Biogas Nicaragua

Background

- Nicaragua's Rural Population and Energy -

In recent years, Nicaragua has reached an important crossroad of growing unmet energy needs and unique alternative energy opportunities. A developing nation, Nicaragua's population is predominantly (>43%) rural. The third poorest country in the Western Hemisphere, Nicaragua suffers from widespread poverty and a lack of access, especially for the rural poor, to a reliable source of energy. In 2005, CAFTA determined 51.9% of the population was below the Nicaraguan poverty line. USAID determined that 75% of the population lives on less than $2/day. The World Bank recently reported that, in 2003, 59% of rural inhabitants did not have access to electricity or a reliable source of energy and reduced access to a reliable source of energy is a determinant of poverty for rural households. But, how can Nicaraguans address their energy needs while still emphasizing an environmentally-friendly, renewable, healthy alternative to burning wood or buying fossil fuels for everyday chores like cooking.

Currently, biomass in the form of wood (both purchased and collected) represents a ubiquitously used and relied on source of energy for cooking among rural populations across all income classes. However, in Nicaragua there is a need to move away from burning firewood and buying fossil fuels (and to adopt more appropriate alternatives) precisely because of the disadvantages associated with these conventional energy sources. Collecting firewood for burning can lead to significant negative environmental consequences. Burning wood for example has proven to be a major cause of indoor and outdoor air pollution. Furthermore, indoor air pollution from solid fuels is ranked by the World Health Organization as the world's 8th largest health risk. Finally, burning wood is largely inefficient and can have a dramatic effect on human productivity and economic development. Cooking with wood takes up more time than cooking with alternative fuels such as natural gas and gathering the wood for this purpose takes up time as well. Buying fossil fuels such as liquefied petroleum gases (LPGs) also inhibits rural inhabitants from saving a larger percentage of their income, simply because they must meet their energy needs. In these situations, it becomes harder, especially for the poor, to climb the social ladder because there is a constant need to dedicate a large portion of time to the day-to-day tasks of cooking (when using wood) and ensuring there is even enough fuel to cook (when having to buy expensive fuels).

- Biogas Technology -

Biogas, or natural gas, is a particularly appealing technology for farmers with livestock, as the excrement from those animals, previously not used for anything other than fertilizer, can be used as the source of fuel for biogas producing digesters (with fertilizer still remaining as a byproduct). We aim to target the community surrounding the town of Diriamba, Carazo, Nicaragua with our project of installing a multi-phase biogas digester for optimized methane production.

Our team, Biogas Nicaragua, will work on the land of an ecological reserve/farm called Rancho Guadalupe to build a prototype, designed at MIT, that reduces retention and startup times, and improves the energy production of existing biogas technologies implemented in Central America. We will work closely with the Rancho Guadalupe Director and students from the National

University of Agriculture to build a full scale prototype and a model rural Nicaraguan kitchen as a proof of concept exhibition for possible adopters of the novel, alternative biogas technology with the goal of documenting and addressing the energy needs of the rural inhabitants of Diriamba, presenting them with an eco-friendly alternative for energy generation with our integrated system.

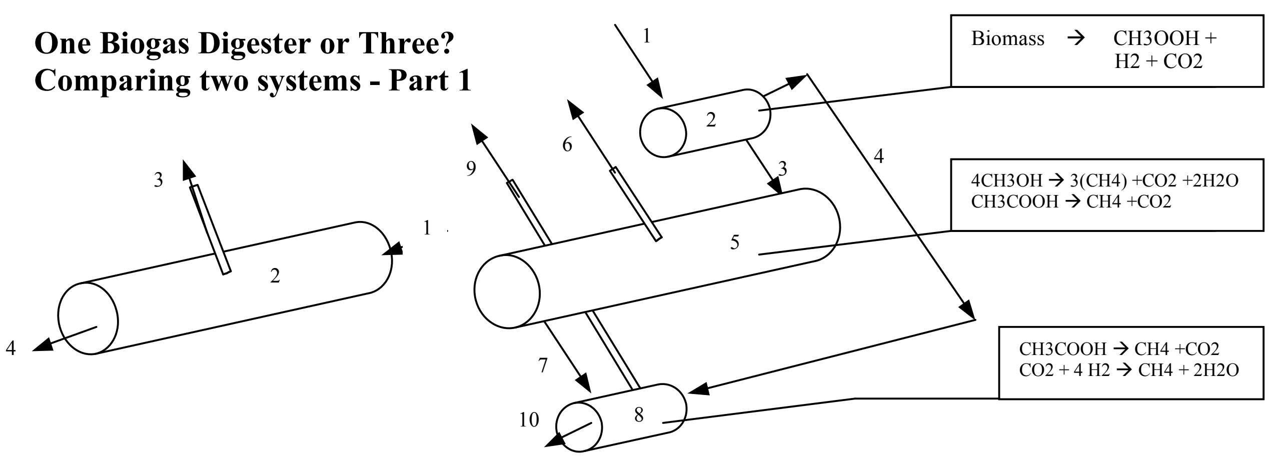
- Current Biogas Technology -

The technology practiced in Nicaragua currently employs long bags of polyethylene plastic material which form tube plug-flow biogas digesters. These digesters are often located in trenches dug into the ground with three basic connections: an input for excrement, and output for exhausted biomass (used for fertilizer), and a connection directing produced biogas to a storage container. However, these digesters have three particularly weak characteristics requiring improvement:

1) the digesters are run as single phase batch reactors which can lead to high retention times
2) the digesters are stand-alone reactors with long startup times and discontinuous energy supply
3) the digesters are often built after other important structures have been built (i.e. the structure of the pig pen and the layout of the cooking quarters are not synergetic with the fuel producing device)

Our team labels these characteristics as design "weaknesses" because they add to the expense of implementing biogas as an alternative energy source. High retention times equate to low efficiency in terms of the time it takes to realize a biogas yield from a biomass input. Long startup times equate to high initial time commitments required for each instance of a biogas digestion. Discontinuous energy supply implies an unreliable method and a need to still rely on other energy sources during intermittent periods. Finally, non-synergetic structures require inefficient and inconvenient connections as well as a layout which may take up more space than is necessary or available. See Fig.1 and Table 1 for a comparison of the current technology with our proposed technology.

One Biogas Digester or Three?
Comparing two systems - Part 1



1. Animal manure is biomass input
2. The only digester in this system, the main digester, contains all the numerous different reactions that take place in the methanogenesis bioprocess.
3. Biogas stream from the digester.
4. Waste output (fertilizer).

1. Animal manure is biomass input
2. Biodigester one (Acid Phase)
3. Acidified material from the Acid Phase digester is input to the Methane Phase I digester
4. Carbon Dioxide gas is recycled from Acid Phase digester I to the Methane Phase II digester
5. Methane Phase I digester
6. Biogas produced from Methane Phase I digester
7. Material proceeds from the Methane Phase I to the Methane Phase II digester
8. Methane Phase II uses carbon dioxide from the Acid Phase and biomass material from Methane I.
9. Biogas stream from Methane II.
10. Output waste stream (fertilizer)

Table 1 – Comparison of features and characteristics of single and tri-phase biogas digester systems

One Biogas Digester or Three? Comparing two systems - Part 2		
	Current Single Phase System	**New Tri-Phase System**
Process Mode	Batch	Continuous
# of Phases/Digesters	1	3
Digester Dimensions (length, ft, radius, ft,)	Digester 1: 30 feet x 3 feet	Digester 1: 5 feet x 3 feet Digester 2: 30 feet x 3 feet Digester 3: 8 feet x 3 feet
pH Control	No	Yes
Startup Time	~14-21 days	~7-14 days
Hydraulic Residence Time (days)	14 days	7 days
Theoretical Biogas Production (ft^3/lb of volatile waste solids)	Stream 1: ~5	Stream 1: 5-6 Stream 2: ~0.3
Methane Stream Purity (volume)	~60%	Stream 1: ~70% Stream 2: >70%
Strengths	- 1 digester is easier to understand than 3 - 1 digester uses slightly less material	- different chemical reactions are separated in different reactors allowing for the optimization of environments with pH and temperature - A continuous process has lower retention time at steady state - A three phase digester solves the problem of slow startup times, especially when one digester bag has to be replaced (the other two can keep running).
Weaknesses	- A batch process combines 3 different chemical reactions in the same space (less efficient) - Once the single digester is exhausted and must be replaced, the process must be stopped entirely - Long startup times - Long retention times	- A three digester system takes longer time to build - A three digester system requires more material and is thus more expensive - A three digester system may be harder to understand/maintain.
Cost in Materials ($) per year (material replaced each year)	$120	$144
ft^3 of biogas produced in one year (assuming 5 lbs volatile solids/day)	5475	7409.5
Cost per ft^3 of biogas produced	~$0.022	~$0.019
Money spent by rural small farmers on Energy (provided by Rancho Guadalupe) per month	$36.44	$36.44
How many ft^3 of biogas money spent on energy could buy per month (assuming plentiful animal waste)	~1656	~1918 (~16% greater output, conservative estimate)

Innovation

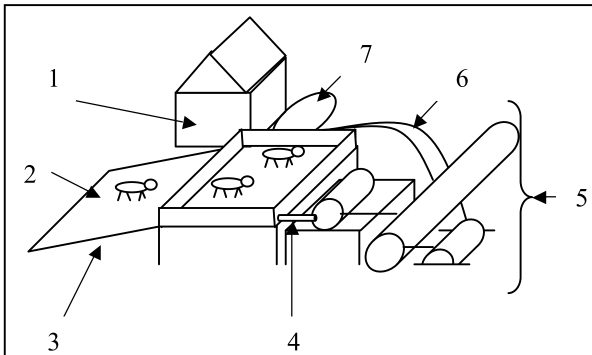
By optimizing the design and process of methane production from biogas digesters we will address the issue of the growing energy need in the area surrounding the town of Diriamba, Carazo, Nicaragua. To address these issues, our team has developed a three-tiered scaffold which was designed to incorporate three interdependent reactors that are part of a multiphase continuous biogas digester. The innovations of our project are:

- Having a three-stage process that allows for separation of the phases of methane production which enables more regulation of the pH in the various production stages resulting in an optimized environment for methanogens and other bacteria to convert biomass into biogas. This then increases the potential for this model to yield more methane per same amount of manure than single-phase biogas digesters.
- Incorporating more process engineering principles into the design of biogas digesters by calculating the optimum size of the polyethylene bags and their relative heights and angles to each other, providing a support structure, and exploiting the natural occurring gravitational force in order to facilitate autonomous process dynamics and achieve a continuous production of biogas at steady state.
- Having an approach to integrate rural house planning with energy structures that involve biogas technology, like our multi-phase biogas digester.

The multiphase continuous process optimizes the existing technology and is achieved by implementing the concept of reaction specialization. Although a biomass digestion can be very simple to perform, the digestion actually possesses several different reactions, “steps”, which require a unique set of environmental conditions. Synthetically creating the right environmental conditions, for example by better controlling the pH, and separating these conditions in space (in three different containers) allows for phase specialization and lower retention times.

The skid of three interdependent biogas digesters allows for a higher throughput into the system. Furthermore, this three part continuous system is more conducive for a regularly scheduled consistent input of biomass (in this case excrement) and regular supply of energy from biogas once steady state is achieved. This allows for the user of the biogas digester to always have access to some biogas without delay.

The structural design layout (see Fig.2) is paramount for continuous operation and synergy with other existing structures. Having the option to integrate this stand-alone structure with an existing system of buildings (i.e. living/cooking quarters and an animal containment system) as well as the option to integrate it into a larger home/animal pen/digester scheme promotes an attitude of intelligent design and infrastructural planning.



1. Nicaraguan farm home
2. Livestock (pigs) manure is used as biomass/fuel for the biogas producing digesters.
3. A ramp is used to transport livestock to an elevated position in a closed pen.
4. Livestock waste is hosed down with water and funneled into the first digester using gravity.
5. The tri-phase continuous biogas digesters are situated such that gravity can facilitate material flow.
6. Biogas is sent to storage bag.
7. The biogas storage bag is near the house and used as needed for cooking purposes.

Fig. 2 Model Nicaraguan Biogas System

Our innovations (see Fig.3) target the energy problem in our Nicaraguan community by providing a steady state source of energy that agrarian farmers in the rural off-grid sections of Nicaragua can rely on to cook food in their homes. This will also lessen the harmful impact they have on the environment, as they will feel less compelled to burn firewood to meet their needs.

Our idea is better than existing solutions to the community need because our device would produce biogas continuously, meaning there is always some biogas when you need it. Our idea would also lead individuals in the community to spend less time collecting firewood and would instill some marketable abilities as they can gain income from installing biogas digesters for others. Our device is friendlier to the environment than the current solutions being used: the burning of firewood and fossil fuels. Because of the design of our device, we can lower the retention time of the biomass and separate the various chemical reactions into different reactors which allows more control over the optimization of the environment for each specific reaction since the requirements for each reaction to take place are not necessarily the same.

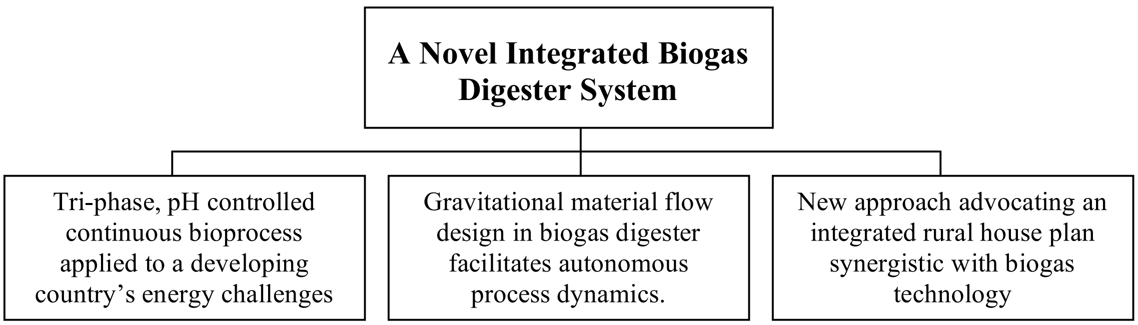


Fig. 3 – Innovation Umbrella

Feasibility

Our team has already accomplished several important goals crucial for establishing the foundation upon which we will move forward with our project. The milestones can be divided up into two categories: work towards developing the technology, including prototype building and testing, and work towards building community relationships with our partners in Nicaragua and Guatemala.

- Developing our Technology -

Since the beginning of the spring semester, our team has designed, built, and begun testing a 1:75 scale-down working prototype of the biogas digester we intend to build in Nicaragua. The similarities between our working prototype and the actual implementation of the full-scale biogas digester in Nicaragua are shown in Figure 5. Experiments with our prototype are currently still running and we will have analyzable data very soon. Along with the development of our prototype, our team has been focusing on creating an exhaustive list of materials for the creation of a full scale reactor in Nicaragua. (For the list of materials and relative costs please refer to the budget).

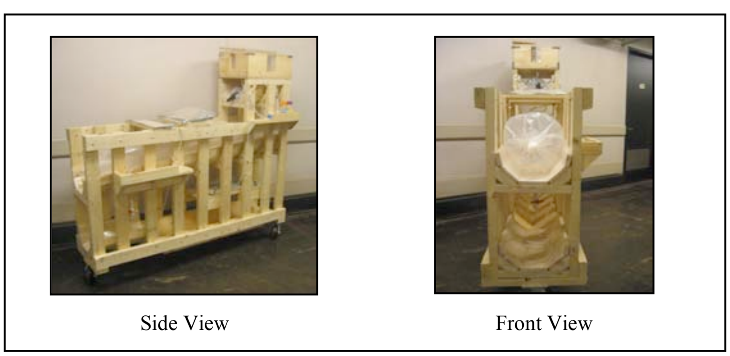
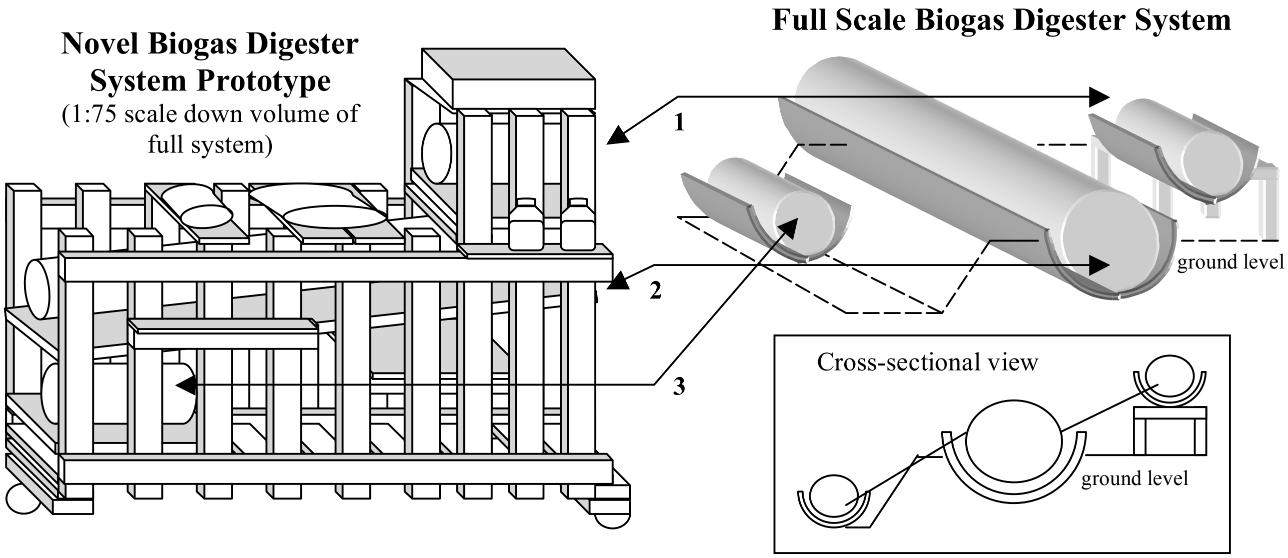


Fig. 4 – Pictures of the 1:70 scale down prototype biogas digester



1. The first step in the tri-phase biogas digester system is an Acidic phase to break down biomass
2. The second step in the process is the Methane I phase, turning acetic acid into carbon dioxide and methane.
3. The third stage in the process is the Methane II phase which uses recycled CO_2 to make more methane.

* Note* although not pictured another innovation of our design is the pH control, not shown.

Fig. 5 – Relating the current biogas prototype to the real world application

- Building our Community Partnerships -

One of the most important aspects of our project is our close relationships with our community partners. Our team has worked hard towards designing a project in which our community partners can take ownership. Our first community partner is our project supervisor, primary contact in Nicaragua, and friend, Mr. Humberto Solorzano, Proprietor and Director of the Ecological Reserve Rancho Guadalupe in the Diriamba area of southwestern Nicaragua. Mr. Solorzano has kindly agreed to host our biogas project on the reserve for the purpose of acting as a platform for disseminating our "eco-friendly" technology to the local community.

Mr. Solorzano is an excellent supervisor because he is well connected with the local community organizations as well as the heads of the local government. He is affiliated with the committee of ecological awareness of Diriamba, and the local association of agrarian landholders. Mr. Solorzano is also open to new technologies and student research. He recently donated 5 acres of the Rancho Guadalupe Ecological Reserve to a local university, la Universidad Nacional Agraria, for conducting ecological research projects. One recently implemented project involved using solar panels to power a water pump for drinking water. This generous donation and the collaboration between the Ecological Reserve and the university exemplify Mr. Solorzano's support for ecological awareness, sustainable development and student research.

Other community partners include a local University, la Universidad Nacional Agraria. Mr. Solorzano will be helping us identify approximately 3 students from the university to help out with the implementation of our program. By involving students from the local university, and soliciting the help of Mr. Solorzano, we will create an ongoing biogas technology research program based out of the Rancho Guadalupe Ecological Reserve. See Table 2 for a complete list of partnerships.

Table 2 – List of Community Partnerships and Roles

Community Partner	Involvement in Project	Reason for Involvement	Location
Mr. Humberto Solorzano	Project supervisor, primary contact, Director of Rancho Guadalupe Ecol. Reserve.	Director of Ecological Reserve, can provide land, assist with material acquisition, fluent in English.	45 Km southwest of Diriamba, Nicaragua
Mr. Roberto Gonzalez	Secondary contact, relative of team member, Xavier Gonzalez	Familiar with the area in Nicaragua, lives nearby the town of Diriamba, can assist with securing housing/food.	65 Km southwest of Diriamba, Nicaragua
Universidad Nacional Agraria (UNA).	Providing a team of students (Mr. Solorzano is assisiting with this because of his prior project experience	Partnering with the local university can provide continuity and sustainability for our project	Km 12 1/2 carretera Norte - Apdo. 453
Ministerio del Ambiente y Recursos Naturales (MARENA)	Consultant group, can show us the most effective way to communicate benefits of biogas	MARENA is an established, reputable environmental conservation organization in Nicaragua with experienced volunteers	Managua, Nicaragua
Cooperativa de productores apropecuarios y agroindustriales de Diriamba(COOPPAAD).	Consultant group, will aid with the identification of new candidates for biogas digestion systems.	COOPPAAD meetings (which are attended by Mr. Humberto Solorzano) can provide a forum for disseminating and gathering information	Diriamba, Nicaragua
Appropriate Infrastructure Development Group (AIDG)	A small NGO working in Guatemala, our team is maintaining a dialogue with this organization to inform them of our progress in Nicaragua.	By keeping a dialogue with this group which is also very interested in developing biogas technology infrastructure in Central America, we are leaving our options open for possible project expansion into Guatemala	Weston, MA Quetzaltenango, Guatemala

- Challenges and Solutions -

For an accurate gauging of the feasibility of our project, an accounting of present and predicted future challenges is in order (see Table 3). To date, we have experienced challenges in nearly every regard from our prototype to our community partner, but we have nonetheless also seen these challenges as opportunities for growth. Two major challenges we have experienced with our prototype have involved 1) the choice of materials for the digester (both our scaled down prototype and what we plan to use for the full scale version) and 2) the connections between the digester bags in our prototype. As far as these

having to change our target from Quetzaltenango, Guatemala to Diriamba,
Nicaragua because our original community partner AIDG did not have the necessary resources or time to support us in implementing our project this summer. This challenge, however, has transformed into a potential opportunity for expansion. Once our project is deemed successful in Nicaragua then we can make use of our relations with AIDG to extend the sustainable benefits to Guatemala in the following summers. We addressed this challenge by finding a great community partner in Diriamba, Nicaragua who is very open to new biogas technologies and is allowing us to make use of his land, cattle, and local connections to make our project a success.

Table 3 – Project Challenges and Solutions

Challenge	Term (short, long)	Status	Solution/Potential Solution	Resources to consult to help solve challenge
Material for biogas container in prototype	Short	Solved	Low density polyethylene plastic	N/A
Gravity controlled Process Dynamics in prototype	Short	Solved	Vertical wooden scaffolding structure	N/A
Making good connections between biogas digester bags	Short to Long	Partially Solved	A combination of using a latex rubber septum with duct tape	MIT D-Lab instructors, AIDG
Selecting the right target community in Central America (switching from one community partner to another)	Short to Long	Solved	A Nicaraguan Ecological Reserve specializing in appropriate technology development is currently the best option for maintaining a platform to diffuse our innovation (in this case to the local community in Diriamba, Nicaragua)	Past MIT D-Lab Guatemala teams, the Public Service Center at MIT,
Biogas Digester maintenance	Long	Unsolved	Involve students from la Universidad Nacional Agraria in maintaining the biogas digester project	Mr. Solorzano
Securing an inventory of Materials in Nicaragua	Long	Unsolved	We could find out who supplies materials to la Universidad Nacional Agraria and see if we can also use the same suppliers.	Mr. Roberto Gonalez, Mr. Solorzano La Universidad Nacional Agraria

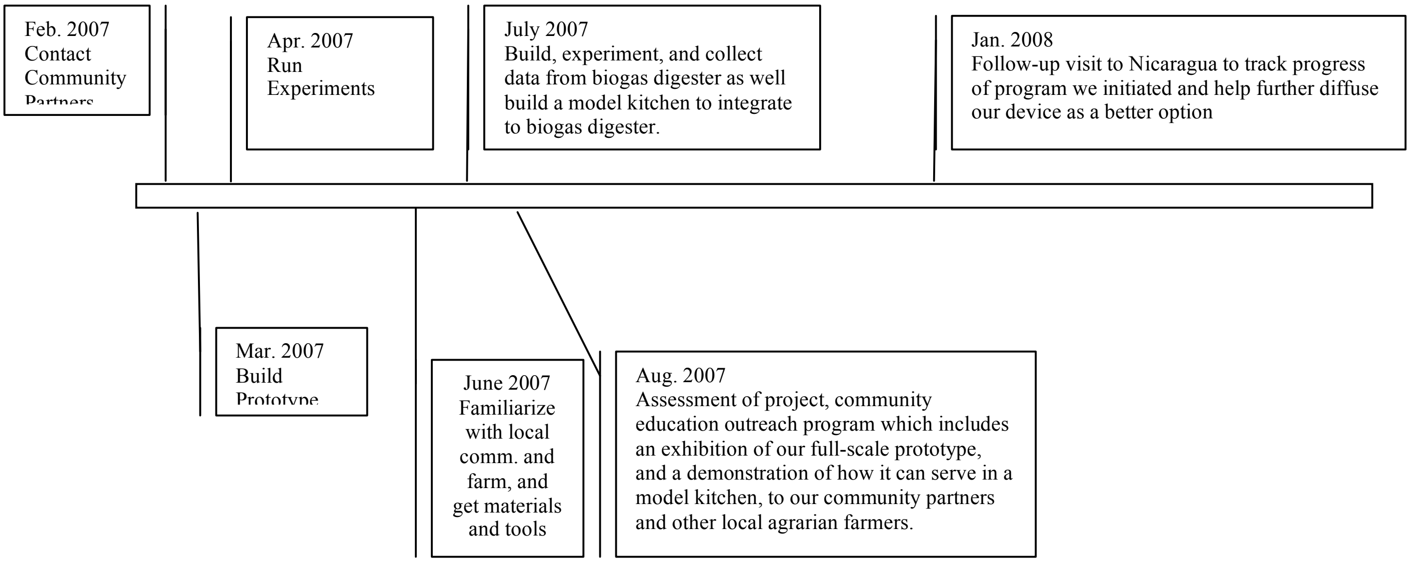
- Sustainable Benefits -

The success of our project and the sustainable benefits that can come from it are not dependent on whether our team's particular biogas digester design proves to be superior to existing biogas technology in Central America. Our goal is to get the students and the proprietor informed and excited about this new alternative technology and to plant the seed of a program geared towards solving Nicaragua's energy problems in the context of biogas technology. Our device is just a tool to get the local community excited and thinking about how to solve their energy crisis. Even if our multi-phase biogas digester fails, we will nonetheless still have the impact of having initiated a program that involves the proprietor of the ecological reserve, the committees he is a part of, and the university he has donated research land to. This impact will remain long after we leave Nicaragua.

However, if our version of an optimal and simple biogas digester actually works and produces more methane than the current design yields, then we will be also leaving behind the "blueprints" to our model to our supervisor, his local committees, and most importantly to the university students running our program in order for this design of ours to diffuse to the rest of the agrarian population.

- Implementation Plan and Timeline -

The first step is to get to Nicaragua and get familiarized with the surroundings. The next day we will take inventory of our materials and tools in order to get any missing pieces or tools throughout the week at the local hardware store. Also taking place in the first week, will be the surveying of the land and animals which we will use to implement our multi-phase biogas digester. Once this is done, we will focus on meeting our community partners by setting up meetings through our host/supervisor.



The next set of weeks will focus on data gathering from the local community through the form of surveys as well as building our biogas digester (about 3 weeks). Once this has been accomplished, we will immediately start experimenting to see how effective our multi-phase biogas digester is at producing more biogas than the current system. This will go on for two weeks, from which then we will move on to assessing the success of our device based on the data collected from the experiments. The last two weeks of our stay will be used to improve on our current design (if necessary), have a presentation with our full-scale prototype to which we will invite our community partners as well as local agrarian farmers to teach them about our device and instruct them on how to install identical ones in their own farms. We will also make use of this time to work with the university students in order to provide longevity to our project by initiating a program that they will continue to run in order to ensure that the benefits are sustainable, independent of our presence.

Over the next following breaks, winter break and summer vacation we will return to Nicaragua to track the progress of our project and see it how it has diffused. We will make sure to apply marketing principles to its diffusion in order for it to disseminate more effectively across the region, but only after weighing the actual benefits that those who adopted our innovation early on noticed over the six-month period. In these follow-up visits we will make sure to inculcate renewable energy and biogas technology information to the local agrarian farmers by organizing and holding seminars for them to attend. Last but not least, we will continue to foster our relationship with the university students from la Universidad Nacional Agraria in order to keep the program we started alive.

- Project Scope -

The geographical scope of our project is to start off with one critical ecological reserve on the outskirts of the town of Diriamba, Nicaragua and have this innovation spread to the nearby, surrounding, small rural villages of La Trinidad, Cenizas, Amayito, Las Esquinas, Masatepe, and San Marcos. We aim to make one full-size multi-phase biogas digester on the land of our superviser, who is an influential and respected community leader, to serve as an impetus to make others follow suit. His influence in the local community and relations with the mayor of Diriamba will be very helpful in the dissemination of our innovation.

If this innovation wins the approval of the large nearby city of Jinotepe then there is potential for this innovation to bounce all the way back to the farms near the capital, Managua, and from there spring board to the rest of the nation. We also have future intentions of working with AIDG and having an analogous program run through them in Guatemala.

Community Connection and Impact

We intend to serve the local agrarian farmers and know that we are providing a service to them because we are helping this community become less dependent on fossil fuels and firewood as fuel and promoting small-scale energy generation system. We are also increasing the local population's access to and knowledge of renewable energy and energy services as well as providing a model of replication that can be adapted to their homes.

The first person affected by our work is the proprietor of the ecological farm "Rancho Guadalupe" which is where we will be installing our multi-phase biogas digester. We strategically chose this person as our supervisor and host because he is an influential community leader and is willing to be an early adopter of this innovation. If our full-scale
prototype is successful at his ecological reserve, then it will have a ripple effect that will inevitably reach the surrounding farms and those of the surrounding towns. We will also be affecting the university students, whom Mr. Solorzano is connecting us with, by giving them an additional project to get excited about and continue their research with.

Our project will affect the local agrarian farmers of the area surrounding Diriamba by providing a device that serves as a continuous source of energy so that they can meet their primary needs of having to use environmentally unfriendly methods such as burning firewood.

Some additional effects that this project will have on us or others is that it will spawn a growing interest in us to facilitate the process of installing biogas digesters in order to make it less time consuming and less material sensitive. We might even venture into starting our own company where we could mass-produce products that can be sold at affordable prices to deal with the aforementioned issues. Some of these products could include preassembled polyethylene bags with proper seals and tubing as well as do-it-yourself kits to install biogas digesters on a larger scale and affect a greater amount of people.

Biogas Nicaragua:
Budget Summary

Effective Dates: June 5th, 2007 (*Month*) **TO** August 20th 2007 (*Month*)

		1st Year Project Budget
EXPENSES		
Multimedia Expenses		$215
Equipment Expense		$4,407
Administrative Expenses		$150
Travel Expenses		$1,300
Living Expenses		$1,970
Contingencies		$804
EXPENSE SUBTOTAL		$8,846
SOURCES OF REVENUE		
Current Revenue		$900
REVENUE SUBTOTAL		$900
GRAND TOTAL		**($7,946)**

Project Expenses

MULTIMEDIA/PUBLICATIONS: EXPENSES FOR PRODUCTION AND DISSEMINATION OF MULTIMEDIA PUBLICATIONS		
Printing/Publications	**Costs**	**Comments**
"What is Biogas" Publication	$125	100 copies at $1.25 per copy.
Sample "New Home Design" Publication	$63	50 copies at $1.25 per copy
What type of Energy do you use survey	$28	200 copies at $1.25 per copy
Multimedia Subtotal	**$215**	
EQUIPMENT PURCHASE:		
Item	**Costs**	**Comments**
5 disposable cameras	$100	To be distributed to local youth in the surrounding area for the purpose of information gathering and survey distribution
Portable pH meter	$629	For experimental analysis in our research. Not for common installation of biogas digesters. IQ Scientific Instruments Inc., Model: IQ150 pH Meter with Micropro
Hydrochloric Acid	$53	Product maintenance
Sodium Hydroxide	$36	Product maintenance
Duct tape	$80	Product component
Polyethylene roll	$110	Product component
Latex gloves	$80	For sanitation purposes and also used to seal crevices where tubing is inserted to bags.
PVC tubing	$245	Product component
Vinyl tubing	$300	Product component
Portable Gas Analyzer	$1,900	For experimental analysis in our research. Not for common installation of biogas digesters. RKI Eagle portable carbon dioxide and methane gas analyzer (used) distributed by Apollo Safety in Boston, MA.
Litmus paper	$25	For experimental analysis in the common installation of biogas digesters.
Miscellaneous supplies, cement, and brick	$850	Nuts, bolts, PVC connectors, materials to build model kitchen for exhibition, etc.
Total	**$4,407**	
ADMINISTRATIVE EXPENSES: TELEPHONE, ONLINE COMMUNICATIONS, EQUIPMENT MAINTENANCE, AND OTHER SUPPLIES.		
Expense	**Costs**	**Comments**
200 Minute phone cards	$50	For making calls to the united States
100 hours of Internet Cafe Use	$100	@1.50 per hour
Total	**$150**	

ALL EXPENSES ASSOCIATED WITH TRAVEL (E.G., TRANSPORTATION, HOTEL, ETC.)		
Expense	**Costs**	**Comments**
3 Tickets to Nicaragua	$1,200	
Taxi Rides in Boston and Nicaragua	$100	
Total	**$1,300**	

LIVING EXPENSES		
Expense	**Costs**	**Comments**
60 Days and Nights	$920	Subsidized in part by local connections
Food for 60 Days and Nights	$1,050	@2.00 per day per person
Total	**$1,970**	

Budget for Making One Multi-phase Biogas Digester

Item	Cost	Comments
Hydrochloric Acid	$4	Product maintenance
Sodium Hydroxide	$3	Product maintenance
Duct tape	$18	Product component
Polyethylene roll	$20	Product component
Latex gloves	$8	For sanitation purposes and also used to seal crevices where tubing is inserted to bags.
PVC tubing	$33	Product component
Vinyl tubing	$17	Product component
Litmus paper	$1	For experimental analysis in the common installation of biogas digesters.
Miscellaneous small supplies	$40	Nuts, bolts, PVC connectors, etc.
Total	**$144**	

Budget for Making One Single-phase Biogas Digester

Item	Cost	Comments
Duct tape	$16	Product component
Polyethylene roll	$17	Product component
Latex gloves	$8	For sanitation purposes and also used to seal crevices where tubing is inserted to bags.
PVC tubing	$27	Product component
Vinyl tubing	$12	Product component
Miscellaneous small supplies	$40	Nuts, bolts, PVC connectors, etc.
Total	**$120**	

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United States Agency for International Development: Nicaragua

United Nations Development Program- Nicaragua

The CIA World Factbook - Nicaragua

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