Portable Biodigester for Urban Living: Turning Household Waste into Fuel

Group 3: Rosebud Continuum
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Executive Summary

Our topic for this project is the biodigester. This is a device that uses bacteria to digest organic waste in an anaerobic environment, producing flammable biogas and a nutrient-rich slurry, which can be used as fuel or fertilizer respectively. We aim to research, design, and develop a small-scale biodigester for residential usage. The approximate size will be 55 gallons. As it is our intent for individuals in low-income communities or educational contexts to implement our design, a preference will be given to materials that are easily accessible and affordable. We will use recycled materials when possible.

Our project location is Rosebud Continuum, a sustainability research and education site located in Land O' Lakes, Florida. Run by Maryann and Sonny Bishop, Rosebud has partnered with the University of South Florida's Patel College of Global Sustainability as a site for research into sustainable practices and technologies.

Biodigester technology has been around for millions of years. In fact, every living human and most living animals contain biodigester technology within their gut. Biodigesters are little more than synthetic stomachs. Other technology needed for this project is relatively rudimentary and includes the following: rain barrel, PVC piping and adapters, biogas collection chamber (i.e. inner tube), adhesives, and measurement and power tools.

For this project, we will evaluate various biodigester designs to determine the best design to implement at a small sale. We will pay special attention to increasing the surface area within the biodigester, as this has been shown the promote more bacterial growth and, consequently, more efficient breakdown of organic matter. We will also consider and evaluate the biogas yields of particular feedstock inputs.

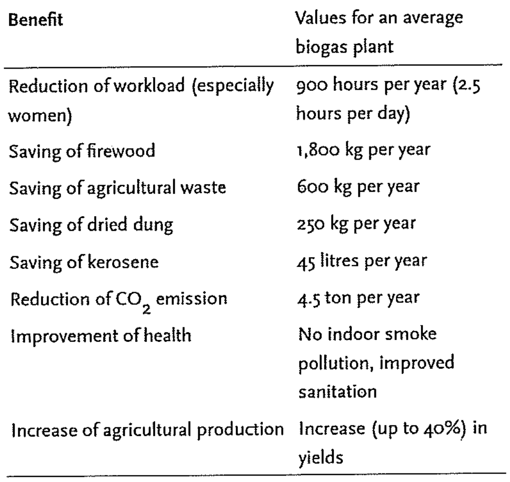
Introduction

Every year, roughly one third of all food produced goes to waste, equating to some 1.3 billion tonnes (Food and Agriculture Organization of the United Nations, 2013). As a result of the energy that goes into overall food production, food waste is a significant driver of climate change, which cuts to the heart of the problem. Not only is food waste impactful on the environment, it is preventable, since biodigesters can be used to convert food waste into fuel (biogas) and fertilizer.

There is a global shift from rural to city living and, as urban development expands, there is less room for composting to return organic waste to the land. These energy-valuable food scraps and other organic residuals are thrown into the landfill where they decompose into concentrated effluent that increases soil acidity and methane gas that is lost to the atmosphere as a harmful greenhouse gases. In fact, over 20% of all methane emissions are attributed to U.S. landfills (Payne, 2014).

By studying small-scale biodigester technology that can operate effectively within homes with limited space, this study hopes to develop a sustainable solution for families in developing countries, particularly those that lack access to energy infrastructure. If a digester can be made using a 55-gallon drum that produces enough gas to supply the needs of a family, biogas might begin to replace biomass, such as wood and dung, as an energy source. Biogas also has the advantage of being useful for electricity generation as well as cooking and heat. An additional benefit of biodigesters is their production of fertilizer; families that grow their own food can increase crop yield by using its digestate (see Table 1).

Table 1. Estimated Benefits from the Installation of a Domestic Rural Biogas Plant.



Benefit	Values for an average biogas plant
Reduction of workload (especially women)	900 hours per year (2.5 hours per day)
Saving of firewood	1,800 kg per year
Saving of agricultural waste	600 kg per year
Saving of dried dung	250 kg per year
Saving of kerosene	45 litres per year
Reduction of CO_2 emission	4.5 ton per year
Improvement of health	No indoor smoke pollution, improved sanitation
Increase of agricultural production	Increase (up to 40%) in yields

Note: Reprinted from *Small-Scale Rural Biogas Programmes: a Handbook* (David Fulford, 2015).

Biogas generation from food waste demonstrates benefits economic, environmental, and social equity—what's known as the triple bottom line. Biogas generation is economically feasible since it takes waste streams such as crop residue and food scraps, saves money by diverting them from landfills, and uses them to produce renewable energy and fertilizer (Maria et al., 2014, p. 1603). This converts a cost to the community into an asset.

This process is also beneficial to the environment in several ways. Firstly, it captures the methane so that it can be burned, reducing it to energy, water, and carbon dioxide, a much less potent greenhouse gas than methane. Secondly, it reduces the need to use chemical fertilizers. This is more sustainable than relying on soil-depleting fertilizers created from fossil fuels for agriculture (United States Environmental Protection Agency, 2019). Thirdly, it reduces the need to burn coal or natural gas for energy, which are nonrenewable fossil fuels (El-Mashad & Zhang, 2010, p.1738). It also reduces the need to harvest trees to burn as biomass, thus slowing deforestation and the resulting soil erosion, desertification and drought, which are significant problems in Africa (Amigun et al., 2012, p. 50).

Home biogas generation also has the potential to enhance social equity. Small-scale biodigesters allow families to generate their own energy for cooking and heat without needing to rely on municipal infrastructure, purchase fossil fuels, or spend valuable time gathering brushwood and dung from the surrounding countryside to use in cooking fires. This self-sufficiency liberates family members who work in the home to spend their money and energy on more enriching activities, and also protects their health by exposing them to less harm from smoke inhalation (Amigun, 2012, p. 48-50). This is a particular consideration in developing countries, where energy infrastructure may be rudimentary and where women spend a large amount of time gathering fuel and water for the family (see Table 1).

Literature Review

A review of literature relevant to biogas generation revealed a range of approaches, from large-scale anaerobic digestion systems for municipal sewage treatment to do-it-yourself instructions for the home renewable energy enthusiast. These systems shared similar concerns, such as the choice of substrate and its effect on biogas quantity; the usefulness of temperature treatments; the effect of loading rate alterations and multi-stage processes; and the prevention of straying outside of the optimal pH range for the effectiveness of methane-producing microorganisms. Since different organic processes are involved in the breakdown of lipids, proteins and carbohydrates, several intermediate steps take place before methane production is possible. These include the generation of ethanol, hydrogen, and ammonia (Amigun et al., 2012), all of which can have impacts on digestion efficiency. Therefore, the choice and treatment of substrate are important for the production of high-quality biogas as well as high-quality fertilizer. There are various factors that can hinder the achievement of complete digestion and subsequently need to be avoided.

Many organic compounds can be used to generate methane, including food waste, agricultural waste, solid waste and manure. Co-digestion often produces superior results to using only one type of waste; for example, when fruits and vegetables were blended with waste mixed sludge at a wastewater treatment plant, performance was improved (Maria et al., 2014). A mixture of 60% food waste and 40% manure was found to be efficient in another experiment (El-Mashad & Zhang, 2010, p. 4027). According to Xu et al., food waste has higher biogas generation capacity than many other materials (2015, p.177); this may be due to the high lipid content, since lipids are found to have high methane-production potential (Wan, Zhou, Fu & Li, 2011, p. 1752). Carbohydrates are the most important component for biogas production. An ideal nutrient ratio is 600 parts carbon, 15 parts nitrogen, 5 parts phosphorus, and 3 parts sulfur. Humidity should be kept between 60% and 80% (Khalid et al., 2011, p. 1741).

High levels of protein result in the formation of ammonia, which in turn produce volatile fatty acids that destabilize the digester (Banks, Chesshire, Heaven & Arnold, 2011). This is primarily due to the formation of acetic acid, which disrupts methanogenic metabolic pathways by dropping the pH too low (Xu et al., 2014). pH is ideally kept between 6.8 and 7.2 (Shen, 2013, p. 84). One way of avoiding this problem is by using a two-phase digester, which results in significantly higher methane production than the single-phase method. The acid fermentation stage is maintained at a low pH with a hydraulic residence time of only a few days. Following this the methanogenesis stage lasts 20–30 days at a pH of 6–8, which encourages the proliferation of slow-growing methanogenic archaea (Grimberg, Hilderbrandt, Kinnunen & Rogers, 2015).

Various experimental methods have been applied to the digestive process to see how methane production can be optimized. One study found that hydrothermal pretreatment of food waste made it more biodegradable and resulted in quicker methane production (Jia et al., 2017). However, another study found that the hydrothermal pretreatment of food waste only increased methane production when applied to fruits and vegetables; otherwise it had the opposite effect (Qiao et al., 2011). Digestion is found to be promoted when the mixture in the generator is stirred (Mattocks, n.d.). The recirculation of digestate was also experimented with. This was found to have the advantage of conserving water, but requires the use of a mesophilic temperature range or imbalances occur (Zamanzadeh, Hagen, Svensson, Linjordet & Horn, 2016). The mesophilic optimal temperature is 35°C with a digestion period of 18 days (Khalid et al., 2011). Loading rate also matters. An excessive organic loading rate was found to over-acidify the digester, lowering methane production. Acidification can be a serious problem for biodigesters because it can irreversibly stun the microbial population (Nagao et al., 2012).

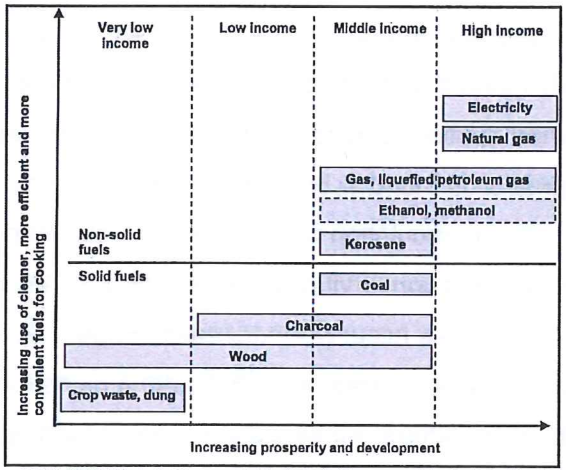
Overview of the Project

Background Information

In developing countries, 2.5 billion people or 52% depend on solid biomass—fuelwood, charcoal, agricultural residuals and animal dung—as their primary source of cooking fuel. "Poverty is inextricably linked to the use of biomass" (see *Figure 1.5*) thus low income households must rely on the most affordable fuel resources available to them. Conventional ovens and poor ventilation linked to the burning of these traditional fuels jeopardize public health in which "about 1.3 million people—mostly women and children—die prematurely every year because of exposure to indoor air pollution from biomass" (IEA, 2006). Additionally, the unsustainable practices used to harvest traditional biomass fuels has ecological consequences (i.e. deforestation linked to fuelwood production) and socioeconomic impacts (i.e. the labor required for fuel collection, typically carried out by women and children, displaces community education and income generation).

Lack of infrastructure in the developing world yields poorly managed solid waste in which "over 90% of waste is often disposed in unregulated dumps or openly burned" (WorldBank, 2019). The uncontained accumulation of waste "serves as a breeding ground for disease vectors, contributes to global climate change through methane generation, and can even promote urban violence" (WorldBank, 2019). However, given the proper funding through NGOs or government subsidies, this discarded waste could be an untapped source of potential energy for low-income communities.

Figure 1.5. Transition from use of biomass fuels to use of modern fuels



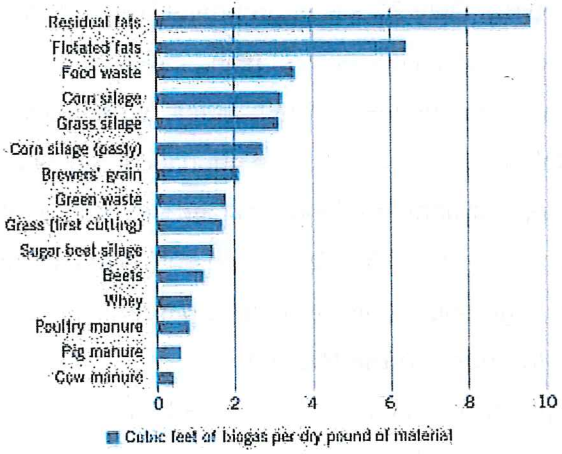
From WHO (2006) (Figure 2: The energy ladder: household energy and development inextricably linked)
Note: Ethanol and methanol are rarely, if ever, used.
Dash: estimate

Figure 1. Transition from Biomass to Modern Fuels.

The Appropriate Rural Technology Institute (ARTI) in Pune, India, has successfully launched 1,000 biodigesters in which each one saves about 0.3 tons of CO_2 annually. The ARTI biodigesters are specifically designed for compact urban living and run off of organic household waste. Unlike manure-based biodigesters, ARTI systems fed on food waste digest more quickly (1-2 days versus 30-40 days) and yield more biogas (1 kg (dry) food waste versus 20 kg of cattle dung to produce ~0.25 kg of biogas) (Ashden, 2018). While an ARTI system is more expensive than a LPG stove ($200 versus $100), the ARTI system halves the amount of LPG used per day (LPG cost per day: $0.60) thus the cost of the biodigester is recovered within two years and potentially less if consumers are actively collecting food waste from their community. ARTI is also in the process of designing its own version of a 'balcony' biodigester in order to further promote the use of biogas within urban settings (Ashden, 2018).

Space constraints aside, cities are an appropriate setting for biodigesters due to the readily available abundance of organic waste discarded every day. Unlike animal dung, food waste generates larger biogas yields (see *Figure 2*) thus is a more practical feedstock source for the urban setting. David William House, author of *The Complete Biogas Handbook*, provides a helpful chart (see *Table 2*) that shows how many gallons of food waste per day are needed to perform basic daily tasks.

Table 2. Biogas Produced by Various Feedstocks.



Note: Reprinted from *Food Waste and Biogas, Part 3* (House, 2014).

Table 3. Gallons of Food Waste Required to Perform Various Tasks.

Use	**ft^3 gas/hr**	**Notes**	**ft^3 gas/da**	**Food waste req'd, 1 gal buckets/day**	**digester (slurry) vol, gal**
Lights, 100 w equiv.	2.5	2 lights, 3 hours in the evening	15	0.5	22
Cooking, per burner	20	2 burners, 2 hours, 2 meals	80	2	120
Hot water, per gal	4.5	Assume 30 gal/da for shower, dish washing, etc.	135	3.5	200
Engine, 100 HP	1600	Small engine (genset?), 4 hours/day	6400	160	9,600

Note: Reprinted from *Food Waste and Biogas, Part 3* (House, 2014).

Biogas energy generation is already an accepted practice in developing countries such as India and China. In rural China, biogas generation using agricultural waste is considered standard (Qiao et al., 2011). Despite this, China has a growing problem with food waste disposal: it comprises 38% of its solid waste at 60 million tons per year, and is increasing by 10% yearly (Xu et al., 2015). Only 20% is appropriately reused. Japan's food waste is 30-40% of its municipal solid waste, which currently is being incinerated rather than utilized for energy generation; since food waste contains so much water, burning it is a highly inefficient way of handling the problem (Nagao et al., 2012). The quantity of food waste in the United States, United Kingdom, France, Germany, Holland, Switzerland, Korea, and Singapore amounts to about 12%, 27%, 22%, 15%, 21%, 20%, 23%, and 30% of their solid waste (Shen et al., 2013), showing that there is a large opportunity for biogas generation using municipal waste streams.

Sustainability Efforts Included in the Project

500 million people in sub-Saharan Africa lack home access to electricity. Half of all deforestation is Africa is the result of gathering wood for fuel. Biogas generation is not yet widely-adopted in most parts of Africa despite the urgent need for renewable energy in impoverished areas. Biogas generation using human and animal dung with the Chinese fixed-dome digester or the Indian floating-cover digester have shown poor performance despite the fact that Africa's warm climate is ideal. It is likely that the failure of biogas technology in Africa has many causes, not the least of which is lack of technical experience, information, and

appropriate involvement of local stakeholders in large projects (Amigun, 2012). India also faces severe deforestation from relying on biomass for energy, since 80% of its energy needs are met by burning wood or dung (Rao, Baral, Dey & Mitnuri, 2010). This data shows that introducing an efficient, affordable biogas generation system such as is proposed in this project would have sustainability benefits socially, economically, and environmentally, particularly in developing countries where household fuel needs are creating an ecological crisis, since biogas is generated with materials available in abundance can substitute for increasingly-scarce natural resources like wood.

Strengths and Weaknesses of this Sustainability Strategy

There are two main factors that will determine small-scale biodigestion as a practical energy solution for domestic purposes. The first depends on achieving optimal working conditions to yield effective biogas supply. The second involves the affordability and accessibility of the materials and equipment needed to construct a biodigester and utilize the produced biogas.

Factor 1: Achieving Optimal Working Conditions – In order for a biodigester to operate effectively, specific growth conditions must be met. Of those, temperature and retention time are particularly important in the design of a portable biodigester for these two factors address two different obstacles: the effects of cold climate on biogas production and lower biogas yield for a smaller volume of slurry.

Biodigester stability depends on temperature. Anaerobic digestion is carried out primarily by mesophilic microbes that thrive at 35℃ (95℉ or “cow gut” temperature) and thermophilic microbes that are most effective at 55℃ (131℉). It has been found that gas production in thermophilic conditions is twice that in mesophilic conditions “although the total gas produced per kilogram of feedstock is not necessarily higher”, (Fulford, 2015). However, the downside to running on thermophilic temperatures is the need for additional energy to heat the biodigester and stricter monitoring because “thermophilic methanogens seem to be much more sensitive to changes than the mesophilic ones” (Fulford, 2015). For this reason, the portable biodigester will be intended for mesophilic conditions.

Running a biodigester is relatively easy in the subtropical climate of South Florida, where sunlight is plenty and the average high temperature stays in the 80℉ range. However, this is not the case for those living in colder climates, thus a mechanism for optimizing heat retention within a biodigester must be incorporated. The difficulty in designing a portable biodigester suitable for all climates is that the system design must remain lightweight and easy to transport;

modifications to optimize heat retention require addition materials that can increase the weight and dimensions of the system. Design recommendations are given in the next section *Factor 2: Construction Affordability and Accessibility*.

Retention time, or the time it takes for feedstock to convert to biogas, is another important element in the portable digester design because in order for a smaller system to generate enough biogas to be useful, a mechanism must be incorporated to optimize biogas generation within a smaller volume. One such way is by increasing the surface area within the system to grow the microbial population and enhance the rate of anaerobic digestion. A method used in wastewater treatment called "moving bed biofilm reactor" (MBBR) utilizes suspended plastic biofilm carriers to provide additional surface area for microorganisms to grow on. Some carriers are of rigid plastic and include geometric incisions to increase surface area whereas others are thin discs that harbor microbes within tiny pores.

Factor 2: Construction Affordability and Accessibility – The construction of the portable biodigester will imitate the design of the Solar C^{3}ities "Pickle Barrel Biodigester" built by Dr. T.H. Culhane in Beit Jala, Palestine in 2016. However, two additional features—insulation and biofilm carriers—will be added to the build in order to optimize heat retention and surface area.

Unlike some biodigesters (typically larger, underground systems) that use bulky and often pricey heat exchangers (i.e. internal pipe network for circulating solar heated hot water), the portable biodigester must remain as lightweight and cost-effective as possible. A reflective insulation is a suitable material because it can be adhered to the outside of the biodigester in a wrap-around fashion to harness solar radiation and insulate the system simultaneously. This lightweight material can be found at home improvement retailers for at an affordable price (Reflectix brand 133.3 sq. ft. roll: $51.68 at Lowe's).

The biofilm carrier to be used in this design will be modeled after a carrier called the MBBR BioChip 30 used by industrial wastewater treatment company, Ecologix. The BioChip 30 uses fine pores to increase its active surface area (> 5,500 m^2/m^3 compared to conventional carriers of $350m^2/m^3$ - $800m^2/m^3$) and is made from polyethylene (PE) plastic. To imitate the BioChip 30, small discs (30mm in diameter) will be cut from PE packaging which is easily obtainable from many electronic retailers. See Fig. 2 for a schematic diagram for the portable biodigester design.

The strengths of this design is that it is inexpensive, easy to build, lightweight and portable, making it ideal for use in small households. It reduces carbon emissions from decomposition and from burning fossil fuels for energy. It can make households more energy self-sufficient while reducing their contribution to municipal waste. It puts food waste back in the carbon and nitrogen cycles. The weaknesses of this design is that it will require a warm climate for efficient operation if it is not kept indoors or insulated well. It is also small enough to be convenient, but not large enough to provide 100% of a household's energy needs. Some of the parts required, such as biofilm, may not be available in every locality. Nevertheless, the fundamental principles should be adaptable to most locations.

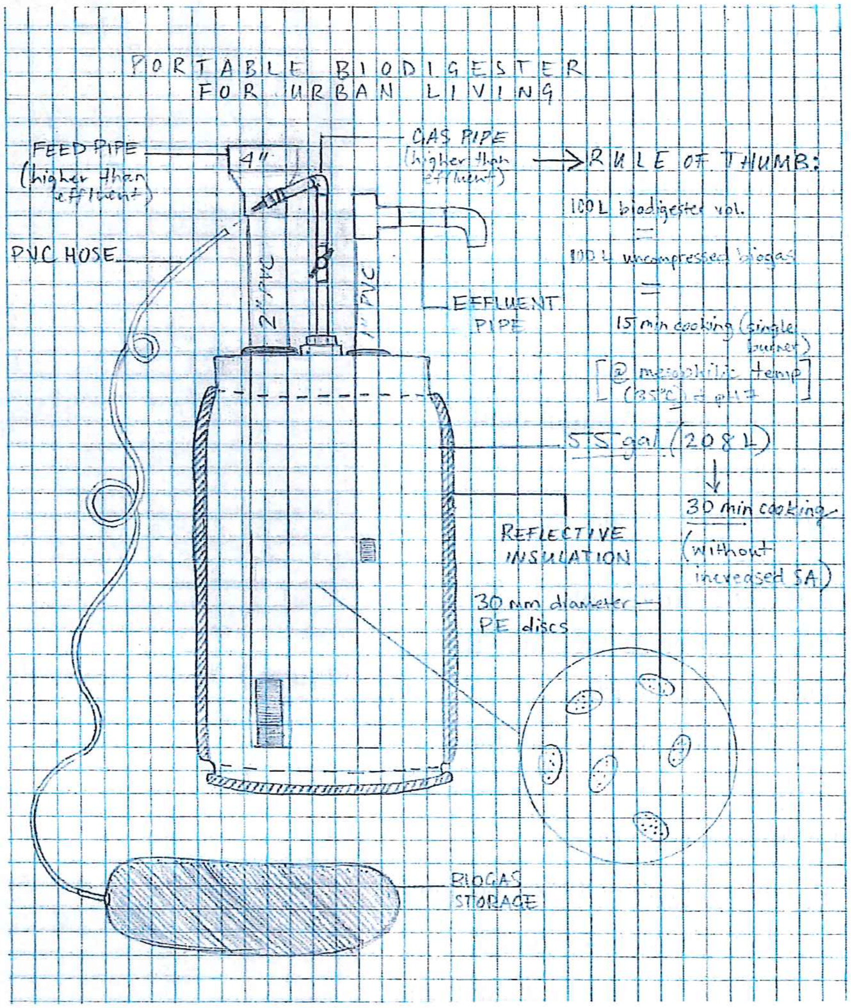


Figure 2. Portable Biodigester Design.

Project Assembly

Materials

Tools and adhesives

- Measuring tape
- Handsaw
- Metal file
- Drill (see Fig. 3)
- Drill bits
- 5" and 3" hole saw bits
- Plumber's Tape
- Silicone Caulking
- Black Paint

Personal protection equipment

- Leather Gloves
- Safety Glasses (see Fig. 4)

Biodigester components

- 55 Gallon Rain Barrel (see Fig. 5)
- 4" PVC Schedule 40 Pipe
    - (cut to length of 47" for feed pipe)
- 2" PVC Schedule 40 Pipe
    - (cut to length of 42" for effluent pipe; additional 10" and 8" sections needed for effluent and gas pipes respectively)
- 1/2" PVC Schedule 40 Pipe (cut into two 3" sections)
- 2" PVC "T" Adapter
- 2" PVC "L" Adapter
- 2" PVC Coupling Socket

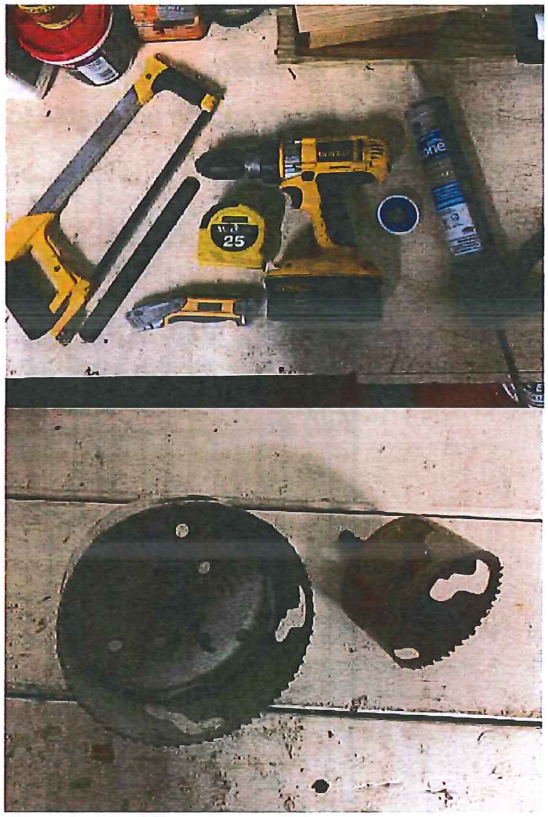


Figure 3. Tools. November 23, 2019.

Figure 4. Protection. November 23, 2019.

- 2" - 1 ½" Bushing
- 1 ½" - ½" Bushing
- ½" PVC Ball Valve
- 2" Bulkhead Fitting
- 2" Uniseal
- 4" Uniseal
- ½" PVC Slip-to-Thread Pipe Adapter (see Fig. 6)
- ½" Hose Barb
- 4" Rubber Funnel
- ½" Metal Hose Faucet

Digester "Floaters" Components

- Polyethylene Foam
- Glass Beads (see Fig. 7)
- Plastic Mesh Produce Bags

Figure 5. Barrel and PVC Pipe. September 23, 2019.

Figure 6. Components. November 23, 2019.

Figure 7. Digester Floater Components. November 23, 2019.

Method

Biodigester assembly.

- Using a drill and the appropriate hole saw bits (5" and 3"), create three holes at the top surface of the rain barrel; one 5" hole (for the feed pipe) and two 3" holes (for the gas pipe and effluent pipe).
- Arrange the holes in a straight line across the center of the top surface; the gas pipe will be in between the feed and effluent pipes.
- Always wear leather gloves and safety glasses when using the hole saw.
- Add silicone caulking to the lip of both the 4" and 2"

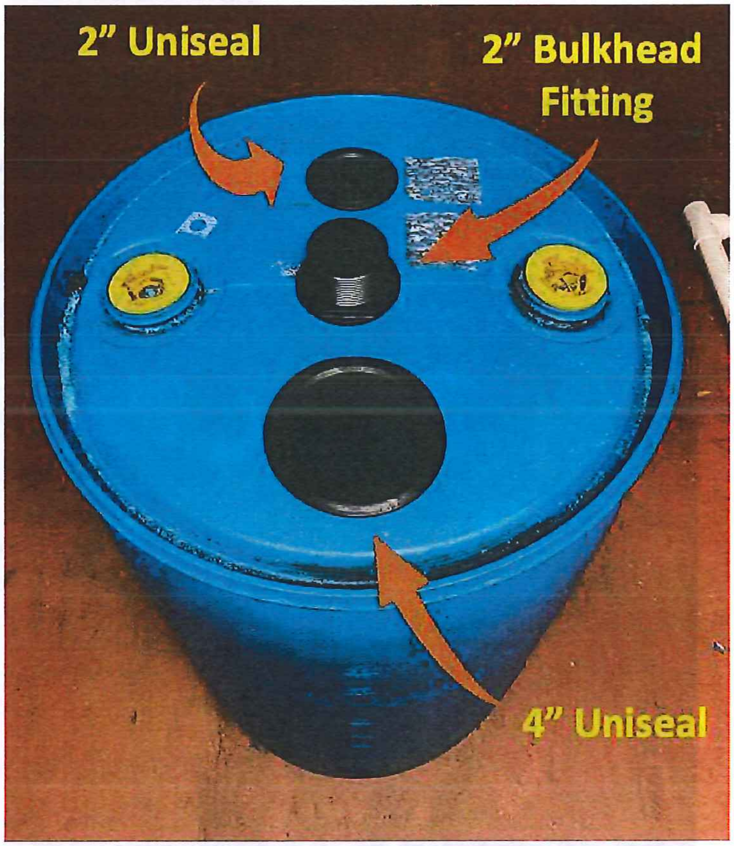


Figure 8. Seals & Fittings Installed. November 23, 2019.

uniseals and fit them into the appropriate holes. Leave to dry overnight. (See Fig. 8).

- Unscrew the nut and remove the washer from the 2” bulkhead fitting; add silicone caulking to the bottom lip of the body and replace the washer; reach through the adjacent 4” feed pipe hole to push the bulkhead fitting from the underside of the barrel surface and up through the central gas pipe hole; screw on the bulkhead nut and tighten. Leave to dry overnight.
- Using a handsaw, cut a 2” PVC pipe so that, when topped with a 2” PVC ‘T’, it reaches 8” inches above the top surface of the rain barrel (roughly a total of ~42” with the PVC ‘T’); this has been found to be the optimal height for facilitating effluent outflow.
- Additionally, cut a ~1.25”x1.25” square from the center of the effluent pipe (this is where the effluent outflow will begin leaving the biodigester). (See Fig. 9).
- Cut another section of 2” PVC (~10”) and attach to the PVC ‘T’ (the hole parallel to the ground) and attach a 2” PVC ‘L’ to the end (this is where the effluent will flow out of the biodigester).
- Before inserting the 2” PVC pipe into the 2” uniseal, use a metal file to sand down the sharp edges and lather with either dish soap or vegetable oil (this will aid in passing the pipe through the uniseal); repeat this process with the 4” feed pipe.

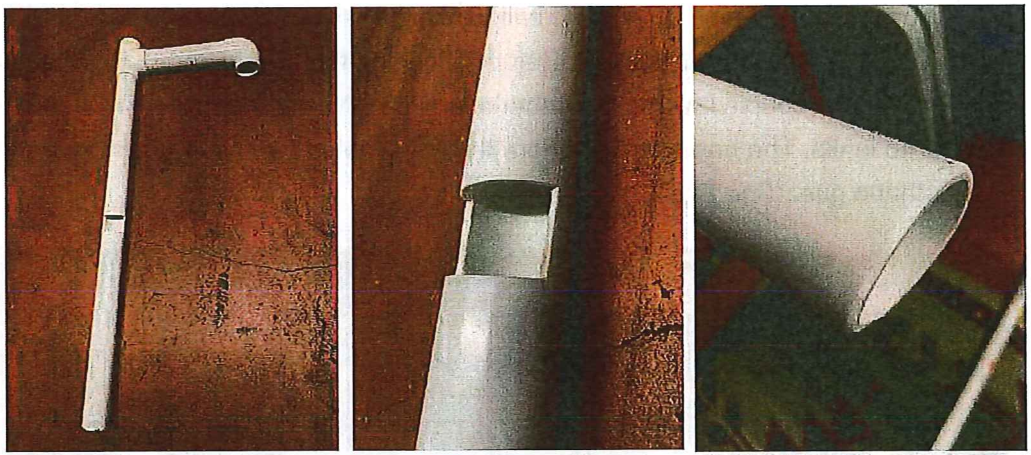


Figure 9. **Pipe Cutting and Fitting. November 23, 2019.**

- Cut the 4” PVC pipe so that it is higher than the effluent pipe. In this build, the feed pipe was made to be about a few inches taller than the effluent pipe (before attaching the rubber funnel). Using the handsaw, cut out a ~7”x4” section from the bottom of the feed pipe; this will allow organic matter to disperse into the bottom of the biodigester. (See Fig. 10).

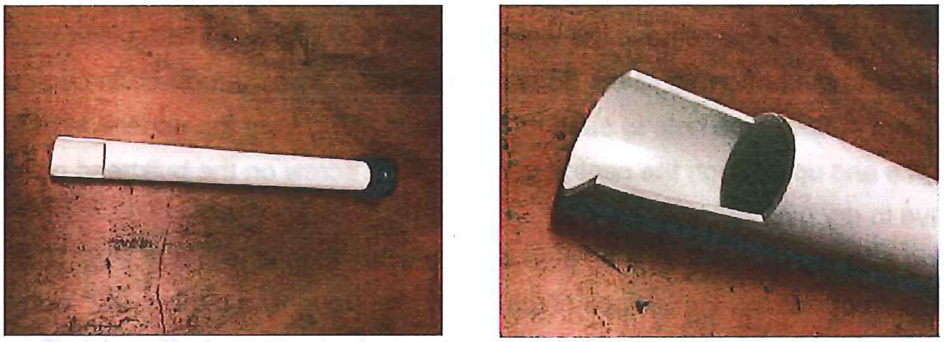


Figure 10. Feed Pipe. November 23, 2019.

- The gas pipe is the tallest pipe and was constructed to convert from 2" to ½" diameters; this ensures that gas can still rise upwards even if debris accumulates at the 2" base of the gas pipe.
- Cut an 8" section of 2" PVC and fit onto the bulkhead fitting; in this order, attach to the 2" PVC section: a 2" PVC coupling socket, a 2" - 1 ½" bushing, and 1 ½" - ½" bushing (these pieces together allow for this 2" to ½" pipe conversion).
- Cut in half a 6" section of ½" PVC pipe; in this order, attach to the 1 ½" - ½" bushing: one 3" section of ½" PVC pipe, a ½" PVC ball valve, the second 3" section of ½" PVC pipe, a ½" PVC slip-to-thread pipe adapter. Before attaching the ½" hose barb to the pipe adapter, wrap a couple layers of plumber's tape around the threads of the hose barb to ensure no leaks. The hose barb is where the PVC tubing can be attached to transport the methane gas. (See Fig. 11).

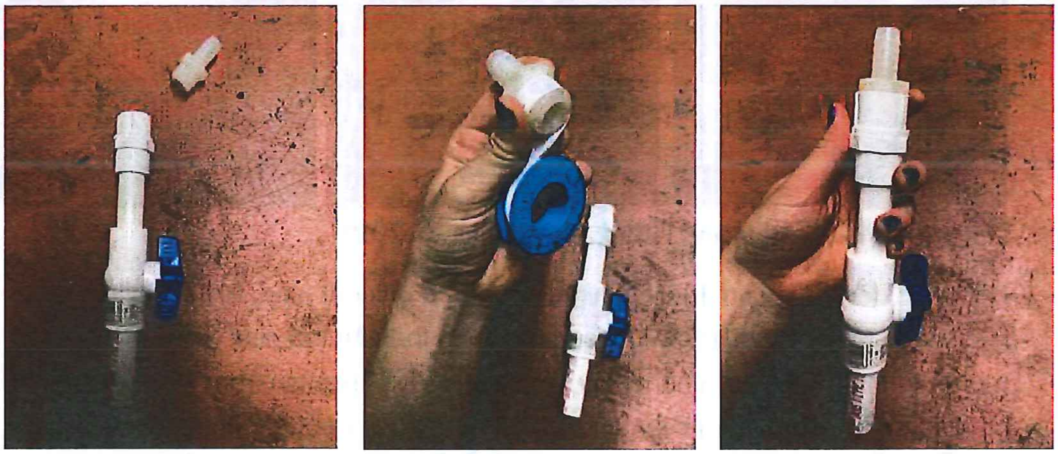


Figure 11. Gas Pipe. November 23, 2019.

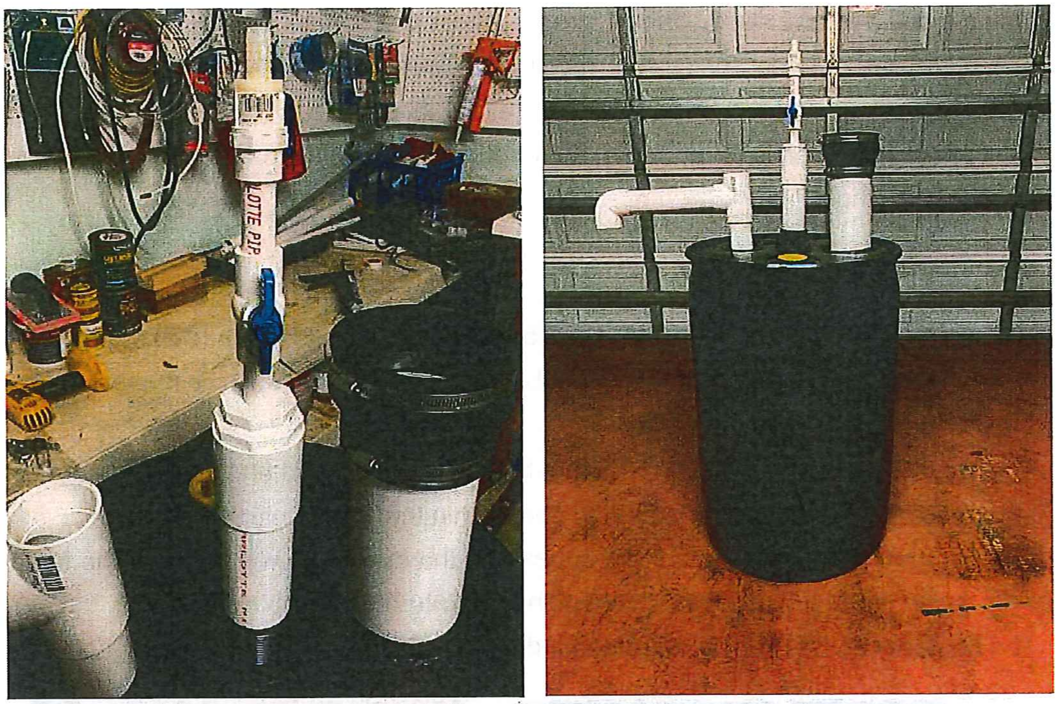


Figure 12. Effluent, Gas, and Feed Pipe. November 23, 2019.

- Paint the rain barrel black; this will aid in solar absorption to maintain the optimal temperature for digestion. (See Fig. 12).

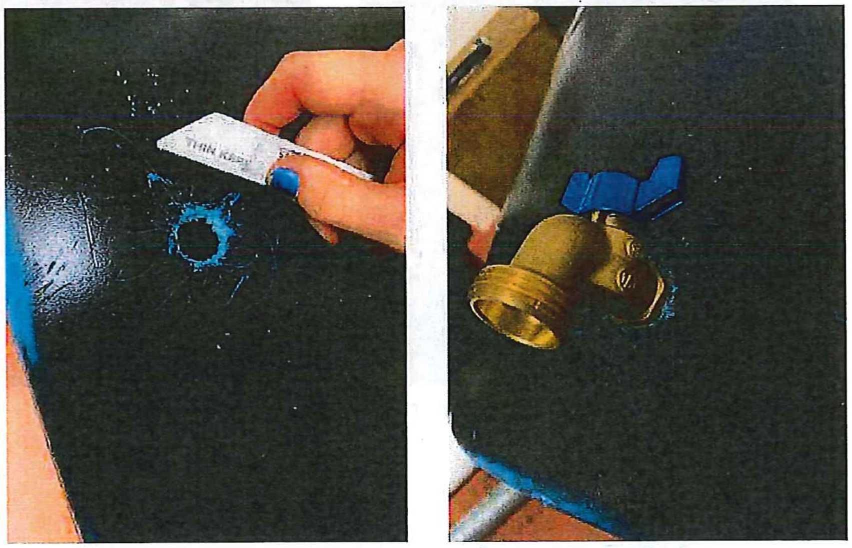


Figure 13. Drain Installation. November 24, 2019.

- Using a drill and any sturdy drill bit, create a hole just smaller than ½" at the base of the rain barrel; using force, screw a ½" metal hose faucet into the hole; this allows the biodigester to be drained and transported easily if necessary. (See Fig. 13).
- If an effective drill bit is unavailable, then a fine-toothed blade can be used to manually carve out the hole.

Digester floaters assembly.

- Using a razor blade, cut ~0.75"x0.75"x0.50" cubes of polyethylene (PE) foam.
- Combine PE foam cubes with glass pebbles together inside a plastic mesh produce bag.
- Tie the mesh bag. (See Fig. 14).
- Test the buoyancy of the floater within a bucket of water; add and subtract foam cubes and pebbles until the floater is able to float within the water column.
- The porous surface of the PE foam cubes and the mesh bag will increase the surface area within the biodigester thus enhancing the rate of anaerobic digestion.
- The floaters can be dropped into the biodigester through the 4" feed pipe.

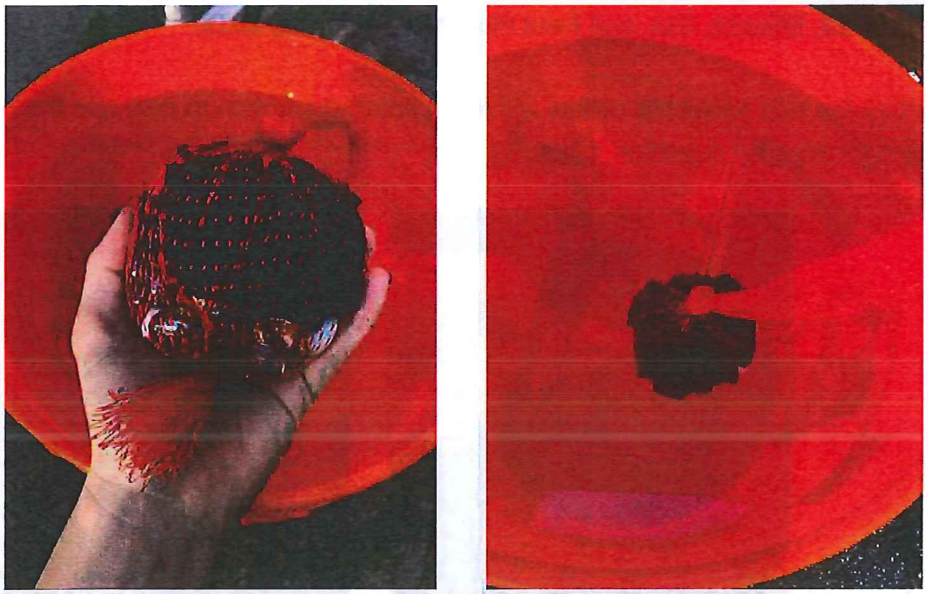


Figure 14. Floaters. November 23, 2019.

Blog

Information on materials and construction for this portable digester is also available on the Rosebud Biodigester Blog: https://rosebudbiodigester.blogspot.com/. Three pages of information are presented, with accompanying photographs. The purpose is to provide step-by-step instructions for the construction of a biodigester that anyone can use.

Project Recommendations

Proposals for Improvement

As a student group new to biodigester technology, there are a few proposals for improvement that may benefit future students and individuals interested in building their own biodigesters. To start, access to the proper tools is necessary but these items are expensive and not affordable to everyone. Perhaps universities and communities globally can invest in a tool rental program that makes it easier for students to turn their designs on paper into tangible prototypes. Without the proper tools, designs lose integrity and may not be as effective as planned. For example, for this portable biodigester, internal surface area was increased by imitating Moving Bed Biofilm Reactor (MBBR) technology. MBBR uses porous discs of a specific size and weight. Unfortunately, a hot wire foam cutter and laboratory scale were unavailable thus making it more difficult to create polyethylene (PE) foam cubes of the same size and weight (see Fig. 7). Additionally, university funding for such projects would allow students to bring out-of-the-box ideas into reality without worrying about financial limitations. A heating element (for maintaining optimal temperature year-round) was considered for this biodigester design but ultimately decided against because it was not within budget.

It would also be ideal to test biogas methane levels as well as quantities of energy produced from a given volume of food waste. To test that methane is present, a burner could be attached to the tubing that transports the biogas out of the biodigester. To test the quantity of energy produced, the length of time that flame continues to be produced by the burner can be measured. This will only require food waste, bacteria, and a few weeks for anaerobic digestion to produce methane, and the acquisition of an appropriate burner. Data collected could include how long it takes the digester to produce flammable biogas; how much food waste equates to what length of flame duration; the difference in energy production between different types of food waste; and whether design flaws are detected that need to be rectified.

Limitations to Addressing Proposed Ideas

The main limitations to these ideas are time and money. Simple proof of concept will only take a few weeks and should be inexpensive, since the only additional materials required are a camp stove and food waste. Gathering data regarding the energy output of different types of food waste will require a few months. Adding a heating element will require a source of additional funding, as will acquiring a hot wire foam cutter and laboratory scale for more precise construction. It would also be interesting to have interested people construct their own biodigesters using instructions provided on our blog site and sharing their results, since the purpose of this design is to popularize home biogas generation for energy production. Getting feedback about instruction clarity, ease of construction, and success of the design would allow the blog to be refined. This would require the recruitment of interested people who reliably follow the instructions as written, who are also willing to collect data and share their results.

Conclusion

Sustainability requires making the fullest use of the resources we consume, including food and the resulting waste. The fact that biodegradable waste is a large share of municipal trash and has a significant carbon footprint suggests that in order to make our cities more sustainable, this waste should be diverted and reclaimed as a source of energy and fertilizer. Making biogas from food waste will reduce the amount of land that is used for landfill, reduce the need to use chemical fertilizer to grow food, and reduce the amount of fossil fuels or wood that is harvested for home energy production. If a transition to biogas production becomes widespread in developing countries, human impact on soil and forest land will be reduced while people with limited financial resources and little access to a power grid will be able to produce their own safe, clean light and heat.

This project is an attempt to create a portable, affordable home biogas generator that nearly anyone can make and use and to share information on how to do this with the general public. Making clean energy available to everyone will increase social equity while protecting the environment. However, although the generator has been built this design must still be tested for effectiveness, ease of use, and efficient fuel-to-energy conversion. Once further data has been collected, the design can be refined and hopefully used by the average person to turn every-day waste into a source of energy independence.

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