to be copied on this discussion to the extent it's via email. Please keep me included.

Dylan Lew mobile 917-597-1634

Sienna Taylor mobile 307-413-9832

Thanks in advance.

Jan Allen, P.E. CMQ/OE, Chief Inventor

Impact Bioenergy Inc.

1001 NW 167<sup>th</sup> St

Shoreline, WA 98177 USA

206.250.3242

Yes! The H25 HORSE (smallest digester we make) shows carbon offset modeling (or 'drawdown' using our carbon offset modeling) of 53 MTCO<sub>2</sub>e pr year, every year. It's even more powerful if you include the local farming without tractors or petrochemical fertilizer. We have a separate model for indoor farming without diesel machinery and 6 harvest cycles per year showing an additional 208 MTCO<sub>2</sub>e per year, every year.

Estimated Drawdown (Carbon Offsets)	
Digester Only	53
Digester + Indoor Farm System	208
liquid plant food output - gallons per week salable product	108
<b>Wet Tons per Year</b>	<b>25</b>
machine footprint (ft2)	160
realistic ground space (ft2)	240

I'm hoping to get you answers tomorrow. Thanks for your patience.

Jan Allen, P.E. CMQ/OE, Chief Inventor

From: Sienna Taylor <taylo245@wwu.edu>

Sent: Wednesday, November 9, 2022 3:11 PM

To: jan.a@impactbioenergy.com

Cc: Amanda Cambre <cambrea@wwu.edu>; Clara Copley <copleyc@wwu.edu>; Liam Flynn <flynnl3@wwu.edu>; 'Tim Tiscornia' <tim.t@impactbioenergy.com>

Subject: Re: (re)introduction from Western Washington Univeristy

Hi Jan, Our project sponsor and the Director of Sustainability Integration for facilities and operations, Amanda Cambre, could not make our meeting last Wednesday but she had a wonderful follow-up question:

Is there and data or documentation for the greenhouse gas equivalent reductions of the Horse digester? I'm not sure if/how the carbon or greenhouse gas mitigation is calculated for a

digester and that will be important to document for the benefits of the system. I didn't see anything formal on their website, but figure he has some info or advice on how that translates from reduced emissions or "energy recycling" and the comparative value of managing methane releases versus literal CO2 reductions.

Let me know if you have any of this data. Also just wanted to check in on your timeline for answering the questions written out in our agenda? The rough draft for our proposal and operational plan is due this weekend so the sooner you have those answers, the better! It would be great to connect with Dylan from Pennsylvania before the end of this week too. We really appreciate your time and assistance.

Thanks again, Sienna

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From: Sienna Taylor <taylo245@wwu.edu>

Sent: Sunday, November 6, 2022 3:42 PM

To: jan.a@impactbioenergy.com <jan.a@impactbioenergy.com>

Cc: Amanda Cambre <cambrea@wwu.edu>; Clara Copley <copleyc@wwu.edu>; Liam Flynn <flynnl3@wwu.edu>; 'Tim Tiscornia' <tim.t@impactbioenergy.com>

Subject: Re: (re)introduction from Western Washington Univeristy

Hi Jan, I hope you had a lovely weekend and I apologize for not sending along my contact info sooner! My phone number is 307-413-9832. Please feel free to pass it along to your university contacts, particularly the Pittsburg model. We are looking forward to reaching out this week. I will also keep an eye out for your written responses to the questions on the agenda. Thanks again for meeting with us. I am excited to get the ball rolling!

Best, Sienna

From: Sienna Taylor <taylo245@wwu.edu>

Sent: Wednesday, October 26, 2022 5:07 PM

To: jan.a@impactbioenergy.com

Cc: Amanda Cambre <cambrea@wwu.edu>; Clara Copley <copleyc@wwu.edu>; Liam Flynn <flynnl3@wwu.edu>

Subject: (re)introduction from Western Washington Univeristy

Hi Jan,

My name is Sienna Taylor and I am part of a student group from Western Washington University who are working to implement an anaerobic digester from Impact Bioenergy, specifically the Horse AD25. We are aware that you have been approached by several different groups over the years. I believe you spoke to a group last spring who conducted a feasibility study but with time constraints and students graduating results have been difficult to achieve. We are continuing their efforts to hopefully see this implementation through. We have narrowed down some information about the location and source of organic material from one of the residential dining halls on campus. When are you available to chat over zoom so we can explain the next steps of our project? I have CC'd our project sponsor, Amanda Cambre, and my teammates, Liam and Clara.

Looking forward to hearing from you soon,

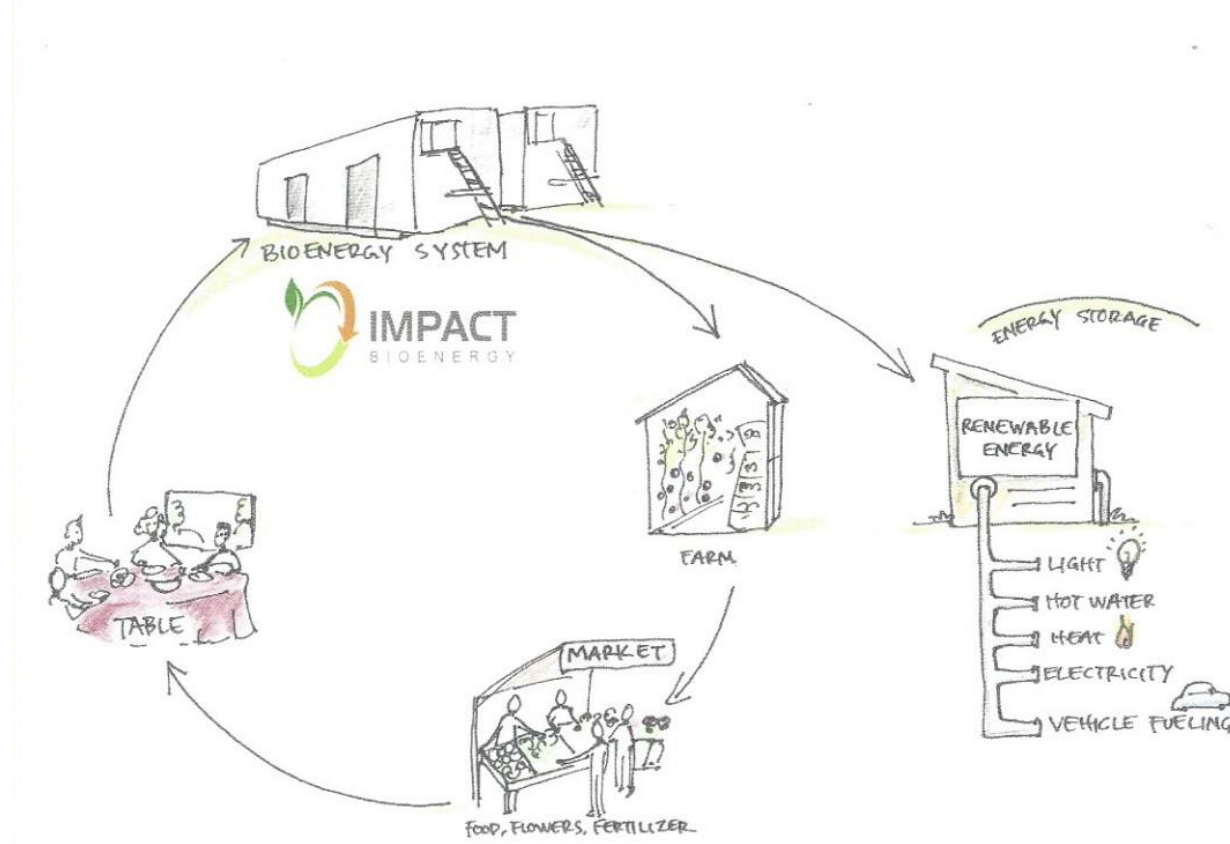
-Sienna



A)

**Project Title:** Anaerobic Digestion on Western Washington University's Campus

Figure 1 – Diagram showing the anaerobic digestion process from Impact Bioenergy



B)

**Project description**

Food waste is a dynamic and multifaceted problem that occurs on a variety of magnitudes. Every year, around 1/3 of global food production gets discarded somewhere along the line of production, distribution, and consumption. This accounts for about 1.3 billion lbs. of food waste each year (Alam et al., 2022; Dou et al., 2016; Xu et al., 2018). Food waste, if it is not composted or utilized in another way, along with other discarded items make-up what is called municipal solid waste (MSW). MSW production is growing paralelly with increased consumption. This is causing landfills to fill up quickly and increaseng demand for more. According to a phone call with an employee at Recycle and Disposal Services (RDS), Western Washington University alone generates 5.6 million lbs. of municipal solid waste (MSW) annually. The MSW is picked up from campus by Sanitary Services Company (SSC) who brings it to Recycle and Disposal Services which is a transfer location in Ferndale. From there, RDS sends waste collected from Western and the greater Bellingham community to a landfill in Arlington, Oregon called Columbia Ridge Landfill and Green Energy Plant. This landfill was opened in 1990

and scheduled to close in 2031. It currently has 61,551,758 tons of waste in place that will continue increasing until its closure date (US EPA, 2017).

As an effort to divert food waste from the landfill, Western has implemented a comprehensive composting program that is utilized in the residence halls, academic buildings, and the dining halls. Similar to MSW, compost is picked up from WWU regularly by SSC through their FoodPlus! program. Once SSC collects compostable materials from campus, it is transported to Green Earth Technology. Green Earth Technology is an LLC out of Lynden, Washington that commercially composts organic material and produces soil amendments, mulch, planting soil mixes, etc. These products are then publicly sold as Certified Compost at market value (*Composting Services - Whatcom County, WA - Green Earth Technology, n.d.*).

The problems that Western is facing amidst climate change are not unique and like most climate problems, cannot be solved with one solution. Food waste is a spoke in the wheel of several larger problems: natural resource depletion, environmental degradation, food insecurity, continued greenhouse gas emissions, public health crises, and perpetuated social injustices, just to name a few. Though it is important to note that all of these problems will not be eliminated solely through a lens of food waste mitigation, they also cannot be solved without it. The most paramount way in which Western and beyond can reduce food waste and therefore reduce exacerbation of the above problems is through the reduction in consumption and generation of food waste in the first place. Out of all food waste generated in the United States per year, 40% of it is wasted at the consumer level (Dou et al., 2016). Increased efforts to reduce consumption at the consumer level is incredibly important, however, until that happens there is a clear need for creative solutions addressing waste that *is* being generated.

As discussed above, composting is one of these solutions, however composting can not be the end all be all. Another prominent solution that is the premise of this proposal is the implementation of an anaerobic digester on Western's campus to mitigate and repurpose the food waste that is coming out of the residential dining halls.

Anaerobic digestion is the process in which complex microbial communities break down (digest) organic material, such as food waste, without the presence of oxygen. In this process, the material is converted into two byproducts: biogas and digestate. Biogas is composed of methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>), hydrogen sulfide (H<sub>2</sub>S), water vapor, and other trace gasses. The main component of biogas is methane (50-70%) which is also the main component of natural gas (Alam et al., 2022; Xu et al., 2018). The similarities in their make-up pose several uses for biogas as a natural gas alternative. Some of these include electricity generation which can be used to power heating and cooling systems, power a generator, charge electric vehicles, etc. It can also be purified into renewable natural gas (RNG) which can be used as propane, or implemented directly into a natural gas piping system. RNG can then be further compressed and used as vehicle fuel or other alternative fuel sources (US EPA, 2019). The other byproduct, digestate, is the organic material that is left over after the digestion process. It is comprised of both liquid and solid components which can be used in tandem, or separately. Digestate is very nutrient rich and is commonly used as a plant fertilizer/soil conditioner (US EPA, 2019).

Anaerobic digestion is growing in popularity as an alternative to composting, another option for landfill diversion, and renewable energy production. More and more anaerobic digesters are being utilized in the United States, though the majority are on a large-scale agricultural level. Popularity for food waste as a substrate is increasing because of the proposed and identified environmental, and financial benefits and incentives, but as of now, only 2% of food waste in the United States is anaerobically digested (Xu et al., 2018).

This project would work in tandem with composting and consumption reduction efforts to increase sustainability, reduce costs to the University, provide valuable education opportunities, and offset emissions. It is important to note that an AD will not be able to completely eliminate the need for continued composting services, but it would provide Western with a different avenue to become a more well-rounded, sustainability minded, innovative, and progressive campus.

Throughout this project there have been collaborations between different departments. The main stakeholders that have been involved in this process include Amanda Cambre and Terence Symonds. Amanda is the Director of Sustainability Integration at Western. She plays a major role in planning, project development, and operational improvement on campus and has been involved in this project since inception in October 2022. Terence Symonds is the Associate Director of University Residences and Facilities. He oversees maintenance and repair activities for residences and dining facilities across campus. Future stakeholders from Western are likely to include Wayne Galloway. Wayne is the Director of Facility Services at WWU and is responsible for custodial operations, pest management, grounds maintenance, and landscaping services. Other important stakeholders have been identified from Impact Bioenergy and communication and collaboration with these stakeholders has also commenced since the early phases of this project. Jan Allen is the Founder and Chief Inventor of Impact Bioenergy and has provided valuable information about their digesters, and the technology of anaerobic digestion as a whole. Michael Smith is the Director of Legal and Business Development at Impact Bioenergy and has also been involved in the project through answering specific questions regarding how anaerobic digestion will fit into the fabric at Western.

Understanding the benefits of a closed loop system supports this need for different strategies and approaches to food waste mitigation. Currently WWU, and most other campuses in the United States, are operating under a mostly linear system. This means that it operates almost exclusively within the linearity of importation and exportation. Food is imported, then food waste is exported. There is hardly any interaction with food waste which perpetuates the harmful mindset of “out of sight, out of mind”. Implementation of an anaerobic digestion would work to break the linearity by recycling Western’s food waste into useful byproducts that will then be utilized on campus. Doing this will decrease Western’s dependency on imports and reduce the quantity of exports.

There are three residential dining halls at WWU: Ridgeway Commons, Fairhaven Commons, and Viking Commons. All of these dining halls serve a varying number of students, with Viking Commons having the highest capacity and Fairhaven Commons having the least.

These dining halls work in buffet style where the students select the type of food that they want and the amount. Whatever they do not eat, they send back into the kitchen where kitchen staff separate the food from the garbage and put the organic material into composting receptacles. The point of having dining hall staff sorting the post-consumer food waste is to reduce the amount of cross-contamination in the compost. Food waste is in two cubic yard receptacles that is removed by SSC at varying intervals that depend on the amount of waste production. The Viking Commons have food waste removed 5x a week, and both Fairhaven Commons and Ridgeway Commons have it removed 2x a week. The food waste that is included in this pickup is both pre-consumer waste and post-consumer waste. Pre-consumer food waste includes scraps that are generated that never make it out of the kitchen. This includes vegetable peelings, meat scraps, and expired food. Post-consumer waste consists of what people don't end up eating off of their plates.

The target for anaerobic digestion will be the food waste from a residential dining hall because of the volume and efforts in contamination reduction. The exact volumes of the food waste from each dining hall are subject to variation. Getting precise amounts of food waste is difficult because SSC picks up the waste and charges the University based on the frequency of pickups, not the amount of material. Some inferences can be made about the volumes through utilization of volume-to-weight conversions provided by the EPA. According to the conversion chart, a 2 cubic-yard receptacle when it is full of food waste weighs around 2,736 lbs. (*Volume\_to\_weight\_conversion\_factors\_memorandum\_04192016\_508fnl.Pdf*, n.d.). Based on this same conversion scale, a receptacle that is 75% full would weigh around 2,052 lbs., and a half-full receptacle would weigh approximately 1,368 lbs. So, a probable range of receptacle volume lays somewhere between 1,368 lbs. and 2,736 lbs. per pickup. Looking at Fairhaven Commons, who has organic material picked up twice weekly, it is inferable 2,736-5,472 lbs./week is generated.

This project has focused on working with an anaerobic digester fabrication company called Impact Bioenergy that is based out of Auburn, Washington. Impact Bioenergy's mission is to utilize waste that is adjacent to food systems to allow for communities and urban centers to reduce reliance on fossil fuels and generate renewable energy while saving costs on energy and disposal (*Impact Bioenergy | Distributed Food Waste to Energy Technology*, n.d.). The specific anaerobic digester that is being considered for this project is part of the HORSE series. HORSE is an acronym for High-solids Organic-waste Recycling System with Electrical output. The HORSE series has different sizing capacities: 25 tones per year, 40 tons per year, and 100 tons per year. Based on the amount of food that is coming out of the Fairhaven Commons dining hall, as well as financial, and spacing considerations, the HORSE AD40 is the focus. 40 tons of food waste equates to 80,000 lbs. If the dining hall runs at full capacity for 10 months out of the year (full capacity would mean that food waste would be in the range of 2,736-5,472 lbs./week) and half capacity during the two summer months (half capacity would generate between 1,368-2,736 lbs./week) then the HORSE AD40 would be able to digest between 30% and 60% of all generated food waste.

Impact Bioenergy design their digesters to be expandable up to 7x beyond the base model (HORSE AD25). All the components of the HORSE series digesters fit inside of a closed and sealed compartment that is around 150 sq. ft. Expanding would entail adding additional containers that connect to the original but expand the capacity for digestate and biogas storage as well as increased amount of food waste that is able to be digested. The HORSE AD40 incorporates two separate containers so the sizing needs would be around 500 sq.ft.

The HORSE AD40 will come prefabricated with accessories such as biogas and digestate storage, a food grinder, a generator, etc. Additional accessories can be implemented into the design and fabrication process based on the desired utilization of byproducts as outlined by the University. The overall timeline for this project ranges at around 12-months. According to Impact Bioenergy, 1-3 months is spent on planning, permitting, and design, 3-12 months is spent on fabrication, and an additional month is spent on delivery and start-up (*Impact Bioenergy / Distributed Food Waste to Energy Technology*, n.d.). Currently, this project is almost complete with the planning, permitting, and design phase. Full completion of this phase will depend on exact specifications of variables such as byproduct use and location.

## **Location**

Choosing a specific site location will be a collaboration of several between several stakeholders and departments on campus to ensure the location fits all needs of the project.

One proposed located is Fairhaven Commons. It is located at the far south of campus and has a loading dock and a parking lot (lot 29G). The lot contains eight standard vehicle parking spaces, one space for University vehicles, four accessible parking spaces, and three regular spaces. There is also several spaces for motorcycle parking. If this site is chosen, there would need to be some lot reorganization. Proposed amendments to the current location may include redistribution of motorcycle parking to a different location that has not been determined. Another option is to move the space for the University vehicle and reduce the amount of motorcycle parking without eliminating it. Another ideal asset is that this site is located in close proximity to the Outback Farm which is a potential recipient of the digestate.

Another possible site for implementation is at the Physical Plant (PP). The PP is located a block south from Buchanan Towers at the intersection of Taylor Ave. and 25<sup>th</sup> st. The PP is home to the Capital Planning and Development Department and the Facilities Management Department. It is also where the Western utility vehicles are kept and neighbors with the Associated Students Recycling Center. This location is being considered because it has space that meets spacing accommodations for the AD and is in close proximity to [potential] direct utilization of byproducts. Logistics at this location that will need to be considered include how to get food waste from the dining hall to the Physical Plant, and utility hookups for water, sewer, and electricity.

Figure 2 – Snapshot of Southern WWU campus map, Fairhaven



Figure 3 – Snapshot of Southern WWU campus, Physical Plant



Both locations along with others will be further considered during future meetings with WWU teammembers and stakeholders and site visits from Impact Bioenergy. For these locations and any others that are identified, there are mandatory accommodations and requirements that must be met. There needs to be at least 480 sq. ft. of space, accessibility to the digester with a utility vehicle, and connections to utility hookups (water, sewer, electricity). Other considerations that can be amendable during planning and implementation is proximity to a dining hall and identified methods to move food waste to the digester, and proximity of byproducts to utilization area.

### **Staffing**

Staffing and time considerations for this project is relatively minimal. In correspondence with Jan Allen, Chief Inventor and CEO of Impact Bioenergy, he eluded that time requirements are in the 4-6 hour range per week. 2-4 hours will be spent feeding food waste into the digester, another 2 hours is budgeted for cleaning, datalogging, testing digestate for certain characteristics (pH, etc...), and equipment care. Additional hours may be needed for transportation of byproducts which, depending on output will be needed twice per week. Once the project is underway, Impact Bioenergy will provide trainings as well as testing and an exam to certify staff as digester operators (J. Allen. Personal Communication, Nov. 10, 2022). It is suggested that the above requirements be filled by a student to increase interaction with the digester and provide experiential and educational opportunities.

Another potential role that can be created in regard to this project is student educator position. This position would be responsible with completing outreach and expanding the focus of the digester beyond those who are directly involved. Potential for this role could include taking current and prospective students on tours of the digester, pursue outreach of the digester through social media integration, and more. This position would be part-time and around 6-8 hours a week.

To ensure project stability and continued momentum, a group of 3-5 students is encouraged to continue working on this project next year. Both students who are currently working on it, Clara Copley, and Sienna Taylor, are graduating. Sienna Taylor is a co-lead for Students for Renewable Energy which is a sustainability focused club on campus. She will work with students to bring them up to speed on the project and necessary continuations which includes student employment and staffing.

### **Utilities**

Utility accommodations that need to be accessible include water, sewage, and electricity. Water accommodations are minimal and used to clean the digester, wash things down the drain, and be an additive to the substrate to promote digestion if the slurry is too dry. All that is needed is a standard garden hose or irrigation pump hose that can have needed output of 2 gallons per minute. Sewage is a more complex utility requirement because sewage lines are located about 10 feet underground. Sewage needed for proper greywater separation. The digester also needs electrical input. A single phase 240 Volt AC circuit along with a 60-amp



electrical service will be utilized to power the grinding, mixing, and heating processes of digestion (J. Allen. Personal Communication, Nov. 2, 2022). It is possible and desirable that the electricity generated from the biogas be recirculated to run the digester. As mentioned before, additional utility utilizations can be requested and incorporated dependent on specific utilizations of byproducts.

## **Emissions Reductions / Utilization of Byproducts**

This project has great potential for emissions reductions at Western. Specific reduction amounts will depend on what specific uses the byproducts used for. Currently, WWU emits around 17,392 metric tons of carbon dioxide equivalent per year (MTCO<sub>2</sub>e). 67.8% of emissions come from natural gas, 32% comes from steam generation, and the remaining >1% comes from electricity (*Energy Manager*, n.d.).

### **Biogas**

When biogas is produced through the anaerobic digestion process, it is separated from the digestate and stored in a container. The chemical makeup of the biogas is 50-70% methane, 30-40% carbon dioxide, 5-10% of hydrogen, 1-2% of nitrogen, and trace amounts of water vapor, and hydrogen sulfide (Alam et al., 2022; Xu et al., 2018). If desired biogas utilization is injection into Western's natural gas system to supplement the steam plant, the biogas will need to be upgraded into renewable natural gas (RNG). To do this, the methane content is increased by removing water vapor, carbon dioxide, hydrogen sulfide, and other impurities. Once it is purified, it can be injected into natural gas pipelines (US EPA, 2019). According to Western's Utility Plan that was last updated in 2017, the total campus natural gas usage is 1,919,702 therms per year (equivalent to 191,970.2 MMBTU). The HORSE AD40 has the capacity to generate ~350 MMBTU per year (*Impact-Bioenergy-Solutions-Fact-Sheet.Pdf*, n.d.). If the 350 MMBTU were used fully to offset 350 MMBTU of the total natural gas usage.

Another consideration is to compress the RNG into vehicle fuel and utilize the biogas as a fueling source for campus utility vehicles. The fueling rate for vehicles is 381,000 BTU per hour. The HORSE AD40 has the ability to generate 350 MMBTU of RNG per year which equates to and can supply around 919 hours of fueling annually (*Impact Bioenergy | Distributed Food Waste to Energy Technology*, n.d.).

Another avenue of utilization of biogas is through electricity generation. Biogas can generate mechanical energy through an internal combustion engine that then rotates an electric generator to produce electricity. The HORSE AD40 can generate 102,574 kWh of electricity per year. Utilization of generated electricity can be considered for charging electric bikes and electric vehicles, it can also be used to power portable generators, or to power the backup generator in Fairhaven.

102,574 kWh averages out to about 281 kWh per day. However, this number will vary in practice because not all days of the year will yield maximum biogas electrical output. For reference it takes 75-100 kWh to fully charge an electric vehicle, and 0.4-0.8 kWh to full charge an e-bike. According to information provided by Western, the emergency backup generator

rated at 45 KW and is used as indoor flow for emergency lights and fire alarms. It is located in the Fairhaven Administration Building in room 114.

An important note is that WWU purchases energy from the Skookumchuck Wind Facility as part of the Puget Sound Energy's Green Direct program. This means that less than 1% of carbon emissions comes from electricity (*Energy Manager*, n.d.). That being said, the most potential for an anaerobic digester as a means to reduce emissions would best be served as utilization of biogas as RNG, but there is potential for electrical output that should also be considered.

### Digestate

Once the biogas is separated in the digestion process, the remaining material is digestate. The digestate is in both liquid and solid form and to increase shelf life, can be dried through a solar process to allow for storage over the winter months (*Impact Bioenergy / Distributed Food Waste to Energy Technology*, n.d.). Digestate has a lot of potential in the realm of emissions reductions and increased sustainability when looking at it through the lens of an alternative to synthetic fertilizer. It is estimated that the supply chain of synthetic N fertilizer amounts to about 2.1% of total GHG emissions at 1.13 GtCO<sub>2</sub>e. When synthetic N fertilizer is applied to a landscape, only a certain percentage of it is up taken by the plants. A bit more is used by soil organisms who metabolize the fertilizer and produce N<sub>2</sub>O, which is a GHG 265x more potent than CO<sub>2</sub>. The remaining fertilizer is leached from the ground and can make its way to the ground water and lead to damaging processes such as eutrophication and addition of heavy metals into the soil (Menegat et al., 2022). By reducing the amount of synthetic N fertilizer that is applied to campus, it would also reduce the amount of N<sub>2</sub>O that is released, the amount of fertilizer that is leached into the ground water and decrease Western's contribution to GHG emissions in the agricultural sphere.

As part of an audit from Western's Facility Management Department, it was found that Western purchases an average of 750 lbs. of synthetic fertilizer and around 200 lbs. of organic fertilizer annually (~950 lbs. total). The HORSE AD40 is estimated to produce around 1,822 lbs. of digestate annually. The digestate produced by this AD is estimated to have Nitrogen-Phosphorus-Potassium levels of 2 to 5%, 1 to 5%, and 3 to 9% respectively with an Organic Matter content of 24 to 53% (*Impact Bioenergy / Distributed Food Waste to Energy Technology*, n.d.). Utilization of digestate as a replacement of synthetic fertilizer supports sustainability because it has slow-release nutrients which means that excess nutrients will not be leached or metabolized and released as N<sub>2</sub>O.

Recirculation of the digestate on campus grounds and in the Outback Farm are ways to support a close-loop system on campus. There are other potential utilizations of the digestate such as selling for market value to generate revenue or partnering with a local farm or landscaping entity. These options will be further discussed in the Cost-Benefit Analysis and decisions regarding specific utilization will be narrowed down as the project progresses.

### Cost-Benefit Analysis

A more in-depth cost benefit analysis will be finalized and included in the full grant application. A meeting between the project team and Impact Bioenergy will clarify and finalize location, utility logistics, and utilization of byproducts. Once those variables are narrowed down and specified a more accurate analysis will be conducted using the specific information. There are several opportunities and possible cost savings potential listed below that may change or be further explained farther along in the project.

Another important note that is viable to the cost-benefit analysis is that in some instances maximum revenue contradicts with efforts for sustainability. In this project, it is recommended that digestate be used as a substitute for synthetic N fertilizer to decrease dependency. If the digestate were to be sold at market value on the public market, there is a lot of revenue potential. According to Jan Allen, digestate from an Impact Bioenergy digester can be sold for around \$15 per gallon. The HORSE AD40 generates 9,000 gallons of digestate annually, so if all 9,000 gallons were sold at a market value of \$15 there is potential revenue of \$135,000 per year. In communications with Terence Symonds, he noted that it may be advisable to use the current project to reduce consumption of synthetic fertilizers on campus, but future expansions or additions to the original AD can be focused on accrual of revenue.

- Cost-Benefit analysis
  - Return on Investment
    - Estimated ROI is 6-10 years (according to Impact Bioenergy)
  - Cost savings from SSC pickups
    - Reduction from Fairhaven pickups of 2x weekly to 1x weekly
      - Save around \$1,250
    - Expansion of the AD would further reduce and maybe eliminate all SSC pickups
  - Cost savings from reducing need for grease removal from grease inceptor at Fairhaven Commons (Invoice from 2015-2019 fiscal years)
    - Bayside Services contracts with WWU
    - Picks up grease from Fairhaven Commons semi-annually (in June and December)
      - \$8,580 price per cleanup
      - 25,633-gallon average but capacity of receptacle is 22,000 gallons – so inceptor is being utilized at 115%
    - WWU is in a two-year contract with Bayside Services that ends 6/30/2023
    - Grease gets taken to Farm Power Northwest in Mt. Vernon where it is digested and used to make electricity/fertilizer
  - Cost savings from redirecting digestate to grounds fertilizer usage
    - ~ 200 lbs of organic fertilizer / year
    - ~ 750 lbs of synthetic fertilizer / year
      - 1 bag of synthetic fertilizer is 50 lbs. and costs \$200 dollars
      - ~\$3,000 annually
  - Cost savings from selling digestate

- Market value of ~\$15 / gallon
- Potential to make around 9,000 gallons per year at market value is revenue of \$135,000
  - Can be used to further invest in sustainability projects or to offset emissions
- Cost savings from utilization of biogas as a natural gas alternative
  - To purify into RNG and compress to fuel utility vehicles
    - How much is spent on gas for utility vehicles each year
    - How much can be replaced with biogas?
  - To include into natural gas piping to the steam plant
    - How much is spent on natural gas to use in the steam plant?
    - How much can be replaced with biogas?
- Cost savings from selling carbon credits
  - Maybe not eligible because Climate Commitment Act says the Act covers businesses who emit over 24,000 tons of CO<sub>2</sub> each year
  - WWU emits around 18,977 tons of CO<sub>2</sub> per year

## c)

### **Who is the intended audience**

Implementation of an anaerobic digester would have several different audiences of varying scales. Identified audiences include other universities, the greater Bellingham community, current WWU students, future WWU students, staff, and faculty.

The main audience that this project is intended towards are the students. Present students will be able to interact and learn from this project through educational signage that will be included with implementation. The signage will be placed near the digester so that it will be visible via foot traffic in the area. The signs will include basic information about the anaerobic digestion process, what the byproducts are and how they are being used, and how anaerobic digestion is enhancing sustainability on WWU's campus. Students will also be engaged through incorporation of relevant anaerobic digestion information into course curriculum. Facets of the AD process can be incorporated into a variety of different courses. Some of the broad applications include soil science, energy science, business and sustainability, and agroecology.

Another way in which students will be in audience of the digester is through hands on engagement and experience. There is great potential for internship, independent study, and paid positions that will involve the AD. Another possibility is the incorporation of anaerobic digestion into a focused interest group (FIG)

Future students are also the intended audience of this project. The AD can be incorporated into campus tours to highlight sustainability to prospective students and family. It

can also be featured on the WWU's website for future students to learn about prior to visiting campus.

Successful implementation would be able to serve as an example to other universities that are also striving for creative sustainable solutions. By making the work done at WWU accessible and comprehensive, it could serve as a template to other campuses across the country to exemplify ways in which food waste can be used to generate a closed-loop system. Another intended audience is the greater Bellingham community. This audience is similar to that of other campuses. Actions that WWU are taking towards increasing sustainability reflects on Bellingham and vice versa. WWU and Bellingham can learn from one another and collaborate through this project and future projects that may follow.

**D)**

**How does this project directly impact the Western student community? How many students will be affected?**

This project will vastly impact the Western student community in several ways. It will affect the students who are eating at one of the four residential dining hall, students who are walking to and from Fairhaven to the main campus, students in sustainability clubs, and students in certain courses.

**E)**

**What are the goals and desired outcomes of your project**

- Emissions reduction
- Production of natural gas alternative
- Production of nutrient rich soil conditioner/fertilizer
- Cost savings
- Improved sustainability
- Increase in sustainability oriented educational opportunities
- Provide guidelines on creative climate solutions to other campuses and communities
- Diversion of waste from the landfill

**F)**

**How will your project positively impact sustainability at Western?**

This project will do a great deal to positively impact sustainability at Western. Anaerobic digestion promotes a closed loop system because the food that is wasted will not leave the facility, it will be recirculated via the anaerobic digestion process and will be reused as biogas or digestate. Then, since the application of the digestate and biogas will remain on campus or be utilized in the immediate community, it will be supporting sustainability and reducing the need of the flow of inputs (natural gas, fertilizer) and outputs (atmospheric CO<sub>2</sub> equivalents, food waste).

Since the process of turning food waste into biogas is part of the natural carbon cycle, biogas as an alternative fuel source is carbon neutral. Utilization of a carbon-neutral fuel source is a very potent way in which sustainability at WWU will increase through this project. Digestate

application on campus or in the community will also increase sustainability. Application of digestate on campus or through working with local vendors or farms in Bellingham strengthens sustainability because it can reduce dependency on synthetic fertilizers.

Another way in which this project will impact sustainability at Western is through increased avenues to divert waste from the landfill. It is important to note that WWU already composts which is another prominent method for waste diversion. However, composting requires a facility which requires land, space, and resources. Additionally composting, though an important process, still emits greenhouse gasses such as methane and CO<sub>2</sub> and is overall an energy consuming process because more energy is lost via GHG emissions and heat loss than can be recovered (Lin et al., 2018). It is important that WWU maintains contracts with SSC composting services, but anaerobic digestion is a prominent way that sustainability can be increased.

## SECTION 2: Project Participants

### a. Team information

Name	Department/School Students provide major/minor	Position: Faculty/staff/student Students provide expected graduation quarter/year	Western email address
<i>Team Advisor:</i> Lindsey MacDonald	Sustainability Engagement Institute	Staff	Macdonal6@wwu.edu
<i>Team Lead:</i> Clara Copley	Major: environmental policy Minor: environmental justice	Student W'23	copleyc@wwu.edu
<i>Team Member:</i> Sienna Taylor	Major: environmental policy Minor: Political science	Student S'23	Taylo245@wwu.edu
<i>Team Member:</i> Terence Symonds	WWU Associate Director University Residences Facilities.	Staff	symondt@wwu.edu
<i>Team Member:</i> Amanda Cambre	Director of Sustainability Integration	Staff	cambrea@wwu.edu

Stakeholder	Involvement in Project
<b>Amanda Cambre</b>	Director of Sustainability Integration WWU
<b>Terence Symonds</b>	WWU Associate Director University Residence Facilities
<b>Tim McLaughlin</b>	Fairhaven Commons Director
<b>Wayne Galloway</b>	Assistant Director – Building Services / Facilities Management
<b>Jan Allen</b>	CEO and Chief Inventor at Impact Bioenergy
<b>Michael Smith</b>	Director, Legal, and Business Development at Impact Bioenergy

### SECTION 3: Project Budget

- a. Provide a realistic budget estimate for the project, based upon research into all anticipated costs. Do not itemize estimated costs within the four categories.

This budget is flexible and subject to minor changes at this point in the project. As specific accommodations such as location, and byproduct usage become cemented the budget will be finalized. This project can be paid for in installments. Impact Bioenergy only requires an installment of 50% to begin fabrication of the digester. It is proposed that an initial installment be granted for \$157,000 with the remaining 50% be granted in a later installment in the next fiscal year.

Item	Cost
Materials	\$300,000
Labor/contracts (student employment)	\$9,000
Promotion	\$5,000
Other	\$
<b>Total budget estimate</b>	<b>\$314,000</b>

- b. The SEJF program encourages the use of additional funding sources to create a collaboratively funded project; include potential funding sources beyond the SEJF that you will seek.

Funding Source	Connection to project	Potential Funds
SEJF		



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## Evidence Tables Template

Suggestion: Make several, each based on the construct/question you are exploring

Table 1: RQ1 or Construct 1

What is the evidence behind...		
Author(s) & Date	Research Method	Findings Relevant to your RQ or Construct
<ul style="list-style-type: none"> <li>It's even better if you want to create your APA style citation and put it here (unless you are using Zotero etc. and then you can just have the authors and date to keep them organized)</li> <li>It's also nice to organize by alphabetical order so that articles are easier to find</li> </ul>	<ul style="list-style-type: none"> <li>Who was the sample?</li> <li>What was the study procedure?</li> <li>Any measures of interest?</li> </ul>	<ul style="list-style-type: none"> <li>What were the main findings or main ideas of the paper?</li> <li>How did they explain these findings in the discussion?</li> </ul>

What is the evidence behind... What organic material generate the most energy when digested anaerobically?		
Author(s) & Date	Research Method	Findings Relevant to your RQ or Construct
<ul style="list-style-type: none"> <li>(Alam et al., 2022)</li> </ul> <p><b>Title:</b> Production of biogas from food waste in laboratory scale dry anaerobic digester under mesophilic condition</p>	<ul style="list-style-type: none"> <li>Three different phases of dry anaerobic digestion</li> <li>Measurement of biogas in three digesters</li> <li>Attempt to see capacity and success with diverting food waste from landfill and building sustainable practices in Bangladesh</li> </ul>	<ul style="list-style-type: none"> <li>Digestibility of different organic wastes determines the amount, quality, and type of organic material</li> <li>Dry anaerobic digestion reduces wastewater production, has improved marketability of digestate, has a more favorable energy balance, more robust technology</li> <li>You can increase digestibility by and gas production by running waste through a beads mill (Increases biogas formation by 28%) and reducing the pH to 2 (increases methane production by 48%)</li> <li>Mesophilic temperature zone (between 20-45°C) is best temperature for bacteria that produce biogas</li> </ul>

		<ul style="list-style-type: none"> <li>• Production of biogas from anaerobic digestion takes time and, in this study, peak biogas production was recorded on the 37<sup>th</sup> day with 2079 ml (0.55 gallons)</li> <li>•</li> </ul>
<ul style="list-style-type: none"> <li>• (Alam e(Xu et al., 2018)</li> </ul> <p><b>Title:</b> Anaerobic digestion of food waste – challenges and opportunities</p>	<ul style="list-style-type: none"> <li>• Which types of food waste produce the most methane gas in biogas formation</li> <li>• Variations in quality of food waste</li> <li>• Post-consumer has highest yield potential</li> </ul>	<ul style="list-style-type: none"> <li>• Highest methane potential of food waste is on a range between 0.3-1.1 m<sup>3</sup> CH<sub>4</sub>/kgVSadded</li> <li>• Lipids have a level of 1.1 m<sup>3</sup> CH<sub>4</sub>/kgVSadded</li> <li>• Then protein, then carbohydrates</li> <li>• Variability in quality because of sources, processes, handling methods, eating habits, culture, climate, seasons</li> <li>• Food waste has more methane potential than animal manure</li> <li>• Home and restaurant have high-methane yield because of high lipid content and balanced nutrient composition</li> <li>• Foods with easily biodegradable carbohydrates achieve high methane yield</li> </ul>
<ul style="list-style-type: none"> <li>• (Shahbaz et al., 2020)</li> </ul> <p><b>Title:</b> Impact of C/N ratios and organic loading rates of paper, cardboard and tissue wastes in batch and CSTR anaerobic digestion with food waste on their biogas production and digester stability</p>	<ul style="list-style-type: none"> <li>• analysis of three co-substrates and their influences on methane yield, biogas yield, and digester stability through looking at parameters such as TAN, pH, VFAs, and alkalinity</li> <li>• importance of increasing C/N ratio</li> <li>• Paper waste (PW), tissue waste (TW), and cardboard waste (CW) as individual mono-substrates</li> <li>• (PW + FW), (CW + FW), and (TW + FW) as co-substrates</li> <li>• Identification of important tests and amounts of important anaerobic digestion processes</li> </ul>	<ul style="list-style-type: none"> <li>• Best co-substrate is (PW + FW) in terms of biogas yield, methane yield, VFA reduction,</li> <li>• PW has highest C/N ration – important to increase ratio of Carbon to Nitrogen because FW (food waste) eats through carbon very quickly</li> <li>• Increasing C/N ration reduces unnecessary formation of TAN and VFAs by stabilizing pH and improving methanogenic movement</li> <li>• Important tests to run are total ammonia nitrogen (TAN), total carbon (TC), total nitrogen (TN), total solids (TS, volatile solids (VS), pH, alkalinity, chemical oxygen demands (COD) and/or biologic oxygen demand (BOD)</li> <li>• pH, VFA/alkalinity ration, and TAN are parameters that predict the stability of the AD</li> <li>• Optimal loading rate (OLR) is around 2-5 VS/L/s</li> <li>• Alkalinity that indicates high level of buffering capacity that enhances the stability of the digester is 4000-5000 mg/L</li> <li>• Range of pH is 7.1-7.8 and can be stabilized through addition of 3-5 mL of NaOH</li> <li>• VFAs must be underneath 50 mg/L for better process stability</li> <li>•</li> </ul>

## Challenges and solutions to anaerobic digestion

Author(s) & Date	Research Method	Findings Relevant to your RQ or Construct
<ul style="list-style-type: none"> <li>(Alam e(Xu et al., 2018)</li> </ul> <p><b>Title:</b> Anaerobic digestion of food waste – challenges and opportunities</p>	<ul style="list-style-type: none"> <li>Literary analysis of common problems associated with anaerobic digestion and potential solutions</li> <li>Need of anaerobic digestion as an food waste disposal method</li> <li>Focus on quantity, composition, and methane potential of various types of food waste</li> <li>Attention on when anaerobic digestion is the appropriate method</li> <li>Problem of capital investment</li> <li>Problem of mono-digestion versus co-digestion</li> <li>Problem of foam control</li> <li>Which types of food waste are most suitable for anaerobic digestion</li> </ul>	<ul style="list-style-type: none"> <li>1/3 of annual food production os lost or wasted through food supply chain</li> <li>- 38 million tons of food discarded annually and 76.3 put in the landfill</li> <li>Anaerobic digestion should be used as a final option for food that can't be economically recycled – impure of low quality</li> <li>Highest disposal rate at consumer end – restaurants, homes, cafeterias</li> <li>Lipid-rich food is most attractive to AD and has highest potential methane production – then proteins then carbohydrates</li> <li>Capital intensive – increase food waste loading for byproduct revenue</li> <li>Mono-digestion leads to digester instability and potential failure at high organic loading rates</li> <li>co-digestion is common with animal manure of sewage sludge – has a lot of benefits</li> <li>when only substrate is only food waste the digester should be supplemented with key micronutrients – research shoes focus on nickel (Ni), cobalt (Co), molybdenum (MO), iron (Fe), and selenium (Se)</li> <li>foam control – foaming occurs when surface active materials in the substrate which lads to biogas no longer being released to gas phase but instead dispersed in the liquid</li> <li>foaming reduces the effective volume of the digester, reduces target dosing and revenue, blocks gas pipes and</li> </ul>

		<p>overpressure valves, can damage digester roof and lead to effluent spills</p> <ul style="list-style-type: none"> <li>• solutions include addition of antifoaming agents but most importantly proper management and operation – cause by stress of microorganisms from over-feeding or input of inhibitors</li> </ul>
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#### Quality and Utilization of Digestate as an Anaerobic Digestion Bioproduct

Author(s) & Date	Research Method	Relevant Findings
<p>(Wang et al., 2021)</p> <p>Long-term characterization and resource potential evaluation of the digestate from food waste anaerobic digestion plants</p>	<ul style="list-style-type: none"> <li>• Analyze characteristics of digestate of food waste (DFW) from industrial scale AD in China for 16 months</li> <li>• Assess the stability</li> <li>• Quantify and identify characteristics and amounts</li> <li>• Dehydrate digestate after testing for VS and TS and before running other tests</li> <li>•</li> </ul>	<ul style="list-style-type: none"> <li>• DFW was mostly stable after 16 months</li> <li>• DFW contains significant levels of organic matter such as lignin and protein</li> <li>• DFW contains abundant important nutrients for plant development such as nitrogen (N), phosphorus (P), and potassium (K)</li> <li>• Carbon was 48.86%</li> <li>• Hydrogen was 7.25%</li> <li>• Nitrogen was 3.08%</li> <li>• Sulphur was 1.4%</li> <li>• Oxygen was 13.82%</li> <li>• Lignin was 34.79%</li> <li>• Protein was 20.04%</li> </ul>



## Analytical Services Quotation

Client: WWU  
Client ID: WES37  
Prepared for: Sienna Taylor

Bid Date: 5/5/2023  
Expiration: 12/31/2023

Approximate 10 to 15 Business Day turnaround time

### Services & Materials included in pricing:

- >Results online or PDF
- >Bottles and coolers for transport

Analyte	Method	Hold time in days	Cost per sample	Quantity	Total
COD	SM5220 C	28	\$54.00	10	\$540.00
TOC	SM5310 B	28	\$63.00	10	\$630.00
TN Total Nitrate	300.0	28	\$79.00	10	\$790.00
TKN	351.2	28	\$48.00	10	\$480.00
TS	SM2540 B	7	\$18.00	10	\$180.00
VS	SM2540 G	7	\$34.00	10	\$340.00
pH	SM4500-H+ B	1	\$18.00	10	\$180.00
					\$3,140.00

## Sandy Skrabut

Sales Representative  
Edge Analytical Laboratories  
1620 S. Walnut St.  
Burlington, WA 98233  
Office 360-757-1400 ext. 102  
Cell 360-770-0151



Hello Sienna,

Sounds like a cool project.

First off, I want to update that we do not have the capability to run TOC in solids by our TOC analyzer. It's only set up for relatively clean water samples. We have a LECO C/N analyzer that can test for total carbon in foods which would include both organic and inorganic carbon. Total carbon by LECO C/N combustion analyzer costs \$19.

We could coordinate to test pH daily. Will the feedstock include liquids? We do not have a probe that can test pH in solids so we may need to dilute the sample with water for pH analysis if the blended slurry isn't fluid enough. We typically will do a 1:1 dilution for foods.

We have larger food processors that hold ~4 cups but typically use magic bullet blenders to blend samples for testing. I think it would be easier for you to collect in a ziplock bag. A quart ziplock bag would be good or ~1/2 of a gallon bag but not sure what you would consider representative for your study. We also have 24 oz. Whirlpak bags that we could provide.

Here the summary of updates to pricing since I am considering this a food/biosolid sample rather than water:

- COD: \$40 per sample, 10 business days TAT
- Total Carbon by Combustion: \$19 per sample, 10 business days TAT
- Total Nitrogen by Combustion: \$20 per sample, 10 business days TAT
- TKN: \$45 per sample, 10 business days TAT
- TVS: \$29 per sample, 10 business days TAT
- pH in food/solids: \$12 per sample, 7 business days TAT.

Let me know if you have any other feedback or information so we can make sure we are getting the data you need.

Kind regards,

**Katie Hallaian**

**Chemistry Technical Director**

[k.hallaian@exactscientific.com](mailto:k.hallaian@exactscientific.com)

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