ENGINEERS GOING GLOBAL

# BIOGAS PROJECT TEAM REPORT

*For the purpose of reviewing the previous work that has been completed on the Biogas Digester Project, restore the project team with new members, and continuing the ultimate goal of developing a low cost, high efficiency Biodigester for residential and commercial use.*


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**EGG Local Projects Chair**


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## Problem Statement

The purpose of this project is to develop a winterized biogas digester and supplemental manual to raise awareness for the viability of biogas as an energy source in mid-Atlantic climates.

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**Background**

The current global landscape regarding climate change is stark. The scientific community almost unanimously agrees climate change is real and poses a very real risk - more volatile storms, eradicate weather patterns, and rising sea levels. However, the global community is slow to react and tangible reform to lower carbon emissions and other factors contributing to climate change are lacking. One of the pillars of possible reform is developing realistic alternative energy sources. This project aims to explore one of the lower cost options for alternative energy - biogas.

It is no secret that the major players in global climate change are the levels of methane and carbon dioxide being released into the atmosphere. When biogas is used as a fuel, it reacts with oxygen to produce energy, allowing these greenhouse gases to be used up efficiently. Biogas is a completely renewable energy source, working entirely off of waste and sewage. When harnessed correctly, it produces no addition to environmental pollution. That being said, it actually reduces the greenhouse effect; it recycles the majority of biodegradable waste that is produced on a regular basis.

While Biogas does create a source of product for the farmers, it also helps the Chesapeake Bay. Often times, manure enters the water system and travels down to the bay. This increase in nutrient concentrations, mainly composed of nitrogen and phosphorous, can lead to massive algal blooms and result in the Chesapeake Bay becoming entrenched in a eutrophic state. Eutrophication of aquatic systems can cause many problems in Bay's ecosystems, which would cause an overall negative effect for the wildlife and economy of the area. To solve this problem, farmers should start to collect their manure and biodegradable materials to make biogas. This would allow farmers to make a profit using a renewable energy source while also helping the ecology and economy of the Chesapeake Bay.

The main focus of the Biogas Digester project is the researching, designing, constructing and testing of biogas digesters for application in mid-Atlantic region farms and residences. A biogas digester turns organic, biodegradable waste into methane gas that can be harnessed as an extremely low-cost energy source via an anaerobic bacterial process. Biogas digesters are commonly implemented in climates

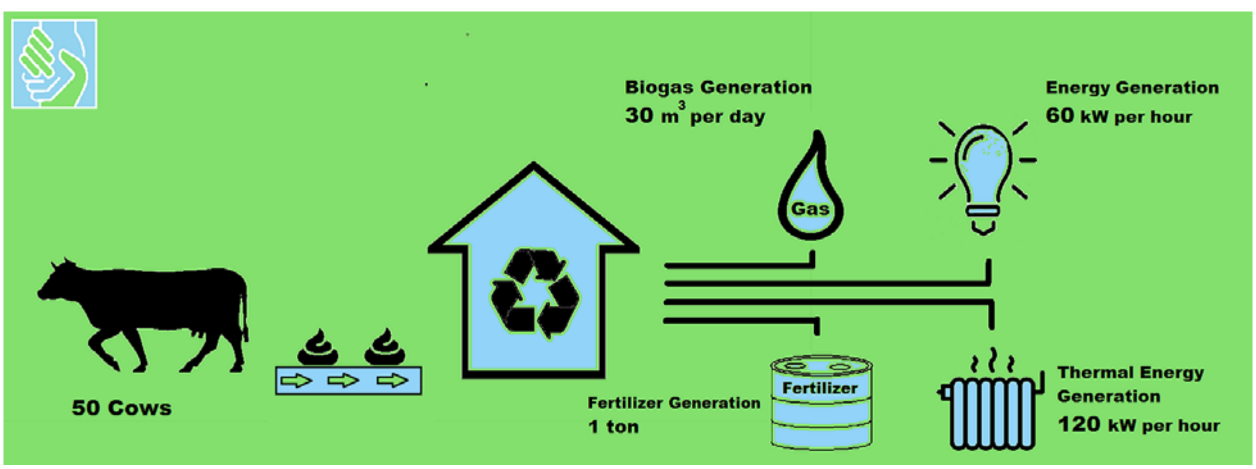


*Figure 1: Biogas Outputs - assumes reactor volume of 30 m$^3$*

where temperatures do not dip much lower than 33 degrees Celsius (approximately 90 degrees Fahrenheit) due to the optimal temperature for productivity of the bacteria within the biogas digester.

Biogas Digester Statistics

- A small-scale biogas plant can save, on average, 4.7 tons of carbon dioxide emissions per year.
- It is estimated that this simple, anaerobic treatment of animal waste and energy could allow over 1,300 tons of methane emissions to be avoided each year.
- When animal waste is used to produce biogas on a farm, carbon dioxide emissions can be reduced by nearly 180% and methane emissions nearly eliminated.

Digester plants isolate and destroy disease-causing organisms that pose a threat to both surface and groundwater. A threat to either of these water systems is a threat to both human and animal health.

Our community of focus is people interested in alternative energy options and their applications. Biogas currently does not have the support it should because it is not understood in this area of the world. We aim to show that biogas can and should be implemented in this area of the world. Sweden leads the world and produces 1.7 TWh of bioenergy a year, over five times more than the United States. China and Germany each produce three times more. The United States is the perfect candidate for increased biogas generation because it is made from a variety of wastes; forestry, sewage, livestock, and agricultural waste can all produce biogas. The United States can utilize biogas in the farming industry to reuse unwanted waste and create products at lower costs and higher efficiency.

## Previous Work

In previous years of the Biogas Digester project, the team has aimed to research biogas digesters, construct their own digester, and perform analyses to ultimately create a pamphlet to distribute to farmers, especially in developing countries, to effectively construct a winterized biogas digester. A few years ago, the team had researched and constructed a semi-working prototype of a floating drum biogas digester that produced enough gas to cook several meals a week. They concluded that this ultimate goal lacked focus and feasibility and took to the drawing board to decide a new direction. After considering many ideas, the team decided to reach out to local farms to see if they would be interested in partnering to build a biodigester on their farm. Since this would be a student project and would not necessarily be permanent, the project team wanted to work with a farm to be able to draw a report about the feasibility of similar projects around Virginia. The Biogas Digester team has recently reached out to many farms, including Morven Farms and Polyface Farms and have already received some positive feedback regarding potential partnerships.

Considering the long-term implications of this project, one must acknowledge the financial and environmental benefits of using biogas as an alternative energy source. The specific polyethylene digester design the team is considering costs under 500 dollars. The implementation of biogas as an alternative energy source is growing, however it is not common to climates like those in the United States. In colder climates, biogas digesters typically incorporate cold-tolerant microbes harvested from lake sediments whereas the project team is aiming to design an innovative and insulating mechanism to winterize our digester (Anthony et Pape, 2011).

## Instructions for Construction of Digester

1. Make sure the bottom of the trench is free of sharp rocks or things that can damage the polyethylene digester
2. Cut two polyethylene bags 1m longer than the desired final length
3. Crawl through the outer bag to make “one tube” with a double coat
4. Cut a small cross hair hole in the double coat towards the middle of the digester
5. Use the rubber pad and the flange screw-nut to tighten the flange so the double coat is caught between this
6. Fasten the inlets to the end of the digester (tire inner tubes?)

“How to Install a Polyethylene Biogas Plant” – Instructions on how to build a biodigester using only a plastic bag, an outgoing biogas valve and a security valve compose a biogas polyethylene plant. This manual was written by Francisco X. Aguilar, an agronomic engineer in the Royal Agricultural College in Circencester in England.

http://journeytoforever.org/biofuel_library/digeste.pdf

## Research

1. Biogas [in general]
    - How to transport/store?
    - Biomethane: safer, less corrosive, more valuable as fuel?
        - Run through compressor and then stored in high pressure tanks
        - Can be liquidfied
        - Can be transported over road, through natural gas tanks

- Made in a biogas generator
    - Official ones sold between $3000-$5000
    - 10-60% converted into energy, approximately 3-18 cubic feet of biogas per pound of input (http://www.motherearthnews.com/renewable-energy/other-renewables/biogas-generator-zm0z14aszrob)

*Table 1: On-Farm Storage Options for Biogas and Biomethane*

| Purpose of Storage | Pressure (psi) | Storage Device | Material | Size ($ft^3$) |
|---|---|---|---|---|
| Short and intermediate storage for on-farm use (currently used on farms for biogas storage) | < 0.1 | Floating Cover | Reinforced and non-reinforced plastics, rubbers | Variable volume usually less than one day's production |
| | <2 | Gas bag | Reinforced and non-reinforced plastics, rubbers | 150 – 11,000 |
| | 2 – 6 | Water sealed gas holder | Steel | 3,500 |
| | | Weighted gas bag | Reinforced and non-reinforced plastics, rubbers | 880 – 28,000 |
| | | Floating roof | Plastic, reinforced plastic | Variable volume, usually less than one day's production |
| Possible means of storage for later on- or off-farm use (could be used for biomethane) | 10 – 2,900 | Propane or butane tanks | Steel | 2,000 |
| | >2,900 | Commercial gas cylinders | Alloy steel | 350 |

Source: Ross et al., 1996.

psi = Pounds per square inch, ambient conditions    $ft^3$ = Cubic feet

- http://www.suscon.org/cowpower/biomethaneSourcebook/Chapter_4.pdf
- Biogas is usually used as it is produced
- Floating gas holder for low-pressure storage (cost-effective)

- How to turn into energy?
    - http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/processes/anaerobic-digestion-general
        - Anaerobic Digestion
            - Results in Biogas and digestate (used for fertilizer)
            - Four Stages:
                - hydrolysis
                - fermentation and acidification
                - acetogenesis,
                - methanogenesis

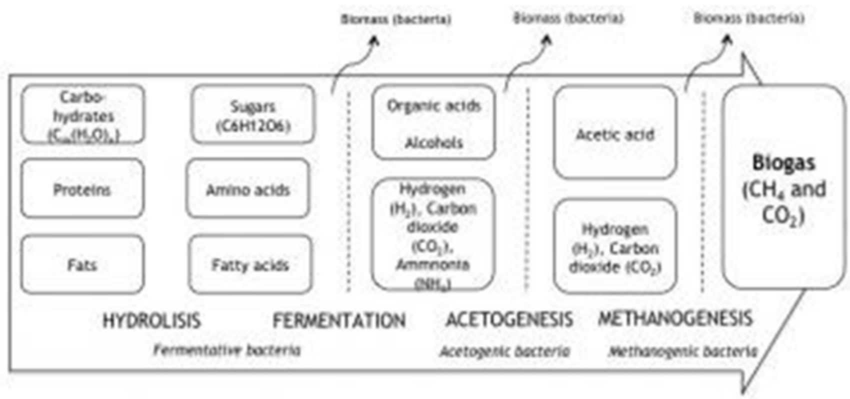


*Figure 2: Biogas Generation Process*

2. How is it used [combustion]?([http://www.sswm.info/content/direct-use-biogas](http://www.sswm.info/content/direct-use-biogas))
    a. Small Scale
        - Combustion engines are typically used (Stirling engines)
            - More efficient
            - Less expensive
        - Used for stoves and lighting
            - Around 300-400L/h for a household stove
            - Per person per meal is around 150-300L biogas
        - Requires modification of stoves to use biogas, larger gas jets and burner holes
        - Average small-scale biogas plant saves up to 4.7 tonnes CO2 emissions per year
        - Reduces workload for collection of firewood
    b. Large Scale
        - Gas Turbines used
            - Cogeneration(CHP) to utilize excess heat as well as electricity
            - CHP leads to efficiency of 89% compared to 55% obtained by conventional plants
        - Used in large scale heating of towns, hospitals, prisons, ect
        - Electricity can be used for supplying a landfill, then the excess can be sold into the power grid
            - Same is applicable in agriculture depending on type of animal manure or crops used

3. Market for selling waste?(Cross Border Bioenergy pdf)
    - Depends on region
    - Selling the gas requires upgrading the gas by removing impurities such as CO2 and hydrogen sulfide
    - Selling of electricity requires an electric grid nearby to combat high connection costs and energy loss
    - Typically more applicable to utilize biogas for an area or plant's needs then selling off surplus

- Not as profitable as typical energy generation, unless supported by investors and government regulation

4. Winterization
   - Would it be possible to head the ground to facilitate gas generation?
     - Only need a minimum operating heat between 55 and 75
     - Need to be heated on the bottom halfway between center and inlet
     - Hotwater
     - Insulation
     - Thermal Blanket
     - Greenhouse
   - Is it possible to use indoors?
     - Greenhouses
     - On grounds?
     - How do you capture/measure the biogas?

5. Where to go with project?
   - Don't give up on Morven?
   - Figure out how to seal
     - Rubber straps of recycled tire tubes
     - Seal with hot iron
   - Figure out what we have and where we left off
     - List of supplies in old archives
     - Supplies are at morvan and in Emily's old house
   - What do buses run on now? ("Clean engine" sticker??)
     - The UVA buses run on some mixture of biodiesel. Biodiesel is made from the oil of plants and animals. It is domestically produced. The percent of oxygen is about 10-12% higher than in regular diesel making it much better for the environment. There is also less sulfur. There are limitations on grand scale making of biodiesel, so most of it is made locally.
     - http://www.virginia.edu/parking/information/sustainability.html
     - http://www.vacleancities.org/cleaner-transportation/biodiesel/
     - The big difference between biogas and biodiesel is 1) biodiesel has diesel in it and 2) biodiesel is not made by decompositions.
     - https://thesustainabilitycooperative.net/2013/12/26/the-difference-between-biofuel-bioethanol-biodiesel-and-biogas/
   - What does Lund (Sweden) do [especially in the cold]? (see Sweden Biogas Success article and Biogas in Sweden article)
     - Since 2005 gasoline fueling stations are required to sell at least one type of biofuel
     - Provide incentives to individuals and publically fund biogas
     - Sweden uses the largest amount of biogas in the transportation sector of any country (over 2000 buses use biogas mixture of 60% biogas and 40% natural gas)
     - Use transportation for urban areas and small scale power and heat generation in rural areas
       - Need to "upgrade" biogas to use in vehicles

- Store mixture in slurry (warmer location) until temperature peaks then put it into the digester
  - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4093558/
  - http://www.wecf.eu/download/2008/Biogascoldclimates_WEB-WECF0608.pdf

6. Problems potentially solved/helped with Biogas
   - Cville UTS
     - If it was easy to convert a biodiesel engine to maybe one that can process biogas, I think it could really be possible for the UVA busses to use biogas. I tried to look up the difference between the engines but I got confused. Not mechanical engineer and there were no pictures :(
     - If it is impossible to convert the engines, I think it's still worth a shot because nearby farms could directly supply to UVA.
     - If this still isn't good, I don't know with the supplies that we have, we could also make biodiesel? This is a really far stretch, but if the processes are similar…
   - Chesapeake (James River)
     - (animal waste contributes to blooms)
     - Lots of farmland in high productivity near james river/chesapeake area
     - So i googled farmland poop in chesapeake and the first 5 results were about chicken poop in maryland being a super big problem… so if they use this chicken poop to make biogas I think everyone would be happy
     - https://4aa2dc132bb150caf1aa-7bb737f4349b47aa42dce777a72d5264.ssl.cf5.rackcdn.com/map_virginia300.jpg
     - "Agriculture is the single largest source of nutrient and sediment pollution entering the Chesapeake Bay. According to 2012 estimates from the Bay Program, agriculture contributes 42 percent of the nitrogen, 58 percent of the phosphorous and 58 percent of the sediment entering the Bay." This is a really big deal because the limiting reactants for plants to grow is nitrogen, phosphorus, and potassium.
     - http://www.chesapeakebay.net/issues/issue/agriculture#inline
     - This is a really long article about how manure is bad for the bay
     - chrome-extension://ecnphlgnajanjnkcmbpancdjoidceilk/content/web/viewer.html?file=http%3A%2F%2Fwww.cbf.org%2Fdocument.doc%3Fid%3D137

7. Greenhouse/winterizing
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   - Use of a hoop house
     - Similar to a greenhouse but is used to heat up the ground directly.
     - Could be small and removable
     - Could even make it ourselves to save money

- Most likely couldn't be used in winter but definitely could make our starting time earlier for the digester in the spring
  - Unable to find hard numbers on what the temperature inside is or how much it can heat the ground
  - http://www.motherearthnews.com/renewable-energy/heating-a-diy-biogas-digester-zbcz1411
- Found this article about making biogas digesters for winter
  - *Mesophilic* digestion takes place optimally around 30 to 38 °C, or at ambient temperatures between 20 and 45 °C, where mesophiles are the primary microorganism present.
  - *Thermophilic* digestion takes place optimally around 49 to 57 °C, or at elevated temperatures up to 70 °C, where thermophiles are the primary microorganisms present.

*Table 2: Operating Temperatures of the Biogas Digester*

| Operating Temperature | Temperature (°F) | Time to break down waste | Pros & Cons |
|---|---|---|---|
| Common | 50-85° | 30 days | Very robust, can withstand day/night temperature changes and extended periods of inactivity. |
| Medium | 85-100° | 15 days | Use caution when changing temperature or loading. |
| High (Not Recommended) | 122-131° | 3 days | Extremely fragile, cannot withstand +/- 5° variation in temperature. |

## Future Goals for the Project

The Biogas Digester project should look to accomplish three main goals. The first is to build a prototype that is low cost, easily assembled, effective and efficient. This will be accomplished by using the past research and work from previous teams along with new information gathered from future teams to create a design. The team will likely receive funding from EGG internal grants or other funding sources within the University. Once the funding is secured, the team will purchase the necessary materials and create the prototype at one of the partnered farms, likely Morven Farms.

The second goal of the team is to create a professional manual that details the materials, construction, and use of the Biogas Digester so that farms can easily implement the system for their own purposes.

The third goal is to spread the manual to farms and educate the public about biogas as a renewable energy source. This will be done by traveling to different farms and towns in the area, attending conferences, and partnering with professionals to increase use of the biogas digester system.

## Citations


Anthony, Katey Walter et Casey Pape. “Denali Emerging Technology Grant: Improving Cold Region Biogas Digester Efficiency.” Web. 2011. <http://acep.uaf.edu/media/60995/Cordova-Final-Report.pdf>.

Brown, Laura. “Gas Bio-Digester Information and Construction Manual for Rural Families.” Web. 2004. <http://www.sswm.info/sites/default/files/reference_attachments/FUCOSOH%20ny%20Gas%20Bio-digester%20Information%20and%20Construction%20Manual%20For%20Rural%20Families.pdf>.