EWB Challenge 2011
Submission Cover Sheet

Instructions

Participating universities may enter up to four team submissions per university per year for external judging (if the EWB Challenge is run in both semesters, the semester in which the course is run follows the submission deadline for that semester).

This cover sheet must be submitted with each team entry. If your university submits four entries, four cover sheets are required.

Each submission MUST include the following:
- Completed cover sheet (MS Word preferred)
- Executive summary as part of the report (for more information, go to http://www.ewb.org.au/submission)
- One (1) electronic copy of the report (PDF preferred or MS Word) via email

Optional:
- Supporting materials (MS PowerPoint presentation, software, video) via email.

Submissions should be sent via either of the two following methods:
1. Email electronic copy to ewbchallenge@ewb.org.au (with completed coversheet) or
2. Via You Send it (for files over 2 MB in size), accessible from details below:
   www.yousendit.com/
   Email: d.loden@ewb.org.au
   Password: P@ssword

Submission deadline (Semester One): 22 July 2011
Submission deadline (Semester Two): 28 October 2011

Please complete this coversheet and send electronically:

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Bio-digesters in Devikulam Report

Assignment 4

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ABSTRACT

As part of the Engineers Without Borders 2011 challenge we have researched and considered a biodigester design, applicable to Devikulam, Tamil Nadu, India, in order to address health concerns over burning of biofuels. Given the developing nature of Devikulam, a reliable and culturally appropriate design and procedure to implement has been developed.

We have selected a concrete box dome-like design to make construction easier than the traditional dome and have encouraged the introduction of crops to accommodate the gas needs of the village for cooking. We have also addressed possible safety issues.
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1.0: Introduction

1.1: Engineers Without Border

Engineers Without Borders Australia (EWB) is a humanitarian, not-for-profit organisation pursuing the betterment of developing communities through engineering practices. They work with communities worldwide through grassroots engineering programs that provide innovative, appropriate and sustainable solutions to the small-scale issues that developing communities face. Moreover they impart knowledge, resources and improved technology with these communities and help develop their livelihoods in partnership with them.

To achieve this goal, the EWB works hand-in-hand with engineering students, graduates, engineers and non-engineers alike. They are primarily concerned with drinking water, sanitation systems, energy, basic infrastructure, communication and engineering education.

1.2: Engineers Without Borders Challenge

Engineers Without Borders works in consort with engineering students in order to educate the wider community about sustainability concerns for developing communities. One of their initiatives is the Engineers Without Borders Challenge (EWB Challenge).

The EWB Challenge is a program for first-year university students. After a community is selected and their specific needs are identified, the EWB composes a design brief detailing the desired outcome. Students work in small teams to develop appropriate designs addressing one section of the brief. To this end, they provide a report describing their design and viability given community concerns and beliefs.

1.3: Devikulam

1.3.1: Village

Devikulam is a small village located in Vilupurram, one of the most underdeveloped districts of Tamil Nadu (a state in Southern India). The village is named after the local pond, which is a central feature of the village. The name means goddess of the Pond or as described by locals ‘Village blessed by God’. Water from the pond used to be drinkable although in recent years has been used for bathing, washing, cattle and swimming [1][2].

1.3.2: Households

The village consists of 86 households. Occupancy is generally between 4 - 7 per household, totalling approximately 358 people, almost all of whom live below the poverty line. While most houses in Devikulam have an electricity connection, ones in the area referred to as the ‘colony’ are generally in very poor condition. They are mostly hut styles with either cement or mud floors, walls made from mud or burnt brick, roofs that are either thatched or made from palm leaf, bathrooms that are usually thatched, no toilet and very limited access to safe drinking water [1][2].

In the village area, most people own a plot of land as well as livestock (generally between 2-6 cows and 2-6 goats per household). However, in the colony only 3 households own land and only about 25% own livestock 2-4 cows or 1-2 goats [1].
1.3.3: Caste System

Devikulam is divided into castes, which are ranked groups of various sizes and breadth. Members of high ranking castes tend to be more prosperous than members of low ranking castes. Lower ranked castes unfortunately are subjected to low standards of living, poverty and social disadvantage. We have identified two major castes in Devikulam, the Scheduled Class (SC - formerly Dalit) and the Most Backward Class (MBC) [3].

The Scheduled Class are unfortunately considered to be ‘broken’ or ‘crushed’, they are thought to be the bottom of India’s caste system. The Most Backward Class is actually an indigenous community or tribes and are considered very primitive [3].

The MBC live in the region known as Devikulam Village while the SC lives in the area referred to as the Colony. The relationship between the two castes is generally very good and caste mingling occurs at certain functions [2].

1.3.4: Occupation

The Main Occupations in Devikulam is agricultural work on farms as most of the village occupants have their own land where the wet lands are utilized for farming rice and coconut, the dry lands for tapioca roots, ground nuts and millets. Residents in the colony however, generally work as agri-coolis (laborers for other farms)[1].

Another profession would be prawn farming in surrounding farms. While prawning does create employment opportunities for the locals, a majority of the jobs are given to people that are outside the local area. Also this business has resulted in many negative environmental impacts as the polluted salty water from the prawn tanks is often swept into people's fields killing the soil and the crops growing there [4].

There are a few adolescent people who have left Devikulam in pursuit of better income and employment opportunities who now live and work in the cities and towns. Also there are a small number of households where the main income is an old-age Government pension of around Rs 400 per month. The average annual income per household in Devikulam varies from Rs 10,000- 60,000, in the colony however, Rs 15,000- 30,000. The Devikulam community also receives revenue from the prawn industry in the area [4].

1.3.5: Education

Since Devikulam is located in one of the most underdeveloped areas its education has also been affected with about 60 percent of the people having attained only primary level education or less. The village's primary school was built 27 years ago and is for children aged 5 - 10 years. For secondary education adolescents have to travel 4 or 16 km to other cites (Nadukuppam and Marakkanam respectively) [2].

1.3.6: Transport

Transport options in Devikulam are very limited as there are no common bus facilities available to residents. Only a few of the household have private transport options. Approximately 12 families in town own a motorbike, one has a tractor and about one third of the families have a bicycle [1] [2].

Only men generally ride bikes, therefore for women, children and older people in the community walking is the only option. Families have to walk up to 4 km to nearby town Nadukuppam for their groceries, secondary education and any other services [2].
1.3.7: Poverty

There is many reasons for poverty in Devikulam. Some of the basic reasons that generally affect rural areas would be unequal distribution of income, high population growth, large families, the caste system as well as low education levels which limits the employment options available [5].

In addition heavy losses were incurred in the livestock sector with cattle, goats, poultry and other animals killed by the 2004 tsunami that caused extensive damage to the Indian coastline. The seawater also affected the standing crop and resulted in the salinisation of soils [6] [2].

1.4: Aim

The focus of the 2011 EWB Challenge is to construct a proposal for the village of Devikulam, aiming to address some of the current local demands through the introduction of sustainable technologies. The areas of which these demands focus on include housing, construction, energy and water supply and sanitation systems.

Our proposal aims at providing the village with an environmentally-friendly waste disposal system that will address the poor sanitation practices that are currently ongoing in Devikulam. Moreover, the solution will also aim to reduce the causes of emphysema among the community.

1.5: Focus Areas

Society:

The consideration of the community’s culture is a vital aspect when it comes to introducing the project to the people of Devikulam, since the community will decide whether they accept the proposal or not. Knowledge of the community’s beliefs and cultural traditions will be a key factor when developing the solution, as some technologies may offend or insult the people.

Environment:

If it is possible, local materials should be used in the solution to decrease costs and support the environment that surrounds the village. The types of materials that will be used include those that are long-lasting; having the ability to endure the harsh weather and climate of Tamil Nadu. This allows the maintenance of the proposed system to be minimal. Observations of the surrounding environment will also be taken into account and will be used to judge the best course of action for our project.

Economy:

The overall project must be cost-effective and provide the local community with a sustainable system. It must be efficient in all it’s functions; allowing for minimal work and a maximum output. The solution will be close to permanent, meaning that the system will not be replaced each year and consequently costing the community unnecessary money. With all of this taken into account, the implementation of our proposed solution will have a positive impact on the economy in the village.
2.0: Fundamental Review

2.1: Project History

December 2009: A women’s centre was built through the ‘Pitchandikulam Project’. The women’s centre serves as a meeting area for all charity organisations inside of Devikulam. Opposite the women’s centre is a tailoring centre where an independent program called “small steps” was set up to allow production of community sewn bags to replace plastic bags for shopping, and to sell to tourists.

July–September 2010: The “Video Awareness Plan” was introduced, to initiate discussion among the community about the negative impacts of dowry practice. The program showed stories of a girl wanting to be married and parents taking high interest loans, only to result in debt and social fall outs. Resulting in the girl committing suicide. It was encouraged that the girls seek each other out and talk about their problems.

21st July 2010: An government approved project was designed to fix the taps and piping in Devikulam. Pipes were replaced with ¾ inch water pipes which a plumber would then together. The community cut pipes to size, and dug the relevant holes.

2.2: Cultural Review

Typically the Indian communities of Devikulam are extremely family orientated, including extended family [7]. The oldest living members of the family generally set boundaries as to what is acceptable and unacceptable. Indian communities are always conscious of the social order, despite attempts to eradicate this tradition [7]. Social orders are still very strong among friends, family members and strangers.

Hindu is the main religion among Devikulam’s residents. A highly morally based religion, Hinduism includes a highly religious text called the Veda [8]. The Veda is broken into four different sections, the Rigveda, containing hymns, the Yajurveda, containing formulas to be recited by the officiating priest; The Shamaveda containing formulas to be sung by the Vedic priests and the Atharaveda containing ancient spell and incantations.

It is tradition for the residents of Devikulam to not use human waste as fertiliser [9]. This is tradition dating back thousands of years, and will be considered throughout in the planning of the project.

2.3: Economical Review

Devikulam’s economy has grown significantly over the past 13 years, with a GDP increase of 5.46% per annum [10]. Agriculture has only contributed to 0.42% of the increase. The government of Tamil Nadu responded to this, and implemented a design to give 2 acres of wasteland to homeless and landless families. It is the governments plan that by doing this, it will enable wasteland to be cultivated into usable crop locations. The government has also encouraged small farmers to pool their operations, to maximise their farming efficiency and enable them to afford more modern farming equipment.
Despite this boom however 22.2% of the rural and 22.2% of the urban population still live under the poverty line [10]. It is the hope of the Tamil Nadu government that their agricultural scheme will solve part of this problem as well.

2.4: Environmental Review

The environment of Devikulam is primarily farm land and housing. There are no Bamboo forests in the immediate area of Tamil Nadu, but are readily available in neighbouring villages. In a Village close by there is a granite quarry where all rock is mined from in the area. The soil quality is still recovering from salinity caused by strong monsoon a few years back. The crops grown in Devikulam are tuber (tapioca roots), ground nuts and millets. Water is readily available in all seasons of the year, but can get scarce during the hotter months.

3.0: Design Requirements

3.1: Functionality of Biodigester

The design for the biodigester must solve the relevant criteria for supplying sufficient amounts of gas to provide the 322 community members of Devikulam with cooking fuel for two meals per day. Any extra fuel created by the biodigester will be pressurised by the pump, stored into gas bottles and sold for extra money.

The overall system must be easy to use. That is to say, the functionality of the biodigester must be simple in order for villagers to use without any difficulty. Also, the system must be of low maintenance as a high maintenance project could result in many breakdowns. This can potentially cost extra resources and money to repair and subsequently cause quick loss of interest from the community.

3.2: Cultural

The design for the biodigester must not be offensive in any manner to the community’s beliefs, ideals or traditions. To successfully integrate a project into the community we must make ourselves known and not be seen as outsiders, otherwise the community will be hesitant and unwilling to be part of the project. To cement this relationship and interest in the project, we will need to encourage the community to participate in as many sections of the project as possible. At points when the community cannot be part of the building process, introductions on how to properly and maintain the project will be held.

Human waste can be used in a biodigester, but the reasons behind it’s use, why it is safe to use and how this will not impact on a lifelong tradition will be explained thoroughly to the community upon introduction of project.

Awareness of Devikulam’s class structure is needed for the introduction of crops. As the lower class lack the amount of fuel for the biodigesters. In order to ensure our project helps the whole community, and not just the upper class, we will need to introduce crops into Devickulum’s lower class.
3.3: Economical

The community will need to become stakeholders in the biodigester design chosen, in order to pay for future upgrades, maintenance and expansion of the current design. The project will initially take advantage from the increased GDSP, to help fund it. Once running the project will be a cheap alternative to a serious problem of emphysema.

As manure has a value in Devikulam, it will not be diminished as it leaves the biodigester, as it will then become liquid fertiliser. New Farming techniques will be introduced to manage this new fertiliser, and to profit from it's new benefits. Crops will also need to be introduced into Devikulam, in sufficient amounts. See Appendix A

3.4: Environmental

The biodigester must be located close to a water source, and not far away from the housing of Devikulam. Space will be an issue among our project as biodigesters are large when dealing with a whole community. To reduce the space needed, the biodigester will be partially buried.

As there are monsoons in Devikulam, and on occasions salt can rise above the water table, we will introduce sweet potatoes. Introduction of sweet potatoes into Devikulam's lower class has been chosen due to their high starch levels and salinity resistance.

To avoid flooding from monsoons, the biodigester must be above the surrounding ground level, as to ensure that all water naturally moves away.

3.5: Safety

As biodigesters could potentially be dangerous if gas was to leak or ignite, certain safety features must be considered such as: what minimum distance should a biodigester be from any housing or other populated buildings; what will be used to identify a gas leak and how problem can be maintained safely; and what design would be the safest for the community to maintain and use? It is a necessity that these points are considered in the design for a project like a biodigester to become a permanent solution.

4.0: Design Options

4.1: Considerations

Proposed solutions must consider the capacity of the community as well as their social barriers. Development of a common sense of purpose is important in order to encourage cooperation amongst the people and improve their working relations as they will be required to maintain and operate the biodigester system.
4.2: Barrel Design

4.2.1: Proposed Design for Barrel Option

The first design considered was one of the many variations of a tank biodigester that involved using barrels/drums to make small biodigesters. This system would be quick to install as it does not require major construction. It is easy to dispose of the waste and would be cheap especially if plastic barrels/drums could be sourced from the area. These would be distributed amongst the community based on the amount of biodegradable waste located in different areas of the Devikulam community.

![Barrel bio-digester using a barrel or a drum. It is quick and easy to install and distribute. It easily disposes waste. Illustration: James Forss](Image)

4.2.2: Functionality

The way in which the barrel design works is that the barrel section is filled seven eighths full with waste and water. The lid is then screwed onto the barrel. The waste will then break down and produce the methane gas which flows through the pipe connected to the lid and then into the rubber ring that contains the gas, expanding as the amount of gas increases. When gas needs to be collected the safety valve will be closed and the gas control valve will be opened allowing the gas to flow to a gas pump used to pressurize the gas into a bottle.
4.2.3: Economical

The barrel design initially has a strong negative impact on the community, as they will be single-handedly funding the project. Once the project is running, it will rarely cost anything other than time to place waste inside of the individual barrels and to pressurise the gas. This impact will allow for money savings on wood, and will allow for excess gas to be sold for profit. This is a costly project for a community, as many materials will be needed to complete the design.

4.2.4: Environmental

The environmental effects of the barrel design are quiet minimal if is maintained properly as it is a completely sealed system. This would mean little to none of the gas will escape the system meaning the system does not give of an smell due to the production of methane gas. To avoid the biodigester from getting washed away by monsoons, it will be housed on the top of a mound. It will be placed 50metres away from the housing of the village.

4.2.5: Safety

Just as the dome biodigester needs safety implemented in the final product the barrel system also needs safety features to protect the community from the biogas. There would be more barrels per class in Devikulam so there is more of a risk that the villagers could be harmed by hydrogen sulfide. Flames have a pronounced risk of setting the community ablaze. The barrels are also closer to homes in the case that explosions occur due to the high pressure build up in these designs. These will have to have pressure gauges on them due to the close proximity to the houses in Devikulam. Alarms should also be implemented for when the pressure reach a specified amount to warn the villagers to empty out the gas being produced. The lids of the barrel systems have to be sealed. If the pressure levels rise the lids can become loose and gas can leak from the biodigester. There should not be any punctures in the barrel. If punctures are found on the barrel and repairs aren't able to be made the barrel can be easily replaced and are also cheap.

Detection of hydrogen sulfide sensors should be used. The smell of rotten eggs will also be an indicator as to whether hydrogen sulfide has been leaking from one of many biodigesters placed around the houses.

For handling, gloves should be used as protection from coming into intact with manure, plants, effluent and the fertiliser it will be producing from the conversion to biogas.

After a leak has been detected, the community, will have to find out which of the barrel systems are leaking gas. When found, the biodigester that is leaking will need to be taken to a clearing away from the houses within the community where repairs are to be made after the gas has dissipated [11]. The barrels that are closer to the houses will have to be treated with more care and can’t have any leaks after being repaired so the community can continue with their uses of the biogas.

The instructions for when the system is at a high pressure is to isolate the barrel which is leaking, turn off the valve, empty some of the effluent, and waiting for the gas to dissipate before repairing the barrel. Ignoring this could cause an explosion, a work around for which could be a pressure gauge with alarm. But at low pressure Barrel is to be secluded, stop draining the barrel, add crops and manure into it and wait for the gas to dissipate before repairing, ignoring this could cause an implosion and a work around can be a pressure gauge with an alarm [11]. The pressure factor remains the same and can cause an explosion that may reach the house, so barrels would need more care when they are being repaired, to ensure that the pressure levels do not reach a critical level within these biodigesters.
A feature that would be implemented in the barrel biodigester system to keep the community of Devikulam as safe as possible is to add a pressure gauge to measure the pressure inside the biodigester. This would minimise explosions and implosions that may occur due to pressure levels that are too high or too low. We would have to be careful and wisely choose the features we want to implement in the design, the reason being that these would be closer to the houses in the community and are more vulnerable to the explosions if they were to occur due to the mass amount of pressure build up inside the biodigester. Also since the biodigesters are closer to houses the community would be at risk of exposure to hydrogen sulfide considering that it will be placed further away from the houses.

4.3: Dome Design

4.3.1: Proposed Design for Dome Option

The second design considered was a dome biodigester. They are one of the more expensive biodigester options due to the high material cost and the requirement that skilled workers need to construct the biodigester. They can handle a large quantity of waste gathered from around the community. All the materials are available in that area of India, making the gathering of materials cheaper.

![Dome bio-digester built into the ground. It handles large quantities of waste. Illustration: James Forss](image)

4.3.2: Functionality

To enable the biodigesters to operate effectively, procedures will need to be introduced to the community when the biodigesters are installed. This includes the collection of waste, having the waste divided up by its type and the processing of waste with the aid of a preparation tray. The Biodigester will also require a gas pump to pressurise the gas into the bottles.
It has three main sections: the Inlet chamber, the main chamber and the outlet chamber that the waste moves through via gravity. The gas is collected from the main chamber as a compressed gaseous bubble which forms in the dome. The gas will be fed by a pipe into a balloon bag then compressed into bottles.

4.3.3: Economical

The dome design is initially an expensive investment as it requires approximately $1300 per unit. It will need to be funded by the community, but will produce a profit through the savings from not purchasing other flammable substances for cooking, and any extra gas can be bottled and sold. This is more expensive to implement than the barrel, but is a longer lasting, and more permanent solution to the problem we set to solve.

4.3.4: Environmental

The slurry from the biodigester contains pathogens. It also contains ammonia which is a greenhouse gas. If the slurry leaks from the biodigester it could poison the water table. The anaerobic digestions that occurs in the digester kills most pathogens which are found in the waste, which makes the slurry safe to use for a fertiliser after it has completed its digestion in the biodigester. There is still a prospect of the soil being contaminated. The components found in the fertiliser produced can be harmful to the soil and water [11].

4.3.5: Safety

Considerations concerning the safety of the people of Devikulam and the environment are that the Methane (CH4) and Hydrogen Sulfide (H2S) that are both present within the biogas that is produced by the biodigester are both highly flammable [11]. Hydrogen Sulfide is a toxic gas and should be handled with extreme caution. This means that if there are any leaks detected in the biodigester the area must be cleared of any naked flames as it can ignite the gas and cause an explosion, as the relative density of the gas is 1.2 where the density of air is 1. As the density of Hydrogen Sulfide is greater than air, the hydrogen sulfide is heavier and when leaking from the biodigester will fall toward the ground [11]. It can cause damage to the central nervous system, irritation in the eyes and skin, and can damage the respiratory system. Even at low concentrations Hydrogen Sulfide produced by the biodigester can cause health problems [11].

Typically a hydrogen sulfide leak is accompanied by the smell of rotten eggs. Alternatively there is equipment available to detect the hydrogen sulfide around in open spaces [11][12].

As the community needs to handle the manure and plants that stock the biodigester and the slurry produced, it is advisable to use rubber gloves as protection from contamination and keep the hands as clean as possible [11].

Leaks in the biodigester can be dangerous especially mainly because of the two very flammable gases that the biodigester is producing: methane and hydrogen sulfide [11]. If the gas accidentally gets ignited an explosion could trigger and ultimately kill someone.

The biogas’ gas ratios can affect how toxic it may be and how efficient it will burn. For instance if there is more methane based in the biogas the more flammable it will be for the user and more danger they will be under. If there is more carbon dioxide based in the bio-gas the less useful the biogas will be as it will not burn as efficiently [11].
The content of Hydrogen Sulfide that is contained in bio-gas is about 100 ppm to 2000 ppm which equates to 0.01% to 0.2%. The more hydrogen sulfide that is present in the bio-gas the less safe it is to use and the more toxic the gas will be. Exposure to Hydrogen Sulfide can eventually cause Pulmonary Oedema [11], which is fluid accumulation that occurs in the air sacs that are in the lungs making it harder for a person to breathe [13].

The protocol the community of Devikulam will need to be educated in is to protect themselves from the dangers of methane and hydrogen sulfide. When there are detected leaks these are the instruction they can apply to reduce the likelihood of a dangerous outcome:

• When high pressure is detected:
  o Possible causes:
    + The biodigester is converting a greater amount of stock than the volume it has been designed for.
  o Consequences:
    + The biodigester tank could break.
    + Explosion may occur.
  o What to do:
    + Turn of the valve.
    + Clear all the surrounding areas.
    + Remove some of the effluent from biodigester.
    + Released the gas and wait until the gas has dissipated.
    + Repair the biodigester.
  o Work around:
    + Use a pressure meter to measure the pressure levels in the biodigester.

• When low pressure is detected in the biodigester:
  o Possible causes:
    + Too low level in biodigester eg. There may not be enough stock inside to convert for its volume.
  o Consequences:
    + Biodigester may break and cause more gas to be leaking.
    + Implosion.
  o What to do:
    + Stop draining the tank.
    + Add more crops, manure inside the biodigester to convert into biogas and increasing the pressure levels.
    + After the release of gas, wait until gas has dissipated clear all surroundings.
    + Repair the biodigester of all damages that may have been caused.
  o Work around:
    + Use a pressure meter to measure the pressure levels in the biodigester.

• Hydrogen Sulfide:
  o Consequences:
    + As mentioned, it causes Pulmonary Oedema.
    + Infected skin.
    + Irritation of eyes.
    + Is toxic.
    + Flammable.
  o What to do:
    + Wear a face mask to protect respiratory system.
• Methane:
  • Consequences:
    + Ignition of flames.
  • What to do:
    + Keep naked flames away from the gas [11].

Safety features to be included in the biodigester are a pressure meter to detect the pressure level that the biodigester is currently producing. This is to indicate when the community needs to add more plants and manure into the biodigester and remove effluent from the biodigester when it is too high, as mentioned in the protocol. A hydrogen sulfide sensor, which detects when it is present, can alert the community so that they may protect themselves when there has been hydrogen sulfide detected [12]. The packaged will be housed as well as the used ones as it will protect them during the wet season. The biodigester will contain a lip at the bottom so there won’t be any overflow of biodigester effluent. The valves controlling the gas flow and the pressure gauge will be housed in order to protect it from the wet weather and from children who may accidentally damage them or play with them.

4.4: Concrete Box Design

4.4.1: Proposed Design for Concrete Box Option

The concrete box design is a design pioneered by Gerardo P. Baron in his home biogas system [14]. It is very similar to a dome digester in the sense that it is a large, partially-buried permanent structure with multiple chambers. The difference however, is that the concrete box is easier to build since it does not require an intricate dome. This reduction in complexity decreases the number of things that can go wrong, reducing the chance of repairs and improving the cost on maintenance.

4.4.2: Functionality

The concrete box biodigester functions exactly the same way as the dome biodigester. Feedstock enters the system via an intake pipe, expelling biogas and effluent. The effluent pushes out older effluent, which then comes out of the system via an exit pipe. Since gas is less dense than air, it rises and remains at the top of the main digestion ‘chamber’.

4.4.3: Economical

The concrete box digester is similarly priced to a dome digester, due to them both being large permanent structures. However since it doesn’t require an intricate dome, it is marginally cheaper to produce than the dome design. All in all, the concrete-box design is slightly less expensive than the dome biodigester.

4.4.4: Environmental

Like the many characteristics described, the concrete box biodigester requires the same environmental considerations as the dome digester.
4.4.5: Safety

A safety consideration of the biodigester is to make sure that the design does not leak in between the joints of the biodigester, so a pressure valve will also be implemented in this design to indicate the pressure level the biodigester is producing [11]. This would also be placed far from the village to prevent gas from flowing into the village as much as possible to ensure that burning of village houses is also minimised. Absolutely no one is to walk on the top of this biodigester. It has a flat top and can break if there is enough weight.

To detect the gases the community will use hydrogen sulfide sensors to measure if there is any currently present.

It is recommended to use gloves to handle the crops and manure that will be placed within the biodigester. Gloves should also be used to handle the effluent and the fertiliser that is going to be produced [11].

After leaks have been detected no one is to go near the biodigester until the gas that has leaked has dissipated and procedures can be applied.

- **High Pressure:**
  - **What to do:**
    + Clear the surroundings of flames and people.
    + Turn off the valve.
    + Remove effluent from within the biodigester.
    + Wait until gas has dissipated.
    + Repair any damages to the biodigester that have been caused by the pressure level.
  - **Consequences:**
    + Explosion.
  - **Work around:**
    + Use pressure gauge.

- **Low Pressure:**
  - **What to do:**
    + Clear surroundings.
    + Stop draining tank.
    + Add crops manure to biodigester.
    + Repair damages caused to biodigester.
  - **Consequences:**
    + Implosion.
  - **Work around:**
    + Read the pressure gauge.[11]

Safety features to be implemented in the design to reduce the dangers to the community as much as possible are a pressure gauge and hydrogen sulfide detector to detect present hydrogen sulfide [12]. The biodigester being far from the houses also lowers the probability of a house catching fire.

4.5: Universal Preparation Tray

The preparation tray is an open-top metal box that has a red line painted inside half-way up the height of the tray; creating a half-way point of the volume on the tray. The tray can also have one of its walls lifted out to empty the load from the tray into the biodigester.
4.6: Manual Powered Gas Pump

The gas produced by the biodigester needs to be pressurised into gas bottles to be distributed amongst the community. Due to the shortage of electricity in the area an electric powered gas pressuriser, the preferred choice, would not be viable at this current point of Devikulam's development. However this is seen as a future upgrade when power problems in the area have been improved. As a substitute, manpower pumps will be installed which can't pressurise the gas as well as the electric system but will be able to achieve the task.

![Figure 4.3: Concrete Box bio-digester is a partially-buried permanent structure with multiple chambers. It handles large quantities of waste. Illustration: James Forss](image)

- **Rest**: Both valves closed
- **Intake**: Gas drawn from gas supply
- **Exhaust**: Gas pushed into tank
- **Main cylinder**: Gas
- **Gas drawn into main cylinder**
- **Exhaust valve open**
- **Gas pushed into tank that is to be filled**
- **Handle lifted**
- **Handle pushed down**
### 4.7: Design Evaluation

The following table portrays and evaluates the three design concepts we have considered using weighted criteria to finalise our choice.

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>BARREL DETAILS</th>
<th>RATING OUT OF 10</th>
<th>DOME DETAILS</th>
<th>RATING OUT OF 10</th>
<th>CONCRETE BOX DETAILS</th>
<th>RATING OUT OF 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>A 44 gallon drum holds approximately 0.167 m³ of gas. To accommodate 15 m³ of gas, you would need 989 barrels. This would be difficult to source, so we assume the expense would be high.</td>
<td>4</td>
<td>The dome has a fair initial cost, but this can be offset by government programs. The design is intricate because of the dome shape.</td>
<td>6.5</td>
<td>The concrete box also suffers from a high initial cost, but this is lower than the dome due to the simpler design.</td>
<td>8</td>
</tr>
<tr>
<td>Gas produced</td>
<td>Assuming strong seals, gas loss will be reasonably low.</td>
<td>8</td>
<td>Assuming strong seals, gas loss will be reasonably low.</td>
<td>8</td>
<td>Assuming strong seals, gas loss will be reasonably low.</td>
<td>8</td>
</tr>
<tr>
<td>Community training</td>
<td>Basic training will be required for a large number of people.</td>
<td>5</td>
<td>A small group of people will have to undergo advanced training.</td>
<td>5</td>
<td>A small group will have to undergo training. The design requires less specialisation than the dome design.</td>
<td>5.5</td>
</tr>
<tr>
<td>Waste removal</td>
<td>Waste removal is as simple as releasing a barrel. However, to augment removal, more barrels are needed.</td>
<td>5</td>
<td>It will bucketed out during normal operation and pumped out during the main cleans.</td>
<td>7</td>
<td>Can be poured out of the effluent pipe during normal operation and pumped out during the main cleans.</td>
<td>7</td>
</tr>
<tr>
<td>Access to materials / tools</td>
<td>Would require barrels, gas valve, gas ring/balloon and tubing.</td>
<td>5.5</td>
<td>Would require cement, bricks, gas, pump and piping.</td>
<td>5</td>
<td>Would require cement, bricks, gas, pump and piping.</td>
<td>5</td>
</tr>
<tr>
<td>Instalment price</td>
<td>Each barrel needs a small amount of work.</td>
<td>8</td>
<td>Dome is considerably more complicated.</td>
<td>4</td>
<td>Box does require a lot of labor, but specialists are not required.</td>
<td>5</td>
</tr>
<tr>
<td>Gas lost in production</td>
<td>There will be a small leakage of gas when transferring between barrels. This should be minimal due to closed valves at each end.</td>
<td>7</td>
<td>If pipes are not properly fitted, slow gas leakage can occur. Better than barrel since barrel is multiplied over number of barrels.</td>
<td>8</td>
<td>Same as dome.</td>
<td>8</td>
</tr>
<tr>
<td>SUBJECT</td>
<td>BARREL DETAILS</td>
<td>RATING OUT OF 10</td>
<td>DOME DETAILS</td>
<td>RATING OUT OF 10</td>
<td>CONCRETE BOX DETAILS</td>
<td>RATING OUT OF 10</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
<td>------------------</td>
<td>--------------</td>
<td>------------------</td>
<td>-----------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Time to construct</td>
<td>No more than a couple of days.</td>
<td>8</td>
<td>Over a week.</td>
<td>3</td>
<td>About a week.</td>
<td>4</td>
</tr>
<tr>
<td>Life-span (without repair)</td>
<td>Steel could be made more brittle by H2S. Balloon needs to be replaced every year, and containers every 5.</td>
<td>5</td>
<td>15+ years.</td>
<td>8.5</td>
<td>15+ years.</td>
<td>8.5</td>
</tr>
<tr>
<td>Repair effort</td>
<td>Easy to 'get into' barrels. Can simply replace defunct barrels.</td>
<td>7</td>
<td>More laborious to repair.</td>
<td>5</td>
<td>Not as easy to repair as barrels, but design can accommodate manhole to improve access.</td>
<td>6</td>
</tr>
<tr>
<td>Smell</td>
<td>There is smell, but this is mitigated by closed valves and units being located away from residences.</td>
<td>3</td>
<td>There is smell, but this is mitigated by closed valves and units being located away from residences.</td>
<td>3</td>
<td>There is smell, but this is mitigated by closed valves and units being located away from residences.</td>
<td>3</td>
</tr>
<tr>
<td>Biofeed</td>
<td>Since number of units will be decided based on needs, these are even.</td>
<td>5</td>
<td>Since number of units will be decided based on needs, these are even.</td>
<td>5</td>
<td>Since number of units will be decided based on needs, these are even.</td>
<td>5</td>
</tr>
<tr>
<td>Safety</td>
<td>Safety Valve. Might be more dangerous and harder to control as the barrels are easy to move and could be taken by the community for individual needs.</td>
<td>5</td>
<td>Since dome is located away from community, safety concerns are less severe.</td>
<td>8</td>
<td>Same as dome.</td>
<td>8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>71.5</strong></td>
<td></td>
<td><strong>76</strong></td>
<td></td>
<td><strong>81</strong></td>
</tr>
</tbody>
</table>

Table 4.1: Table portrays and evaluates three design concepts.

Each criterion was carefully assessed using the weighted criterion of figure 1.2, and found that both designs were viable however design 3 resolved to be the best for Devikulam’s needs.
4.8: Material Evaluation

4.8.1: Material Options


Local mud bricks: Allows for community involvement in the building of the biodigester. Does not fare well over extended periods of time against concentrated liquids and may leak. Not long lasting. Requires a lot of maintenance.

Marble blocks: Located locally in a nearby quarry. Allows for community involvement in shaping of marble blocks. Shaping of the dome would be difficult and dangerous to those who are not qualified, resulting in a professional needed to build the biodigester. Could result in leaks if not sealed properly. Requires a little maintenance.


Manual pump: Stainless steel, 2KG. 6l lever manual pump [16].

4.8.2: Final Selection

It was decided that we would use RDC’s Fibre Concrete for the main biodigester material, as it is a long term solution, which would require minimal maintenance and is easy cast into a variety of shapes.

RDC’s Fibre concrete was chosen over the bricks as we were afraid that the mortar in the bricks might begin to crack and/or leak and concrete has a longer life expectancy.

The concrete will be used to create the 3 sections of our biodigester; the inlet chamber, the holding dome and the outlet/overflow chamber. To counter the lack of community involvement when the concrete is being laid, we will teach the community the new farming techniques involving the use of liquid fertiliser.

High-density polyethylene pipe (HDPE) was chosen over PVC Pipe, as it is a much longer lasting, and can hold gas better than it’s competition as it can be heated to create heat-fused joints that are leak tight. The polyethylene pipe requires much less maintenance than the PVC, which is important as replacing the pipe is very difficult.
4.8.3: Material Uses

**Fibre Blend Concrete:** Used to make the dome, inlet column, outlet column and overflow tank[17].

**80mm high-density polyethylene pipe:** Use to connect the pipe and manual pump together[18].

**80mm High Density Polyethlene Pipe connectors:** Used to connect pipe.

**80mm High Pressure Hydraulics Fitting:** cemented into the dome. Black pipe slides over to produce seal between pipe and dome[19].

**Manual Pump:** Used to pump gas from the waste storage tank to Gas bottles. We chose a manual pump as it cost less and required no power to use.

4.9: Design Summary

The implementation of the 2 types of biodigesters, green waste and cow manure, will be able to accommodate for the cooking needs of every person inside of the village, effectively stopping emphysema cases amongst the village.

Five biodigesters will be implemented amongst Devikulam's two major classes. Two 15m$^3$ Biodigesters will be given to the upper class, to be used as a green waste and a animal waste. Two 15m$^3$ Biodigesters will be given to the lower class to be used as green waste and animal waste. 15m$^3$ tans were chosen as they enabled room for future population and waste growth and they were only $550 more than the 12m$^3$ tanks.

As Devikulam can be assaulted by monsoons, we had to ensure that water would not enter the biodigester [monsoon]. This should not happen as our biodigester is water tight, however we devised the idea of creating a mound around the biodigester, ensuring that all water, despite it’s vast quantities, would travel down the mound away from the biodigester, ensuring that no feedstock would escape.

As shown (Appendix B), the biodigesters will be located just outside of the main body of housing in Devikulam. There we will have the 5 biodigesters 2 green waste, 2 manure waste, and one human feces waste biodigester. On the opposing side of the village, the sweet potato crops will be planted and harvested. The Potato crops are planted next to a water source, allowing easy irrigation.

The safety features are: A pressure meter to detect the pressure levels that are in the biodigester. This is to indicate when the community needs add more plants and manure into the biodigester and remove effluent from the biodigester when it is too high. A hydrogen sulfide sensor so the community can be alert and protect themselves when there has been hydrogen sulfide detected [20]. There will also be housing around the electrical system that will be integrated with the biodigester, this is because the electrical system could get damaged in the wet season. The packaged gas is also going to be housed as well as the used ones as it will protect them during the wet season. The biodigester will contain a lip at the bottom so there won't be any overflow of effluent of the biodigester. The valves controlling the gas flow and the pressure meter will be housed due to protection from the wet weather and from the children who may accidentally touch them.
5.0: Implementation Strategy

5.1: Overview

The implementation of the project is an important stage, as it is the ‘make or break’ point of a project. If we were to insult the community, or discourage them by isolating them from the project, it would result in a failed plan. To avoid such a disaster we will need to be aware of the cultural differences and pay respect to all those we communicate with.

The introduction of the project will be for the whole community, and will cover the introduction of the biodigester and the new crops. New farming techniques will be covered in the plan, as well as how to maintain the system. We will strongly support the creation of groups to maintain the biodigester system, and the small farming operation.

The introduction of how we plan to implement the project to the community includes communal respect, construction knowledge, community participation and careful planing, all of which is discussed in more detail as follows.

5.2: Procedure

The method for the implementation of the Concrete Box design is as follows.

1. Introduce ourselves to the community
2. Introduce our project and design to the whole community.
3. Answer community concerns
4. State if they accept the project, they will need to be stakeholders.
5. Encourage the community to participate in the construction of the project.
6. Begin Construction
7. While concrete sets and cures, teach the new farming techniques
8. Finish construction
9. Help organise the community groups to manage maintenance, farming operations and a treasurer.

5.3: Plan Drawings

This details the plan for the biodigester. The biodigester is composed of concrete walls and separate into two chambers. The main chamber is where the anaerobic digestion occurs and the side smaller chamber is where effluent is deposited in preparation for extraction.
At the preparation tray (mentioned earlier) there is place to break up fibrous material before funneling into the biodigester. To the left and right one can access the effluent and biogas respectively.

5.4: Materials Components and Costing

Considering the need to introduce the biodigester to a developing community, cost is a concern. We have selected the concrete box biodigester since that is the cheaper option when compared to the dome biodigester.

Although more expensive than other non-permanent solutions, we felt that it was better to introduce a permanent solution with a fix up-front cost since that would be easier to seek funding for.

The costs are outlined in Table 5.1.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 tonnes Fibre Blend Concrete</td>
<td>$1458+labour</td>
</tr>
<tr>
<td>100m 90mm high-density Polyethylene Pipe</td>
<td>$783.75</td>
</tr>
<tr>
<td>12x90mm High Density Polyethylene Pipe Connectors</td>
<td>$435.60</td>
</tr>
<tr>
<td>12x90mm High Pressure Hydraulics Fitting</td>
<td>$104.50</td>
</tr>
<tr>
<td>Manual Pump</td>
<td>$107.09</td>
</tr>
</tbody>
</table>

Table 5.1: Outlines the cost of each component needed for the concrete box biodigester

Total Economic Impact = $3,210.21
It should also be noted that due to the fact that one of the outputs of the biodigester is biogas, which is used for cooking purposes. Any extra gas produced by the biodigester can be bottled and sold. This introduces an extra commodity for Devikulam and a source of profit.

5.5: Roll Out Program

Upon arrival, a community meeting will be organised, to introduce ourselves in order to familiarise ourselves with them and their needs and create relationships with the people. This step is important, as it breaks down the barriers of us being outsiders and uninterested in their needs.

The following day another town meeting will occur to explain what our project is and how our design will help their standard of living. In this step, we will encourage community involvement in all areas, whether it be in working, simply assisting or observing. These three actions create the feel to the community that this is their project, and is part of their new lively hood. Explanation of why we are introducing new crops to their community will be introduced, and reasons to why this would be a worthwhile investment for them to take.

We will address the farmers concerns of losing their fertiliser to the biodigesters, by explaining that the output slurry of the biodigester will be a new and equally efficient fertiliser, and that the new technique to using this fertiliser will be taught. After the town meeting, the biodigester locations will be marked out with spray-paint, and with the help of the community, the digging of the five biodigester holes will commence.

Once all biodigester holes have been completely dug out, a worker from RDC Concrete will come out with cement trucks full of a fibre blend concrete, and cast the biodigester. This process will take a few days to complete, and then concrete must set for one day, and cure for 2 days after. During the concrete stage, the 80mm high pressure hydraulic fitting will be cemented into the top of the dome of the biodigester. While the biodigesters are setting and curing, The new farming methods of using liquid fertiliser will be introduced, including the new benefits.

Once concrete has set and cured, the EWB staff and community will then use the High Density polythethylene Pipes and connectors, to attach the pipe to the hydraulic fitting. The other end will then be connected to the manual pump. We will then demonstrate and then teach the community how to work the manual pump.

As the concrete biodigester is a very low maintenance system, we will teach many members from each class how to monitor the safety of the biodigester and encourage the cleaning out of each of the biodigester once every year.

The forming of a farmers group within the lower class of the community will be formed, consisting of about 10-12 farmers, who will oversee and maintain the introduced sweet potato crop[20]. As the community will be stake holders in this project, one member of this group will be a treasurer, and manage the communities money. Once a group has been formed, the new techniques to growing the sweet potato crop will be introduced and encouraged.
5.6: General Training

Their will be general training for the whole Devikulam community which will include basic safety procedures and how to use the new bin system that will be implemented with the biodigester system. A number of people from the community will receive more advanced training.

Also, training seminars and study groups will be held to educate people on how it is beneficial for them to use the liquid fertilizer, what type of waste is the most efficient to fuel the biodigester and how the digester works.

5.7: Waste Training

5.7.1: Waste Collection

To collect waste from the community there will be checkpoints so the waste can be collected from where it’s generated. The waste needs to also be separated, as some waste is unable to go in the bio digester and others need treatment before the go in.

5.7.2: Separation of Waste

Coloured coded bins would be the most affective method in the separation of waste, as when the locals fill the bins with their waste materials they will distribute the materials in the appropriate bins. For example: green bins for plant wastes, blue for animal waste, red for human waste (if the community chooses to), gray for general waste and yellow for recyclable materials. Many countries have a similar bin system, Australia being one of them, that break their waste into a 3-bin service for organics (food and garden waste), recycling and residual garbage [21].

5.7.3: Treatment of the Waste

Before many of the materials are fed to the bio digester they may required to be prepared for the process. Also all materials need to be added with a certain amount of water when entering the biodigester

Plant matter needs to be chopped up before it to go into the digester as they are made from large compounds, such as cellulose which take longer to break down. The chopping speeds up the breakdown process as it physically makes the compound smaller and increases the surface area of the break down reaction. However, all the workers need to be taught is: the more finely divided the solid is, the faster the reaction happens [22]. This could be done with a sharp spade. To assist in this we designed a preparation tray so that the waste and water added can be roughly measured and the plant matter can be broken up by a shovel in the tray.
Waste Products

Plant
Food: Cooking scraps
Animal: Dung
Human: Feaces
Recyclable: Plastics and glass
Landfill Waste: Wastes that can’t be re-used

Process Waste

Plant matter is broken up by cutting or tearing it apart:
Can be done using a spade or a pulveriser
No processing is required unless the waste are large solids:
Large solids such as expired cuts of meat
No treatment required: Even through much of the waste is plant matter
it has been processed by the animal digestive system
No treatment required: It has been processed by the human digestive system
Taken to recycle plant
Taken to landfill

Feed Waste to Digester

Add the same mass of water as plant waste
Add the same mass of water as food waste
Add the same mass of water as animal waste
Add the same mass of water as human waste

Output

Methane Gas
Fuel source
Slurry
Liquid fertilizer
New Products: Plastics, Glass or building materials
Buried Waste

Figure 5.2: This diagram show how various wastes will be processed in the Devikulam community. Diagram: James Forss
6.0: Impact Assessment

6.1: Environment Impacts

The current practice of human waste disposal in Devikulam is open defecation [9]. As a result the Devikulam community and its environment are endangered by poor sanitation practices and are prone to outbreaks of disease and contamination.

Devikulam is home to a few water sources. Two being the local ponds, named Devi Kulam and Vannang Kulam, whilst the other sources are bores. Engineers Without Borders Australia has noted that the village's current practice of waste disposal has the “potential to transfer pathogens to both water and food supplies” [9]. In addition, the organization has also stated that during monsoon seasons, “polluted water from the pond and surrounding areas that is contaminated with human or animal waste could flow into the bore and pollute it having significant implications for human health” [9]. Hence, the continued practice of open defecation poses a great threat to Devikulam's environment and can cause heavy consequences for its community.

Open defecation carries significant risks to ecosystems as fresh excrement contains nutrients and pathogens, which can render waterways uninhabitable. In particular, human waste contains organic materials that decompose through micro-organisms, which involves the use of oxygen. The amount of oxygen used in this process is known as the Bio-chemical Oxygen Demand or BOD. Thus, the greater the BOD in the waste, the more rapidly oxygen is depleted in the stream [23]. If such waste manages to reach a waterway, less oxygen will be available for aquatic organisms. This causes these organisms to suffocate, be stressed or possibly die.

Another concern that open defecation poses in Devikulam's environment is the health of the livestock and any wildlife that make their home in the area. Open defecation leaves fresh excrement to decompose, allowing harmful pathogens to spread and endanger the health of these animals. The possible consequences include widespread sickness and even death, which can damage Devikulam's ecosystem and contaminate the village's resources produced by their livestock.

Replacing the practice of open defecation with biodigesters considerably decreases all of these hazards to the environment by containing the waste in a secure area; preventing outbreaks of disease and contamination. Moreover, biodigesters make use of excrement and organic waste by converting it into a resource that is beneficial to the environment. Since excrement is a rich source of nitrogen and other nutrients, it is a great fertilizer for plant growth [24]. This will provide a notable advantage to not only the plant life occurring in Devikulam, but the crops and vegetables that are farmed in the area as well.

However the biodigester can also produces some issues with its output, in particular the use of fertiliser. Fertiliser provides soil with extra nutrients for plants to feed on, but excessive use of fertiliser can allow a surplus of nutrients to be present in the soil. This allows the possibility for these nutrients to be easily washed away into waterways, leading to abnormal nutrient levels in the environment. These abnormal nutrient levels cause eutrophication, which encourages plants such as algae to grow in waterways [25]. These plants remove oxygen from the water and make it difficult for other organisms to survive.

This concern can be effectively addressed by having farmers using fertiliser efficiently. That is to say, applying the right amount of fertiliser at the time of the year when the crops require it most [25]. This will ensure that the nutrients provided by the fertiliser are absorbed by the plants; allowing them to grow in a manner that will not leave a surplus of nutrients behind.
6.2: Social Impacts

Currently the practice of open defecation in Devikulam leaves human waste exposed around the village. Due to this, the exposure of fresh, human excrement poses serious risks to the health of people that live in the village and their well being.

A key concern regarding human waste is the bad odour that it emits. This odour is due to the hydrogen sulphide (H2S) compound within waste, which can be detected at relatively low concentrations; between 0.005 – 0.025 parts per million in air [24]. Given the human waste being dumped in open areas around Devikulam, the bad odour that is emitted from it would be easily noticed and repugnant for the villagers.

The main threat that open defecation poses to the people of Devikulam is the health hazards. Human waste carries pathogens and decaying organic matter which can easily infect and cause serious sickness in humans. Furthermore, parasitic eggs and cysts in human waste can remain viable in soil, water and on plants for many months after the waste has be removed [26]. This means that the waste left exposed around Devikulam, due to open defecation, is in fact creating a breeding ground for parasites and disease, which applies even when the waste is no longer visible.

<table>
<thead>
<tr>
<th>BACTERIA</th>
<th>DISEASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonella typhi</td>
<td>Typhoid</td>
</tr>
<tr>
<td>Salmonella paratyphi</td>
<td>Paratyphoid fever</td>
</tr>
<tr>
<td>Leptospira</td>
<td>Leptospirosis</td>
</tr>
<tr>
<td>Yersinia</td>
<td>Yersiniosis</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>Diarrhoea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WORMS</th>
<th>DISEASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schistosoma haematobium</td>
<td>Schistosomiasis</td>
</tr>
</tbody>
</table>

Table 6.1: The disease germs contained in human urine [27].

<table>
<thead>
<tr>
<th>BACTERIA</th>
<th>DISEASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campylobacter</td>
<td>Diarrhoea</td>
</tr>
<tr>
<td>E. coli</td>
<td>Diarrhoea</td>
</tr>
<tr>
<td>Salmonella typhi</td>
<td>Typhoid fever</td>
</tr>
<tr>
<td>Salmonella paratyphi</td>
<td>Paratyphoid fever</td>
</tr>
<tr>
<td>Other Salmonellae</td>
<td>Food poisoning</td>
</tr>
<tr>
<td>Shigella</td>
<td>Dysentery</td>
</tr>
<tr>
<td>Vibrio cholerae</td>
<td>Cholera</td>
</tr>
<tr>
<td>Other Vibrios</td>
<td>Diarrhoea</td>
</tr>
<tr>
<td>Yersinia</td>
<td>Yersiniosis</td>
</tr>
</tbody>
</table>

Table 6.2: The disease germs contained in human faeces [27].
The use of biodigesters helps prevent all these health hazards by securing human waste in closed location; containing all the bacteria and diseases that would otherwise spread due to open defecation. Moreover, the output of the waste from the biodigester is not considered as much of a ‘health hazard’ compared to the input waste due to the anaerobic digestion within the system. Anaerobic digestion creates an artificial environment where dangerous and infectious pathogens are killed due to the high temperatures within the interior of the biodigester [28]. As a result, disease pathogens are drastically reduced and often killed. It is important to note that this process does not rid the waste of all pathogens; instead it reduces their levels so that the output of the waste can be used safely.

One important concern that the EWB stated was that the “implementation (of biodigesters) would require significant support as the idea of using human waste as a fertiliser clashes with local beliefs and values” [9]. To address this issue, it was decided that due to the delicate matter of the belief system and culture in Devikulam, human waste would not be used as a source of fertiliser as it could be rejected by the villagers and potentially insult them. Instead only organic waste, such as livestock waste and decaying plant life, would be used to feed the biodigester and consequently used as fertiliser for the crops in the farms. Human waste would still be disposed into the biodigester and converted into a safer form to be disposed of, but not utilised as a fertiliser.

6.3: Economical Impacts

The economic impact from the proposed biodigester solution is cost effective given its sustainable nature and the opportunity it provides to produce profit.

The main materials used include fibre-blended concrete and high-density Polythene piping. Whilst the Polythene piping is durable and cost-effective, the fibre-blend concrete can initially seem expensive for the village. However this type of concrete is long-lasting, can endure concentrated fluids and most importantly the concrete does not require community involvement, which all means minimal maintenance. Four tonnes of this concrete will approximately cost $1458, whereas the high-density piping (including the pipes and its connectors), will cost around $1219.35. A high-pressure hydraulics fitting would also be included in the required items to build the biodigesters; this will add another $104.50 to the total cost.

The proposed solution involves five biodigesters being implemented in the village. Excluding the manual pump, five biodigester systems would consist of all the materials and costs described just previously. Only four manual pumps will be implemented into the solution, where one pump costs approximately $107.09. This would mean four manual pumps will cost around $428.36, refer to Table 5.1 for costs.
7.0: Conclusion

7.1: Detailed Outline of Solution

In our proposal, we have addressed the issue of poor sanitation practices in Devikulam by proposing the implementation of biodigesters in the village. We have discussed the special considerations that need to be addressed in the biodigester models that we compared. Our final solution was a partially buried concrete box. Although more expensive than the barrel solution we decided that a permanent solution would be better.

The concrete box in a two-chamber design. The first chamber is where the actual anaerobic occurs. Waste enters this chamber via an input pipe. Through a gas pipe on the top the townspeople can extract gas. The final effluent then enters the second chamber. The effluent can be taken from the chamber and used as fertiliser.

We also discuss safety concerns and a roadmap to implement the system.

7.2: How Solution Improves Standards of Living

The solution improves the standard of living by curbing the communities need for the burning of biofuels, preventing the town problem of emphysema. Since human waste is also used we can address the issues of sanitation as well.
References


Appendices

Appendix A:
The following pie charts represent the amount of potato waste that will need to be introduced into Devikulam’s lower class to subsidise the amount of fuel needed.

Diagram: Matthew Merigan

Appendix B:
The biodigesters will be located just outside of the main body of housing in Devikulam.

Illustration: Michael Abbott
Individual Reflection:

Michael Abbott

As a mature age student, I have been working in team environments for many years. I found that the university team environment is different in a lot of ways.

Firstly it was enjoyable working with school-leavers. I found the team’s level of enthusiasm very high, and the search for new ideas and design alternatives refreshing. Over time I have developed a sense of cynicism surrounding new ideas and it was interesting to find that often the cynicism is unwarranted.

I found the biweekly presentations to be growth-building. I have done a bit of public speaking in my professional life, but have never really been able to get rid of the butterflies that attack before a presentation. I think doing presentations so many times reinforced that it’s just nerves and also got me used to having to stand in front of people and talk.

As for the reports, I found I need to be careful where I expend my energy. In the professional environment I typically wrote a report as a full time task, with a small number of unrelated tasks that I would have to perform as part of my typical work duties. At university however, the report is only a quarter of my overall work (given four subjects). So I need to be very careful where I allocate the time to work on report related tasks. I found I expended a lot of energy earlier on in the semester which made it more difficult to have the full amount of energy to write the final report.

I found the EWB organisation to be a worthy goal. Often we concentrate on the direct symptoms of developing communities like food supply. It’s good to see an organisation tackling the more long term issues as well. My only criticism during this project is that I think EWB’s gatekeeping is a too strict. With such heavy reliance on our design being appropriate for the community we need as much insight into their concerns as possible.

Overall I found this to be an exciting and rewarding experience.
Individual Reflection:

James Forss

I believe the EWB project has had a number benefits in my learning. It has allowed me to build on my team work skills, project management skills, report writing skills and oral presentations.

Starting out at university and being asked to work as a team to complete the semesters work at the beginning was unfamiliar territory and I was a little apprehensive. However the team work of this assignment was very beneficial as it allowed me to advance my understanding of how to work with others effectively to achieve a final goal. As a group we found nominating tasks to individuals according to their skills and strenghts an effective way to work on this assignments as a team. I was mainly responsible for the design aspects in the team which lead me to draw a number of the diagrams in this assignment. These diagrams would develop and improve due to the sharing of idea's during our team meetings which we would have twice a week. I also learnt a number of effective ways to work with team member from home. This was done via google docs which allowed all team members to work on a word document at the sames time. A great advantage of google docs is that you can also have a chat forum connected which allowed us all to communicate quickly rather than emails that can be unreliable and a slow method of getting a returned query.

My project management skill also improved greatly while doing this project. This was due to the fact that deadlines needed to be met regularly either in the form of an oral or a written report.

There were also other outside commitments over the same time period which also needed to be dealt with. To manage my time I had to allocate certain days during the week to this project, which I could not waver from. I found if I did not stick to my plan it would lead to a pile up of work that would force me to sacrifice some of my commitments to allow me to catch up. The managing of time while doing this project helped me learn how to allocate the right amount of time to tasks and knowing the quality that needed to be produced in this time helped. Failing do so would lead to poor work.

Report writing skill were also important during in this project. A well organised plan was created first so we new what information we needed to obtain. We were all allocated individual topic areas to research and collect the relevant information. This was put into Google doc where it was constantly edited until it reached the standard required.

The last part of this EWB project that I found beneficial was the oral presentation. Each presentation I found that I improved and gained more confidence. Answering questions correctly and being able to think on your feet clearly and logically is a skill that will be needed when industry.

Overall it has being a great experience and I have enjoyed working with my group. We are all various ages with different experiences that can be drawn on and have worked together well.
Individual Reflection:

Matthew Merigan

The three most important things that I have learnt from this project have all resulted around working with a team. In school years, a team was where I would work hard in a group of slackers which always resulted in me doing the whole project by myself, relying on no one else's help other than my own, as they were just forced to do the project whereas I cared about the end result. Now in an adult environment, I was confronted to see others wanting to help, wanting to take part, and most importantly who were constantly reliable. This was of difficulty to me at first, as instinctively I needed to take control and do it all myself. This project enabled me to see the true meaning of what it is to be a team, and a team didn't consist of just me anymore. Hence from this environment I learned how to let go of the reins and allow someone else to control the direction and participation of each team member. I learnt how to work as a team unit rather than doing it all by myself. I also discovered that having a variety of ages and backgrounds in your group members, was not a nuisance, but an advantage as it enabled a new look on perspectives, and different skills to that of my own.

I think I have drastically improved my presenting skills, as from Dr Wu's encouragement, I no longer feel I need to hide behind my speech, but actually use prompt cards and talk and communicate to the audience. From continual bombardment of tough questions (mainly from the navy boys) after our speech, I learnt confidence in answering questions and admitting I do not actually have the answer but will find out and give them there desired response.

This class has changed my career directory slightly, as I no longer want to be just an electrical engineer, but eventually own my own company focusing on renewable energy, solar in particular. Dr Wu's speech about how we wrote assignment 1, to get the marks, and didn't actually consider the task, was what woke me up to my dreams, and not to what is required of me. It was this point that I realised I no longer needed to follow the trend, but branch out.

The three pieces of advice I would give to those about to do this subject is this is not a bludge subject, but the heaviest workload subject you will have as a first year, listen to your tutors and lecturers, as half the time what they say is actually useful, and finally choose a project that is fun because you do it for twelve long weeks.
Individual Reflection:

Jake Kios

The most important things I have learnt to do when working in a team is to set deadlines, so after the deadline has been met the team can move onto the next task and set another deadline for that. It is very important to have a way of communicating through email, mobile phone and set up meetings once or twice a weeks to assess how the team is progressing overall in the project. When we set up meetings we book a room at the library to discuss issues that arise. The other important thing I have learnt to do is to leave enough time to check spelling, grammar and the structure of the report and to also format.

The personal skills I think I have improved by reading what I have written and check if it flows well, when it doesn't flow I would go through and reword some of the written work completed. Presenting wise I try to learn the speech so I don't have to look at the notes that I have prepared to remind me what to say next. Also communicating with the team members and asking questions when I am stuck on something or the paths we take in developing the solutions to our biodigester system. Also I had look on one of the discussions on EWB website if there soil had clay earlier during the development of our solution. Also questions asked I have also been able to answer on my topic which is the safety aspect of the system.

The experience gained during this project will come in handy when working in groups, and has given me a taste of what to expect in a working environment. In the workplace I think there will be projects where I will have to do written work in groups and communicate with one another, whilst determining which design would be the best fit for the solution based on criteria and the need for the customer. The extra experience gained from the EWB project is the knowledge gained from working on improving communities that have poor living standards, that will also come in handy in the workplace by developing systems that can improve the living standards of communities that aren't that high.

Advice I would offer to student who are going to participate in the EWB is to plane everything etc. set deadlines, as you may start to panic if everything is left too late, try to assign an area of the report to each person and set up meetings whenever possible to assess how the team is going and the overall progress that the group is making. Make use of online storage places like Google Docs all that needs to be done is to create documents and join with the team so they can all edit the documents and make comments, this can also be used as a way of communicating as it has a chat room. The last piece of advice i would offer to anyone who participates in the challenge is to make use of effective communication by means of mobile phone , email to ask questions to team members as Google has email setups for groups that may be doing group projects. Join the EWB forums to pose questions about the specific region that the project will be based in the particular area which may be anywhere, from poorly sanitised areas to areas that have poor income. Even make use of social networking as a way of communication and even instant messengers, also online instant messengers.
Individual Reflection:

Prabhath Kodikarage

The EWB project has taught me many things that will not only benefit my academic life, but provide important skills to use in my career after I graduate as well. When we were first assigned this project, my initial response to it was my typical attitude used towards high-school projects; an assignment that needed to be completed in order for me to pass. However after weeks of work, providing presentations and reports along with my team, I found there was more to it than it meets the eye.

This project enables first-year students to take a small grasp of what it is to truly work in a team. This includes setting deadlines, organising meetings, team management and finding ways to collaborate our work together. All these skills and tasks were new to me and in a sense, quite refreshing. This was because in high-school, group assignments for me included only completing our given sections in a project and handing it in. This project brought up a whole new side of collaboration, where communication was a necessity.

One of my weakest areas, and something I have tried avoiding in my high-school life was public speaking. This project in particular emphasised in that area and due to that, I have drastically increased my oral presentation skills. I initially had to use cue cards to present assignments, and at times I would read off the cards like I were reading a book aloud. However, after more practice and chances at presenting our work, I began not to rely on my cue cards and instead, speak using my own knowledge and memory of our assignment. Moreover, our tutorial class also used members of other teams to chair and assess presentations. I was chosen to chair at one of these presentations and it provided a whole new perspective when it came to seeing the flaws of our work. This is a great advantage and has allowed me to question what needs to be included in our project ever since.

The EWB project has taught me many things, but the three most important include setting deadlines for our work, organising meetings on a weekly basis to update our team, and lastly to take into account the criteria of an assignment. Also the sustainable nature of this project has in a way modified my career direction; in the sense that it has reinforced my dream of becoming an electrical engineer specialising in the field of renewable energy.

On an ending note, I would advise new students attempting the EWB project in the future, that setting deadlines in a project is essential for its completion. It is something I have noticed with other groups who have not set deadlines and have subsequently submitted low-quality work. Also team management is another vital aspect of this project. Learning to collaborate together and keeping the team in line allows work to be completed effectively and efficiently. Finally, brushing up on your writing skills is a key component of the report section of this project. It can be easily noticed and will be assessed whether it being poor or excellent.
**Individual Reflection:**

**Ariel Zochowski**

Coming in from the electronics production industry working in a team environment wasn’t anything new for me although this group project was definitely one of the most interesting projects and it taught me a lot about group dynamics with members of a different age.

Some of the things I have improved on were my writing and presenting skills, I have never been a good writer but having to do it almost on a daily basis helped me develop this skill, also all the feedback given by Professor Hong Ren Wu was very helpful.

When it comes to public speaking, seeing other classmates being as nervous as I was, and the mistakes they were making, helped me recognise the areas I had to improve on. Even though I still have a long way to go, I now possess the knowledge on how to further develop that skill.

This project hasn’t changed my career direction as I already have it figured out pretty well, however it will most definitely influence the way I would approach any task or project I might encounter in the future.

A few things I would recommend any student attempting this kind of project do, would have to be plan ahead, set deadlines, organize frequent group meetings, in our case even though each of the team members was assigned to do a different part of the research and sections of the report writing, if we didn’t have everything planned out properly we wouldn’t be able to finish it on time as all the elements of the report heavily relied on each other.