Sustaina-Loo Sanitation Solution
EWB Challenge 2011

Fab 4
Joe Karren Durlabh Pande
Ash Wu Chameka Madurawe
Vanukkam Devikulam!

We write to you from Sydney Australia as part of the Engineers Without Borders (EWB) challenge that features you as its target community. When we were challenged to propose an innovative and sustainable engineering project to improve your township this year, we were thrilled and honoured to offer a helping hand to such a beautiful area. Our team is called ‘Fab 4’ and we’ve designed a communal toilet facility which improves local access to sanitation without drawing on local water or energy supplies. Instead, it produces valuable resources out of human waste.

But before we tell you anything about what we would like to propose, we must first ask if you believe there is difficulty in accessing sanitation in Devikulam. EWB initially stated that access to sanitation was a primary issue in your community, and research supports this, however if we are to implement any project in Devikulam, we feel an imperative to consult with those receiving it first. Community consultation is a huge step in making any project community-driven, and this is what we would like to achieve for you.

Now, the description of our sanitation facility may be quite difficult to understand at first, and it also may be relatively awkward to talk about, but adequate access to sanitation is a hard-pressing issue which we all must tackle. Sourcing your local knowledge, materials and labour, we hope that through the construction of our Sustaina-Loo system that you will tackle it with us.

Basically, the following report outlines, describes and evaluates our provision of a sanitation disposal facility to your area in the form of a communal toilet. We know that freshwater and energy is a scarce and vital resource in Devikulam, and that is why this facility uses rainwater catchment roofing structures to autonomously collect rainwater. Better yet, solar energy is absorbed by the roof material and heats the collected water, giving you the capability to enjoy hot showers using the facilities inside. Like any communal toilet, this facility features the shower and four other toilet cubicles containing urine separating squatting basins (these are similar to conventional basins but a little more complicated).

But the beauty of the Sustaina-Loo system is its use of your wastes! Faeces, along with any other suitable organic material you wish to add, is collected in a ‘biodigester’ beneath the facility, decomposing it to form methane gas. This gas is collected in a cylinder and can be used as a supplement for cooking gas, highly combustible, clean for your lungs and most of all, free! Associated is the by-product of this process, compost, which is also a valuable resource, and this can be sold to local markets for significant profits (as we’ve calculated in this report).

But the key idea and belief of ours is that none of these characteristics are set in stone. Upon consulting with you, educating the benefits of effective sanitation and convincing you of the positive social, economic and environmental implications of the Sustaina-Loo facility, you may want to make significant changes to the project. We are determined to make this project user-driven, with your exclusive knowledge of the Devikulam community – your own community – guiding us in delivering an effective sanitation system to help your community and subsequent generations.

This letter is the first step. Thankyou!

Regards Fab 4

University of Sydney, NSW Australia
Executive Summary

Over 2.6 billion people, or 1/3 of the world’s population, are without a safe and private place to urinate and defecate (WHO, 2011). Fast becoming a symbol of global poverty, poor sanitation is especially present in the populous country of India. In the town of Devikulam on India’s east-coast, inadequate access to sanitation dampens the self determination and dignity of local residents and facilitates the spread of disease. As part of the EWB Challenge, we have proposed the introduction of a sustainable and self-sufficient community toilet system; one that operates off water and energy collected and generated autonomously. As a hygienic sanitation disposal facility, Fab 4’s Sustaina-Loo will improve the access to sanitation of Devikulam residents and prevent the spread of diarrhoeal diseases, raising their standard of living in a long term, sustainable manner.

Of local construction and materials, our design features a small wooden building with a heat absorbent polyethylene roof which can be extended during heavy rains. The purpose of this roof is to collect rainwater, which flows via gravity to a storage section under the roof and gathers in small reservoirs of water created by its undulating inner surface. During the day, heat from the sun is absorbed by the polyethylene material and trapped in these small reservoirs, effectively heating the collected water to provide hot showers. Inside the facility are four toilet cubicles containing urine-separating squatting basins, one shower and a hand cleansing area. All the freshwater used by the showers and sinks is directed to a permeable membrane filter which purifies the water for re-use. Faeces from the basins are directed to a polyethylene biodigester beneath the facility and undergo anaerobic digestion in a low oxygen environment, outputting usable biogas which can be removed and stored for use in heating, cooking and electricity. The now pathogen-free ecohumus remaining in the digester can be used as topsoil preventing road erosion. Harnessing energy from the sun, collecting and reusing its own rainwater, and converting human faeces into a valuable resource, the Sustaina-Loo is a low cost, low maintenance and long-term sanitation solution.

Implementing this design also needs to be supported by ongoing education to highlight its health benefits and transition Devikulam residents away from open defecation. Its construction will also be community-driven, with local residents forming guiding the whole project from the initial consultation stages, all the way through to construction and maintenance. This is with an aim to enhance the user equity of the project and ensure its sustainability and effectiveness into the long term, concurrent with the financial, environmental and cultural constraints presented to such a system.
Team Reflection

Like most groups of university students entering the EWB challenge, we were all strangers to each other until the day we united as Fab 4. With different backgrounds and ideas, tastes and interests, we believed that the only commonality we shared was the apprehension and confusion of entering the chaotic life of a university student. This was the case initially, however when we conducted our first group brainstorming session, we discovered that we all shared an overwhelming desire to succeed in the EWB challenge, and in the process make a difference to the world. We believe that Engineers Without Borders has given us the opportunity to build skills in teamwork and communication, and more importantly challenged us to step up and become not only model citizens of Australia, but citizens of the world.

Exchanging email addresses to liaise, update and share with each other ideas and research has been effective in facilitating the operations of our team. With the ability to share ideas in real time instead of waiting for the bi-weekly tutorials and the accompanied group session, our internet communication greatly benefited the formation and propagation of ideas in the beginnings of the challenge, while it has also aided in the collation of our report as we enter the later stages of the project.

As part of our project proposal, we were required to form a team constitution (see Appendix A) assigning roles and responsibilities of each member and providing contingencies in the case of group conflict. Despite this, we did not experience any problems nor did we require use of the measures put forward by the constitution at any time during the semester.

With regard to group roles and functionality, we formed a very successful strategy involving one group editor and three group researchers. The editor compiled, edited and refined the information given by the researchers, who found the required information to put the team’s innovative ideas into practice. The reasoning behind this is that it was important to maintain one ‘voice’ in order to ensure clarity and consistency in the report.

The only difficulties faced by Fab 4 have been those associated with the design of our system. Creating a facility to alleviate the sanitation issue in Devikulam and similar third world communities comes with many hurdles and obstacles, risks and contingencies, and countless factors to consider. With firm resolve to implement a biodigester solution to our facility, we had trouble deciding which user interface to include and whether or not to involve urine separation in our design.

As the smallest of four groups entering the EWB challenge at Sydney University, we believe that we hold a uniqueness that sets us apart from the other larger groups. There was no contempt or frustration involved during the challenge, nor was there any absence of communication, only loyalty.
and unity as we strove and succeeded in overcoming various obstacles to deliver a successful project.

Team Roles

Our team constitution (see Appendix A) was formed after a teamwork activity aimed at finding each individual’s strengths and weaknesses in the aspects of creativity, organisation, leadership and other traits. By completing the activity, which involved scores from a series of questions based on what we believe are our strengths, we found that Durlabh was well suited to creativity, Joe to organisation, Chameka to evaluation and Ash to leadership. What has been a surprising realisation upon reflecting back to this initial activity is the fact that these indeed emerged as our unique strengths over the course of the challenge - Durlabh with his crazy ideas, Ash with his constant motivational emails to the team, Chameka with her critical analysis of every nuance of our design and Joe with his ability to compile the tremendous amounts of data and information into an effective report. In essence, we have recognised the characteristics of effective teamwork, whereby each member provides a role most suited to them such that it adds to the clockwork of a cohesive team.

As such, the roles of the team members have been quite distinguishable over the period of the challenge. Below are the general roles that came about naturally after countless research tasks, including the need for a leader, creator, evaluator or a manager.

- Ash – Team Leader & Motivator
  Ash was immediately confirmed as the leader and motivator in Fab 4, demonstrated by his regular inspirational emails titled ‘Motivation!’ and emphasis on adhering to the marking criteria.

- Chameka – Evaluator and Artist
  Chameka eventuated as the person to make judgement on any queries or issues put forward by the team. Her skill at drawing also meant that she was designated the task of creating the educational posters of our implementation stage.

- Durlabh – Creator and Innovator
  While the ideas of the team were generally built upon by equal contributions of each member, Durlabh emerged as the problem solver of the group. When faced with technical issues, he came up with innovative solutions to move forward

- Joe – Organiser and Writer
  Joe was designated the task of compiling and editing the tremendous amounts of information gathered by the team into a report. This responsibility also required him to organise the team and the ideas they provided into an effective and useable form. Joe was also responsible for the collection of materials that were used to construct a successful prototype.

In relation to the report itself and the creation of a finished work, it would follow that we used a system involving three researcher and one editor. Ash, Chameka and Durlabh would find the relevant information to cover each section of our report, and Joe would edit and compile it into a
format with a single ‘voice’ essential for it to be understood easily by the reader (or by Devikulam stakeholders).

We all believe this was a very efficient method of completing the EWB Challenge, and are certain that it improved our ability to work as a team. Even at times when the workload became too great for our team editor, all three of the other group members volunteered to take an extra workload, demonstrating the companionship of an effective team. More importantly, this team has become a group of friends.

Individual Reflections

Joe Karren – Aerospace Engineering

Upon looking back at my EWB experience, I do shudder at some of the late nights I had to endure in compiling this report (and some of the horrible smells involved in the creation of our working biodigester!). I found it quite difficult to balance this subject and the workloads of my others during the course of the semester. As the group editor, I was charged with the responsibility to compile the ideas of Fab 4 into a cohesive report that effectively encapsulates our idea. However, after a four month break from study altogether, I found this extremely difficult and hence my first year at University has been quite an eye-opener. The EWB challenge has really been a challenge.

However, I have learnt and understood many new things since completing this task. I’ve gained an appreciation for the difficulties involved in engineering projects, especially those to be implemented in far away countries such as India with different languages, cultures and environments. There are so many factors and risks to consider, so many contingencies to be made, and so much research to be done that it initially forces you to reconsider your options. Do I really want to be an engineer?

Of course I do. This subject is definitely where my true passion in life lies. Suggesting innovative solutions to complex problems is so fulfilling, and this sense of accomplishment is increased dramatically when you know you’re helping impoverished people to enjoy the same rights and freedoms as we do in Australia (that every human being is entitled to). This challenge has instilled in me an awareness of the proportion of the world’s population living without sanitation, and the social, mental and physical ramifications this can have on the disadvantaged.

Above all else, the EWB challenge has taught me the benefits of effective teamwork, and how one’s workload can be reduced significantly when you have others to support you. Many times I had to ask my team mates for help with my roles because of the additional demands of my other subjects, and they were always willing to help. I soon realised that they were no longer my team mates. They were my friends.

For me, the EWB challenge has been a highly worthwhile experience, and I have felt a great sense of accomplishment at compiling a thesis-size report in just a few months. In essence, it has given me a taste of what it means to be an engineer.
Ash Wu – Biomedical Engineering

Upon entering the first few Advanced Engineering classes at Sydney University, we were instantly struck with the opportunity to design and implement a project that would be implemented in another country (India). This left me confused and unconvinced about the EWB challenge, because I thought to myself Why would communities trust the work of first year University students? However, following the formation of our team Fab4, all doubt of our Project Design had eventually left me as I began to see our teamwork, consistent application and similar values transform into a well constructed project proposal. Following this, I began to read the winning reports of preceding EWB challenges and realized that our team has what it takes to design the winning project for the 2011 EWB challenge.

As the semester crawled along, my perception and understanding of the EWB challenge completely changed. It was no longer just a compulsory task that is the Advanced Engineering course, but an opportunity to stand out not just as citizens of Australia, but as role-models of the world; an opportunity to voice as a team, what we believe were the fundamental issues of the world and an opportunity to practice creativity and innovation in hopes to implement a unique solution to these issues.

In terms of handling the workload of the Advanced Engineering assignments (project proposals, reports, prototypes and their presentation) that were in other words necessary steps practiced by successful engineers every day, I engaged in daily research and sent e-mails to my three other project partners, assigning whom will do what tasks – which proved to be very successful. I thought of researching and forming information from the data as very time consuming - which was inevitable, as many different sources needed to be read and referenced. To address the countless hours of researching, I convinced myself that this process would eventually contribute to new knowledge, and perhaps lead to a successful project that would ultimately improve the quality of life within communities. This was my main source of motivation for this challenge.

To conclude my reflection of participating in the EWB challenge as a humanitarian engineer representing Sydney University, I want to say that I have absolutely no regret with participating in this challenging yet satisfying learning experience, which has extended my professional, interpersonal and engineering skills. I am confident that the EWB challenge has set me aside as superior amongst other first year engineers, and for that I am thankful.

Durlabh Pande – Aerospace Engineering
The EWB Australia Challenge 2011 has been a rather long and exhausting one. Over the last thirteen weeks I, along with the rest of my group, have been constantly burdened with researching, writing reports, preparing presentations and prototypes, etc. This challenge has taken up a vast amount of my time and it has been rather difficult to do my part for the group at various occasions. However it wouldn’t be fair to say that I haven’t enjoyed these last few weeks working on the challenge. It has been very different from any other subject I have ever done in my life and has given me the engineering experience I require to move further in my career.

From my first Advanced Engineering tutorial it was stressed that I should find a group immediately so that we can get organised and start working on our project, since the first report on our progress was due in Week 4. I formed a group with the three people around me and luckily this group turned out to be exactly what I needed to get the project done. Our group was smaller than the others, which worked to our advantage since we got to know each other very quickly and made quick progress with our ideas. The other three members of my group were friendly and also highly focused, but since they lived rather far away from university we communicated mostly through tutorials and emails. This didn’t deter us though, and once we had established that we wanted to work with sanitation we worked effectively and finished the first report, and did rather well. We also worked effectively throughout the rest of the semester and each of us had brilliant ideas throughout the way which enhanced our project. Now that we are approaching the end of the challenge I’ve realised that I couldn’t have asked for a better group and was very lucky to work with these people, and hope to do so again someday.

We have learnt much as a group over these last few weeks, however I have also gained a wealth of knowledge and experience personally that will help with my life. I have realised that I was rather naive back in high school, shut off from the real world, with most of my knowledge of the world gained from news reports and National Geographic Magazines. It is through this challenge that I have gained insight into various problems faced by communities living under the poverty line, and also how solutions can be designed to help these people. At the start of this semester I had no engineering experience and the idea that we had three months to design an entire engineering solution to help a real community seemed ludicrous. However over these last few weeks while I have struggled to finish everything effectively and within the deadline I realised that this was the perfect way to bring us into the engineering faculty. The lectures which taught us about teamwork, leadership, etc would not have been nearly enough to help us with our engineering career; this project was required for practical experience. It has helped me realise what it means to become an engineer.

I feel that this has been the perfect semester for me, especially with Advanced Engineering, and this project has been a great introduction to what I hope to learn over the next five years. I have worked very hard, struggled on several occasions, but in the end I have managed to complete this project, with the rest of my group, and I feel like each of us will take something different from this occasion, since our duties have been varied on several occasions. The most important thing I have gained from this challenge is a basic understanding of what an engineer is and what he or she does. I have also gained hope that I can become an engineer one day, and that this is no longer just a dream but an existing reality.
Chameka Madurawe – Biomedical Engineering

I still remember the day I got the letter with the offer to do the advanced engineering subject at the University of Sydney. It took me a while to make the decision whether I should accept the offer or not because I was confused about what actually this subject was. Coming to the first advanced engineering class I realise this subject mainly involves group work, which made me more interested on the subject. But I still didn’t have a clear understanding about the objectives of the subject.

After beginning our project it become transparent what the University was trying to develop in us, as future engineers of the world. Before I came into this class I thought of engineering as a career where you developed equipments or facilities based on amazing scientific theories. But now I’ve had a taste of the true beauty of engineering. It’s just not simply constructing something, but is putting together all the aspects such as community needs, ethical issues, ideas, innovation and liabilities to improve products that are targeted to improving the quality of life in the one world we live in. This is why I agree with our groups’ idea for developing a sanitation system because I wanted to experiment how successful we can be by putting all the above aspects together in shifting the lifestyle of a community to a whole new and improved level.

Moreover, what I most appreciated most about the EWB challenge was the group work. Initially I knew no one in the class on the first day. Looking back, now I have made great friends in the class. I actually enjoyed attending the bi-weekly advanced engineering tutorials because we learnt something new and interesting about the engineering world every day.

In addition the greatest experience I got from this subject was the challenge of the project. At first I thought it was impossible to construct a report that was 80 pages long in just one semester. But now we have done it. Getting it all together step by step kept us on track throughout the whole semester. It made me understand the underlying aspects of the engineering discipline (particularly Humanitarian Engineering) and also made me feel like a young engineer as I have already completed a project in my first semester of Uni. Also, this challenge provided me with the great opportunity to apply what I learnt as an engineering student to a community desperately requiring humanitarian aid.

On the other hand, I must say this challenge was a very exhausting process in terms of the never-ending hours of researching. With the workload and pressure imposed from other subjects, I lacked sufficient time and effort to perform thorough researching on all areas of the project. Nevertheless, I am glad I embarked on this amazing journey and opportunity that is the EWB challenge, and am very much appreciative of the experience that I’ve developed through this challenge.
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**Anaerobic Baffle Reactor** - an improved septic tank because of the series of baffles through which the wastewater flows resulting in improved treatment.

**Anal Cleansing Water** – water used for anal cleansing.

**Biogas** – the mixture of gases released by anaerobic digestion (70% methane, 25% carbon dioxide and 5% nitrogen, hydrogen sulphide and water)

**Blackwater** – a mixture of urine, faeces and flushwater and is highly pathogenic.

**Brownwater** – Blackwater without urine (generated by urine-diverting flush toilets)

**Compost/Ecohumus** – earth-like decomposed organic matter used safely in agriculture

**Dried faeces** – faeces dried at high temperature becoming sanitized powder

**Dry Cleansing materials** – paper, rags, leaves or stones (materials other than water) used for anal cleansing.

**Faecal Sludge** – partially digested sludge or slurry after blackwater storage.

**Faeces** – solid excretement produced in the bowels

**Flushwater** – water used to transfer the waste from the user interface to the next stage

**Greywater** – water generated from washing and cleaning, containing some pathogens.

**Loading Rate** – the rate of input of organic material into a biodigester

**Stored urine** – urine that has been hydrolysed naturally from storage, becoming more sanitized and with a pH of 9.

**Stormwater** – rainfall runoff from roofs, gutters and other solid surfaces

**Urine** – liquid excretory product produced by the kidneys

**Vectors** – flies, rats and other organisms associated with the spread of pathogens from faeces.
2 Introduction

2.1 Problem Identification

Human rights are those basic rights and freedoms which all human beings are entitled to; that is, the right to life and liberty, equality before the law, shelter, food, water. Among these is a human being’s basic right to sanitation, because the requirement to dispose of human waste transcends gender, age, race or religion – a purely universal human trait. Sanitation is the provision of facilities and services enabling the maintenance of hygiene and safe disposal of human urine and faeces (WHO, 2011). However, inadequate sanitation across the world today is becoming a major source of disease, especially in developing regions, and also fast becoming a symbol of global poverty. Approximately 2.6 billion people currently lack the resources and infrastructure to be able to defecate and urinate in a safe and private place (WSSCC, 2010), and failure to manage human effluent in a sustainable manner can eventuate in the contamination of water and soil, and the spread of diseases such as cholera and dengue fever.

India, soon to be the world’s most populated country (Ferguson, 2011), is perhaps at the centre of this global humanitarian problem. Especially in rural areas, overwhelming levels of poverty and lack of basic infrastructure forces residents to urinate and defecate in a public place or at best poorly engineered toilet arrangements. In the remote community of Devikulam in South East India, the common practice of open defecation and urination presents a health issue for all its residents because it may contaminate both food and water sources (EWB, 2011). Located in the remote region of Panchayat, Devikulam is isolated from waste infrastructure and it is extremely difficult and costly to process and remove waste from the region.

Public defecation in Devikulam can transfer pathogens and therefore contaminate both water and food supplies. There are three bores in Devikulam that are the source of the community’s water, however all have been found to contain bacterial populations and one has been identified as saline (EWB, 2011). Furthermore, during monsoon periods, heavy rains can cause pathogens to be transported from defecation sites to the bores via floodwater, thereby contaminating the water supply.

Several wastewater treatment systems have been introduced in nearby regions with limited success. Dry or compost toilets, which don’t require water and have safe waste disposal characteristics, have been commonly implemented and have had various adoption rates based on each village’s social dynamic (EWB, 2011). Other programs have included baffle reactors, septic tanks and composting toilets but have been unsuccessful due to a number of reasons; the requirement of money and resources among them.

Previous project teams in Devikulam have explored the possibility of community toilets, however after some consultation with the locals and review of existing facilities, they feel that there will be ongoing problems with maintenance since nobody will take this responsibility. They have decided to
build single toilets, with one toilet servicing a single household, and only ten of these are expected to be built.

To solve its sanitation problem, Devikulam community requires a low maintenance, low input human waste system that will effectively contain and dispose human effluent. Without infrastructure and facilities for Devikulam residents to defecate hygienically and privately, the spread of disease will continue. Our design uses innovative thinking and creative analysis to create a sustainable and viable solution to human sanitation problems existing in Devikulam. Furthermore, we hope to develop a framework that provides effective sanitation infrastructure to improve the living standards of human beings on a global scale.

2.2 Imperative - Our View

Humanitarian engineering is undoubtedly the central idea in all that our project represents. Considering around 90% of today’s engineering is directed at 10% of the world’s population (HESE, 2011), we see the EWB challenge as an opportunity to make a difference. Learning about Devikulam - a community with so many areas for improvement – it has been difficult to concentrate on finding a sustainable, long-term solution for just one aspect. With issues ranging from reusable energy to water, transport to housing, which challenge is the most important to address in order to improve the life of Devikulam residents?

Sanitation, for us, takes precedent over any other issue in EWB’s list. Every human being, regardless of their race, religion, age, gender or culture, must defecate and urinate, and they deserve the right to complete this in a safe, private and hygienic place. Producing about 2lbs of faeces and around 500ml of urine on average each day, this matter must be disposed of in a clean and hygienic manner which is comfortable for the community.

Furthermore, and in support of our personal view, the United Nations Development Program (UNDP) set in 2000 the Millennium Development Goals (MDGs) - eight international development goals that all 192 United Nations member states have agreed to achieve by the year 2015. Among these is ‘Target 7C’, aiming to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation (MDG, 2011).

With little infrastructure or facilities in order to dispose of their waste, Devikulam residents face daily hardships in maintaining a sense of hygiene and privacy when going to the toilet. More importantly, the practice of public defecation can eventuate in the contamination of their water supplies during heavy flooding. In order to improve the living standards of its residents and minimise the spread of pathogens and water-borne diseases, Devikulam urgently requires the development of a sustainable, long-term solution for human sanitation and waste disposal.
2.3 Objective

Our objective is to provide a sustainable solution to sanitation issues in Devikulam and thereby improve the quality of life of Devikulam residents. Furthermore, we aim to design this solution such that it requires little to no operating costs and creates a resource from human and other organic waste. Obviously, this solution would need to be cohesive with the environmental, social and economic characteristics of our designated partner – Devikulam Village, Tamil Nadu, India.

2.4 Design Criteria

As a unique community, Devikulam requires a unique solution to address the issue of sanitation and the health impacts it creates. The success of the sanitation design that we aim to produce will be determined by its fulfilment of the following requirements listed below. This ensures design is suitable for the community and also ensures that any social, economic or environmental costs are minimised.

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>Description</th>
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<tbody>
<tr>
<td>Access to Adequate Sanitation</td>
<td>The design should provide a facility for all residents of Devikulam to adequately dispose of their waste in a hygienic, safe and private place.</td>
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<tr>
<td>Reduction of pathogens</td>
<td>The system should bring about a large reduction in pathogens in human waste and acts as a treatment mechanism.</td>
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<tr>
<td>Improved hygiene</td>
<td>The design must also incorporate measures to improve the hygiene of local residents</td>
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<tr>
<td>Compatible with Traditional practices</td>
<td>The use of this system must be integrated with traditional practices to allow for familiarity and congruency with established community values.</td>
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<tr>
<td>Effective use of locally available materials</td>
<td>To reduce capital costs of construction, the sanitation facility should utilize a large portion of its construction components from locally available materials.</td>
</tr>
<tr>
<td>Economically feasible</td>
<td>The long term costs of the system must be balanced by the potential economic gains of the system</td>
</tr>
<tr>
<td>Production of Outputs</td>
<td>Rather than intaking waste and disposing waste, this facility should create a resource from waste, enabling sale or utilisation by residents.</td>
</tr>
<tr>
<td>Sustainability Maintainability</td>
<td>The system should be a self-sustainable which incorporates recyclable functioning, and should be a long-term solution for the community to justify the initial capital costs. Maintenance of the this system should also be simple and inexpensive.</td>
</tr>
</tbody>
</table>
2.5 Ethical Responsibilities

Engineers design innovative solutions to problems throughout the world, and use their knowledge and skills to benefit the community. Engineers sometimes have to make tough decisions in order to accomplish their project, and so it helps to have a Code of Ethics which engineers can abide by when designing their project. Engineers are given a lot of power over their projects and hence must act responsibly in order to achieve the best solution without hurting the environment or community.

The Engineers Australia ‘Code of Ethics’ has four major parts; Demonstrate Integrity, Practice Competently, Exercise Leadership and Promote Sustainability. Each of these parts has further sub criteria. The engineer must have a well-informed conscience, be honest, trustworthy, and respectful. They must be competent and also maintain and act on adequate knowledge. They should also communicate effectively, encourage diversity, engage with the community and foster their wellbeing, balance present and future needs, and uphold the reputation of engineering. The ‘Guidelines on Professional Conduct’ breaks this code down into more pieces; however this doesn’t have to be followed as strictly (Engineers Australia, 2011).

In the case of Devikulam, the code of ethics requires us to be responsible while designing our project, and be respectful of the needs of the people. We need to be honest with the people about all aspects of our sanitation system, and need to let them know every nuance of the design and the ramifications it would have on their lives. We need to be respectful of their customs but also reinforce the benefits of our system to them, and let them know that it would improve their health and living conditions, and also their economic wellbeing. We need to gather all our information and consider many scenarios to compile this data together, and only then can we try to implement our project. We need to be careful not to diverge from this ethical code and we must be especially respectful of the fact that it is not our life which is changing significantly, it is the life of the people of Devikulam. The present and future needs of the people regarding this sanitation system must be considered today because it is an purely ethical requirement necessary to move forward.

We agree to abide by the Code of Ethics and accept all ethical responsibilities that come with our project, as we would with any professional engineering project in the real world.
## 3 Background

### 3.1 Living Conditions in Devikulam

Devikulam is a small village located in Nadukuppam Panjayat, Marakkanam Block, Tindivanam Taluk, Vilupurram District, Tamil Nadu, India (Buzza n.d.) The nearest major city to Devikulam is Pondicherry (EWB 2011). There are a total of 358 people (86 families) living in Devikulam, either in the colony, village, or Thoppu. Most houses have a typical occupancy of 4 – 7 people who have been living there between 20 to 70 years.

Households are mostly hut styles with cement or mud floors, thatched or palm leaf roofs, and walls made out of mud or burnt brick. The main occupation in Devikulam is farming or agricultural labour. Devikulam only has a primary school for children 5 – 10 years of age, so people need to go to the nearest village Nadukuppam for secondary education as well as for food and other services.

The roads are mostly gravel, however there is a tar road between Devikulam and Nadukuppam. Bikes are only ridden by men and therefore women and children have to walk. They often complain about the unsanitary conditions since open defecation usually occurs along the road between these two villages (Buzza n.d). In response, dry or compost toilets have been implemented in the region but with limited success (EWB, 2011).

There are two castes in Devikulam; the Scheduled Class (formerly ‘Dalit’) who live in the colony, and the Most Backward Class (MBC) who live in the village (Buzza n.d). Most houses are connected to the power grid, own land between 2 - 5 acres and have some livestock including cattle, goats and chickens (EWB, 2011).

The central feature of the village is its primary pond adorned with a healthy population of lotus plants, which was once used as a source of clean drinking water but is nowadays used for bathing, washing cattle and swimming (Buzza n.d). Another bore in the colony has water which is considered saline, so is only used for cleaning and swimming, but not drinking. Out of the two other bores in area, one is no longer functioning so the other one is currently being used for drinking and supplying the water storage tank and is located near the pond. Salt-water intrusion levels are rising, however for the time being this bore remains safe for drinking. In addition, bacterial presence, in particular E Coli., has also been detected in the water, and this is a major issue that must be addressed (EMS, 2011).
3.2 Environmental Conditions in Devikulam

Devikulam is nestled in the tropical state of Tamil Nadu, and is located near the south eastern part of the Indian peninsula. The climate in the coastal area of Tamil Nadu, including Devikulam, is tropical with minimal variation in the summer and winter temperatures. Devikulam experiences a warm and humid climate for most of the year and temperatures soar during the summer months of April through to June, reaching up to 40°C with high humidity. Temperatures in Pondicherry, the closest city to Devikulam, range from 26°C to 38°C for the most part of the year. The summer season is mostly dry with a clear blue sky (SITT, n.d.).

Tamil Nadu experiences winter from November to February, however temperatures only fall slightly and average around 20°C. The associated monsoon period during the months of October to December brings heavy rainfall accompanied by thunder and lightning. The monsoon showers result in a significant fall in temperatures and an constitute a major proportion of the average annual rainfall recorded, about 998 mm a year. The months of December - February are usually the best time to visit Devikulam, right after the monsoon period (Maps of India, n.d.).

There is an area of about 3 - 4 acres of public land that is covered in coconut trees and plants. The ground water level in Devikulam is relatively high, and the community is concerned about the increasing salinity of groundwater supplies. Much of the land in Devikulam was spoiled after the 2004 tsunami when salt-water encroached on the groundwater supplies. Agriculture was severely impacted and soil quality has only recently begun to improve in the area (DES, 2006).
3.3 Propagation and Impacts of Pathogens

3.3.1 Pathogens

A pathogen is a biological agent with structural, biochemical or genetic traits which render it virulent, causing disease in its host (McElhatton & Marshall, 2007). Human effluent and a lack of hygiene are implicated in the transmission of many infectious diseases including cholera, typhoid, hepatitis, polio and dengue fever (Sulabh Envis, 2011). These diseases are a result of pathogenic organisms altering the function of bodily systems in their human host, creating inflammation, malignancy and tissue breakdown. It is estimated that around 2.2 million people die annually from pathogen-related diarrhoea and also that 10% of the world’s population is severely infected with intestinal worms related to inadequate sanitation (Murray and Lopez, 2001). This is perhaps attributed to the fact that over a third of the world’s population is without a safe and private place to defecate and urinate.
### Table 2: Common pathogens and disease related to sanitation

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Disease</th>
<th>Transmission and Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella Typhi</em></td>
<td>Typhoid</td>
<td>Faecal-oral route.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fever</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Insomnia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Diarrhoea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Abdominal pain</td>
</tr>
<tr>
<td><em>Shigella flexneri</em></td>
<td>Bacillary dysentery</td>
<td>Faecal-oral route.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Dysentery (diarrhoea with blood and mucus)</td>
</tr>
<tr>
<td><em>Vibrio Cholerae</em></td>
<td>Cholera</td>
<td>Faecal-oral route.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Severe diarrhoea and vomiting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Death in hours due to hydration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Very contagious and easily spread.</td>
</tr>
<tr>
<td><em>Escherichia coli.</em></td>
<td>E. Coli. infection</td>
<td>Faecal-oral.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Severe diarrhoea with or without blood.</td>
</tr>
<tr>
<td><em>Hepatitis A &amp; E viruses</em></td>
<td>Hepatitis A &amp; E</td>
<td>Faecal-oral route.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Also transmitted via contaminated/uncooked foods</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fever and nausea</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Body weakness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Both short term and long term cases</td>
</tr>
</tbody>
</table>

(Who Factsheets, n.d.)

#### 3.3.2 The F-Diagram

The F-diagram, first depicted by Wagner & Lanoixs (1958), is ideal for modelling the typical faecal-oral transmission of sanitation-related pathogens. It represents the multiple methods of transmission, displaying that even if humans remove chances of physical contact with faeces, pathogenic microorganisms may still be transmitted via animals, plants or materials which have also made contact. This means that faecal matter and the microorganisms it contains may be found in food, water and remain in the soil, contaminating it for extended periods of time. The F-Diagram
emphasises the importance of proper human waste disposal in preventing pathogens moving between mediums, and as the diagram illustrates, this can be as simple as the latrine type or hand cleansing.

![F-Diagram](image)

**Figure 3: The F-Diagram**

People may not die from pathogenic diseases related to the improper disposal of waste, but they and others will lose days or weeks of work being sick or caring for the sick, and this will impact on their wealth, which is already a huge problem in this community. Often these illnesses impact on children or the elderly because their immune systems are not as strong as adults. It is also important to recognize that people may transfer the disease without showing any symptoms. Hunt (2001) highlights the fact that across the world, 75% of the people infected with cholera do not develop any symptoms, and the pathogens are shed via their faeces after 1-2 weeks in their system to potentially infect other individuals.

![Open defecation](image)

**Figure 4: Open defecation**
3.4 Gender Issues

Perhaps a less obvious humanitarian issue interrelated with the global need for adequate sanitation is the equality and empowerment of women, who require differing sanitary needs to men. In developing regions, the restricted access to sanitation forces community members to defecate publicly, in poorly ventilated store-rooms or at rudimentary squatting basins. While men can simply urinate and defecate behind a tree or bush, Narasimhan (2002) argues that women have a lesser tendency to do the same and are thus handicapped to a life of hardship. She reinforces this message, explaining the dire situation of some women in rural areas where limited public toilets instil in them an imperative to reduce their eating and drinking in order to reduce their need to go to the toilet (See Appendix B).

This additional disadvantage of women and the behaviour it induces may cause health issues separate from those related to the transmission of pathogens from faeces. Anaemia, dehydration and other illnesses can arise from the reduced intake of necessary foods and water, and this continues to disempower women in areas where access to sanitation is inadequate. This not only threatens their physical wellbeing, but also impacts on their self-determination and sense of self – deep psychological impacts and behaviours which propagate throughout communities.

The importance of involving both women and men in the management of water and sanitation has been recognized at the global level, starting from the 1977 United Nations Water Conference at Mardel Plata, and also the Millenium Development Goals. Efforts directed at involving women in the formation and construction of sanitation projects will help improve the perceptions and equity of women, and hopefully eliminate the problems aforementioned. First and foremost, the improvement of sanitation in developing countries will not only improve the health of all its residents by reducing the possibility for pathogen transmission, but it will also empower women and improve gender equality.

3.5 Background on Bio-digestion

3.5.1 What is Biogas?

Biogas is a gas produced by anaerobic digestion (in the absence of oxygen) of organic material, and is comprised of 70% methane (Jones et al, 2008). Thus, a bio digester is a system (usually a tank) that processes organic material to produce this biogas. This process is ultimately called biodigestion and usually features an air tight vessel whereby these anaerobic reactions can occur.

3.5.2 Input Materials

According to Jones (2008), in theory any organic material can be decomposed anaerobically to produce biogas, but some materials work better than others. In general, materials need to be rich in energy and easily digestible. Manure works very well, supplied from cows, pigs, or horses.
Biodigesters can be fashioned from septic tanks, but the waste production is often not sufficient to produce enough biogas, and cleaning agents such as bleach kill the anaerobic bacteria necessary for digestion. Plant material can be used, but acidic matter should be avoided for it disturbs the anaerobic processes. Plant matter is also often low-energy and slow to digest, creating a number of difficulties for digesters relying solely on such material. Lignin is the not easily digestible material that must be regularly removed from biodigesters, and is created by partially digested plants and other materials. To minimise lignin content and ensure low maintenance requirements, it is important to ensure materials such as manure with a high carbon and nitrogen consistency are used.

3.5.3 The Process

There are three main stages during the process of biodigestion whereby different bacteria present within the organic material consume and deposit specific elements and compounds.

The first stage is called “hydrolysis”, where insoluble organic polymers such as carbohydrates and fats are broken down into sugars by hydrolytic bacteria. These materials are further decomposed to form ammonia, carboxylic acids and carbon-dioxide, resulting in a new gas atmosphere composition of around 80% carbon dioxide and 20% hydrogen. (WASTE, n.d.)

The next stage is “acidogenesis”, where organic acids formed during hydrolysis are converted by acetogenic micro-organisms to form acetic acid, resulting in falling carbon-dioxide and hydrogen concentrations.

The final stage is called “methanogenesis” where methanogenic bacteria convert the acetic acids into methane. As a result, around 70% methane comprises the atmospheric environment of the biodigester which is used as a fuel source.

The solid waste left at the bottom of the biodigester may also be used as fertiliser or top-soil as it is now significantly less pathogenic. During the different stages of anaerobic reactions, pathogenic organisms are outcompeted for resources and their population subsequently decreases. The leftover ‘digestate’ is the residual fibrous material left at the end of processing. End-use ranges from landfill cover, landspread for agriculture or the production of a high quality soil conditioner after an additional maturation process. The quality of the original input biowaste determines the quality of the digestate at the end of the process (WASTE n.d.)

![Flow Chart](image-url)
3.5.4 Optimal Conditions for Anaerobic Digestion

The conversion of volatile acids to methane by methanogenic bacteria is significantly influenced by the temperature and pH levels within the biodigester. To optimise methane production, it is ideal to regulate temperatures and pH levels or place the system within an environment in which these conditions pre-exist. The conditions can be monitored using probes, and in addition, one can further facilitate optimum through regular and efficient mixing of the contents of the digester to improve the contact between the materials.

Temperature

The temperature significantly impacts the rate of hydrolysis and methanogenesis, and according to Tchobanoglous (2003), most biodigesters operate in the mesophilic temperature range (24-36°C), which provides a stable biogas environment. Moving into the thermophilic range (50-58°C), the destruction of pathogens and the creation of methane accelerates, however stability is sacrificed.

Gas production efficiency generally increases with temperature, roughly doubling for every 10°C rise between 15° and 35°C. However the quantity of ammonia in a digester also rises with the increasing temperature and this has a known inhibitory effect on methanogenic bacteria (Biogas Aust. n.d).

pH

The pH level of biodigesters tends to be self regulating due to the fact that it is bacteria which command the conversion of compounds and acids (Tchobanoglous, 2003). An example of this is that the reactions within the digester which relate to the formation of carbonic acid tend to contribute to the acidity levels, however simultaneously, this acidity is offset by the formation of bicarbonate ions. Nonetheless, in order to ensure optimal production of methane, it is advised to monitor the pH levels so that they lie between 6.5 and 7.5.

Figure 6: Typical Biodigester Process
3.6 The Biodigester: Previous Case Studies

3.6.1 Costa Rica

Case studies in Costa Rica show manure works very well as an input to produce bio gas because it is rich in nutrients (specifically nitrogen compounds and carbon), easily digestible and has low acidity levels, and these characteristics are compatible with bacteria involved (Fandel, n.d.). There are many different styles of bio digesters. In Costa Rica, one popular biodigester style is known as "media bolsa," consisting of a large underground tank that is covered by a large, inflatable plastic sheet. Another style used is called the "salchicha" ('sausage' in English), consisting of a plastic bag spread out in a ditch with tubes attached at each end to supply and remove the organic material. Studies also found that the production of biogas was significantly affected by the temperature of the surrounding environment - if the temperature drops below 20 degrees Celsius, the reaction slows down (Fandel, n.d.)

3.6.2 Cambodia

In Cambodia it is well known that fuel wood and charcoal is the traditional source of energy for domestic cooking. The primary reason why most families prefer to burn firewood and charcoal is due to its cheap price and availability as a resource compared to other energy sources. Due to fall in the number of natural forests and accelerating demand for available wood fuels, the need for renewable and sustainable energy has gained more emphasis in Cambodia and associated has been the increase in use of bio digesters.

Government and non-government agencies in Cambodia have recently implemented programs to disseminate the biogas technology to rural families in order to improve both livelihood development and environmental conservation (Lauridsen, 1996). The 2009 EWB Challenge winners from the University of Western Australia implemented a unique biodigester solution for floating communities in the Tonle Sap region of Cambodia (EWB, 2011).

3.6.3 Rural India Biogas Projects

There have been several projects involving the development of bio-digesters in 20,000 households in the Hassan and Kolar districts of the Indian state of Karnataka (UNFCC, n.d.). These projects are aimed at improving the livelihoods and living conditions of poor rural communities by replacing traditional wood burning stoves with methane stoves. This is an attempt to reduce the health issues associated with smoke inhalation, which according to the World Health Organisation (2011), attributed to over 1.5 million deaths in women and children each year.
3.7 Biodigester Variations

Different variations in biodigesters exist as a result of specific community needs, goals and varying levels of effectiveness (see Appendix C). The size, mode of operation and placement of the biodigester can have a detrimental impact to its suitability and hence fulfilment of its design goal. These variations include;

3.7.1 Size

Input capacity and hence methane production is proportional to the size of a biodigester - the larger the biodigester, the more methane is produced per unit of time. Determining this size is dependant on the amount of input available (or the loading rate), the methane required and the available space for the vessel itself. To power several lighting systems and provide cooking gas for a family of 4-5 people, Fry (1973) believes that this will need around 200 litres of gas per day. Depending on the system’s efficiency in relation to temperature, pH and loading rate, this would require a digester of around 2m³ capacity.

3.7.2 Mode of Operation

The mode of operation of a biodigester refers to its process of input and output and generally encompasses two systems used commonly today;

- **Batch Fed Digesters** – involve a self-contained tank sealed off with a batch of organic material left to ferment for a given period of time until a sufficient amount of methane is produced. They are simpler to manufacture yet require significant effort to clean, load and seal and they offer quite sporadic gas production.
- **Continuous Digesters** – involve small amounts of material being fed to the digester daily, with an input pipe for undigested material, an output pipe for digested slurry and a valve to release or store the methane. The outlet pipe must be lower than the input pipe in order to ensure the (lighter) digestate is pushed out into a storage tank. These can generally be modified to be used in a toilet facility, with the input of faeces provided directly by the toilet piping.

3.7.3 Placement

The placement of a biodigester refers to its position (vertical or horizontal/displacement). Batch fed are great example of these and usually involve a vertical cylindrical tank whereby waste is inserted via an input chute, gas rises to the top and digestate gathers at the bottom to be manually removed later. They are generally easy to operate, however normally feature poor mixing of organic matter and hence irregular pathogen reduction. Continuous fed digesters are substantially better at producing uniform pathogen production and are generally in displacement forms. Displacement systems are horizontally placed and involve the input material gradually displacing the lighter digestate and slurry, pushing it out into another tank.
4 Sanitation Disposal

Sanitation is a multi-step process in which wastes are managed from the point of generation to the point of use and/or disposal. A sanitation system is comprised of products that move through various functional groups. These functional groups consist of technologies which are implemented in the correct context to successfully treat or dispose of the waste.

There are four primary considerations in sanitation system design;

1. User interface; through which the person comes into contact with the system.
2. Type of Disposal System; the nature of pre-collection
3. Collection and Storage/ Treatment; required to store the waste and allow it to decay.
4. Use and/or disposal; where the waste is applied or safely disposed of.

4.1 User Interface

The user interface is the method by which the sanitation is accessed and is the technology with which the user interacts. There are several main user technologies with different characteristics, their suitability varying between communities and countries.

4.1.1 Dry Toilet

A dry toilet is a waterless toilet system involving a raised pedestal or squat pan sitting above a drop-hole. Faeces and urine fall through this hole and are collected in a pit below the apparatus. This is a very simple design, easy to use, comfortable and arguably a more natural option compared to other methods (Tilly et al. 2008). The squat pan or pedestal can be produced from local materials such as concrete or wood and are appropriate for almost every climate. It does not require a constant source of water and is inexpensive to maintain and implement. However, there are some drawbacks. Strong odours normally emanate from the pit, even if it equipped with a vent, and the pile is normally visible through the pedestal, causing some discomfort. If the pedestal is not well sealed over the pit, stormwater may infiltrate and cause it to overflow releasing the faecal matter into the surrounding area.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>No need for a constant source of water</td>
<td>Odours are noticeable</td>
</tr>
<tr>
<td>Built with locally available materials</td>
<td>Excreta is normally visible</td>
</tr>
<tr>
<td>Low capital and operating costs</td>
<td></td>
</tr>
</tbody>
</table>

4.1.2 Urine Diverting Dry Toilet

A urine diverting dry toilet is one that features a divider so that urine is diverted away from the faeces with little effort from the user. The urine is drained from the front area of the toilet, while the faeces fall through its own section and into a chute or pit. It is important to ensure that the urine does not enter the pit (and vice versa) because the faeces is normally covered with ash or earth in order to dry it out as compost. However this depends on the method of storage and treatment. Some diverting toilets feature three different holes (for faeces, urine and another for anal cleansing water), however these are a more complicated design and create the risk of fluid entering the faecal
pit. Appropriate for most climates, a urine diverting dry toilet is easily manufactured using plastics, ceramics or wood. However, its implementation may require education of the target community because the system itself may not be intuitive and may involve early users making mistakes or being deterred (Tilley et al, 2008).

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>No need for a constant source of water</td>
<td>Requires education and acceptance</td>
</tr>
<tr>
<td>Negligible odour and insect problems</td>
<td>Prone to clogging if misused</td>
</tr>
<tr>
<td>Built with locally available materials</td>
<td></td>
</tr>
<tr>
<td>Low capital and operational costs</td>
<td></td>
</tr>
</tbody>
</table>

4.1.3  **Urinals**
Urinals are designed for urine only and are underestimated in their potential benefit to communities. Generally targeted at males, they can be wall mounted units which channel and collect the urine, and can be water-based or waterless. Water based urinals use between 4 and 10 litres of water per flush, and the water and urine are channelled into a storage tank with a sealing mechanism to prevent odours. Waterless systems vary in design and can involve a valve or seal which opens and then closes when not in use. When men have access to a urinal, they can be persuaded away from urinating in public, which improves the sanitation characteristics for the rest of the community. It involves no change in behaviour and is generally accepted. Some designs even incorporate a target on the urinal wall can also improve aiming and make the system more user friendly (Tilly et al. 2008).

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>No need for a constant source of water</td>
<td>Normally only useful for males</td>
</tr>
<tr>
<td>Built with local materials</td>
<td></td>
</tr>
<tr>
<td>Low capital costs</td>
<td></td>
</tr>
<tr>
<td>Negligible odour problems</td>
<td></td>
</tr>
</tbody>
</table>

4.1.4  **Pour Flush Toilet**
A pour flush toilet is similar to a regular flush toilet however it does not involve a continuous flow of water from a cistern; rather, it is flushed via the input of water by the user. Also like a regular flush toilet, it features a water seal which prevents odours from escaping, and the force of the poured water (usually from a height) is enough to force the faeces up and over the curved water seal (usually around 20-30 degrees). Due to high demand, manufacturers have produced low cost pour flush toilets with varying requirements for the level of pour-water needed (e.g. low requirement versions involve separating toilet paper and other materials from the toilet in order to ensure no blockages). Pour flush toilets are easy to use and adequate for all climates, however there must be a plentiful supply of water even though they use less than conventional cistern toilets. Additionally, they are more susceptible to blockages and thus require more maintenance (Tilly et al. 2008).
4.1.5 **Cistern Flush Toilet**

A flush toilet is usually made of porcelain and consists of a water tank which provides water for flushing excreta out of a bowl and into a water sealed pipe system. Depending on the design, cistern toilets use from 3-20L of water per flush, and the water in the cistern above the bowl is released by a lever. These systems are safe and user-friendly provided they are kept clean, and are suitable for all climates. However, they should only be used if there is a plentiful supply of water available and a collection/storage and treatment solution is locally available. A skilled plumber is required to properly install a flush toilet, and it is recommended that flush toilets only be implemented if the hardware is readily available locally. Despite their effectiveness at disposing of human effluent, some low-use water models may require more than one flush to drain away the faeces, thus defeating the purpose of their efficiency.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water seal prevents odours</td>
<td>Requires constant water source</td>
</tr>
<tr>
<td>Excreta is flushed away before next user arrives</td>
<td>Higher Maintenance</td>
</tr>
<tr>
<td>Low cost</td>
<td>Requires education</td>
</tr>
</tbody>
</table>

4.1.6 **Urine diverting flush toilet**

This is similar to a cistern flush toilet except the faces and urine are diverted away from each other via separate basins in the toilet bowl. In the rear basin where faeces are collected, water from the cistern flushes the solid waste out and a water seal prevents odours from escaping. In the front basin, urine is collected without water, however a small amount is used to clean the sides when flushed. A urine diverting flush toilet is suitable when there is a use for the urine and a specific treatment solution for the faeces, and is good for when there is a limited supply of flushing water available. However, this technology requires dual plumbing which complicates its installation, and its implementation must feature educational provisions to prevent misuse or confusion (Tilly et al. 2008). Washing the bowl with a mild acid or hot water can prevent the build up of minerals and prevent the decay of piping material. Additionally, some manual removal may be required periodically. To prevent blockages, piping should be installed with at least a 1 % slope and sharp angles should be avoided. Larger diameter pipes can be used for lower maintenance. (Tilly et al. 2008).

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires less water than conventional flush toilet</td>
<td>Varying capital and operational costs</td>
</tr>
<tr>
<td>No odour problems</td>
<td>Labour intensive maintenance</td>
</tr>
<tr>
<td>Easy to use</td>
<td>Require education</td>
</tr>
<tr>
<td>Effective if there is a use for urine or faeces</td>
<td>Requires water</td>
</tr>
</tbody>
</table>
4.2 Disposal Systems

At a global scale, there are generally eight sanitation disposal systems used most commonly. Each has its own positives and negative characteristics, and these must be considered to implement a sanitation system specifically suited to the user community. Factors such as funding, environmental regulations, cultural beliefs and pre-established practices must all be taken into account in order to design a successful project.

These systems incorporate the user interface and determine the movement of the human waste over the next stages.

4.2.1 Single Pit System

This system uses a single pit to collect and store the excreta. The inputs include faeces, urine, flushwater, anal cleansing water and dry cleansing material. The two user interfaces used in conjunction with this system are the dry toilet or pour flush system. The interface is directly connected to a Single Pit or Single Ventilated Improved Pit (VIP) which collects and stores the excreta. Once the pit is full, it can either be filled with soil and a tree planted, or it can be emptied and the faecal sludge transported to a semi-centralised treatment plant. This is one of the least expensive systems to construct, however maintenance costs may still be high. It is best suited to rural areas; with appropriate soil for digging new pits and emptying old ones, where there is sufficient transport and access to empty pits, and areas which aren’t prone to heavy rains so the pits don’t overflow. This system is common in most parts of the world, however finding a system with proper transport, treatment and disposal is rare. (Tilley et al. 2008)

4.2.2 Waterless System with Alternating Pits

This system produces a dense, compost-like material by using alternating pits with no flushwater. The inputs include faeces, urine, organics, anal cleansing water and dry cleansing matter. The only recommended user interface is a dry toilet and anal cleansing water should be kept to a minimum. The dry toilet is directly connected to a composting chamber which collects human excreta. While one pit is filling with excreta, the other remains out of service. When the pit in use becomes full, it is covered and the other pit is emptied of the nutrient-rich and hygienically improved humic material formed from degraded faeces, and put back into service. Thus, the pits alternate in use and the cycle continues indefinitely. The compost/ecohumus generated from this pit does not require centralised treatment so is transported for use and/or disposal. This material is safe to use in agriculture, however if there are concerns about its quality then it can be composted further. The system can be used where space is limited and requires only manual transportation. If a continuous source of soil, ash or organic matter is provided then the storage period can be reduced. It can also be minimised if
the pit is aerated and kept very dry. It is very appropriate for water-scarce areas or where there is opportunity to use the compost. (Tilley et al. 2008)

4.2.3 **Pour Flush system with Twin Pits**

The inputs to this system include faeces, urine, flushwater, anal cleansing water, dry cleansing materials and greywater. The primary user interface is a pour flush toilet. It uses twin pits lined with a porous material which allows the effluent to infiltrate into the ground while solids accumulate at the bottom. It takes a minimum of two years to fill a pit. While one is filling, the other remains out of service in a similar way to the waterless system with alternating pits. The sludge removed from the pit is manually emptied & transported for use and/or disposal. Once again, semi centralised treatment isn’t required since the sludge is degraded and no longer as pathogenic. However, this system should only be installed where there is a deep groundwater table since the effluent directly infiltrates into the ground. The soil should be able to continuously absorb moisture. Dry cleansing materials should be disposed of separately. Alternatively, the sludge can be directed towards an anaerobic biodigester which produces methane gas for cooking and leftover compost (Tilley et al. 2008).

4.2.4 **Waterless System with Urine Diversion**

This system is designed to separate the urine from faeces for beneficial use. Inputs to the system include urine, faeces, anal cleansing water and dry cleansing material. The two interfaces used are the Urine Diverting Dry Toilet or Urinal. A third diversion for anal cleansing water can be made but these are not common. Dry cleansing materials should be collected and disposed of separately. Alternating Dehydration Vaults are used for the storage of faeces and these are watertight in order to make sure no water is present. A constant supply of ash, lime or dry earth is provided to reduce odour and vectors (flies). Separately, the urine can be stored in tanks or used for land application, irrigation, or soil Infiltration. The dried faeces pose little human risk and can be removed manually for use or disposal from the vaults. The success of the system depends on efficient urine/faeces separation and a suitable drying agent. A dry, hot climate helps dehydration and the anal cleansing water and urine can be transported for other uses in irrigation and agriculture (Tilley et al. 2008).

4.2.5 **Blackwater Treatment System with Infiltration**

This system is required to store large quantities of water. The inputs include faeces, urine, flushwater, anal cleansing water, dry cleansing material and greywater. The two possible user interfaces are the pour flush toilet or cistern flush toilet. The blackwater generated from the user interface flows directly to a septic tank, an anaerobic baffled reactor, or an anaerobic filter. The greywater is treated directly with blackwater, however can be separated for water recovery.
processes. The effluent generated flows to the ground via a soak pit or leach field and the leftover faecal sludge is transferred to a treatment facility for further treatment. Human contact should be avoided prior to treatment since this waste is highly pathogenic. The treated effluent can be used for irrigation, aquaculture, other agricultural activities or it can be disposed. This water-based system is suitable for both anal cleansing water and dry cleansing material. The capital investment is high and it uses significant amounts of water, however it can be shared by various households (Tilley et al. 2008).

4.2.6 Blackwater Treatment System with Sewerage

This system is very similar to the previous system, except in the way it deals with effluent. The effluent is transported from the collected blackwater to a semi-centralised treatment facility via a sewer network. An interceptor tank is required before the effluent enters the sewer, degrading the material to produce both effluent and faecal sludge. The excavation and installation of the on-site storage technology as well as the infrastructure required for the sewer are costly. If there is no existing treatment facility, one must be built to ensure the blackwater isn’t directly sent to a water body. Commitment to operation and maintenance of the sewer network is required. Labour is also required in maintaining and desludging the interceptor tanks, and an improperly kept tank can adversely impact the whole community. This system is well suited to dense urban locations with no space for on-site storage technologies and also to areas with high groundwater tables since the sewers are shallow and watertight (Tilley et al. 2008).

4.2.7 Sewerage System with Urine Diversion

The inputs to this system are urine, faeces, flushwater, anal cleansing water, dry cleansing material, stormwater and greywater. This system uses a urine diverting flush toilet (mentioned in the previous section) and possibly also a urinal in conjunction with the UDFT. The brownwater flows directly to a semi-centralised treatment facility via a simplified or gravity sewer network, while the urine is linked to a storage tank which is transported for use in agricultural sectors. UDFTs are not very common and generally expensive due to the need for high quality plumbing. This system is used when there is need for the collection and transport of urine, water is scarce or if the treatment plant is generally overloaded. Reducing nutrient load by removing the urine also optimises treatment of the faeces. (Tilley et al. 2008)
4.3 Collection and Treatment of Human Waste

This report has already mentioned that human waste can be a serious health hazard as it is a good vector for both viral and bacterial diseases. A major accomplishment of human civilization has been the reduction of disease transmission via human waste through the practice of hygiene and sanitation, including the development of sewage systems and plumbing. A variety of simple storage mechanisms have also been developed and implemented to eliminate the toxicity of human waste and enable safe and responsible disposal/reuse.

4.3.1 Dehydration Vault

Dehydration vaults are used to collect, store and degrade faeces. Faeces will only dehydrate when the vaults are watertight and when urine and anal cleansing water are diverted away from the vaults. They are especially effective in hot, dry climates where the chance of rainwater intrusion is minimal, and they result in the production of compost as pathogens are starved. They are easy to produce and maintain, involving a dry toilet single/alternating pit system whereby multiple users deposit their wastes comfortably. However, the users must be mindful not to urinate in order to keep moisture out of the pit, and this may reduce the system’s effectiveness and popularity.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be built and repaired with locally available materials</td>
<td>Requires education and acceptance to be used correctly</td>
</tr>
<tr>
<td>Because double pits are used alternately, their life is virtually unlimited</td>
<td>Requires constant source of ash, sand or lime</td>
</tr>
<tr>
<td>Good in rocky and/or flooded areas</td>
<td>Requires a use/discharge point for urine and faeces</td>
</tr>
<tr>
<td>Excavation of dried faeces is easier than faecal sludge</td>
<td>Urine and faeces require manual removal</td>
</tr>
<tr>
<td>No real problems with flies or odours if used correctly</td>
<td></td>
</tr>
<tr>
<td>Does not require a constant source of water</td>
<td></td>
</tr>
<tr>
<td>Low (but variable) capital costs depending on materials; no or low operating costs</td>
<td></td>
</tr>
<tr>
<td>Small land area required</td>
<td></td>
</tr>
</tbody>
</table>

4.3.2 Composting

Composting refers to the process by which biodegradable components are biologically decomposed under aerobic conditions by microorganisms (mainly bacteria and fungi). A Composting Chamber converts excreta and organics into compost. Compost is a stable, inoffensive product that can be handled safely and used as a soil conditioner. The setup of a composting chamber is generally the
same as that of a dehydration vault, except they involve a less permanent design and easier access requirements due to the removal of degraded faeces (now compost) for use in agriculture.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>The compost that is removed is safe to handle and can be used as a soil conditioner</td>
<td>Leachate requires secondary treatment and/or appropriate discharge</td>
</tr>
<tr>
<td>Can help reduce the volume of solid waste generated by diverting organic material into the composting unit</td>
<td>Requires expert design and construction supervision</td>
</tr>
<tr>
<td>Can be built and repaired with locally available materials</td>
<td>May require some specialized parts</td>
</tr>
<tr>
<td>Long service life</td>
<td>May require long start up time</td>
</tr>
<tr>
<td>No real problems with flies or odours if used correctly</td>
<td></td>
</tr>
<tr>
<td>Low-moderate capital costs depending on emptying;</td>
<td></td>
</tr>
<tr>
<td>Low operating costs</td>
<td></td>
</tr>
<tr>
<td>High reduction of pathogens</td>
<td></td>
</tr>
<tr>
<td>Does not require constant source of water</td>
<td></td>
</tr>
</tbody>
</table>

4.3.3 **Biogas Reactor (Biodigester)**

An Anaerobic Biogas Reactor is a chamber or vault that facilitates the anaerobic degradation of blackwater, sludge, and/or biodegradable waste. It also facilitates the separation and collection of the biogas that is produced. It is generally a composting chamber which also harnesses the methane produced during the anaerobic processes, enabling further utilisation measures. See section 3.5 for more information.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation of energy</td>
<td>Requires expert design and skilled construction</td>
</tr>
<tr>
<td>Low capital costs</td>
<td>Gas production below 15°C is ineffective</td>
</tr>
<tr>
<td>Underground construction minimises land use</td>
<td>Digested sludge and matter still requires treatment</td>
</tr>
<tr>
<td>Long life span</td>
<td></td>
</tr>
<tr>
<td>No electricity input required</td>
<td></td>
</tr>
</tbody>
</table>
4.4 Use of leftover wastes

The previous sections exploring the characteristics of various sanitation systems demonstrate that human waste is not always waste. Rather than simply treating and disposing of urine and faeces, human waste has beneficial uses if the proper measures are introduced. In our project, we aim to effectively treat waste to minimize the spread of disease while at the same time creating a new resource for the community.

Biodegradation is the chemical dissolution of materials by bacteria or other biological means. For example, the process of biodegradation in a biodigester produces biogas and other organic materials such as compost and fertilizer. Typically, this bio gas is comprised of methane (50-75%), carbon dioxide (25-50%) and varying quantities of nitrogen, hydrogen sulphide, water and other components (Tilly et al, 2008). The energy obtained from the bio gas can be used to produce electricity or heat.

The compost and the fertilizer from the bio digester or other devices/storage systems can also be used in many different ways:

4.4.1 Agriculture

Adding compost as a conditioning agent to the soil enriches the nutrient value of the soil which is favourable for crops and in horticulture. Although the toxicity has been removed from the effluent during its degradation, the matter remains nutrient rich. Also a compost infusion sprayed onto plants that are being attacked by pests or diseases can benefit plants and prevent diseases from spreading.

The following table outlines the use of each element contained in compost and fertilizer for agriculture (University of Tennessee, n.d.);

<table>
<thead>
<tr>
<th>Nutrient element</th>
<th>Function in plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Promotes rapid growth, chlorophyll formation and protein synthesis</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Stimulates early root growth. Hastens maturity. Stimulates blooming and aids seed formation</td>
</tr>
<tr>
<td>Potassium</td>
<td>Increases resistance to drought and disease. Increases stalk and straw strength. Increases quality of grain and seed.</td>
</tr>
<tr>
<td>Calcium</td>
<td>Improves root formation, stiffness of straw and vigour. Increases resistance to seedling diseases.</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Aids chlorophyll formation and phosphorus metabolism. Helps regulate uptake of other nutrients.</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Amino acids, vitamins. Imparts dark green colour. Stimulates seed production.</td>
</tr>
<tr>
<td>Boron</td>
<td>Aids carbohydrate transport and cell division.</td>
</tr>
<tr>
<td>Copper</td>
<td>Enzymes, light reactions.</td>
</tr>
<tr>
<td>Iron</td>
<td>Chlorophyll formation.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Oxidation-reduction reactions. Hastens germination and maturation.</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Aids nitrogen fixation and nitrate assimilation.</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Essential for nitrogen fixation.</td>
</tr>
</tbody>
</table>
4.4.2 Erosion control
Topsoil loss is a serious environmental issue, threatening fragile ecosystems and also man-made communities. A layer of compost spread over a disturbed area of soil is called a compost blanket. With excellent absorbency and a high capacity to hold water, compost is not tilled into the soil but remains on the surface to temper the impact of rainfall. Even small amounts can help, but typical recommendations call for a 5 cm layer to insure adequate surface coverage. Grasses and other plants may also be introduced into this layer of topsoil in order to collect and retain more soil, thereby further preventing erosion (AASHTO, 2002). Considering this, the ecohumus leftover at the bottom of a biodigester can be used in road construction to reduce/prevent soil erosion.

4.4.3 Generating Income
Fertilizer is widely used around the world. Selling fertilizer to individuals and firms will generate an income at a zero cost because the biodigester waste is supplied as a by-product. Biogas can also be stored and sold for use in electrical, cooking and heating applications (see Section 6.3.2 for more information).

4.4.4 Electricity and Heating
The biogas released during anaerobic digestion of human faeces can be utilised to provide electricity and heat to communities, or sold as a useful portable energy source. The flammable methane gas may be directed to a specialised generator or simply to a simple stove for safe and reliable cooking gas. Alternatively, it can be pressurised into a storage bottle and sold, or used later for similar purposes.

4.5 Comparison of Sanitation Systems
There are many unique waste disposal systems each with their own strengths, weaknesses and suitability. To implement an innovative waste management solution for the Devikulam community, we must learn through the study of existing systems, evaluating their effectiveness with regards to the purpose for which they were designed. But which system is most feasible for implementation in the remote community of Devikulam? The trade-off table on the following page attempts to evaluate each system with regard to the overall design criteria we hope to fulfil. Obviously, there are many different combinations of user interfaces and disposal systems, however we will only evaluate the few which we initially chose as possible designs. They include the single and alternating pit dry toilet systems, the pour-flush system and the urine diversion system. The following criteria are based on what we believe are important factors to consider in choosing a disposal system for the Devikulam community. The scores range from Poor (1) to Excellent (10) in fulfilling these criteria;
The four chosen systems have been judged according to their suitability and applicability to the tropical, third-world community of Devikulam. Considerations have been made with regard to the lack of clean water supplies, energy and storage capabilities, and also the environmental and cultural characteristics of the area. Additionally, and perhaps the major determinant of the winning design, the need for cohesion with the biodigester has also been considered. Thus, according to the trade-off table, the urine diversion system is the most suitable system.

While the dry toilet systems are inexpensive and low-maintenance, their suitability in relation to the use of a biodigester fails because using them would require the residents to defecate only and not urinate at the interface (which goes against the purpose of our design). The pour-flush system also fails immediately because it requires significant amounts of water and also because it is not compatible with a biodigester. The urine diversion system, on the other hand, is waterless and directly compatible with the use of a biodigester, separating urine and faeces using different compartments at the interface. The faeces are deposited in the biodigester while the urine flows to a storage area for re-use or removal.

The system satisfies basically all of the design criteria we initially formulated. It obviously improves access to adequate sanitation and also results in a reduction in pathogens when used in conjunction with a biodigester. The shift away from public defecation and towards the use of an established sanitation system will also improve hygiene significantly. A urine separating design may also be adapted to be compatible with traditional practices, for example, a urine separating squatting basin would be cohesive with the conventional use of squatting basins throughout India. It would also be able to be produced using locally available materials – ideally clay or ceramics – as the design is not exceedingly complicated, only involving two separate basins with separate pipes. The use of local materials would also make it economically feasible and sustainable in the long term, since any repairs would be easily completed at an insignificant cost. Lastly, and perhaps most importantly, this sustainability would be enhanced by the production of outputs which could be utilised or sold, and a
urine separating design would be able to achieve this in harmony with the biodigester – re-using both liquid and solid human waste.

Although there are some drawbacks to using this system, notably the (although low) higher initial capital cost compared to other designs and the need for education prior to use, we have decided to set this as our designated system at the current time. If we encounter significant obstacles during the consultation or implementation process which threaten the viability of our project, we will remove the urine diversion aspect and employ another method.

Figure 7: Basic layout of a urine diversion system
5 Our Design

See Appendix D for Organic and Water Flow Cycles

5.1 The Design

We aim to create a communal toilet facility which requires no inputs and is therefore a self-contained, long-term sustainable unit. Rainwater will be collected by roofing structures and unique water storage mechanisms, and some of this water will be heated by harnessed solar energy. A biodigester will also reuse human faeces through biogas production for use in electricity, heating and portable energy. In providing this ‘Sustaina-Loo’, we hope to offer an alternative to public defecation and thus improve the access of Devikulam residents to a safe means of sanitation. When other systems fail due to extensive ongoing maintenance requirements, unconsidered environmental impacts or lack of resources, our design flourishes because of its capacity to operate and offer a complete sanitation system with toilets, showers and hand-washing facilities without any inputs for an extended period of time.

The Sustaina-Loo features a small, wooden building 3 metres high, 5 metres long and 3 metres wide, with a total interior space of around 13 square metres. A black heat absorbent polyethylene tarp is mounted on hinged support struts attached to the side of the building, such that water funnels from one side and then under the tarp itself. The hinged struts offer the capability of tarp extension 3 metres on each side during periods of high rain in order to maximise water collection, creating a maximum surface area of approximately 33 m². Alternatively, these sides can be retracted during periods of high wind to prevent the destruction of the structure. The area of tarp directly above the facility is secured closely to an undulating plastic inner-roof such that small independent water storage sections are created between the tarp and the crests of the inner-roof. During the day, heat from the sun trapped in the sections upon absorbance by the polyethylene tarp. At the same time, heat will also be transferred into the metal inner-roof at the tarp-attachment points thereby heating the water from beneath as well. It follows that solar energy is absorbed by the polyethylene tarp and trapped in these small reservoirs of fresh water, effectively heating them. The undulating roof we are using will feature a distance of 250 mm between crests and a depth of 300mm, and considering the facility is 3 metres wide and 5 metres long, this means a total of approximately 8000L of water can be stored in these heat spaces. Excess water that does not fit into these solar-water-cells can overflow onto a side-mounted gutter and funnel into a 2000L water tank on the side of the building. Thus, our facility is supplied by collected rainwater, some of which is heated by harnessed solar energy for use in hot showers, the rest being used for anal cleansing water and hand-washing basins.
Inside the facility are four toilet cubicles containing urine-separating squatting basins, a shower compartment and a hand cleansing area. Separated urine from the basins flows to a separate tank which can be removed and the urine sent to a processing facility for reuse in agriculture or disposal. Water used by the shower and hand washing sinks will drain to underneath the facility and pass through an inexpensive Polyetheretherketone (PEEK) membrane filter which separates sediment and microorganisms. This semi-purified water is stored in a 3000 L water re-use tank and can be accessed and used for washing, or in times of drought can be used to supplement the local water supply.

Faeces from the interface are directed to a 2 m$^3$ capacity continuous-feed biodigester consisting of a polyethylene bag situated beneath the facility and anaerobically digested in a low oxygen environment, outputting usable biogas. An external input/opening is also connected to the biodigester whereby other organic wastes such as food scraps and animal effluent can be emptied to increase the amount of biogas produced. The biogas will flow out of the digester and into a conventional gas storage bottle located beneath the facility, with pressure inside the bottle increasing as methane content grows higher. A pressure gauge is attached to indicate when it is time to remove the bottle for use, with a valve seal preventing gas from escaping when the bottle is removed. Consisting primarily of methane, the gases in this bottle can be utilised via conventional gas bottle methods and used to generate heat or electricity.
Nutrient rich, non-pathogenic waste left over after anaerobic digestion will also be utilised. We have been advised that there is a risk that cultural beliefs may prevent us from using this towards local agriculture which was our initial idea, so we believe it would also be feasible to sell it (see section 6.3.2) or use it as a topsoil compost blanket for areas near the road between Devikulam and Pondicherry. This area is known to experience heavy erosion during Devikulam’s wet season and the heavy monsoon rains it brings (EWB, 2011). Sometimes floodwaters can encroach on the road and remove vital foundations, requiring repairs which aren’t completed for significant periods of time. A compost blanket would reduce the chances of these situations occurring by tempering the impact of rainfall, preventing road erosion and thereby reducing the risk of poor road structures inhibiting transport to and from the village.

The facility functions essentially like a conventional communal toilet system in that it provides four working toilets, a hot shower and sanitary handwashing basins with soap dispensers. However, it is unique because it produces the water and energy needed to operate autonomously and also enables the creation of two valuable resources (methane gas and ecohumus) when used regularly. In this way, it can be regarded as a project which increases the access of Devikulam residents to sanitation and also alleviates their standard of living by providing usable resources.

5.2 Prototype Construction

We recognise that there may be various flaws and risks in our design that must be considered and minimised prior to implementation. As a self-contained sanitation facility with the purpose of improving the hygiene and health of Devikulam residents in a sustainable, low-cost manner, all aspects must be considered. For example, the size and shape of the biodigester must be tailored to the characteristic Devikulam population – one that is too small may not produce enough biogas,
while one that is too large may not provide adequate conditions for efficient anaerobic digestion. In order to gauge the importance of these issues, the construction of a prototype was conducted by members of Fab 4.

Our design can be categorised into two major systems; the biodigester system and the physical facility. The biodigester system includes the complexities involved in reliably producing useable biogas using faeces, while the physical facility encompasses the operation and integrity of the overall unit including the design of the showers, cubicles, sinks, walls, roof and tanks. As such, our prototype construction stage consisted of two parts; the building of a working biodigester and the production of a rudimentary model of the complete facility.

See Appendix E for Primary Photographs

5.2.1 Biodigester Primary Research: Biodigester Prototype

Aim(s)

In constructing a biodigester prototype, our initial aim was to manufacture a vessel which would, when supplied with dog faeces, produce usable biogas and hence demonstrate the operation of a working biodigester. Additionally, our second aim was to determine the adequate size, shape and nature of the biodigester to be installed in the Sustaina-Loo facility. Although our biodigester will be of the continuous-feed nature, our prototype was a batch-fed type due to inconsistency in faeces supplies and ease of construction. Nonetheless, it was still as effective in delivering answers and fulfilling the goals of the prototype stage.

Process

To demonstrate the operation of a biodigester in general, we used a variety of materials found within major shopping centres and faeces provided by pet dogs owned by members of Fab 4. This involved the purchase of a 10L water storage bottle from ALDI supermarket which was later emptied of its water and dried for use as a biodigester tank.

Table 5: Favourable Characteristics of ALDI Water Bottle

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Cheap</td>
<td>-$5.50</td>
</tr>
<tr>
<td>Ideal Size</td>
<td>the bottle was sufficiently large to produce adequate methane yet small enough for easy transportation.</td>
</tr>
<tr>
<td>Incorporated Lever Release Mechanism</td>
<td>previously used for water. Now used for methane release (proven airtight).</td>
</tr>
</tbody>
</table>

Figures 10 & 11: ALDI water tank and air-tight release valve
Initially, we also painted the vessel black to ensure maximal heat absorption, because we were inclined to leave it in a sunny area where temperatures are highest. However, upon realising that autumn conditions in Sydney were too cold for effective biogas production, the vessel was housed in a Jacuzzi owned by one of the Fab 4 members. In this way, the biodigester could operate in the mesophilic temperature range, producing biogas in similar conditions to the sub-tropical Devikulam climate.

We are confident that no animals were harmed during the collection of the dog faeces, which were collected and placed in the vessel by dropping through the open lid-hole. This was considered the most unsanitary aspect of the construction process, so rubber gloves were used during the handling of the faeces.

Encountering problems in the amount of available dog faeces to be used as input, we also began adding food scraps to boost methane production. Filling the digester to around 1/3 capacity, we simply aimed to ensure that there was enough material to provide a compactness which facilitated efficient contact between the bacteria, food scraps and the faeces. When closing the device, we made an effort to squeeze excess air from the vessel so that the air content was minimal, because anaerobic bacteria produce methane ideally in a vacuum.

The functioning of the prototype proved to be very successful in producing useable biogas. The testing phase yielded reliable results, with consistent portions of methane being released after each check up. Upon removing the vessel from the Jacuzzi, we observed that the container had expanded due to high gas content, and we released the methane and stored it in inflatable balloons. By doing this we were able to keep the methane for use in gas bubble flame experiments, and also monitor how the rate of methane production changed as the material inside continued to be digested. With regard to the latter, we observed (as expected) that methane production gradually fell as more and more material was used up. Eventually, there were insignificant amounts of methane being produced, signalling a high proportion of digestate – the digested, and pathogen-free content leftover after the digestion process.

We generally experienced two major difficulties in the construction and functioning of the prototype. Firstly, we initially envisioned the prototype as a design which would display Bunsen burner properties (i.e. flame above valve opening). However, we soon found that the pressure and volume of the gas was not sufficient to provide this constant flow, so we were forced to develop a new method – the methane bubble testing (see below). Secondly, we also found that the storage of methane in one brand of balloons would result in an absence of flammability when an attempted burn was made. We could only speculate that the permeability of that specific brand of balloon was higher and hence the methane (lighter than air) gas escaped through the balloon material. To remedy this, we simply shifted back to the use of the original balloon brand.
The methane bubble testing method was proposed by members of Fab 4 to solve the problems associated with observing whether methane had been produced or not. It follows that the flammability (and hence presence) of the methane can be tested by passing the biogas through soapy water, such that small lighter-than-air bubbles are produced. Holding a flame to these bubbles would yield a spectacular combustion process, with the bubbles turning to fire. This was conducted in a well ventilated room using adequate safety equipment and supervision, and was found to be extremely successful in testing for the production of methane.

**Figures 13 & 14**: The production of methane bubbles and the ignition of methane bubbles
Overall, the construction of the prototype biodigester was highly successful in giving us an indication of the areas of difficulty in biodigester construction. It allowed us to demonstrate the production of methane and highlighted the importance of temperature on the rate of methane production. The inflatable balloons can be interpreted as representative of the gas bottles used to transport the methane once pressure has reached a designated level, while the gas bubble experiments undertaken by releasing this methane from the balloons symbolised the use of the biogas tanks for cooking or heating.

In relation to size, our 10L water bottle provided quite a significant amount of biogas, however difficulties in harnessing this gas arose due to storage problems. We believe that, depending on the usage statistics of the Devikulam facility, the required biodigester would need to be approximately 4m x 1m x 0.5m, resulting in a volume of around 2m³ (see section 3.7.1). This would be sufficient to fill a gas bottle within a week, however changes can be made depending on the performance rates of the digester during the testing phase.

To see videos of the Biodigester Test Phase, go to http://www.youtube.com/user/jkar000?feature=mhee

5.2.2 Facility Prototype

The construction of the facility prototype began with computer assisted modelling (CAD) showing the basics of our design. Using the ‘Rhinoceros’ CAD software, this modelling helped us compose a visual interpretation of our design such that we could assess the benefits and drawbacks of certain components. In essence, it laid the foundations of what we believe the final facility will look like when installed in Devikulam.

Durlabh was the primary creator of this CAD model. He demonstrated how the software enabled us to rotate and move the model to be viewed from different directions, and this was extremely effective in guiding the prototype design phase from that point onwards. We were able to visualise the roofing structures and understand how the tarps and inner-roof would need to be constructed to enable the efficient flow of water. We also noticed that the side mounted water tank could be positioned in a way such that only a certain amount of water would be able to be used in the shower, leaving fail-safe amount for the more vital hand-washing facilities. As such, we modified our design such that the outflow pipe for shower water would be higher than the outflow pipe for the sinks, and thus once the water in the tank is below a certain point the shower will not function anymore. Although we expect the tank to be relatively full at all times due to plentiful rainfall (Buzza n.d.), this is a mechanism to ensure that essential hand-washing facilities are always available.

The CAD model of the Sustain-Loo system also allowed us to visualise the required under-floor space where the biodigester, ecohumus, gas and water-reuse tanks would be kept. The primary determinant was the expected radius of the fully inflated biodigester - approximately 500mm. Thus, we have designed the under-floor area to be 550mm high to ensure that the biodigester does not press against the roof. With regard to horizontal floor space, to achieve a volume of 2 m³ the
biodigester needs to be 4m x 1m x 0.5m, and we will therefore designate the sizes of the other tanks to use up the remaining space.

As a result of these conclusions, we were able to develop a rudimentary model of the complete facility in order to gauge the ideal size and layout of the components. It included an illustration of the extendable tarp and rainwater catchment/heating system and a layout of the showers, sinks and squatting basins, along with a space for the biodigester. Constructed using a myriad of materials found at stationary stores and supermarkets, the simple model uses bubble wrap to illustrate the undulating inner roof surface and heating system and a black polyethylene sheet to demonstrate the roof’s water catchment method. The cubicles are separated by skewer sticks and the whole facility is constructed of shoebox material, with an openable section to illustrate the location of the biodigester and storage tanks.

Although it is extremely simple and small, the construction of this model was of tremendous value in ironing out the flaws of the design, giving us the ability to assess a real physical model rather than just a computer simulation. It also enabled us to present a physical representation of our design to the class during the prototype presentation and gain value feedback from other students and our tutors.
Overall, the construction of these two prototypes was extremely beneficial in affirming some of the positive aspects of the system and eliminating any infeasible components. It enabled us to determine the necessary sizes of several crucial components and also determine the difficulties associated with methane production. As such, we were ready to deliberate on the implementation process of our system and the necessary community consultation which must occur prior to any introductions to Devikulam.
6 Implementation Process

See Appendix F (Implementation Gantt)

6.1 Community Consultation

It is perhaps a moral requirement and an ethical responsibility to consult with the community on all matters relevant to the introduction and long term operation of any project. As a result, our implementation will not begin until reasonable actions have been taken to gather opinions and ideas on the nature of the project. In addition, negative feedback on certain aspects of the design will be critically considered in order to incorporate any possible improvements or modifications. Involving several community meetings, the system will be presented and explained, and attending residents can actively ask questions, make contributions or lodge criticisms.

Separate meetings will also be held for the elders, Scheduled Class (formerly Dalit) residents and Most Backward Class (MBC) residents. This is simply to improve the effectiveness of the consultation process by allowing the distinguishable groups in the Devikulam community to voice their opinions comfortably and the meetings to progress without conflict. After all the information has been gathered, the project will be implemented or adapted in a way that is compatible with the views put forward in these consultation meetings.

Not only will there be a consultation stage prior to the construction of the facility, but there will also be two more periodic consultation programs – one after the education process and another during the testing phase. This means that the community consultation stage extends over the whole period of the project’s implementation process and therefore allows modifications to be made throughout the period rather than just at the beginning. The letter contained at the start of this report is perhaps the first contact we will have, and is a prime example of the type of consultation we will be pursuing.

6.2 Possible Community Perspectives

In response to the first consultations, there may be many varying opinions within the community on the nature and feasibility of the system. While the various commendations or criticisms would be dealt with at hand by members of Fab 4 at Devikulam, it is necessary to attempt to predict the possible community reactions and perspectives so that we are best prepared to respond.
6.2.1 Positive Reactions

**Health Appreciation**

With an idea of the vast reduction in the chance of disease propagation as a result of the increased access to sanitation, it is highly likely that the community will appreciate this sanitation system as a positive contributor to their standard of living. Providing a hygienic and comfortable place to dispose human and other organic waste, as well as adequate hand-washing facilities and showers, the system will reduce the chance of pathogen transmission and thereby improve community wellbeing.

**Economic Appreciation**

As a public facility built and assembled by residents, the sense of equity in the Sustain-Loo project will be welcomed by the community. Additionally, the existence of an economic value to the system will also gain appreciation because the community members will be supplied with new resources in gas and ecohumus. Selling these on the local market or utilising these resources within their community will help them earn a profit or reduce other costs in cooking and heating, enabling future economic prosperity.

**Physical Appreciation**

One of the special features of this sanitation facility is the sustainable collection and heating of water, enabling the provision of hot showers and freshwater without draining physical or monetary resources. Perhaps residents will see the ability to have a shower as a privilege and luxury, resulting in successful use of the facility simply as a novelty. Even if it may be a novelty, its use will surely benefit the community. While the clean freshwater generated by rain collection system will be used exclusively within the facility, the filter re-use water is also likely to arouse appreciation from community members as it can supplement their existing water supplies.

6.2.2 Negative Reactions

**Output Utilisation Arguments**

The generated outputs of the biogas and fertiliser may arouse disagreements between Devikulam residents on the nature of utilisation. Some factions may wish to use and share the resources between themselves, using the methane for local cooking and the fertiliser to prevent road erosion during the wet season. Others may want to engage in selling both these resources, valuing money over the physical resources presented to them. Furthermore, the direction of the generated money would be decided by the community, and this may evoke further arguments on why and where to invest it. Of course, this issue is solely one in which the Devikulam community will need to address.
themselves, and we believe that the provision of a valuable resource owned by the community outweighs the negative implications arising from how the community copes with this resource.

**Cultural Objections**

The unconventional (and perhaps artificial) method of treating, processing and eventually reusing human waste may challenge the preconceived ideas, values and belief systems of Devikulam residents. We recognise that the use of generated ecohumus as a fertiliser for local plants is perhaps likely to clash with the local culture, and this is why we have placed more emphasis on its use as a compost blanket because this way it has minimal connections to the community’s food supplies. With regards to the use of methane gas, we do not believe that the risk of rejection is to the same extent because it is a valuable gas which can be used for cooking to reduce reliance on wood fuels, thereby preventing inhalation of smoke and also reducing cleaning requirements for (predominantly) female residents.

We do recognise that despite our best efforts to educate and publicize the benefits of the system, there may still be community backlash in response to possible conflicting characteristics. However, we are confident that our system is tailored to the community’s specific needs and practices, and hence that these disagreements will be minimised. Of course, any negative responses will be dealt with to the best of our ability by modifying certain aspects, but it is important to note that any other small disagreements will need to be dealt within the community themselves.

**6.3 Operational Considerations**

**6.3.1 Location**

Within Devikulam, household occupancy is generally between 4 - 7 people. Most houses have thatched bathrooms without a toilet and open defecation is the common practice. There is also a group housing scheme whereby houses are provided by the Government to residents of the Scheduled Class (Buzza, n.d). As a result, open defecation and the health risks it creates may enable pathogens to transfer more quickly between residents and thereby increase the threat of disease in these areas. We believe the most effective location for our sanitation facility will be near this communal housing facility. It will also ensure usage by a number of people and therefore enable easier monitoring of its impact. Through the knowledge of its impact on these residents, we can therefore estimate its effectiveness in other areas before investing in new units in other locations.

**6.3.2 Educating the public**

It is of crucial importance to educate the public on the need to use the facility and how to use it. We will promote the health benefits of the system by first educating the public on the pathogenic risks
associated with their traditional defecation in public areas, and how our facility enables an improvement to this. Posters, brochures and community seminars will be conducted to facilitate this ongoing education (see Appendix F).

Table 6: Advantages and Disadvantages displayed to Devikulam users

<table>
<thead>
<tr>
<th>3 Main Disadvantages of current system</th>
<th>3 Main Advantages of Sustaina-Loo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Health Costs of Open Defecation</strong></td>
<td>Improvement in health</td>
</tr>
<tr>
<td>a) Increased chance of disease (esp. diarrhea)</td>
<td>a) No flies</td>
</tr>
<tr>
<td>b) Absence of hygiene</td>
<td>b) No smell</td>
</tr>
<tr>
<td></td>
<td>c) Reduced chance of disease</td>
</tr>
<tr>
<td></td>
<td>d) Availability of fresh water</td>
</tr>
<tr>
<td><strong>Waste of resources (faeces) and failure to catch rainwater.</strong></td>
<td>Resource Gain/Savings</td>
</tr>
<tr>
<td></td>
<td>a) Free supply of fertilizer/topsoil /Possible sale</td>
</tr>
<tr>
<td></td>
<td>b) Free energy (methane)</td>
</tr>
<tr>
<td></td>
<td>c) Free hot water</td>
</tr>
<tr>
<td><strong>Absence of Privacy</strong></td>
<td>Dramatic increase in privacy and comfort</td>
</tr>
</tbody>
</table>

Posters containing directions on how to use the interface will be located at the entrance of the facility and on the inside face of the cubicle doors. They will include sentences in both English and their language (Tamil), with diagrams attached on methods of use, benefits of adequate sanitation and correct/incorrect inputs to the biodigester. We have recognised that, in producing these posters, we are required to be mindful that they are neither condescending nor over-complicated.

In addition, a selected group of residents (e.g. elders or those with an education) can be given an in depth knowledge of the benefits of the system and its technical details. As a result, they will be responsible for the spread of knowledge, publicity and ultimately the facility’s popularity. Furthermore, a smaller group of these residents can be hired to form the maintenance crew who maintain the facility in the long term (see next section).

![Figure 16: Example of a poster educating the public against current methods of defecation (See Appendix D)](image)

6.3.3 **Maintenance**
The self sustainable characteristic of the facility reduces the need for ongoing maintenance. The polyethylene bags used in the bio digester are easy to obtain and cheap. The need for water and
energy is eliminated due to the design of the system. However, the integrity of the facility is still very important due to its status as a project produced solely to improve the health of its residents. To prevent water stagnation, blockages and the health risks these could create, the selected maintenance crew would need to regularly clean and check systems. Removing the waste contents of the bio digester, replacing polyethylene bag and manually extending the tarp during heavy rains will also be included in the long-term maintenance requirements. The maintenance crew, formed of local residents, could be funded by the income generated by the facility; however the details of the need and cost of this crew would arise after adequate knowledge has been gathered during the testing phase.

6.3.4 Number of units and Monitoring
Initially, we plan to install the one unit mentioned above and monitor its effectiveness for a period of 6 months. If the project is a success then further units will be introduced depending on areas of need, with changes and improvements being made to the design according to community feedback. In particular, the main road between Devikulam and Nadukuppam has been found as a common place for open defecation, with women and children (who must walk because only men ride bikes) complaining about the conditions (EWB, 2011). As such, if our studies and research deem the first unit is a success, we will immediately implement a second, modified unit in this location to remedy this problem.

The monitoring process
The monitoring process is highly important because measurements on the success of the project will determine the actions we take from the moment of its introduction. The monitoring process for our project can be divided into three categories;

1. Usage data
Ongoing community consultation will be performed to gather community feedback from Devikulam residents. Through this, we can assess the community’s thoughts and opinions, and gather statistics on the number of people benefiting from the system. The most appropriate way to gather usage data is by using a data counter at entrance of the facility, whereby users simply press a button and the count increases by one. This gives a close approximation for the average usage of the facility. We do recognise that the accuracy of this data will rely on the honesty of residents, but are resolute that a usage counter will give a general indication of the facility’s popularity.

2. Monitoring the wellbeing of the facility
The maintenance crew charged with the upkeep of the facility will also be employed to monitor such issues as cloggages, vandalism or corrosion. During the initial implementation process it is very important to educate this crew on how the system works and what technologies are involved, so when a problem occurs they will know exactly what actions to take. During the initial development stages, we as volunteers will perform and demonstrate the role of maintenance engineers, passing on our knowledge to these local residents.
3. Monitoring the functioning of the facility
   a) Water retention
   A water meter can be connected near the output from the water tank to measure the flow rate of water to the shower and sinks. A similar water meter can also be fixed near the input to the tank and thus a rough idea of the circulation of water through the system can be obtained, also assessing any minute leakages.

   b) pH and bacteria levels
   Since the water and the biogas from the system is not used in drinking or preparing food, moderate levels of pH and bacterial levels are not dangerous. A rudimentary water filter will be in place to filter most bacteria from the system. Testing will be conducted during the initial implementation stage to assess the pH levels and conditions of bacterial growth.

   c) Biodigester methane production
   According to Lauridsen (1996), for every 300 kg of human waste, 0.6 cubic meters of biogas is produced. We consider the environmental conditions of Devikulam almost ideal for optimal methane production, so we will use this knowledge as the baseline for our testing. This testing will be conducted measuring the consistency over time of the completion of gas bottle capacities in the facility.

4. Validation Testing
The validation process involves testing under certain conditions of the functioning of the design as compared to its predicted functioning in theory. To validate our design we will engage in three general testing initiatives.

   a) Functional testing
   This is undertaken to ensure the system satisfies the integration goals of the project. For example, during the monsoon season a test can be undertaken to evaluate the effectiveness of the extending tarp roof. This will allow us to observe any concerns such as the amount of water the roof can gather and store, the validity of the heating process and if the extended tarp is compromised by heavy rain and wind.

   b) Performance testing
   Performance testing is to ensure that the throughput, response time, and latency are within the expectations of the community. For example, whether the rate of production of methane during different temperatures between different seasons is enough to satisfy the demand will be a primary testing consideration.

   c) Regression testing
   If any modifications or changes are made to the facility as a result of functioning or performance testing, then a regression test should be undertaken to ensure that the changes made did not cause the component to violate requirements in some new way.
6.4 Financial Considerations

The implementation of any project also involves the evaluation of the costs involved in purchasing the materials - both locally and internationally. Our Sustaina-Loo facility is designed to be highly cost-effective, with long term benefits associated with the potential sale of resource by-products.

6.4.1 Expected Costs

Imported Materials

Those materials not found within the immediate vicinity of Devikulam or within the Tamil Nadu region will be purchased in Australia and brought over by Fab 4 members. Although we have attempted to minimise the need for these purchases, the following components are of crucial importance to the system and must therefore be acquired with maximum confidence in their integrity.

The polyethylene for the tarp and biodigester cannot be produced locally, nor can the showerhead nozzle which must be water efficient and anti-corrosive. The chosen polyethylene tarps are to be purchased online for AUD $21.95 (Hardware2u, n.d) per metre which is cheaper than the same material sold at Bunnings Warehouse (2011) which sells for AUD$135.50 per metre. For the showerhead nozzle, we’ve decided to purchase a stainless steel water saving showerhead with an adjustable water pattern available on the online sales data base Gumtree (2011) for AUD$10.

The filtration system for used water involves the use of water a permeable polymer membrane. Generally a flat sheet of fine mesh with a polymer material over the top, it allows water to filter through but does not allow salts or large organic molecules to enter the vessel. Polyetheretherketone (PEEK) polymer is graded one of the most advanced filtering membrane polymers, ideal for use in the Sustaina-Loo system (Victrex, 2011). The R.S. online shop sells the constituents of the filter for a total of AUD$64.50 (Australia R.S, n.d).

Locally Available Materials

Anant Laxman Ltd (2011), an Indian plastics manufacturer, supplies corrugated plastic roofing at a price of $6 per m² and this will be used for the inner-roof heat spaces above the facility. Norwood (n.d.), based in Mumbai, sells PVC piping for $2.50 per metre, and this will be used in the facility’s plumbing to facilitate the flow of water into the storage tanks and faeces into the biodigester. The methane gas storage tank can be purchased from a number of suppliers including gas stations or chemical wholesalers, and we estimate these to be around $40.

Timber, labour and clay is readily available in the Devikulam community, and by utilising local resources for our construction, we hope to strengthen the level of community ownership in the project. Clay involved in manufacturing the various tanks, sinks and surfaces is extremely accessible within the community, as are the various wooden components needed to support the facility and define cubicles, walls and floors (EWB, 2011). The specific prices have been difficult to determine, as price systems are less defined in India however we hope to contract local workers and hence define our own prices for these materials. Buzza (n.d.) explains that most residents living in Devikulam work in the agricultural sector, so we will make the assumption that the provision and fabrication of
useable timber and clay could be completed after a total of 60 hours of work with around 6
labourers working at $1 per hour, totalling at $360

<table>
<thead>
<tr>
<th>Material</th>
<th>Price per unit (AUD)</th>
<th>Units required</th>
<th>Price (AUD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imported</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyethylene Tarp</td>
<td>$22</td>
<td>40</td>
<td>$880</td>
</tr>
<tr>
<td>Showerhead</td>
<td>$10</td>
<td>1</td>
<td>$10</td>
</tr>
<tr>
<td>Polymer Filter System</td>
<td>$64.95</td>
<td>1</td>
<td>$64.95</td>
</tr>
<tr>
<td>Gas Storage Tank</td>
<td>$40</td>
<td>1</td>
<td>$40</td>
</tr>
<tr>
<td>Local</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC Piping</td>
<td>$2.50</td>
<td>20</td>
<td>$50</td>
</tr>
<tr>
<td>Corrugated Plastic Roofing</td>
<td>$6</td>
<td>15</td>
<td>$90</td>
</tr>
<tr>
<td>Timber and Clay</td>
<td>-</td>
<td>-</td>
<td>$360</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1494.95</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Of course, along with purchasing these components, Fab4 will address the need to organise effective
transportation for both these local and imported materials. The transportation methods will be such
that the total cost is minimized and imposes minimal harm to the environment. In attempt to satisfy
this, the initial implementation could involve the contracting of other community workers to bring
materials over, with a payment of future resources generated by the facility once up and running.
However, most of the transportation arrangements will be made upon implementation.

The remaining factor is that of building costs, which will depend on the level of community
involvement. The tasks that need to be completed for this facility to operate are the construction of
the wooden structural framework, interior tiling, roofing and tank attachments and
assembly/installation of the biodigester, squat basins and showerheads. The level of skill required
for this is not excessively high, but it would be ideal to have a skilled manager or members of Fab 4
guiding the construction process. The cost assessment for this area is also vague, as the specific
pricing is determined by the wage Devikulam residents are willing to work for. However, the
payment of wages is perceived as a worst case scenario, as we are hoping the community will
welcome the project enough to volunteer their own time during construction.

We believe that the education and publicity preceding construction will motivate significant
amounts of community involvement due to the range of social, environmental and economic
benefits felt by residents. As such that the construction of this facility is expected to be based on
volunteer work by us and local residents, and this will strengthen the sense of equity shared by the
user community while at the same time minimising the additional costs of the system’s installation.

Overall, the cost of construction, implementation and maintenance of this facility are minimized by
the fact that this project is an opportunity for the community to make it their own. With an
abundant supply of labour and primary materials, and an intended minimisation of the need for
regionally supplied materials, inexpensiveness has been central idea in our design. Considering the
above cost assessment, which has been made with several assumptions due to the lack of resources
and knowledge, we estimate that the total initial capital cost would be around AUD $1600. Of course, the consultation and education stages may yield alternative methods of acquiring materials and completing construction, so cheaper methods may become available.

Although by rural Indian standards, $1600 is quite a large total, we expect it to be offset by the earnings made by the systems outputs (see next section).

6.4.2  Expected Income

We expect that the methane and ecohumus outputs of the system could possibly generate an income if sold by Devikulam stakeholders. This income could be used to offset the initial capital costs or at least cover maintenance/repair costs into the long term. While an addition of regular cooking fuel supplies to the local market would no doubt be welcomed by neighbouring villages, we believe that the use of methane within the Devikulam community would be best practice because of production fluctuations, volumes and the need for safety standards.

This leaves the ecohumus/fertiliser output as a potential resource to be sold, and this is why we have created a brief business plan to initiate the process.

Table 8: Ecohumus Sales Plan

<table>
<thead>
<tr>
<th>Market Analysis Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are five major markets for fertilisers in today’s world; Agriculture (food, crops), landscaping (golf courses, fields), nurseries (reforestation), government (public areas, roads) and residential use. India is the world’s third largest producer of organic fertiliser, and there is significant competition in this sector. (Mid-Atlantic Recycling n.d.). With regards to the use of ecohumus as a topsoil to prevent erosion, the general marketability is reduced because generally only governments are charged with the maintenance of roads.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are 39 households in Devikulam whose primary source of income is from agricultural labour (Buzza n.d.). Some of the fertiliser produced from our sanitation system could be sold to these households at wholesale prices to be used in crops and as a soil conditioner for plant growth. Pondicherry is the closest city to Devikulam, about 55 km away, another potential market for the sale of ecohumus generated in the biodigester. The government might also be a potential consumer of our product because there are several parks, the most famous being the Botanical Gardens and Government Park. The Pondicherry government may also wish to use our product as a compost blanket for the road network throughout the city. Residential or commercial use may also be an option, with many farms, various golf courses, hotels and housing areas littered throughout the area. With a population of 973,289 people according to the 2001 census, there have to be thousands of households who require fertiliser as a soil conditioner (PondicherryOnline n.d.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Market Trends and Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>The demand to use compost in farming and other agricultural work has been growing rapidly in recent years. Market trends have been tilting more towards organic fertilisers than chemical variants</td>
</tr>
</tbody>
</table>
In Pondicherry and Devikulam, the market for cheap, organic fertiliser would be especially robust due to the rising levels of salinity in local groundwater tables (Buzza, n.d.). This is threatening the wellbeing of the agricultural industry, and farmers could use this resource to retain freshwater and boost plant growth.

**Competition**

Our sanitation system produces organic soil enhancements, while most other dealers in Pondicherry sell chemical fertilisers, and this is beneficial to our sales plan because there is a growing market for organic variants with today’s increased environmental consciousness (Mid-Atlantic Recycling n.d.). Allwin Bio Organic and Rom Vijay Biotech Pvt Ltd are perhaps our largest direct competitors, operating out of Pondicherry and dominating the local market (FAO, n.d.).

**Prices**

There isn’t much information on the prices of organic fertilizer in India, however news reports claim that drastic price increases in the cost of chemical fertilizers have made organic fertilizers equally as viable economically (CNBC, n.d). The prices of chemical fertilizers vary depending on what chemical is present, with the average price around 40 Rs./kg (~AUD$1). Thus, if we were to engage in selling the fertiliser, we would set a price roughly equal to or below this to gain popularity in the market.

**Calculations**

We expect that the loading rate of our biodigester will be around 25 kg of new input material per day. Thus, if the biodigester is well established 25kg will input displaces 25kg of leftover ecohumus each day, then we should get the same amount of fertiliser production rates. Selling at 40 Rs per kilogram would achieve a daily income of approximately 10,000Rs (AUD$25).

The above business plan outlines the possible directions of trade in ecohumus generated by the Sustaina-Loo biodigester. If marketing operations are successful and we gain a regular customer base for the sale of fertiliser, the calculations above yield a yearly income of around $8000 per year. This could completely cover implementation costs in under a year as well as ongoing maintenance and repair costs, leaving money to invest in new schools, facilities or other Sustaina-Loo units in Devikulam. Now this is very ambitious, especially when one considers the fact that this ecohumus is generated by human waste, and this may dissuade some customers. Nonetheless, we are confident that some profit can be made from the sale of biodigester outputs, it is simply in the hands of Devikulam residents to make the most of this resource.

We must also consider the monetary savings to be made off the utilisation of methane gas in cooking and heating applications. Not only does this reduce reliance on wood fuels and thereby improve the health of residents due to the absence of smoke inhalation, newfound free-time not spent collecting firewood or cleaning sooty utensils can now be spent working or recreationally. This ultimately improves the standard of living of Devikulam residents, enabling them to improve their economic situation in addition to health and wellbeing.
7 Evaluation

7.1 Design Assessment – Strengths & Weaknesses

7.1.1 Strengths

The primary input into any communal toilet system is clean freshwater, and this is a relatively rare commodity in Devikulam (see Section 1.1). Thus, the first major advantage of our facility is its long term sustainability factor, requiring little to no user inputs of water or heat energy. This is because significant portions of rainwater are autonomously collected by the roofing structures and stored in some 10,000 L of tank space.

Furthermore, energy from the sun is trapped within the innovative inner-roof-tank mechanism such that hot water is generated daily. This is without any use of electricity or artificial heating, providing hot water for use in the showers and sinks – a luxury arguably taken for granted in Australia and a kind gift to third-world Devikulam residents.

Separately but along those same lines, additional energy is generated through biodigester processes, whereby human faeces are broken down such that three major benefits occur. Firstly, bacterial processes within the digester fiercely out-compete any pathogenic organisms, decimating their numbers and thereby offering a method of treatment of the faeces. Reduction in pathogen content on-site will vastly reduce the chance of disease transmission. Secondly, Devikulam residents can benefit from the conversion of human waste into a valuable resource – methane – which can be utilised for cooking, heating or electricity generation. Lastly, the ecohumus leftover after the anaerobic reactions can be used as a fertiliser to accelerate plant growth or a compost blanket to reduce road erosion.

The end result is the provision of a facility which offers Devikulam residents an alternative to public defecation, improving access to sanitation and thereby reducing pathogen transmission. However, this involves minimal incursion of operating costs on the user community because the facility is designed in such a way as to utilise its surrounding environment. In addition, it also provides other resources to the community rather than just disposing waste. It re-uses community faecal matter, animal matter and waste scraps and produces useable biogas and fertiliser, which can be sold to make a profit and improve the economic wellbeing of the community or used locally to prevent expenditure on energy or road repairs.

7.1.2 Weaknesses

In relation to the physical design, it will be hard to ensure that environmental conditions co-operate with the operation of the facility. The average annual rainfall in Devikulam is around 998 mm, meaning that our facility (with a surface area of 33 m²) can retain around 33 kilolitres per year. However, it is important to recognise that environmental conditions fluctuate and are never guaranteed, so there is a possibility that rainfall could be larger or smaller than this value.

Similarly, during periods of cloud cover or colder weather, the heating mechanism involving the absorption of sunlight will be less effective. This means that during monsoon periods, showers may
not be provided with hot water, however we believe that this won’t be a significant problem considering temperatures remain between 20°C and 30°C during that time (see section 3.2).

Similarly, with regards to the usage of the facility, education measures can only work to a certain extent to prevent misuse or overuse of the facility. If taps are left on or showers are taken too often, the level of water held in the storage tanks will continue to dissipate and the facility will be ineffective in providing basic sanitation infrastructure.

Overall, the positive design traits of the Sustaina-Loo system far outweigh the possible drawbacks related to misuse or unforeseen circumstances, however we are willing to make the modifications necessary along the way to ensure its success.

### 7.2 Contextual Implications

#### 7.2.1 Health and Social Impacts

Facilitation of the improvement of hygiene and access to sanitation is perhaps the centrepiece of all that this design represents. Welcomed for its low input and high output nature, this disposal system will reduce the potential spread of pathogens between Devikulam residents. Buzza (n.d.) writes that a majority of males in Devikulam both defecate and urinate publicly, and this means that upon heavy flooding, pathogens at these sites could be transported into local water supplies. With the provision of sanitation facilities comes a reduced desire to defecate publicly, meaning that the chances of this contamination occurring are less. Furthermore, water supplies in the Sustain-Loo facility can be accessed as drinking water during heavy rains or flooding when the chance of contamination has risen. The total result is an increase in the health of local residents through the reduction of one source of disease generation, and an alternative to drinking contaminated water. Adverse health conditions associated with the emission of smoke will be greatly reduced if resident elect to utilise the produced methane as a replacement for wood fuels. Chronic illnesses with symptoms including respiratory disorders and eye irritations will fall as bio-gas technology provides a cleaner solution to wood combustion. In addition, kitchen maintenance is eased, with soot accumulation on kitchen utensils eliminated. The time gained from lesser time spent on home maintenance can especially benefit women in the community who now, along with having a safe place to urinate and defecate, can invest more time in education and leisure activities.

Along with these all important health benefits, the implementation of the Sustaina-Loo facility within Devikulam will also generate a range of social benefits felt by all members of the community. Fundamentally, the introduction of a new facility into the remote Devikulam community will surely arouse attention from a majority of the local population, arousing the formation of opinions, contributions and group communication. Current relationships between the Scheduled Caste (Dalit) and the Most Backward Class are generally good, and the introduction of a project involving both
groups will provide impetus for further inter-communication and collaboration. Community members will also benefit from the sense of ownership generated during the consultation, education and construction phases. From the outset, we aim this to be a community-driven project, and this will be initiated at the very beginning consultation. The construction stage will also involve local materials and labour, and this means that anyone in the community can take part in the erection of the facility. This will confirms the ownership and social equity is shared between the community members as a united group. If nothing else, social benefits will arise from the increase in health and wellbeing of residents, and also the economic implications related to the facility’s resource output.

7.2.2 Economic Impact

With an initial capital cost estimated at around $1600, the introduction of the Sustaina-Loo system may impose some financial hardships on Devikulam residents if they are charged with its establishment. Buzza (n.d.) states that the mean annual household earning in Devikulam is 20,000 rupees (AUD $420) and this means it would take the yearly income of four families to finance the implementation. On the other hand, if one considers that there are 86 families living in Devikulam earning this average wage, the initial capital cost would be covered by $17 from each family. Though not significant in Australia, this is relatively expensive in Devikulam and would thus impose a financial hardship on residents. However, it is manageable and worthwhile considering the reduced maintenance costs and sale of outputs. With regards to the sale of ecohumus as a fertiliser, possible returns of around $6000 a year will surely finance the implementation and ongoing maintenance of the facility with more to spare.

Apart from the initial capital cost, eliminated expenses in water and electricity enable the flow of money to other areas in the community. In terms of output utilisation, biogas can be stored and used as a cooking/heating fuel and as a result, previous expenses in these areas are reduced. Alternatively, the sale of biogas and/or ecohumus may also help to develop Devikulam’s economy, enabling the investment in new infrastructure such as schools, shops and health facilities.

7.2.3 Environmental Impact

The design encompasses the use of technologies and mechanisms to utilise natural resources without impacting on the local environment. Autonomously collected rainfall reduces reliance on local water supplies and solar heating minimises electricity use and hence the production of greenhouse gases.

Expected is a significant reduction in public defecation associated with the shift to hygienic disposal, which as well as reducing the spread of disease between humans, will prevent the circulation of pathogens in plants and animals. Furthermore, the presence of our sanitation system will promote the cultivation of local plants through the use of the ecohumus as a soil conditioner, boosting local
crops. Alternatively, it may be used as a compost blanket to prevent erosion, thereby protecting both man-made and natural environments.

In relation to the adoption of methane gas as a cooking fuel, the depletion of natural forests is a major problem in India and is only exacerbated by the constant use of wood as a cooking fuel. Apart from the health impacts it presents, this also results in the loss of habitat and depletion of natural resources. Thus, the use of methane to supplement cooking fuels will thereby reduce demand for such wooden fuels and minimise environmental problems.

7.3 Risks and Contingencies

The sanitation system designed by Fab4 is a relatively simple design that is less likely to exhibit problems compared to more complex systems. However, no design is without fault and there are several possibilities that need to be considered for the long time functioning of this model. Incidents can and usually do happen, and preparation is required beforehand to remedy these incidents so the system is reliable and effective.

7.3.1 Safety Risks

Explosion of bio-digester vessel may occur if a flame or ignition source is brought into the valve of the container, potentially causing major burns, and in the worst case, fatality. The chance of this happening have been significantly reduced by our design in two ways; our facility situates the bio-digester under and within the facility, away from potential ignition points, and the natural absence of oxygen in the digester will prevent combustion from occurring.

Similarly, if there is extensive build up of biogas in the bio-digester container, accumulation of pressure may also lead to an explosion. We believe that our use of a polyethylene biodigester tank will minimize this risk because the seams will simply rupture if pressure exceeds a certain point, resulting in the harmless release of gas.

Lastly, if methane leaks from the ruptured digester and enters the enclosed facility, it might cause asphyxiation by displacing the oxygen to below 19.5% in the facility’s local atmosphere. Similarly, the leakage of Hydrogen Sulphide produced in the biodigester will cause further health issues, a highly toxic gas which can result in severe and chronic illnesses after just a few minutes of exposure. As such, Sustaina-Loo is designed to be well ventilated (as are all communal toilet facilities) to reduce the risk of asphyxiation or poisoning.

7.3.2 Environmental Risks

At times where the rainfall and recycled water exceeds the amount used by the community, the storage tank may overflow after an extended period of time. Although our storage tank design will be a sufficiently large size tailored to the community’s current use, we consider this out of our control and even perhaps a sign that our system is working well. To ensure, however, that the precious water is not being wasted, an outlet valve will be situated on the tank whereby residents can capture surplus water and use or store it elsewhere.
Airborne particles may enter the pipe and filtering system where water passes through. Occasionally, larger particles such as leaves or twigs may enter the drainage pipes and accumulate to form a blockage. This blockage will retard the rate of flow of water and may cause stagnation and even contamination. To prevent this from becoming a safety issue, regular maintenance will ensure no blockages are present. The same goes with the upkeep of the polyethylene roof, with regular cleaning essential to hygienic water collection.

The showers, sinks and taps in each of the cubicles require water from the storage tank, which collects its water from rainfall and has no other source of constant water supply. However, Devikulam receives the vast majority of its rainfall between the wet season months between July and December, with smaller amounts falling in the dry season. To remedy this, local community members could be encouraged to insert less sanitary water from local bores into the heating tank and/or the side storage tank in an effort to enable continued use of the shower and sinks. However, this is unlikely since we are already re-using the spent sink, shower and anal cleansing water via a filtration system and output to a re-use tank.

As with a lack of rainfall, a lack of sunlight is also possible although much less likely. Devikulam has a hot and humid climate and the sun is active during most days. However, it is possible that during the monsoon period Devikulam would have sufficient cloud cover to reduce the effectiveness of the absorbent black tarp roof, resulting in an absence of hot water. This will only be a temporary dilemma resulting in minor hardships in hot water for residents.

7.3.3 Operational Risks

It is also possible that some systems in the facility will degrade and eventually fail in the long term. Although the facility has been built to be sustainable in the long term, it has also been designed to be inexpensive should any replacement parts be needed. Most will be available locally, however some harder to purchase items will be kept in stock within the village. Maintenance crews would be charged with the task of dealing with these issues.

Also associated is the possible misuse of the in relation to the input of unacceptable materials into the biodigester. These can easily be removed, however, educative posters should instil the required knowledge in locals to prevent such a situation from occurring.

7.3.4 Cultural Risks

Perhaps a possibility which will prevent the development of the project from the very beginning is that our model will clash with local customs and beliefs or would be unacceptable to use by the residents, having no beneficial impact whatsoever. Education will be the primary contingency to combat this possibility, highlighting the importance and benefits of our design. For example, while methane is not a problem, the Devikulam community might not particularly appreciate the idea of recycling human waste to create fertiliser as it clashes with their local beliefs (Buzza n.d.). However, if the people are still against our model after education measures have been exhausted, we will be forced to edit our model in such a way that it is appropriate. In this case, the fertiliser would be sold off as soil conditioner, or if that still clashes, will be used as top-soil to prevent road erosion during the monsoon period.
Conclusion

Fab 4 are motivated not only to win the 2011 EWB challenge but also to provide a lasting impact on the lives of Devikulam residents. As privileged students living in the ‘lucky country’ of Australia, we feel an imperative to address the lack of sanitation in developing countries, something which we unintentionally take for granted. We can imagine a future where all human beings are given the basic right and capability to defecate and urinate in a safe and private place, with the disposal of their human waste occurring hygienically and without risk to their local community.

By implementing our ambitious Sustaina-Loo design in the remote Devikulam community, we believe we will have a profound positive impact on the health and privacy of local people. Furthermore, our design requires minimal inputs and converts waste to valuable commodities which can be used to improve the material standard of living or sold to improve the economic prosperity of the village.

According to our design criteria, our team aimed to produce a sustainable waste management system which was proficient in reducing the pathogen content of human faeces to thereby improve the health and wellbeing of Devikulam residents. This system was designed to be compatible with the Devikulam community and concurrent with their economic and cultural limitations, and this is why we attempted to incorporate local materials and processes to develop the project as a community-led initiative. The production of useable outputs was another of the design goals we hoped to fulfil, as this would reflect back on the economic considerations of the system. Utilising its local environment, our Sustaina-Loo system is sustainable and cost effective, transforming wastes into resources such that it will pay itself off in the long term.

To achieve the aforementioned design, extensive research was conducted, and a variety of appropriate technologies were considered as possible solutions. From the outset, we set our hearts on the biodigester solution, as it was highly sustainable, cost-effective and innovative compared to other sanitation disposal methods. We also conducted extensive amounts of research on typical user-interfaces in order to make our facility as compatible with pre-established practices while remaining cohesive with our biodigester. We concluded that a urine separating squatting basin, not at all common throughout the world today, would be the most feasible option.

The result was an innovative sanitation disposal system contained within an imaginative physical facility. Collecting heating its own rainwater via clever storage space and use of materials, the outer walls of the Sustaina-Loo do not give it the appearance of any regular communal toilet. Inside, hot showers and sanitary hand-washing facilities offer Western luxuries to Devikulam residents, and perhaps most importantly, they are offered a safe and private place to urinate and defecate.

The biogas produced in the process is rich in methane and thus the option to capture and use this gas as an energy source for cooking and lighting it extremely alluring. Use in cooking applications by the Devikulam community could improve health and reducing cleaning for female residents, who are empowered by newfound time, money and sanitation facilities. Furthermore, the digester effluent was discovered to be a nutrient rich fertilizer, and we envisage it being sold on the local market as a competitive organic fertiliser. We estimated, based on limited knowledge, that this could generate thousands of dollars per year if properly marketed. The idea of recycling is extremely important in
modern day engineering, with the realisation that the quantity of resources available on the Earth is only finite, we have attempted to involve suitable initiatives to promote the re-use of human waste and spent water.

We recognise that there are countless factors to consider when implementing a project such as this, and we are determined to overcome any obstacles presented to us along the way. Our goal is to produce an innovative, low-input, long-term sanitation solution to prevent the practice of open defecation and urination which enable the spread of pathogens, and we believe we have addressed almost all possible details in order to ensure success, or at least successfully deal with failure.

As a team we have come thus far, and are willing to put in the concerted effort towards a world where every person enjoys the basic human rights they deserve. We have realised that the most basic right to adequate sanitation is a great place to start, and we thank EWB for challenging us to step up and voice our ideas – exactly what is needed for the bright minds of today to move forwards into a positive future.

Figures 18 & 19: We believe our system is sufficient to improve basic rights to sanitation
8 **Recommendations**

- We recognize that our facility would perhaps be more effective if it featured female and male sections. As a team (with one female member), we have deliberated on whether this is a problem and have concluded that the pull factors of adequate sanitation outweigh the push factors associated with an inter-gender communal toilet. If this were a problem, Devikulam residents could simply install two facilities or modify the walls to separate male and female sections.

- We also recognize that the cost and income assessments in this report were compiled with minimal success in finding reliable information on pricing in India, let alone the Devikulam Region. As a result, we are firm that upon implementing the program, the actual costs and incomes will become more available to us and we will pursue those figures instead of these assumptions.

- Following from the last point, the consultation process will also be largely determined by the reaction we receive to our initial publicity efforts. In this way, our actions and decisions in construction and implementation will be largely community-driven and occur as relevant stages are completed.

**Most importantly, as with any engineering project, the plans, actions and decisions made in this report are based on limited knowledge of the end conditions in which the Sustaina-Loo facility will be installed. Thus, it is important to realise that major decisions will occur not only on the basis of this report, but also at the discretion of well-informed Fab 4 members volunteering during the construction of the facility. Nonetheless, we believe compiling this report has given us the skills and knowledge required to ethically and realistically formulate and prepare an engineering project.**
9 References


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Sustainability-Sanitation Solution
EWB Challenge 2011  Karren, Pande, Wu, Madurawe

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# Appendix A – Team Constitution

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## Our Vision

FAB 4 aims to use innovative thinking and creative analysis to create a sustainable and viable solution to human sanitation problems existing in developing countries. We acknowledge the health risks associated with a lack of sanitation, and hope to develop a framework which provides effective sanitation infrastructure which improves living standards on a global scale.

## Role Statement

The team has formal roles in place to provide individual and mutual accountability. Every person shares leadership, every person will be designated an equal workload, and every person’s opinion will have equal weighting with the other team members. However, based on the team exercise completed in Week 3, specific members are suited to specific roles. It is important to note that these roles do not define that person, who may choose to become active in other roles for the benefit of the team.

**Leader** – Ash  
**Moderator** – Joe  
**Creator** – Joe/Durlabh  
**Manager** – Ash  
**Organiser** – Joe  
**Evaluator** – Chameka  
**Finisher** – Chameka

As a result, different tasks will be naturally allocated to those suited, however task allocation will occur from week to week under the consensus of the team.

## Procedures and Policies Statement

The team’s policies and procedures governing such things as attendance, tardiness, absenteeism, task preparation, timeliness, quality of work, and conflict resolutions, penalties and rewards are as follow:

- All team members must attend team sessions unless they have scheduled classes or have a flawless excuse.
- All members must give an effort which ensures we achieve a high distinction. It is important to note that this effort takes into account additional workloads from other subjects, so while it may not be the absolute best effort, it is reasonable considering the other pressures placed on them.
- If a person is absent from a team meeting without explanation or reasonable cause, they MUST give $5 to EACH team member.
- If a person is late to a meeting, they will be subjected to scrutiny by other members and possibly given an extra workload as penalty.
- Each person’s work quality must be of a very high standard and not require proof reading by others.
- If a person has other assessments or workloads from other subjects that require their time, they may ask the team for a slightly lessened workload. However, they will receive a higher workload at a later date.
- Situations of conflict or indecision will be subjected to a team vote. If this vote is hung, Jonathon will make the final decision.

## Commitment by Members

_I participated in formulating the vision and goals, roles, and procedures as stated in this contract. I understand that I am obligated to abide by these terms and conditions. I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract._

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University of Sydney | 1061 Advanced Engineering
Appendix B – Gender-Related Sanitation Issues (Article)

Sanitation: The hidden gender problem
Absence of proper sanitation is affecting women’s lives.

Bangalore, July 2002 (WFS) - Munni sits holding a plate laden with three large rotis topped with a generous helping of spicy dal (lentils). She is hungry, but will not eat it yet. Covering the food with another plate, she quietly puts it away, while her husband and two teenage sons quickly polish off what is on their plates.

"Yes, I am hungry. I have not eaten since morning, but if I eat now I will have to go to the toilet by the time the food is digested -- and there is always a long line at the washroom. We have just two toilets for women in this camp. So I eat only one meal a day, to minimise the number of visits to the toilet," she says. Munni and her family are getting used to living in makeshift transit accommodation, on the outskirts of Bangalore, after their house got burnt down along with those of 57 other families in the neighbourhood. While both men and women among the displaced families face the trauma of uprooting, loss of belongings and lack of amenities, the women suffer an additional dimension of cruel handicaps that do not apply to the men - that of attending to nature’s calls and bodily functions.

The lack of sanitation facilities compounds the trauma of displacement and loss. For instance, in Gujarat, a fact finding team found that there were only 22 toilets for 10,000 persons in one of the relief camps set up for those who had to flee from their homes following the recent communal clashes. This gross insufficiency means that both men and women have to queue up, but while the men can (and often do) stop to empty their bladders by the roadside, the women cannot.

As some of the women affected by the limited access to toilet facilities confess, the only solution available is to ensure that their need to use a toilet is reduced as far as possible. Some of them say that this means they hesitate to drink water even when they are thirsty. This in turn means that their health suffers, because denying the body sufficient fluid intake can result in kidney problems and other illnesses, some of them serious. These health hazards are in addition to those that both men and women, as displaced persons in relief camps, face in terms of unsatisfactory living conditions.

In a programme on the problems faced by persons forced to survive in makeshift shelters, telecast recently by the BBC, one indigent woman of Mumbai spoke about how she eats only once a day due to the absence of toilet facilities. "The men can manage somehow and relieve themselves whenever they want, they can walk around and locate some place behind a bush, but we women can't do that," she remarked. Since coming to live in that shanty town, she has developed anaemia due to reduced food intake.

Predictably, many women of that colony share this deficiency for the same reason. Poor health in turn reduces their work productivity, and also makes them vulnerable to frequent infections and debilitating illnesses. No male, living in similar dwellings in the same colony, seemed to suffer from
this kind of handicap - of being forced to restrict the frequency of food intake because of the lack of toilet facilities.

Given the existent cultural constraints on women, women do not relieve themselves in public the way men do. Educated and well-dressed men will get out of a car and urinate by the roadside without feeling abashed - a state of mind few women, rich or poor, young or old can reach. Women tend to hold on, control and force their bodies into punishing (and often harmful) restraints because that is what socio-cultural norms decree.

The latest Human Development Report estimates that only 31 per cent of the population in India has adequate sanitation facilities, as against 73 percent in Vietnam, and 68 per cent in Zimbabwe, for instance. Among the displaced and uprooted, however, this percentage becomes even lower, because a temporary shelter is rarely seen as more than a room with a roof.

Dr Almas Ali, a medical practitioner working with non-governmental organisations (NGOs) in Andhra Pradesh, estimates that gynaecological and urinary tract problems run higher (almost one-third) among women who lack access to sanitation facilities. The absence of facilities is not merely because of poverty but also because of the cultural inhibitions and constraints regarding women's bodily functions.

According to statistics compiled by the UN, women and children make up 80 percent of the world's refugees and displaced people. If anything, their need for facilities is thus greater than that of men. And yet, no more than scant attention is paid to this need, even by aid agencies and NGOs that organise supplies of food, milk, blankets and medicines.

During the Kosovo war two years ago, for instance, a refugee woman in a transit camp pointed out that few relief organisations thought of bringing supplies of sanitary napkins for the women, which are "as essential as food for the daily meal", as she put it. She said she waited till women volunteers turned up to mention her need.

Echoing this point of view, the women of one family affected by the earthquake in Gujarat last year said, "We can speak boldly about the lack of sheets and pillows and blankets, but somehow find it difficult to bring ourselves to mention toilets. That is a subject we are not supposed to mention, it's not done. It is considered improper, unbecoming. Sharam aathi hai (we feel ashamed)."

"Sharam" (shame) is what being a woman is all about, even if it means attending to perfectly natural and normal functions. And that continues to be so, even today, in spite of all the advances that the female half of the population has chalked up in various fields.

Sakuntala Narasimhan
July 2002
Appendix C - Biodigester Design Variations

CRDT(2009)

Sustainable Sanitation Solution
EWB Challenge 2011
Karren, Pandc, Wu, Madurawe

Model  Technical construction  Construction cost  Gas production and uses  Maintenance and duration  Problems

Plastic tube  Easy and simple installation  Easy to clean and use  Gas production
Use, durable, long with high pressure
 Requires regular maintenance, especially for cooking. Requires gas lamp with high pressure, can store gas for both cooking and gas lamps. Relatively easy to fix, last up to 20 years. Material lasts between 2-2.5 years. Easy to transport, with local materials, easy to fix, but difficult to repair.

Concrete rings  Requires skilled construction, taking 7 to 10 days for construction. Easy to purchase materials from local market. Approx: 200 USD
Stores enough gas for cooking but not lamps. Requires regular maintenance, especially gas reservoir. Well maintained systems last up to 20 years. Difficult to repair. Less maintenance, especially gas needs regular maintenance.

Brick and Mortar  Requires skilled labor construction, taking 5 to 7 days for construction. Easy to purchase majority of materials locally. Approx: 450 to 500 USD
Stores gas for both cooking and gas lamps with high pressure. Easy to use. Requires regular maintenance, especially the pressure valves. Relatively easy to fix with local materials, but difficult to transport bricks.

Concrete cone  Requires skilled labor construction, taking 5 to 7 days for construction. Easy to purchase majority of materials locally. Approx: 300 to 350 USD
Stores gas for both cooking and gas lamps with high pressure. Easy to use. Requires regular maintenance, especially the pressure valves. Relatively easy to fix with local materials, but difficult to transport bricks.

Appendix C – Biodigester Design Variations

CRDT(2009)
Appendix D – Organic & Water Flow Cycles

(hand Drawn See Hard Copy)
Appendix E – Primary Research Photographs
## Appendix F - Implementation Gantt

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<td><strong>Facility Development: Dhowkulum Village, Tamil Nadu, India</strong></td>
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<td><strong>Appendix C</strong></td>
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<td><strong>Implementation</strong></td>
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<td><strong>Gantt</strong></td>
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<td><strong>Long Term</strong></td>
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<td><strong>Long Term</strong></td>
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<table>
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<tr>
<th>Feedback Stage</th>
<th>Third Consultation</th>
<th>Community Survey</th>
<th>Facility Output Sale Begins</th>
<th>Maintenance Begins</th>
<th>Facility Construction Begins</th>
<th>Community Consultation Begins</th>
<th>Second Consultation Begins</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

**Notes:**
- 1Ft: First Fortnight
- 2Ft: Second Fortnight
- 3Ft: Third Fortnight
- 4Ft: Fourth Fortnight
- 5Ft: Fifth Fortnight
- 6Ft: Sixth Fortnight
- 7Ft: Seventh Fortnight
- 8Ft: Eighth Fortnight
- 9Ft: Ninth Fortnight
- 10Ft: Tenth Fortnight
- 11Ft: Eleventh Fortnight
- 12Ft: Twelfth Fortnight

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Appendix G – Educatve Posters

Two more hand drawn see hard copy

Acceptable Material (Manure, Faeces, Low-Fibre Vegetable Scraps)

Unacceptable Material (Plastics, Bottles, Artificial Products)