Biodigester Stove (/Biodigester+Stove)

THE ANAEROBIC BIODIGESTOR PROJECT

Turning Waste Into Clean & Sustainable Cooking Fuel

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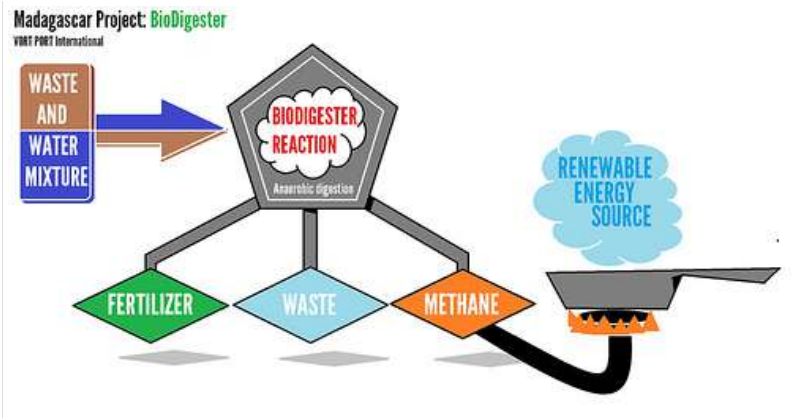
The Problem:

Indoor cooking fires that burn wood and other organic waste are one of the highest causes of respiratory disease and death in the developing world. Sustainable waste management and crop fertilization are additional problems often encountered in developing areas.

The Idea:

Biodigesters provide a unique solution to waste treatment issues and the need for cleaner cooking fuels. Bacteria digest organic wastes, producing methane that can be harvested for cooking. Methane, being the simplest hydrocarbon, produces more heat per mass unit (55.7 kJ/g) than other complex hydrocarbons. Coal and oil are more chemically complicated than natural gas and they release a variety carcinogens into the air upon combustion. Burning methane releases only carbon dioxide and water. Since biogas is mostly methane, the combustion of natural gas releases fewer byproducts than other fossil fuels.



source: http://vortportblog.wordpress.com/tag/biodigester/

The biodigester is an interesting appropriate technology concept because it has the potential to close multiple sustainability "loops", while also having the potential to create a service industry, revolving around around the installation and maintenance of the system. It can produce a fuel for cooking using available waste resources, such as organic wastes, or even waste from outhouses. This will help in waste and pollution control, and is especially applicable to agricultural and animal farming communities. Furthermore, a methane flame burns considerably cleaner and more efficiently than wood, which will help reduce indoor air pollution, which is a leading cause in pulmonary disease. Finally, the solid digestate left over from the digestion process can be used as a fertilizer.

Decision Matrix

The weighting is out of a total of 100%, each criteria is scored 1-10, with 10 being the most favorable.

	cost	reproducibility	Ease of implementation (complexity)	Projected yield	Difficulty of maintenance (parts)	total
IMPORTANCE	0.25	0.2	0.25	0.2	0.1	1
5 gal bucket	10	9	10	2	8	8
55 gal drum	6	9	10	6	9	7.9
(3) – 5 gal buckets in series	8	8	9	4	7	7.35
Floating drum	2	3	2	7	7	3.7
Bag in hole	8	7	4	9	2	6.4
Plastic trash can	9	9	8	5	8	7.85

We have arrived at the 5 gallon bucket and the 55 gallon drum being our most viable options.

source: http://www.k4health.org/docs/437376/tag/6914

55 Gallon Drum Wins!

The 5 gallon bucket and the 55 gallon drum were exceptionally close (the plastic trash can was as well), but we decided to go forward with the 55 gallon drums as we felt they would be easier to work with (easier to attach fittings too), and that the increased volume would hopefully yield more biogas.

Elaborating on the Problem:

We are designing our biodigester with the community and environment of San Pablo, Guatemala, in mind. Through our initial literature search, we expect to encounter several problems both general to biodigesters, and specific to San Pablo.

General Biodigester Problems:

- Achieving a high ratio of biogas production to biomass substrate
- Achieving high concentrations of methane in our biogas production
- General design and manufacturing issues
  - In ground, above ground
  - Expandable vs. fixed gas collector, integrated vs. separate gas collector
  - How do we keep it anaerobic?

San Pablo Specific Problems:

- Identifying what biomass is available for use as substrate
  - What waste is most easily available?
  - What yields the most energy?
  - How is it collected/who collects it?
  - What are the ideal ratios of solid "volatile" substrate to water, for each kind of substrate?
- How inexpensively/unobtrusively can we implement this technology?
  - Can we retrofit septic systems?
- What are San Pablences willing to do for this technology?
  - Will they maintain it?
  - Will they use human waste?

The Plan:

Our main goal is a proof of concept for an affordable biodigester that will be able to provide fuel for a single family home. Since many of the single family biodigesters hold a volume of 1000 gallons or more, we plan to design our prototype on a smaller scale with the initial goal of producing enough methane to boil 2 kg of water.

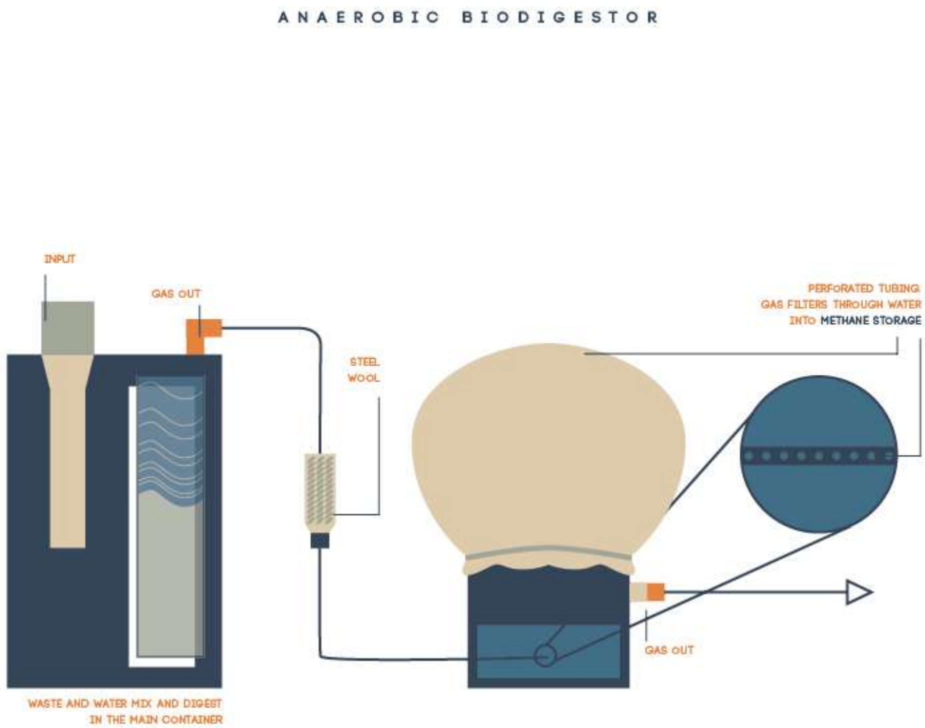
The bacteria that perform anaerobic digestion are sensitive to pH and temperature, and prefer to be in a warm and slightly alkaline environment. The pH should not drop lower than 6-6.5, and the anaerobic digestion is only efficient above about 60 degrees fahrenheit. By building a greenhouse for the digester unit, we hope to heat up the digester during the day, as well as insulate it from lower ambient temperatures and trap heat generated by the digestion process. The pH can be regulated using a buffer solution to avoid any dramatic fluctuations. Additionally, we should be careful to not introduce any considerably volatile feedstock (such as starch) at first, since this will ramp up the acetogenic stage and drop the pH before the methanogenic bacteria have enough time to become established.

The gas produced contains methane, hydrogen sulfide, and carbon dioxide. We have designed two gas filters aimed at removing these impurities to yield a more pure methane fuel. By running the gas through steel wool, the hydrogen sulfide will oxidize (rust) the steel and will be removed. An added benefit of performing this step is that hydrogen sulfide is the gas responsible for the pungent odor sometime associated with biodigestion. The second filter contains water and calcium carbonate which will remove the carbon dioxide as the gas bubbles through.

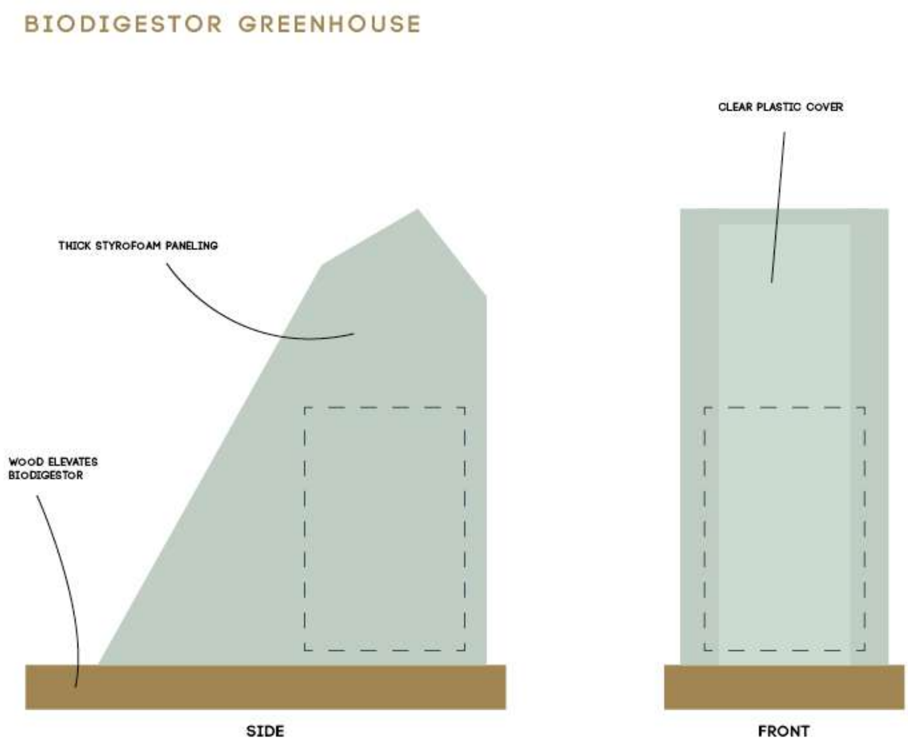
It appears that this is a popular technology with many prototypes and functional designs out there already. However, we do anticipate some challenges: fitting the joints and seams tightly enough to trap the gas effectively, producing a gas that is has a high enough concentration of methane for combustion, and making sure that our design is capable of being successfully scaled to its proper size. There may be additional cultural challenges to implementing this technology in the community; community members may not want to handle organic waste, especially human waste, or deal with the daily maintenance of the digester. Someone in the community would have to learn how to perform more intensive maintenance on the digesters to insure that they are operating efficiently. This could potentially be addressed by building a business model around the digester installation and maintenance. Furthermore, the initial start-up investment of installing a biodigester-stove system can be significant.

Schematics:

The schematics below depict the design of our biodigester, gas filtration & collection, and our greenhouse. Some minor alterations have been made to the actual system from the design shown in the schematic. Eventually we will update the schematics to reflect our actual designs.



The input pipe extends into the digester to keep biogas from bubbling out through the input hole. The cut-away shows denser digestate settling down to the bottom of the digester, where most of the anaerobic digestion takes place. The upper part of the digester is mostly water and well digested material. The gas exits the digester through 1/4" drip irrigation valves/tubing (Note: we are finding out that this may be too restrictive), through the steel wool filter and into the base of a 5 gallon bucket. The gas bubbles up through the water/calcium carbonate mixture in the base of the bucket and up into a trash bag. When gas is needed, the gas out valve is opened (3/8" tube for increased flow) and pressure is applied to the bag. The gas flows through the gas out valve and to the stove/generator. Also not shown in this diagram is and outlet valve placed 6" from the top of the digester to drain fluid. This makes room to load the digester, and the fluid can be used as a fertilizer.



The greenhouse is constructed of 1.5" thick insulating foam, clear plastic painters tarp, and duct tape. This is fairly simple construction, however, not necessarily durable. The greenhouse and digester are raised approximately 3" off the ground on a wooden platform to keep the system insulated from the ground. Only one digester is kept in a greenhouse, and the other is kept outside as a control. The goal is to determine whether a digester can be passively kept above 60 degrees fahrenheit (when the average ambient temperature is below 60), and observe whether this temperature difference is enough to affect a considerable difference in biogas production.

Build Progress:

The digesters, gas filtration & collection system, and greenhouse have been mostly completed. The digesters have been loaded and are hopefully producing gas. We still need thermocouples/thermometers and something to measure the pH to start testing the variables between the two digesters.

Here are some pictures of the digester construct:

 **Ben adding expanding foam.**	 **Expanding foam.** This creates more surface area for the biofilm (bacteria) to attach to. Unfortunately the foam did not adhere very well.	 **Cutting the input hole.**
 **Cutting the input pipe.**	 **Applying silicon sealant to the input flange.**	 **The finished input pipe and gas outlet.**

Redoing the input pipes. Attaching the input pipes with silicone is a very crude method, and not particularly durable. This will work for the short duration of the class but will need to be better built for extended use.

And some pictures of the greenhouse construction:

Foam greenhouse walls.

Completed greenhouse.

Making sure the digester fits.

Raised floor construction.

Raised floor. This helps keep the digester insulated from the ground.

And a picture of the gas collector:

The bike pump was used to inflate the collector via the gas line and test the gas out valve. It works great!

The completed system!:

This is a front view of the control digester and the warmed (greenhouse) digester.

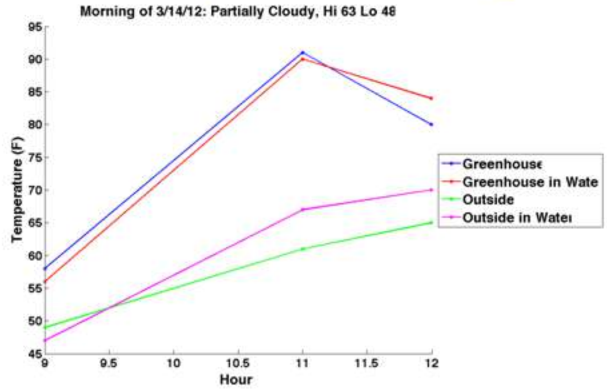
UPDATE Feb 26, 2012

The digesters have been loaded for about a week and a half. We have had a lot of trouble with the input pipes becoming unsealed (no surprise here), but we think we have them well enough sealed to complete the experiment. We need thermometers/thermocouples and something to measure the pH. We are deciding whether we want to add septic tank starter to jumpstart the digestion process (cheating, but might help us get some results before class is over).

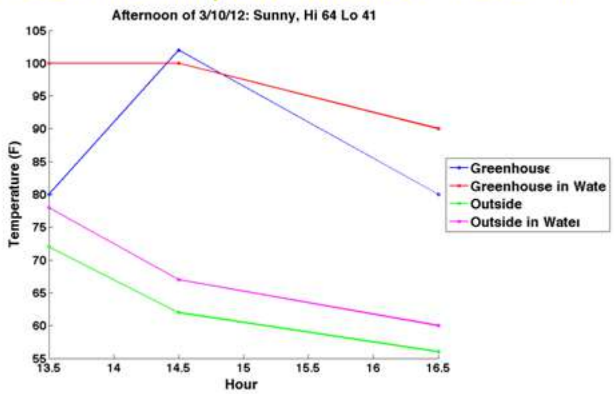
The digesters *are* producing some gas. It doesn't seem to be much at this point, and the pressure doesn't seem to be high enough to overcome the resistance of the relatively small gas line. hopefully this won't be a problem for long. They are definitely producing some gas, however, because as I (*Spencer) was adjusting the fittings and my roommate was standing about 100' downwind, he yelled "why does our driveway smell like farts?!". So at least we've succeeded in annoying my roommate. Yay!

Temperature Data:

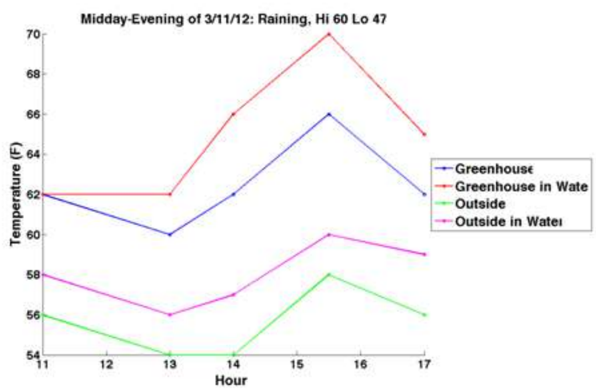
Water Temperature Lags



Peak Temperature: 102° F



In the Rain



These figures show that our greenhouse was successful in passively heating our biodigester. The temperature readings for both inside and outside the greenhouse were taken in the air and in a cup of water to simulate the internal biodigester environment. The water cups were used because we did not want to open out biodigester chambers and expose them to additional oxygen, nor did we want tp submerge our meath thermometer in poop water. There were multiple readings conducted throughout each temperature test day.
We were lucky enough to have a great deal of variation in weather between our test days, and the greenhouse was successful in keeping the biodigester warmer even on a rainy, cloudy day.

Advice for future groups:

- METAL barrels
  - Don't expand/flex under pressure from gas production
  - Easier to work with
- OR: Floating Drum
  - MUCH simpler
- Don't use silicone under tension
- Search for literature using the term "anaerobic digester"
- Double layer plastic sheeting on greenhouse to create an air gap for insulation
- Use larger hose diameter
- Keep your goals & objectives specific and in perspective!

Where we are going:

Our experiments have shown us that this needs to be executed on a much larger scale in order to produce the quantities of gas necessary for cooking. We feel that this concept should be adapted to work with a restaurant or farm instead of a single family home. This also provides a potential business model for people willing to maintain large scale biodigesters. Alterna has expressed interest in coming up with a way to implement large scale biodigesters in Bolivia.

Literature Search:

1. http://www.ruralcostarica.com/biodigester.html
2. http://www.alterna-la.org/en/projects/biodigesters
3. http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/8825/report/0
4. http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/8825/report/F
5. http://www.habmigern2003.info/biogas/Baron-digester/Baron-digester.htm
6. http://www.habmigern2003.info/biogas/Baron-digester/biodigester-design.pdf (schematic for digester)
7. http://www.mekarn.org/procbiod/prest.htm
8. http://www.appropedia.org/Process_for_testing_biodigester_effluent_fertilizer_quality_in_lab_with_IRRI
9. http://www.fao.org/AG/aGa/agap/FRG/FEEDback/lrrd/lrrd10/3/chau1.htm
10. http://www.appropedia.org/Biodigester_effluent_fertilizer_quality_(IRRI)
11. http://www.fao.org/sd/EGdirect/EGre0022.htm
12. http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/semi-centralised-wastewater-treatments/b

New polymeric material removes CO2 from air:

1. http://www.popsci.com/science/article/2012-01/new-material-can-pull-carbon-dioxide-right-out-air-unprecedented-rates

Biodigester Design (Phillipines)

1. http://www.habmigern2003.info/biogas/Baron-digester/Baron-digester.htm

Biodigester Design with HDPE

1. https://docs.google.com/viewer?a=v&pid=gmail&attid=0.1&thid=134fda2bae0845a3&mt=application/pdf&url=https://mail.google.com/mail/?ui%3D2%26ik%3Dea37a94d85%26view%3Datt%26th%3D134fda2bae0845a3%26attid%3D0.1%26disp%3Dsafe%26realattid%3Df_gxnw4ks60%26zw

Biochemical Background Information: Structure of a Cellulose Degrading Bacterial Community During Anaerobic Digestion

1. http://web.mit.edu/velsonj/Public/anaerobic-biogas.pdf

Cellulase and Sugar Formation by Bacteroides cellulosolvens, a Newly Isolated Cellulolytic Anaerobet

1. http://aem.asm.org/content/48/2/446.full.pdf

Cellulase, Clostridia, and Ethanol

1. http://mmbr.asm.org/content/69/1/124.full.pdf+html