Toolkit: Anaerobic Digester

Anaerobic Digester

Problem Statement

Simply put, wasted food is a wasted resource no matter the industry or scale. What sustainable solutions can we create to divert food waste from landfills? Can diverting food waste from landfills be profitable?

Hypothesis

The anaerobic digester project at The Plant is designed to alleviate several problems facing urban environments, including energy production and use, waste management, transportation costs, and even soil conditions. The technology's replicability and scalability create a compelling case study of energy and waste efficiencies by reusing what is conventionally considered "waste" to create several valuable outputs. This project has potential to shape practices and policy in urban areas throughout the country.

Rationale

A key principle in Bubbly Dynamics' business philosophy is realizing benefit from resources considered "waste." The digester project takes this concept to a higher level by harnessing an input that conventionally creates financial and environmental costs and using it to build community wealth. The anaerobic digester project will advance social, environmental, and economic benefits in conjunction with the building's operations and when considered as a stand-alone project.

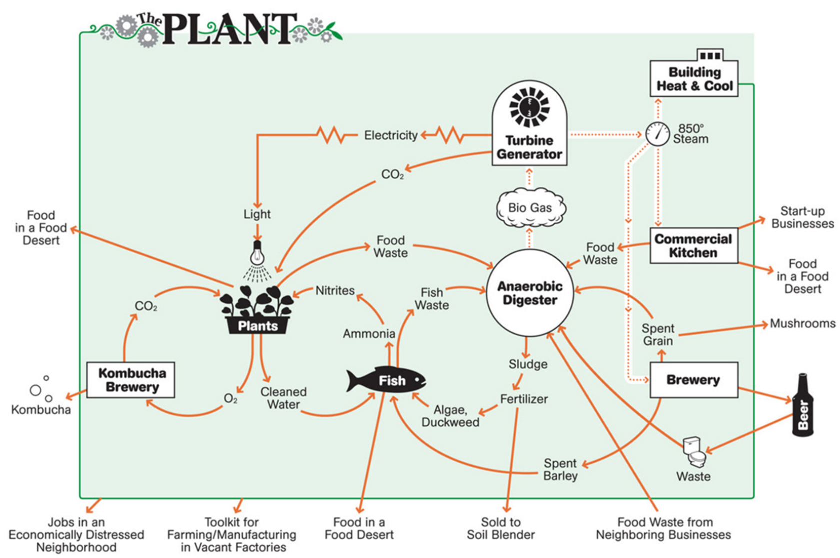
Full-scale anaerobic digester at The Plant.

We envision the digester as an opportunity to provide food-waste processing alternatives to businesses in the surrounding urban area, while unlocking the revenue potential of this valuable waste stream. Waste from the building will be a fraction of the volume of the waste processed by the digester, which, at its maximum capacity, will process approximately 32 tons of feedstock a day. To put that into perspective, a small car weighs about one ton. The digester will demonstrate that even food-production businesses, which are typically waste- and energy-intensive, can operate sustainably by closing waste loops.

This project will demonstrate that our approach to energy production and waste handling is instrumental to creating a more resilient urban area. We believe we can prove that the concept of an urban digester can pay for itself and encourage replication, thereby accelerating the impacts from our project. The equipment and infrastructure to be installed are durable and will last decades.

The digester will also allow us to promote the benefits of re-imagining food waste as a resource to populations from schoolchildren to professionals. We are committed to informing the public about this technology and the opportunities for this closed-loop system, which will be a replicable model providing flexibility to scale up in different contexts.

Over time, we have seen growing interest from potential food-scrap providers, especially from smaller waste haulers seeking lower transportation and landfill costs, who also find value in the marketing benefits of processing waste at a renewable facility. Likewise, the increase of urban agriculture, green roofs, and smaller scale gardens has created good demand for solid and liquid digestate from landscape or garden centers selling soil amendments and growing media.



Conceptual diagram of the closed-loop systems of The Plant at full build-out.

John Edel, founder of Bubbly Dynamics, inside the full-scale anaerobic digester.

Process

Over the course of approximately one month, the digester processes the inputs — food waste — into outputs as described below. Revenue will be realized from tipping fees for accepting food waste and from sales of the three types of outputs produced during processing.

Inputs

The completely enclosed, odorless anaerobic digester will consume all the food waste produced at The Plant and by neighboring food manufacturers contracted to tip specific inputs, as well as food scraps supplied via private waste-hauling agreements that ensure a quality input. Waste haulers will be responsible for collecting, transporting, and depositing compostable waste, including waste from fruits and vegetables, grains, meat, bones, and dairy as well as the organic by-products from the production and preparation processes of the same. This feedstock will be permitted to vary in content from load to load, provided that the parameters for the inputs are met.

Sources of food waste are anticipated to be:

- Food scraps: restaurant waste, grease trap cleanup (with or without water), and meat waste
- Industrial food process waste: brewer's grains, cannery rejects

Food waste from conference centers, corporate events, restaurants, or similar are also suitable inputs for anaerobic digesters; however, these inputs are difficult to keep clean (uncontaminated by packaging or other noncompostables) as required for systems without depackaging equipment to clean and sort inputs on-site.

The feedstock for our system may include only limited packaging. All plasticware, plates, bowls, cups, containment bags, and other items normally considered suitable for commercial composting, regardless of their manufacturer claims, will need to be sorted and separated out of the feedstock prior to tipping into the digester storage devices. This requirement may be revised as anaerobically digestible trash bags and serving ware become readily available.

The hauler or its designated representative will be responsible for the quality of the feedstock and separating materials as needed and will be charged a fee in the event that inappropriate waste was delivered. Unless specifically agreed otherwise, materials separation will be completed off-site.

Outputs

Anaerobic digesters produce three different, valuable materials:

- Humus-like **solids**, which can be mixed with soil for a light-weight green roof soil blend.
- Nutrient-rich **liquids**, which can be diluted and applied anywhere that needs fertilizer; higher-value uses are being explored as described on the following page.
- **Biogas**, which is about two-thirds methane and one-third carbon dioxide and has an energy value of approximately 54% that of natural gas.

Benefits :: Use of Outputs

The biogas produced will be a sufficient volume for several uses at The Plant. After a scrubbing process to remove impurities, it will be used in Whiner Beer's three million BTU process steam boiler; in boilers to heat algae in Back of the Yards Algae Sciences' outdoor algae bioreactors, under development as of summer 2021; and for building and digester heating. Biogas will also be used in boilers serving tenant spaces and common areas, for coffee roasters, and similar equipment.

The project will be able to provide discounted energy rates (after accounting for the reduced energy values) for use of the biogas in the building.

Moreover, the production of a methane-rich biogas, typically considered a liability, would be captured and put to beneficial use. When methane is released in to the atmosphere, it acts as a highly potent greenhouse gas. However, when captured and utilized as fuel, methane serves as an energy source, reducing the amount of potent greenhouse gases entering the atmosphere.

Over time, new opportunities have arisen, particularly from purifying and utilizing the nutrient-rich liquid digestate as an input to other processes, as described below.

Experiment :: Maximizing the Value of the Outputs

While the baseline digester concept, creating value by processing food scraps, is sufficiently compelling, the team at Back of the Yards Algae Sciences (BYAS) is powering research and development to maximize the value of the outputs from the full-scale anaerobic digester. At The Plant, Bubbly Dynamics and BYAS designed and constructed a pilot-scale digester, which simulates the conditions of the full-scale anaerobic digester. The pilot-scale digester facilitates testing of the liquid output for suitability as an input to the algae-production process. Specifically, the current concept is to explore the use of the algae as a growth stimulant to improve the speed and yield of plant growth.

Why are algae so important?

Together with bacteria, micro-algae are the foundation of the Earth's food chain. They produce about half of all the oxygen on the planet and process huge amounts of carbon dioxide through photosynthesis. Microalgae such as Spirulina, Chlorella, and Porphyridium produce proteins, fatty acids, and vitamins. They can be used as a natural, plant-based source of protein and food coloring, as well as for nutritional and pharmaceutical purposes.

Feeding an anaerobic digester requires an inoculant, similar to how a starter is needed for sourdough bread. We sourced our inoculant from the Little family farm in Hebron, Indiana. The pilot-scale digester was fed five liters a day of a "compost smoothie" made from general food waste from the building. After about six weeks, the liquid digestate was sufficiently stable and consistent for testing.

We then processed the digestate through a screwpress to separate the liquid from the solid. We pumped the liquid into mixotrophic and phototrophic bioreactors, in which BYAS has been growing various types of algae.

BYAS utilizes a Cedex bioanalyzer in the Circular Economy - Cellular Agriculture (CECA) Lab, which is being used to analyze liquid digestate samples. Research continues to establish the anticipated value of the liquid digestate, after which we will resume financing activities for the industrial-scale digester. Successfully using food waste as an input into a high-value food-production process will be an advanced example of a true closed-loop process.

Growth trials to date have had successful results. The process that separates chlorella from the growth stimulant product removes NPK (nitrogen, phosphorus, and potassium) and converts the product to polysaccharides. The trials show promising results in large-scale trials on forty acres of corn at the Little family farm, with darker green and considerably taller plant growth than the control group, as well as in smaller tests on strawberries in the indoor lab.

Currently located in BYAS's indoor Algae-Digester (AD) Lab, the pilot-scale digester will be moved to an outdoor greenhouse to facilitate scaling up their research. The greenhouse is in planning, with expansion slated for 2022.

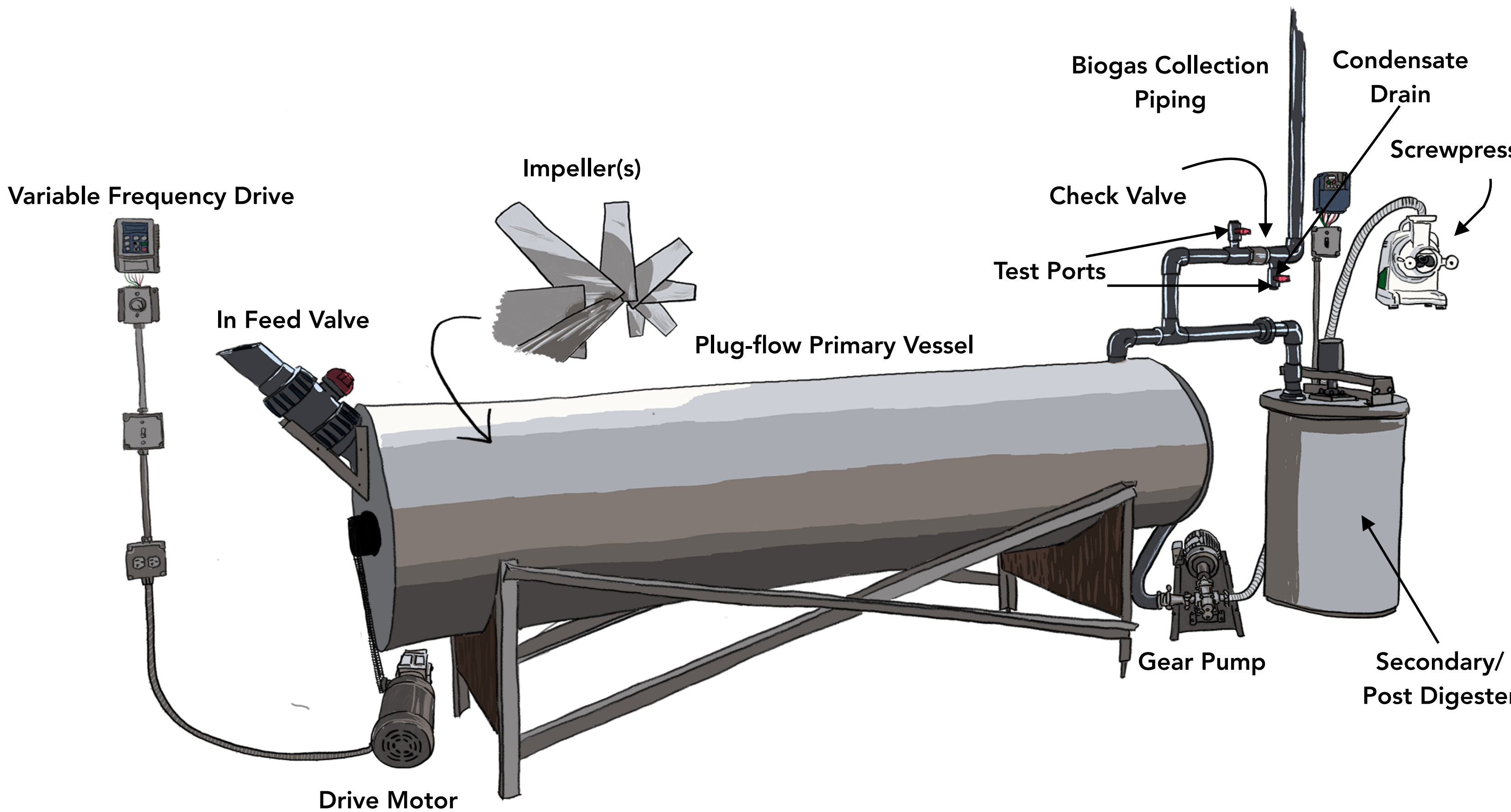
Pilot-scale anaerobic digester in BYAS's AD-Lab.

Glass photobioreactors grow algae in circulating water with light, nutrients, and CO_2 captured from Whiner's brewing process.

Pilot-Scale Digester :: Plug-Flow System Parts

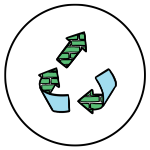
An **in-feed valve** feeds food waste into the **plug-flow primary vessel**. A variable frequency drive connects to a drive motor which controls the speed of internal impellers, spaced evenly along the inside of the tank/vessel. The digestate mixes for about 30 minutes every day, keeping the liquid from settling out.

Biogas collection piping connects to the top of the **plug-flow primary vessel** at the opposite end of the **in-feed valve**. This external tube pipes out biogas produced by the digestate, and includes a **check valve** which stops contamination from outside air and biogas back-up. The excess biogas is piped through the roof where it would safely flare off. For the full-scale digester, the biogas will be captured for use in electrical and heating purposes. The **secondary/post digester** includes a vertical stirred reactor and a drain at the bottom, which allows for liquid to be dispensed and used in trials to grow algae and mycelium.



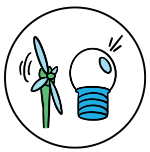
Project Benefits

Successful implementation of the anaerobic digester project will create many benefits and efficiencies.



Materials + Resource Efficiencies

Anaerobic digestion is a prime example of turning a "problem" – wasted food – into a resource. Through the digestion process, food scraps are converted into useful outputs: biogas, humus-like soil additives, and a liquid by-product which, at its most basic form, may be used as fertilizer. Research and development continues to maximize the value of that liquid.



Energy Efficiencies

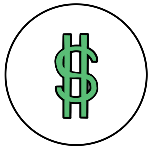
Biogas captured through the digestion process may be used as fuel for heating or converted to electricity via a combined heat and power system, decreasing reliance on the energy grid. Naturally occurring methane from the decomposition process in landfills would otherwise be flared off or released to the environment, creating greenhouse gas impacts.

Land Use, Transportation, and Air Quality Benefits

Anaerobic digesters may be operated in dense urban settings, creating a compelling alternative to transporting waste long distances to conventional landfills. Local processing of food waste thereby also reduces transportation, energy, and labor costs from waste hauling; traffic congestion; and air quality impacts.

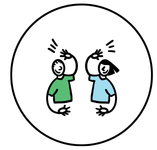
Digester technology is well proven in Europe but relatively unknown in the United States, though industrial-scale composting has been increasing. Local governments in the Midwest have generally been slow to appreciate the benefits of removing organic waste from the general waste stream, though the City of Evanston and Village of Oak Park are leading the way locally, working with a compost hauler to divert food scraps from the landfill. Cities on the coasts such as New York City, Seattle, Portland, and multiple California municipalities have similarly identified the benefits of diverting organic waste, either through digestion or composting facilities.

Finally, there is particular benefit to site a digester in dense areas where the solid outputs can be used locally or, in the example of The Plant, on-site to build soil.



Cost Benefits

Once operating, the anaerobic digester will provide an additional source of revenue in the form of tipping fees from food-production facilities and other sources of food waste. It will no longer be necessary to pay for food waste from the building and spent grain from the brewery to be composted. Farms at The Plant will have a direct source of high-quality compost on-site, allowing them to reduce costs for purchase and transport of compost from outside companies.



Social Benefits

As a hub for modern, sustainable food production, The Plant is an asset to the community and beyond, bringing high-quality jobs to the Back of the Yards neighborhood, a community that has been hit hard by job loss and disinvestment due to the closing of the Stock Yards and the phasing out of the meatpacking industry.

The digester itself will bring additional jobs to the facility. On a broader scale, fewer resources of all kinds are used and wasted, meaning a cleaner, healthier environment for a disinvested neighborhood.

Water Efficiencies

Locally, the Metropolitan Water Reclamation District of Greater Chicago utilizes anaerobic digesters as part of their operations to recover nutrients and energy in the wastewater cleaning process. Stormwater and wastewater is otherwise treated at reclamation sites in a water-intensive process.

Alternative Approaches

During the course of our research, we have explored the following strategies, which may be useful in a different context but did not meet requirements for our small-scale approach.

Integration with a Combined Heat and Power System

Anaerobic digesters can be part of a comprehensive renewable energy approach by being integrated with a combined heat and power (CHP) system. This approach both produces fuel and generates electricity, creating a significant opportunity for energy savings and carbon footprint reduction.

While a broader renewable energy generation system, with a digester and CHP, was part of our initial planning, it was not feasible due to State energy code. We did not wish to go off the grid, to accommodate maintenance of the system and to provide back-up service in the event of technical issues.

Through discussions with our electricity supplier, ComEd, two options came to light, both of which would have increased fees to tenant businesses and for Bubbly Dynamics as owner/operator of The Plant and the energy system:

- Bubbly Dynamics could pursue certification as a retail electric supplier; however, this was not a good fit for our situation at The Plant due to the relatively low amount of power generation anticipated for the level of complexity required to certify.
- Parallel operation could be established, where Bubbly sells power generated on-site to ComEd, which would then sell back to individual tenants. This alternative also involved reduced efficiencies and selling/buyback rates that were not cost-effective to the producer.

While not feasible for our specific application in Illinois, a comprehensive renewable energy system utilizing a digester and CHP might be a fit in states with more progressive energy policies, such as California, or in other countries, particularly those subject to electricity interruptions where increased service reliability is needed.

Options for Biogas Use

The biogas produced by our system is expected to be a sufficient quantity to fuel uses on-site, without significant excess. However, we did explore the possibility of scrubbing and feeding converted biogas into the Peoples Gas grid. Similar to the arrangements proposed by ComEd, the conditions required for an interconnection agreement were not a good match for the small volumes of gas that the digester would produce.

Likewise, during our research, we learned about the feasibility of developing a clean energy station on-site, for converting the biogas to natural gas and filling CNG-fueled trucks or tanks. In addition to not being appropriate for the small volumes of biogas to be produced, this use at The Plant was not desirable, as it would not complement the farming and food-production businesses here.

Options for Processing Inputs: Depackaging Equipment

A broader variety of inputs may be accepted with the addition of equipment to process the incoming waste stream. Depackaging equipment is commonly used for digesters accepting wastes that are likely to be contaminated. For example, waste from grocery stores may include plastic wrapping, metal twist ties, stickers, and rubber bands; food waste from event venues or restaurants may come with improperly sorted landfill or recyclable waste.

Options for Processing Outputs: Dewatering Equipment

The nutrient-rich liquid digestate can be considered a liability, in that its composition can change if the inputs vary, and its value can not be established until it is made. Further, the value of the digestate is reduced with miles traveled, given the logistics of hauling liquid.

Absent an alternate strategy such as we are exploring in partnership with Back of the Yards Algae Sciences, dewatering equipment is needed to process the liquid digestate into a humus-like soil additive. Equipment to separate the solids from the liquids by centrifuge would be needed for this process, though the remaining liquid would need to be tested for suitability of its disposal; depending on its composition, it may require special accommodation.

Anaerobic Digester-Based Biorefinery

In collaboration with Back of the Yards Algae Sciences (BYAS), Bubbly Dynamics piloted the use of anaerobic digestion as a biorefinery — a system for biochemical extraction rather than energy generation. For this experiment, Bubbly Dynamics designed and built a pilot-scale anaerobic digester to process targeted inputs — including glycerin bottoms, algae and fungal biomass, and food waste — as a way to explore the potential for waste stream valorization through the recovery of secondary metabolites.

Secondary metabolites are organic compounds produced by microorganisms, plants, or fungi that are not essential for basic growth but have functional or bioactive properties. These can include compounds used in pharmaceuticals, food and beverage products, and cosmetics.

As part of this pilot, BYAS successfully extracted mitragynine and GABA-rich compounds from the liquid digestate. These compounds have applications in the food and beverage industries as well as in cosmetic and pharmaceutical formulations.

This approach opens new economic pathways for urban communities to explore waste stream valorization through anaerobic digestion. The results provide a foundation for scaling biorefinery models that integrate anaerobic digestion with targeted metabolite extraction, offering practical tools for cities to rewire their economies using the waste streams they already have.

Additional Resources

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