The Green Machine - Design Project Report

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Executive Summary

Remote locations of the Indigenous communities in Cape York make the collection of waste through municipal services challenging (Engineering Without Borders n.d.). Due to this, waste is often separated, then either incinerated or landfilled. One of the most demanding waste streams that must be damaged is produced by generic whitegoods such as washing machines. Inappropriate disposal of washing machines impacts both the ecosystem and waste management as side effects. Our goal is to provide an alternative to existing washing machines so as to reduce the need for electrical laundry machines.

We assessed several possible solutions in order to achieve our goal. The design objectives were narrowed down: to minimising cost, maximising local resources, maximising economic benefits, minimising negative environmental impact and maximising community engagement. A net weighting (percentage) was established for each design objective. This enabled us to determine which objectives were valued most and then we proceeded to compare the design options against these said objectives. As an outcome of this extensive design selection, we chose the bike powered washing machine as our preferred design option.

A bike powered washing machine can be assembled using material available in Cape York. This region also faces extreme weather conditions, the hot and the wet. During the wet season, these remote locations become almost completely inaccessible from the outer regions. Therefore, it is important that the solution created is sustainable within Cape York. Electrical energy, although a necessity is inadequate in these regions. As the solution we provide results in a sustainable, locally sourced, eco-friendly washing machine that will help with waste management in remote bush locations, we believe that it may truly make a difference. Furthermore, since this design is man-powered, it will ensue the conservation of electrical energy that can be utilized for other essentials.

Each machine will cost around $299, which is much lower than the price of a general washing machine and is also a reasonable amount as the median weekly income of households in the Cape is $987 according to statistics.

We as a team, are confident that if implemented, this design is capable to assist with waste management and conservation of electrical energy in the Cape. This report was written with the intentions of bettering the living quality in the remote bush locations of Cape York.

Table of Contents

Contents

1. Introduction

1.1. Background

The Engineers Without Borders (EWB) Challenge for 2020 has collaborated with first year engineering students and CATFAb (CfAT) in Cape York to provide solutions to the real problems that the community and environment face in remote bush locations. Groups of students were able to choose between 7 design areas, each area focusing on a different issue that is currently affecting the Cape York area. The ultimate goal of this EWB challenge is to implement the best design from each area given the consent of EWB and the Cape York indigenous community, such that the lives of the community are improved.

1.2. Problem Definition

The Cape York peninsula is located in Queensland, Australia and is home to the Indigenous communities. Due to its remote location, it makes the collection of waste through Municipal waste collection services very challenging. The processing of the produced waste by the Indigenous communities usually begins by separation, then through to either landfill or incineration.

It is arduous to maintain the waste produced by generic white goods in Cape York communities. White goods purchased by these communities have a short lifespan so when they go out of use, it is cheaper and takes less effort to replace them than repair them. This causes a very inappropriate disposal of generic whitegoods in the cape, accumulating waste and harming the local environment in the process.

Figure 1. Inappropriate disposal of washing machines and tires (Engineering Without Borders, n.d.)

Problem Statement:

> *Generic white goods in remote locations are difficult to maintain and create large amounts of waste in the community which are strenuous to dispose of.*

Additionally, the need for energy in the Indigenous community of Cape York, is high as it is scarce. Producing an alternative to a major existing white good will result in reducing the power consumption in Cape York, which can be then used for other necessities.

2. Background

Engineering Without Border have joined forces with the Centre for Appropriate Technology to implement creative, simple and locally sustainable solutions for infrastructure challenges. This is in order to support the people in regional and remote Australia in the choices they make as to maintain their relationship with Country.

2.1. Social Setting

The total population of Cape York is 9458 people which consists of 50.8% males, 49.2% females and 2312 households. The average weekly income of households is $987 and the average weekly income for an individual is said to be $333 (Australian Bureau of Statistics 2017).

Table 1. Information on the average weekly income of Cape York residents (Aboriginal and/or Torres Strait Islander people) (Australian Bureau of Statistics 2017)

Residents of Cape York	Individual	Households
Average weekly income	$ 333.00	$ 987.00
Monthly mortgage payment		$ 2100.00

2.2. Geographical Information

Cape York is located towards the North of Queensland, Australia and it is currently the largest unimpaired wilderness in North Australia. The east coast of Cape York borders the Coral sea, whereas its West Coast borders the Gulf of Carpentaria. The land in the Capes is mostly flat and quite infertile largely due to the laterization of soil. Cape York faces extreme weather conditions, heavy monsoon from November to April and then proceeded by a very dry season from May to October (Wikipedia n.d.). Annual rainfall in the Cape is very high, reaching 1753.3mm on average per year and during this heavy wet season, Cape York becomes almost inaccessible to the outside due to flooding of major roads (Australian Bureau of Meteorology 2020).

Table 2. Information of average monthly rainfall in Cape varying with the seasons

Month	January	February	March	April	May	June
Mean rainfall (mm)	370.6	352.1	370.9	255.5	69.1	26.1
Season	Heavy monsoon		Dry season			
Month	July	August	September	October	November	December
Mean rainfall (mm)	19.7	9.5	6.4	14.9	56.7	194.6
Season					Heavy monsoon	

3. Design Requirements

The designs considered for this project will have to meet a set of requirements. This will be enable us to tally out the best design option for this project. These design options include the following:

3.1. Sustainable and simple alternative

The concept of the solution must be basic with an uncomplicated, straightforward design and function. It must be relatively carbon neutral and must reduce the amount of electricity used. This decreases the harm the current machines cause to the local environment and doesn't contribute to greenhouse gasses and global warming.

3.2. Minimal difficulty in maintaining and repairing

The design must be self-sufficient to some degree, it must be low maintenance, and any maintenance needed for the solution must be able to be recognised easily, such that the solution should give an indication of what needs maintenance if any is needed at all. It should be sturdy, durable and flexible in most outdoor conditions that it will be exposed to. This decreases the effort required to run the product and increases the chances that the user will get the product repaired instead of disposing of it in the bush.

3.3. Improved longevity and efficiency

This means that the product must have improved longevity and quality. The main function of the product itself must also be improved and therefore must also be more reliable. Thus decreasing the time it takes for the product to irreparably break, decreasing costs and effort to source and dispose of materials.

3.4. Made of recycled or reused material

The solution should be made of relatively small and sturdy parts which can easily be recycled. Plastics and materials harmful to the environment should be avoided. The parts must also be able to be reused and must not be prone to breaking easily. This allows the design to be environmentally friendly and means that once the product breaks, the working parts can then be reused again or can be recycled and be used for something. Smaller parts are also easier to recycle and therefore will decrease the likelihood that they will be inappropriately disposed of.

3.5. Lower running cost than existing white-goods

The product must be inexpensive to run, and ideally should have a zero-running cost. Costs regarding maintenance and repairs should be as minimal to the user as possible. This saves money for the user and allows it to become a more realistic approach.

3.6. Must benefit all members of the community

The solution must be something which improves the quality of life of all the residents of Cape York. This ensures that everyone in the community can rely on the solution and ensures that it is considerate of all users.

3.7. Should not pose any severe risk or hazard

It must not be dangerous to use or cause harm. And it must not require vigorous training to avoid hazards. This minimises risk to the community and means that most people can use it.

3.8. Must not violate any cultural guidelines

The solution must support and be approved by the local indigenous community and must not violate or pose a risk to their cultural guidelines, heritage, or practises. This means that the community will use and trust the product and increases the likelihood that it will be integrated in their everyday lives.

4. Design Criteria

For our design to be successful, it must overall accomplish the following:

4.1. Wash clothes and agitate water

The main function of the machine is to wash clothes, and thus it must be able to agitate clean water and soap to do so. This continuous action must be repeated many times by the machine to wash a single load of clothes in a way that is efficient and of equal quality to washing a single load of clothes in a household washing machine. As this is the case, the repetitive action of agitating the water must either be automated by the machine, or if it is manual, it must not be laborious to the extent that it poses the risk of physical harm or strain on the user.

4.2. Use clean water and soap

The machine must use clean water and soap to wash the clothes. This is to ensure that the washing method is to the same hygienic standard that the household washing machine is, so that this does not decrease the quality of life of the user, and so that it does not destroy the clothes. The use of clean water can be achieved by using clean tap water, or by implementing filter into the machine which then uses the filtered water to wash the clothes.

4.3. Materials must be appropriate

The material of each component of the machine must be chosen such that it maximises the longevity of the product. For example, the chamber of the machine cannot be made of a material that is dissolvable or rusts in water, that cannot handle large weights such that it breaks easily, and it cannot be made of a material which melts in warm water and destroys the clothes inside. Any metal components of the machine must be made of a metal which does not rust easily in case those parts are exposed to any water or moisture from the machine.

4.4. Appropriate chamber size

The chamber in which the clothes are being washed must be of an appropriate size. That is, it must be of a volume large enough so that it is able to hold the same amount of clothes as a normal washing machine, and so that it is able to hold enough water to wash the clothes with ease. But as there is a possibility the solution will need to be able to move or rotate, it cannot be so large that it's weight poses a risk to the community and becomes a hazard, for example, someone might get hurt when handling it. The weight also must not be heavy enough that it decreases the functional life of the product. If the machine is being moved or rotated, large amounts of weight might deteriorate the material of the chamber and the machine itself. It also might be strenuous on the mechanisms and joints of the machine, meaning they might break and would need to be repaired or replaced more often.

4.5. Decrease inappropriate disposals

A decrease in the amount of garbage being inappropriately disposed in Cape York must occur as a result of the machine being implemented. One of the major purposes of this machine is to ensure that it's longevity and maintenance needs are improved from that of the household washing machine. Although this improves the quality of the life of the residents, the overall effect of this is to ensure that users see repairing and maintaining broken or damaged machines as a better option rather than discarding them in the bush. Or if they do continue to discard them, the rate at which the washing machines are being discarded must be slowed.

4.6. Locally sourced materials

Materials for the machine must be sourced locally or within the Cape York area. This decreases the costs required to source the materials to make and repair them as there will be less costs associated with the transportation of the materials from one part of the country to the other. As well as this, supplying materials from local sources supports and helps the community, such that the machines will hold more value to them if they see it as a result of the community effort. Thus they will be more obligated to have the machine maintained and repaired. This also means that those who supplied the materials will be able to provide direct information about their products and materials. As a consequence of this, when it comes to repairs and maintenance, they are able to assist EWB with their knowledge.

4.7. Improve community lifestyle

The machine must ensure that the lifestyles of the community and those that use the solution have not been decreased or worsened in some way. Instead, it should be in our best interest as engineers to improve their everyday lives to the best of our ability. If the residents are not enthusiastic about the machine, then this will make their lives harder, and as a consequence, the machines might be discarded in the bush and the community will revert back to using household washing machines, thus changing nothing and if anything, increasing the amount of garbage disposed inappropriately in the area.

5. Design Options

We explored 3 possible design options and expanded on each with their own benefits and constraints. We then compared these possible options with each other and a list of design objectives to systematically determine which one would best solve the problem statement, fit the design criteria, and meet the design requirements.

5.1. Design option 1: Bike powered washing machine

One of the options we explored was to use pedal power from push bikes to generate energy which will then be used to agitate the water and spin the clothes in the washing machine. This eliminates the need to power the washing machines with electricity and instead maximises the clean energy generated from rotating the pedals of the bike. The machine attached to the bike will consist of a chamber attached to the back wheel of the bike which spins as the wheel turns, effectively agitating anything inside.

As electricity is not required, this minimises the cost required to operate the machine and means that the machine does not need to be fixed to a power-point to operate. But because of this, manual labour from the user is required to operate the machine, and thus this might not appeal to the community given that the household machines currently in use require minimal effort from the user to operate it. The concept of the design also minimises the negative effect washing machines in the area will have on the environment as new water will not need to be constantly cycled throughout the machine, and instead, the same water will be used throughout the cycle of the machine. As these are also not ideal to keep as one per household as they take up a lot of space, these will most likely be scattered throughout the community, thus encouraging community engagement. The materials used for this design can also be locally sourced from nearby the community. Despite this, the bikes used might pose a risk to the environment if they are not properly disposed of if they are broken.

5.2. Design Option 2: Manual washing machine with optional electricity

This option involves the design of washing machines that can be operated by both manual labour and electricity. The user manually operates the machine by turning a crank at the top of the chamber, which rotates the chamber around the yaw axis. The machine is designed so that a battery can be attached to it and it is able to function automatically.

The manual part of the washing machine helps save electricity and thus helps the community save money, and the electrical component of it means that the community will be able to have the option of normalcy if they are not able to manually operate the machine themselves. But this design means that the electrical component will need constant maintenance as it may have a higher chance of being prone to breakage. Because of this, this machine may produce the same problem with the current washing machines in use in the Cape York area such that if broken or in need of repairs they will be disposed of in the bush instead of seeking proper maintenance or disposal methods. The battery also poses this same problem, but this can cause major harm to the environment as the contents of the battery (such as metal oxides) are toxic to the local flora and fauna. This design can be placed in households, but one per household increases the expense and the running costs of the machines, and this also means that more will most likely end up in the bush, so the residents will have to be limited to communal washing machines. Although this improves community engagement, this also means that the machines are going to be maintained more due to the constant use.

5.3. Design Option 3: Rotating Barrel with a crank

This design is similar to the design option above, in which the chamber is rotated manually by a crank, except that the crank is attached to a side of a barrel which is held up by a frame, and the barrel is then rotated about its pitch axis. A tap is attached to the barrel so that water can be drained, and the top can be opened and closed securely. The frame it is attached to balances the barrel off the ground so that it is able to be spun manually.

Old water barrels of any size can be used for this which helps minimise the amount of landfill in the Cape York area, but the problem with this is that the frames for the barrels will need to be specific to the barrel size, meaning that these parts cannot be bought in bulk and thus the costs to make these frames are increased. Although this can help reduce the landfill in the area, once these barrels break, there must be a way to ensure that they don't end up as landfill again and instead are properly disposed of. The weight of the barrel may also pose a risk, if the frame is not able to handle the concentrated weight of the barrel when loaded and moving, then this may be a serious hazard to anyone around the barrel, and may result in injury. As any barrel size can be used, this means that smaller barrels are able to be used for individual households, and thus improves the quality of life of those residents as they will not have to travel to wash their clothes. Larger barrels can be used in communal areas for those who don't have individual household barrels, so that community engagement is still encouraged. Despite this, the larger barrels require more physical labour to operate and thus, may result in physical exertion or injury. Because of this, training may be required for barrels of a larger size.

6. Detailed Design

6.1. Design Selection

Before comparing the design options against the design objectives, we determined which design objectives we valued more for this project. This was accomplished by each member ranking the importance of each objective such that the total sum of each member's objective rankings is 100.

Table 3. This table shows each group member's ranking of the design objectives and how the sums of those scores are weighted

Design Objectives	Group member				
	Thirandi	Isabelle	Rish	SUM	Weighting
Minimise cost	20	10	15	45	41%
Maximise local resources	30	10	10	50	41%
Maximise economic benefits	10	15	20	45	41%
Minimise negative environmental impacts	30	35	40	105	100%
Maximise community engagement	10	30	15	55	50%
TOTAL	100	100	100		

Each design option was then ranked on a scale from one to five based on how well they achieved the design objectives. A ranking of one means that the design option does not meet this objective, and a ranking of five means that the objective fits the objective perfectly.

Table 4. This table shows the design options being ranked against the design objectives

Design Objectives		Scores		
	Weighting	Option 1	Option 2	Option 3
Minimise cost	41%	3	3	4
Maximise local resources	41%	3	4	3
Maximise economic benefits	41%	4	2	2
Minimise negative environmental impacts	100%	5	3	4
Maximise community engagement	50%	4	3	3
TOTALS		22	15	16

These rankings of the design options are then converted to weighted scores which are determined based on the results from Table 3 above.

Table 5. The weighted scores of the design options

Design objectives	Weighted scores		
	Option 1	Option 2	Option 3
Minimise cost	1.2	1.2	1.6
Maximise local resources	1.2	1.6	1.2
Maximise economic benefits	1.6	0.8	0.8
Minimise negative environmental impacts	5.0	3.0	4.0
Maximise community engagement	2.0	1.5	1.5
TOTALS	11.1	8.2	9.2

As shown in Table 5, the weighted scores show that Design Option 1, which is the bike powered washing machine ranked the highest out of the design objectives. Thus, is the better design option to explore and expand on in comparison with the others in order to meet the design criteria.

6.2. Design Inspiration

The principal element of our design is based on SpinCycle by Richard Hewitt (SpinCycle n.d.). In his design he invented a pedal powered washing machine using some very simple equipment used in our day to day lives. He has also written a technical guide so as to inspire other young engineers and inventors to fabricate solutions of this kind.

6.3. The Preferred Design Option

This design uses the aid of bicycle, metal frame and barrel to wash clothes. A metal frame is attached to the back wheel of the bicycle, lifting it up so that this wheel comes intact with the barrel while the front wheel of the bicycle remains on the ground. The frame secures both the back wheel and the barrel, as an outcome of this, them the bike is pedalled the barrel turns washing the clothes inside. We call this design, The Green Machine.

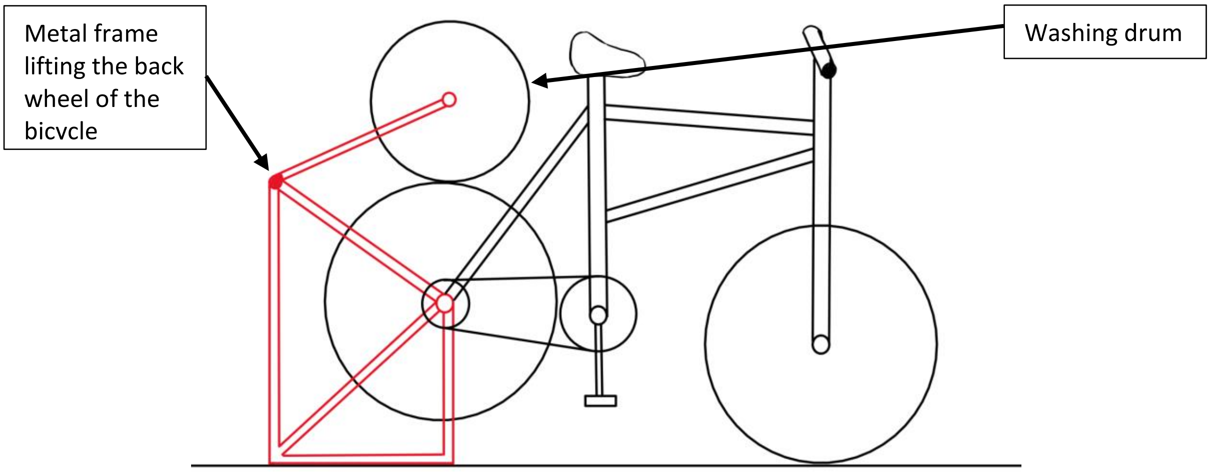


Figure 2. Basic overview of the design

6.4. Main elements of the design

- Barrel
- The bicycle
- The metal frame
- Repurposed tire
- Stunt pegs
- Wooden plank

6.5. Detailed description of the parts

6.5.1. Barrel

The plastic barrels that have been disposed in the Cape York can be reused for this design. Ideally, they would be in good condition, can be sanitised and reused for washing of clothes. The barrel is used to hold the clothes, it acts as the washing drum. When the frame is in the position shown in figure 3, the placed above the back tire of the bicycle, so that when the wheel rotates due to pedalling, the barrel turns, washing the clothes. As we do not have the dimensions of the barrels that are being disposed in the Cape, we used the dimensions of a 60 Litre blue plastic barrel from AdMerch Australia to decide the dimensions of this design (AdMerch n.d.).

Figure 3. This image shows the barrel we have used to determine the dimensions of the frame (AdMerch n.d.).

Dimensions of the blue barrel:

1. Height = 615mm (24.2126 inches)
2. Width diameter = 275mm (10.8268 inches)
3. Assumed diameter of body = 300.4mm (11.826772 inches)
4. Capacity = 60 litres

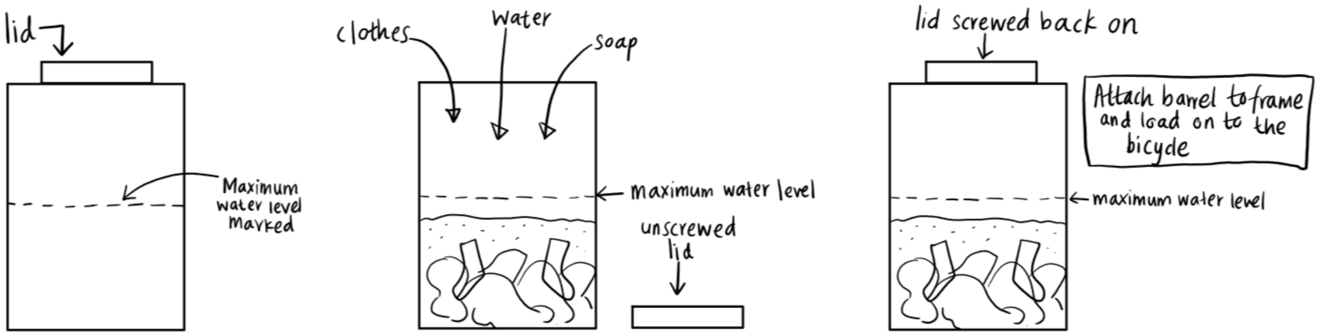


Figure 4. Series of images showing how the washing drum will be loaded.

Unloading the washing drum is also done similarly to the process shown in Figure 4. After pedalling for an adequate amount of time, the greywater is disposed and the clothes are left to dry.

6.5.2. The Metal frame

The metal frame is essential to hold the back wheel of the bicycle off the ground so that when the bike is pedalled, it remains stationary. This frame elevates the bicycle 2 inches above the ground. This will ensure the safety and stability of the user. Lifting the back wheel of the bicycle by 2 inches will also establish proper contact with the barrel.

Table 6. Lengths of the components of the frame

Component	Length
Average diameter of a bicycle (a) / in	24.5
Average radius of a bicycle (b) / in	12.3
Average thickness of a bike wheel (c) /in	1.9
Average length of a stunt peg (p) / in	4.0
Diameter of barrel (t) / in	12.8
Radius of barrel (r) / in	6.4
y1/ in	14.3
y2 / in	26.5
y3/ in	13.3
y4/ in	18.0
y5/ in	14.7
x/in	18.8
Ws/ in	9.9
Wb/ in	9.9
d/ in	7.2

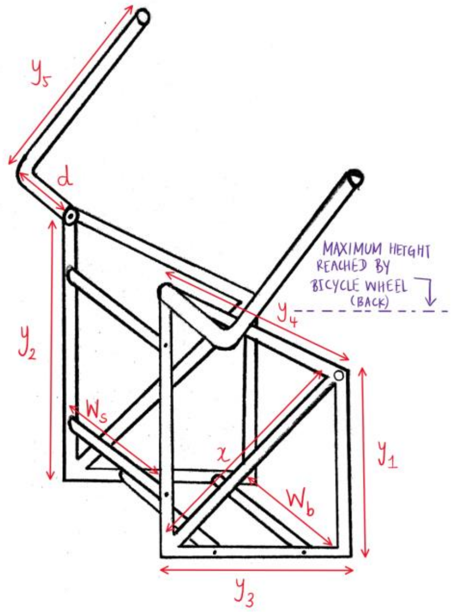


Figure 5. The frame with components labelled

This metal frame consists of four types of removable parts (coming in pairs) that can be assembled without much difficulty. These components are as shown below:

1) **The side supports**

   The frame parts Y_1, Y_2, Y_3, Y_4 and X are all attached through welding. They also have two holes in order to attach the component Y_5 and the bicycle wheel.

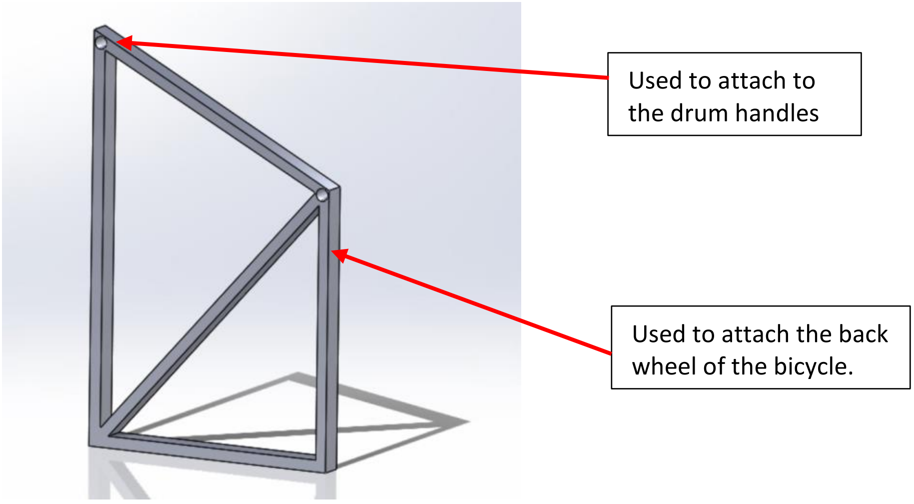


Figure 6. The side supports

2) **Support bars**

   These are the components W_s and W_b, there are 4 in total. This element gives the frame more stability and is attached by fixing a bolt into the screw-hole in the support bars through side supports (Y_1-Y_2-Y_3-Y_4-X).

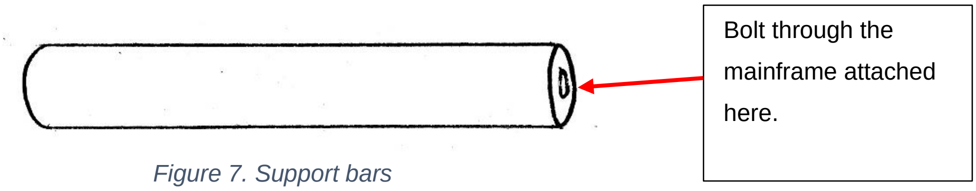


Figure 7. Support bars

3) **Drum handles**

   There are 2 drum handles in the frame. The handles help the user attach the washing drum to the frame and keep the drum secure while the bicycle is being pedalled for the washing of clothes. The drum handles attached to the side supports by fastening bolts through the side supports and into the handles (along with nut-fasteners). They are joint to the washing drum through bolts and eye-bolts (Figure 8).

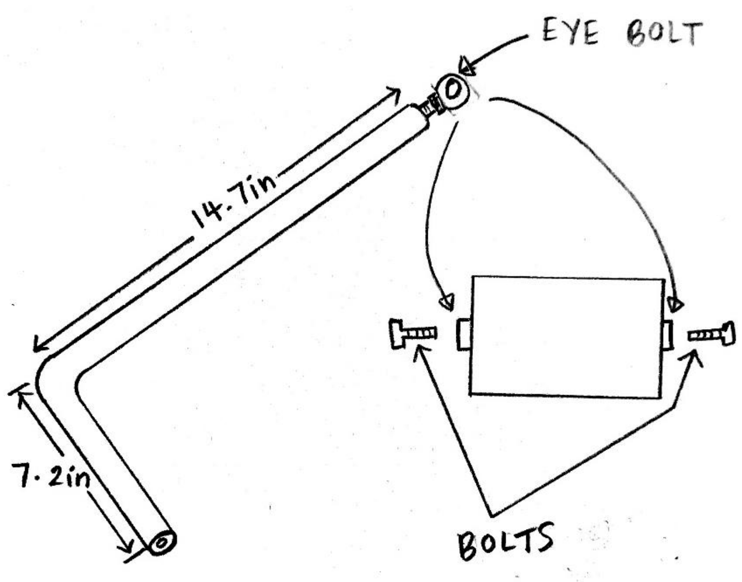


Figure 8. Drum handles basic overview and how they are attached to the washing drum

6.5.3. The Bicycle

We suggest re-using disposed or old bicycles that aren't in use for this, although since the metal frame and barrel are detachable it would work for any simple bicycle. The function of the bicycle is to replace the motor that are used in electric washing machines to turn the washing drum. In this scenario, when the bicycle is pedalled, it causes the washing drum to rotate. Therefore, with the aid of the agitation device fixed inside, it washes the clothes.

6.5.4. Re-purposed tire

In Cape York, many tires from various vehicles are just disposed into the environment in an ill-suited fashion as displayed in Figure 1 (page 4). These tires can be repurposed in this design instead of being thrown away.

The tire will be centred around the length of the barrel, will be parallel and in-contact with the tire of the bicycle wheel. Figure 6 shows how the two tires will align.

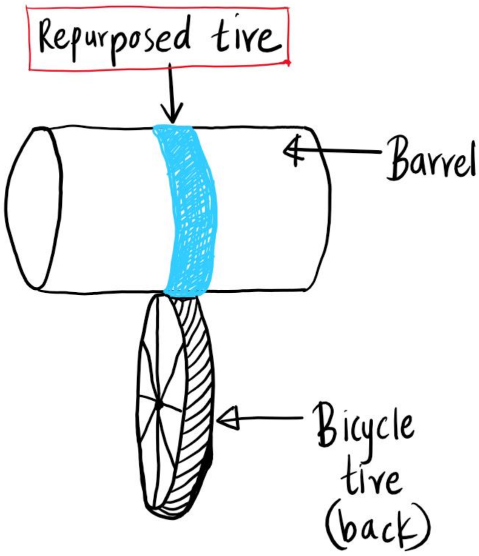


Figure 9. Drawing illustrating how the repurposed tire will be positioned with the bicycle and the barrel.

6.5.5. Stunt pegs

The function of this unit is to enable us to attach the frame on the bike. The stunt pegs (110mm) will be attached to the back wheel of the bike. The bike can now be latched on to the frame using these.

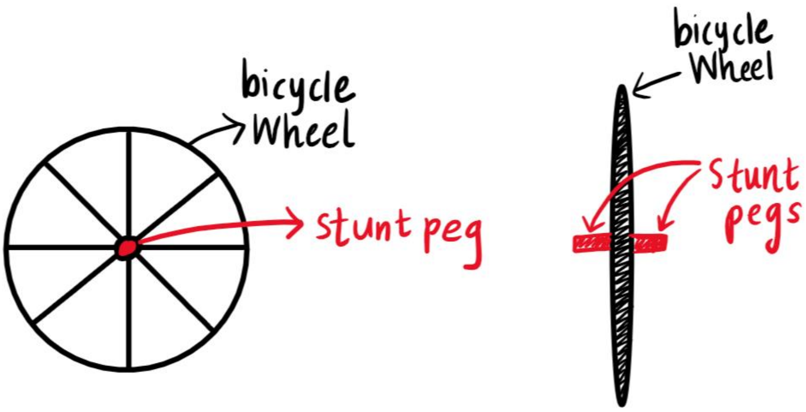


Figure 10. Sketch of how the stunt pegs will be attached to the bike

6.5.6. Wooden Plank

A short plank of wood is fitted to the inside of the barrel to act as an agitation device. This will allow the clothes to be washed more thoroughly as it agitates the water, clothes and soap (or detergent) inside. This wood can be obtained from bush timber, which is in plenty at Cape York. Figures 8 and 9 depict how the plank will be attached to the barrel.

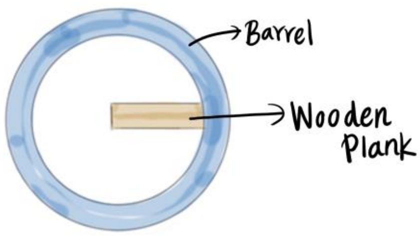


Figure 11. Cross-section of the barrel with the wooden plank attached.

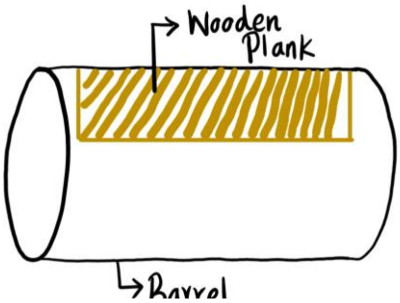


Figure 12. Cross-section across the length of the barrel depicting how the wooden plank is attached.

6.6. Prototyping

6.6.1. Prototype construction

A simple prototype was made of the frame, barrel and back wheel of the bike using the following materials to construct each part:

Cardboard was used to construct the back wheel of the bike, and side sections of the frame. To enforce the back wheel, three layers of cardboard were glued together to add more surface area for the barrel, allowing it to balance with ease, whereas the cardboard sections of the frame were only made with one layer.

Matchsticks, and an unfolded paperclip were used to create the rest of the frame. There are two parallel matchsticks which act as the base of the frame when the barrel is resting on the wheel, and the paperclip is used to connect the part of the frame attached to the barrel and the part of the frame attached to the bike together. The paperclip also acts as the two joints which allow part of the frame to rotate such that the barrel is able to switch positions.

Another matchstick was used to connect the wheel and the frame together, this matchstick also allows the wheel to spin so that the prototype can function as intended.

A film container was used to act as the barrel, it is connected to the frame by two thumbtacks so that the barrel can spin. The lid of the barrel can be opened, allowing objects such as small rocks to be placed inside to test how the weight of the barrel affects the prototype.

Finally, hot glue and a rubber band was placed around the wheel and the barrel respectively to act as the rubber of the wheel and the rubber around the barrel, allowing more tractions between the two when they are both spinning.

Figure 11. Image of the side of the prototype when the machine is spinning.

Figure 14. Image of the front of the prototype when the machine is spinning.

Figure 15. Image of the side of prototype when the barrel is resting on the frame.

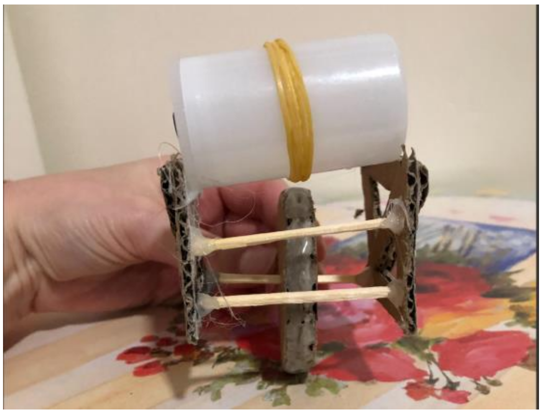


Figure 16. Image of the back of the prototype when the barrel is resting on the frame

6.6.2. Prototype Analysis

From this prototype, the following was discovered:

The wheel must have a wide enough width so that the barrel is able to balance comfortable while spinning, and so that it is able to carry heavy loads without damaging the bike. Thus, road bikes or lightweight bikes are not recommended for this machine.

The parts of the frame attached to the side of the barrel must be made of a strong material, and it must be centred, and securely attached to both the rest of the frame and the barrel, otherwise this may cause the machine to unbalance while spinning, which means it might topple and may cause injury to the user.

The heavier the barrel is, the more effort is required for the user to spin it. This also means that there is more friction between the barrel and the wheel, causing the rubber on both to heat up and wear down. Because of this, it is recommended that the user does not fill the barrel too much with water and clothing, and that the user does not pedal too quickly. This is to avoid damage to both the machine and injury to the user. Due to the friction, the bike may need the back wheel to be maintained more often than the front wheel as well.

6.7. Constraints of the design

6.7.1. Capacity

The volume of clothes washed by the device is comparatively lower than the volume that can be washed by a generic washing machine. This constraint facilitates easy lifting of the washing drum when filled and effortless balancing on the bicycle wheel.

6.7.2. Physical Strain

Due to sustainability purposes, this design does not use any electrical energy, therefore the washing chamber must be physically rotated. Although assisted by the bike and pedal, this often requires a considerate amount of physical strain.

6.7.3. Time Consuming

Commonplace washing machines does not demand the user's constant presence. This is however due to them using electrical energy to carry out the task. This design does in fact need the user's presence as it is manpowered.

7. Implementation Plan

The implementation of our design required us to look at every possible factor within the project that might affect the Cape York community socially, environmentally, and financially. The task then was to form a plan that manages every aspect that is involved in the implementation phase in sourcing materials, building of the design and the designs continual in functioning.

7.1. Project Management

7.1.1. Gantt Chart

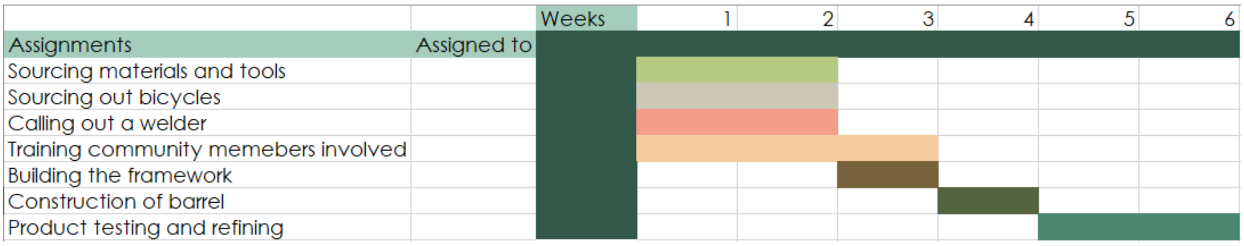


Figure 12. The Gantt Chart

The whole project can take up to and estimated time of 6 weeks to complete. Approximately the first two weeks are spent looking for material, tools and a welder for construction to start. During this time to the members of the Cape York community who are willing to participate in the project undergo training for the first 3 weeks on how to build the barrel and some aspects of the framework. They also learn how to use the machine, but it is quite user friendly. Once a welder is found they are to start building the frame, some members of the community can participate. The actual construction of each component should take a week. The actual machine should be built by week 5 of the project, which will be the start of testing the machine and making improvements, adjustments, basically any changes that will help the machines capability on helping the people of the community to wash clothes.

7.2. Risk Management

As a team we went through potential risks that are possible whilst understanding the client brief that was provided to us:

Table 7. Potential risks, measuring level of impact and solution methods

Potential Risk	Likelihood	Consequence	Risk Score	Mitigation
Project	3- Possible	1- Minor	3	• Disaster Plans • Recovery plans
Accidents and material damage (Safety)	4-likely	3- Moderate	12	• Preventive Maintenance to avoid interaction with parts • -Training and education on how to use the product safely
Weather (External)	5-Almost Certain	4- Major	20	• Preventive Maintenance • Quality Assurance inspection and testing • Recovery plan

7.2.1. Project Risks

Project risks are defined as risks that may be faced in circumstances of planning and the delivery of the project. These could be materials being hard to source and project dependencies. We have come up with disaster or recovery plans that we could quickly implement to fix the issues. In table 3, the risk score for project risks is given 3/25, making it close to harmless and solutions to fixing it quite simple.

Solutions to Project Risks:

- Sourcing material – majority of the materials are metal based, luckily for the simplicity of the design, wood such as bush timber (sourced locally) can be utilised to make the entire frame. Change in materials means change in tools you will require and an individual who is skilled in carpentry to build the design.
- Project dependencies – The design consist of factors or objects that it relies on. These include generic factors like money and specifics like a bicycle. Preferably an

unused bicycle and drum that is found in or near the community should be used, but in the situations where we do not have those resources, there is always an option in buying them from a wholesaler/retailer. Financially the green machine is a lot cheaper than your average washing machine. The designs simplicity is its reason for its financial viability. However even if budget becomes an issue like we said before there are backup plans that involve the design to be constructed with replacement and/or recyclable material.

7.2.2. Accidents and Material damage (Safety Risk)

Safety risks appear in forms of accidents, material damage and basically any possible situation that risks the safety of people or product. Whilst designing the green machine we brainstormed on safety hazards that may surface during the implementation phase, some of these were: injuries related to handling tools, injuries related to using the machine and ways to preserve good material. We analysed the its likelihood and impact giving it a score of 12/25. Safety risk can cause damage to the design implementation, but we have mitigation methods that provide a reduction on its likelihood.

Solutions to Safety Risks:

- Injuries obtained during construction – Tools that are being used to build the green machine can cause harm like the: TIG welder, which exposes the user to metal fumes, radiation and can cause damage to the eye, and handyman tools (hammer, drill, wrench) can cause damage to a person when not used properly. Our direct approach to these risks is acquiring a professional welder who has expertise in their field and training the people of Cape York community in using basic tools required to building the design and to undergo maintenance practices when required. During construction all members of community participating in constructing will be provided PPE equipment ensuring less risk, greater safety.
- Injuries obtained when using product – The product is very user friendly but training on using the product will be provided to anyone willing to participate. It is as simple as riding a bike. Only difference now is pedalling the bike does not move your position, it spins the elevated back wheel, spinning the drum. Possible risks when using the green machine are falling with the bike, burning yourself when pouring in hot water and fiddling with moving parts when the machine is running
- Material damage - We want to avoid any inefficiencies and to do that we are to ensure materials are used appropriately and precisely, with caution. To prevent materials being damaged we set clear instructions through the method on how to build the green machine and include engineering drawings to provide an insight on

what the finished product should look like. Basically, we are providing support to whoever might be constructing this machine with detail so that materials and money is not wasted due to misunderstandings and mistakes.

7.2.3. Weather (External Risk)

External risks are other factors outside the project such as competitors and weather, that can impact the designs successful implementation. The only external risk known to us regarding the green machine is the force of nature (mostly weather). At first, we took note that wet seasons might affect the use of bikes since we were planning to keep them transportable, now however the frame being detachable makes it safe from travelling anywhere in the wet seasons. The projected risk score given to 20/25 has lowered drastically to 5/25 due to its lack of consequence to the design and its capabilities

8. Deliverables

8.1. Cost effective alternative

In correspondence to the dimensions of the design, the material used for it and welding costs we calculated a rough estimate for our preferred design option. Additionally, we also roughly calculated the average price for a washing machine in Cape York using rates from Bi-Rite, Cape York, Australia as it is a whitegoods shop in the Cape. As shown in Table 1, the average weekly household income of the Cape's residents is $987, and the median monthly mortgage payment is $2100. Roughly calculating, the amount of left per household per month is around $1848 (without reducing the amounts spent on food, electricity, and water). The price of an average washing machine in the Cape is around $700, calculated using the pricing for washing machines in Bi-Rite (Bi-Rite Home Appliances 2019); only washing machines ranging between $800 and $449 were considered, Table 9. The estimated cost for this design on the other hand is $298.83, which is only 42.69% of the price of a washing machine in the Cape as can be seen in Table 10. Therefore, we believe that this design and product can make a real difference in the lives of these people and waste management in these remote bush locations.

8.2. Materials and Tools required

The design does not require a great variety of tools. Materials should be moderately accessible, and tools are available at any hardware store e.g. nearest Bunnings Warehouse. The green machine requires a very small budget of precisely $298.83 as calculated in Table 7. Saying that however, some materials can be replaced with recyclable or used material rudecing both the projects carbon footprint and costs involved for construction. If the conservative path is chosen then additional tools and materials will be required.

Materials List:

- Barrel (new or re-used)
- Metal or Wood (conservative path)
- Bicycle (new or re-used)
- Repurposed tire
- Stunt pegs
- Wooden plank (sourced from bush timber)
- Nuts and bolts (Long and short)
- Washer head screws
- Tek
- Eye bolts

- Compression Washers
- Rubber Washers
- Screws (conservative path)

Tools List:

- Drill bit
- Welding tools (provided and handled by welder)
- Wrench
- Screw driver
- Tape measure
- Hammer (conservative path)
- Handsaw (conservative path)
- Jigsaw

8.3. Instructions on building The Green Machine

Important: A welder is required for steps 2-9 and anyone participating in building the design must have taken training for the use of simple handyman tools. Refer to diagram on page 20 for a picture model representation.

Framework:

1. Firstly, ensure you and everyone involved is wearing forms of PPE equipment required.
2. Using the Jigsaw cut all length of metal according to Table 3. Make sure to cut two of each length.
3. Referring to the diagram of framework on page 20, attach length “y1” on the end and perpendicular to length “y3”. Attach length “x” to the end of length “y3” and length “y1” forming a right-angled triangle. Repeat this twice for two sides of the frame.
4. Attach length “y2” to the triangle at which “y3” is attached with length “x”. Now attach the end of length “y4” along top of the triangle where length “y1” is attached to length “x”, to length “y2” forming a trapezium like shape. Repeat this twice
5. To attach both sides of frame, weld both length of “Wb” to the bottom of each side of the trapezium as shown in the referral diagram.
6. Now weld both lengths of “Ws” like you did on step 5, to the back of the frame.
7. Weld length “d” of metal to length “y5” forming an "L” like shape. Repeat this twice for each side of the framework.

8. At both corners where “y2” and “y4” connect, use a jigsaw to cut the corner horizontally resulting in a flat surface.
9. Drill in a hole through that flat surface and weld a nut on top surrounding the hole, on both sides.
10. Drill a slightly larger hole onto each “L” bar which will fit onto the flat surface of “y2” and “y4.”
11. Line up both “L” bars on the flat surfaces with their holes and screw bolts in it. Use nuts to tighten the bolts.
12. At the end of each length “y4” that connects to length “y1” use a jigsaw to cut out a courter of a circle shape. Weld the middle of the stunt peg perpendicular into the cut-out shape.
13. Now unscrew the bolt from the centre of the rear wheel of the bicycle. Bolt in the stunt pegs by lifting the rear wheel of the bicycle.

Barrel:

1. Using the repurpose tire, super glue it around the middle of the barrel. Cut pieces of tire if necessary, to fit the circumference of the barrel.
2. Drill into the top part of metal length “y5” to on both sides and screw in an eye bolt. Refer to first diagram on page 24
3. Firstly, place the wooden agitator block into the barrel. Mark on the backside of the barrel where the wooden agitator block would be. Using a drill bit make two holes, both through the barrel and into the wooden agitator block.
4. Now for each hole you will be putting a washer head screw. While doing this you will have to also put in rubber and compression washers on the outside surface of the barrel and a rubber washer in between the agitator and the inside of the barrel to prevent leakages. Do this for both holes. The agitator is fitted according to the length of the barrel meaning it will apply pressure, not requiring a nut or compression washer in the inside.
5. Cut out four wooden squares of about 15mm thick, and any width and length so the backside of the barrel is set amid two blocks and the lid is also set amid two blocks.
6. Now from pieces left of your repurpose tire cut out strips or squares to cover the hole from the inside of the barrel.
7. Place a wooden block on the outside of the barrel and the rubber tire strips where each hole will go inside the barrel and put a wooden block over it, so the rubber tire is amid the inside of the barrel and the wooden block. Drill through the barrel making 5

holes on each side like you see in a dice. Repeat this for the remaining two blocks, more rubber tire strip and with the lid of the barrel. Make sure you drill all the way through both square wooden blocks.

8. From the inside of the barrel screw in 4 bolts (excluding the middle hole), through the wooden block, rubber tire, barrel and out of the wooden block on the outside. Screw in a nut for each bolt to secure it in place. Repeat this for the lid.

9. For the middle hole screw a nut close to the top of a longer bolt. Then screw the longer bolt through the eye bolt into the barrel from the outside through the inside where you will secure it with a nut. Make sure you did not forget the rubber tire strip on each hole inside the barrel in step 7. Tighten the nut on the top of the bolt onto the outside wooden block. Repeat this for the lid of the barrel. Once that's done the project is completed.

8.4. Instructions on using The Green Machine

1. Attach the frame to a bike by bolting in the stunt begs to the centre of the rear wheel.
2. Spin open the lid, then unbolt the "L" bar shape that is connected to the lid of the barrel, from the flat surface of "y4" and "y1".
3. Input the dirty clothes with hot water and washing detergent. Whilst the drum is rests sideways on the rear tire.
4. Bolt back the "L" bar shape onto the flat surface of "y4" and "y1" with the nut and spin the lid shut on the barrel.
5. Ensure none of the bolts and nuts are loose.
6. Get on the bike and pedate at a steady to fast pace.
7. Pedal for 10 – 15 minutes, spin open the lid and this time unbolt "L" bar shape of the barrel side.
8. Pour out all the water and fit the "L" bar shape back into place
9. Spin shut the barrel and pedal to let the clothes spin (draining the water) for about 5 minutes
10. Repeat step 2, take out clothes and squeeze out the excess water, getting it ready to hang.
11. Once finished bolt "L" bar shape back into the flat surface and spin the slid shut.
12. (Optional) Unbolt the stunt pegs from the centre of the rear wheel of bicycle. Allowing the frame to be removed and ready to attach onto another bicycle.

8.5. Maintenance

The only forms of maintenance required with the green machine is the cleaning of inside the drum every week. Greasing of the eye bolt and the bolt that spins within it is not necessary however it can possibly decrease friction when pedalling improving efficiency. Spraying or painting the frame for rust protection is not necessary since its stainless-steel however, stunt pegs might require rust protection. Pegs can also be created by cutting it out from stainless steel rods, providing rust protection to stunt pegs as well.

9. Conclusions and Recommendations

9.1. Recommendations

The design is bound to produce a significant amount of greywater, therefore the use of "plant-friendly" detergent is recommended. This way the grey water produced can be repurposed for plants or crops as greywater can boost plant growth due to its vast amount of nutrients. It is suggested that washing detergent with the following ingredients are avoided (This Old House 2020) (Allen 2017)

- **Salt and sodium compounds** - Building up of salts in the soil can hinder the capability of plants to absorb water and nutrients.
- **Boron** - This is a micro-toxin that may damage the plants even in miniscule quantities although it is not harmful for humans.
- **Bleach** - Contains chlorine that kills microorganisms including the ones that are in fact useful for the plants.
- **Alkaline solutions** - This is non-compulsory as it only affects the soil pH which can be maintained externally.

Another recommendation would be a small group of stakeholders sharing a single frame, barrel and/or bicycle. This will reduce the quantity of production and will also be beneficial to the environment as it reduces the waste.

It would also be a great opportunity to create jobs in remote areas for the stakeholders by opening a rental service for this design. As a result, it will create a local source of income as well as assistance in using the device for the handicapped. This will also ensure proper maintenance and repairing, hence increasing the lifespan of this appliance.

Furthermore, it is recommended that the steel and other parts required are purchased through a wholesale retailer so as to reduce the production costs. It can also be advised that extra nuts and bolts are included in the product package to ensure a quality service and facilitate quick repairments of the device.

An additional suggestion would be to create a product manual or instruction booklet that will be a part of the merchandise. This will promote good upkeep of the device and enable any person with or without technical expertise to repair this simple instrument.

9.2. Conclusion

Our team went through a comprehensive study to come up with several design options that may suit the conditions of remote bush locations. We then determined the ideal solution that meets the required design criteria. In studying the conditions faced by the residents of Cape

York, the weather at this location, the main infrastructure of a washing machine and researching on currently available designs in the market, we have devised a solution that caters the needs of the communities in remote bush locations. For sustainability purposes and reducing the aggregation of waste, this solution is constructed to conduce reusing and recycling of waste material in remote bush areas. Moreover, this product can boost healthy relationships between the stakeholders as a result of having a communal space in which this device has been installed as said in the recommendations section. This provides a positive social impact for the communities of these locations. However there are also some constraints associated with the design. These include a smaller load than generic washing machines, requirement of physical activity and the restriction of having to remain put during the washing of clothes.

Through many stages of design development, we have come to the ensuing conclusions. This design is a simple, sustainable alternative to the washing machine, which is although essential also creates a large amount of waste in the Cape. Since the design requires no technical skills to repair and maintain, it aids the difficulty of mending and upkeeping generic whitegoods in remote bush locations. It also assists with the collection of waste in these locations, reducing the need to dispose waste in the bush or of transporting waste to a city to be disposed of. The design can help with the accumulation of waste through Cape York, largely through encouraging recycling or reusing material. It can be concluded that the design satisfies the needs of ‘Design Area 6: Waste and Reuse (6.2 CATFab alternatives to electric goods)’ (Engineering Without Borders, n.d.). This report was written with the intention of improving the lives of our stakeholders through addressing Cape York’s issues of waste and reuse.

10. References

AdMerch n.d. 60, *Litre Blue Barrel | DR5060,* viewed 31 May 2020, <https://admerch.com.au/product/dr5060-blue-60-litre-barrel/>.

Allen, L 2017, *Greywater, Green Landscape*, Storey Publishing.

Amotor 2019 *Amotor Bike Pegs Aluminum Alloy Anti-Skid Lead Foot Bicycle Pegs BMX Pegs for Mountain Bike Cycling Rear Stunt Pegs Fit 3/8 inch Axles,* viewed 2 June 2020, <https://www.amazon.com.au/Amotor-Aluminum-Anti-Skid-Bicycle-Mountain/dp/B07YDFP2QB>.

Australian Bureau of Meteorology 2020, *Climate statistics for Australian Locations*, viewed 30 May 2020, <http://www.bom.gov.au/climate/averages/tables/cw_027004.shtml>.

Australian Bureau of Statistics 2017, *2016 Census QuickStats,* viewed 30 May 2020, <https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/IREG303?opendocument>.

Bi-Rite Home Appliances 2019, Laundry, viewed 03 June 2020, <https://www.birite.com.au/product-category/laundry/>.

Bunnings Warehouse n.d., *Metal Mate 30 x 30 x 1.6mm 1m Galvanised Steel Square Tube*, viewed 03 June 2020, <https://www.bunnings.com.au/metal-mate-30-x-30-x-1-6mm-1m-galvanised-steel-square-tube_p1130465>.

Engineering Without Borders n.d., *Design Area 6: Waste and Re-use*, viewed 31 May 2020, <https://ewbchallenge.org/design-area-6-waste-and-reuse>.

Service Seeking 2019, *Cost of Welding Services*, viewed 03 June 2020, <https://www.serviceseeking.com.au/blog/cost-of-welding/>.

SpinCycle n.d., *Story*, viewed 03 June 2020, <https://spincycleproject.wordpress.com/about/>.

This Old House 2020, *Plant-Friendly Soaps That Are Safe for Greywater Irrigation*, viewed 05 June 2020, <https://www.thisoldhouse.com/gardening/21015581/plant-friendly-soaps-that-are-safe-for-greywater-irrigation>.

WeCycle n.d., WeCycle, viewed 03 June 2020

<Available at: http://www.wecycle-melbourne.com/>.

Wikipedia n.d., Cape York Peninsula, viewed 31 May 2020

<https://en.wikipedia.org/wiki/Cape_York_Peninsula>.

11. Appendices

11.1. Appendix A: Calculations for the metal frame

Average radius of a bicycle in inches, $b = \frac{a}{2} = \frac{24{\cdot}5}{2} = 12.25$

Radius of barrel, $r = \frac{t}{2} = \frac{12.8268}{2} = 6.4134\ inches$

As mentioned above, the bicycle wheel will be elevated by 2 inches above the ground (calculation for y_2 shows this):

$$y_1 = b + 2 = 12.25 + 2 = 14.25\ inches$$

$$y_2 = y_2 + b = 14.25 + \ 12.25 = 26.5\ inches$$

This was added so as to give the bicycle wheel more freedom within the frame:

$$y_3 = b + 1 = 13.25\ inches$$

Pythagoras theorem was used to calculate the lengths of the bars that go across.

$$y_4 = \sqrt{(y_1 - y_2)^2 + y_3^2} = \ \sqrt{(26.5 - 14.25)^2 + 13.25^2} = 18.045082\ \text{inches}$$

$$x = \sqrt{y_3^2 + y_1^2} = \sqrt{13.25^2 + 14.25^2} = \ 18.79162\ inches$$

y_5 was calculated this way to ensure that the centre of the barrel is in line with the centre of the bicycle wheel:

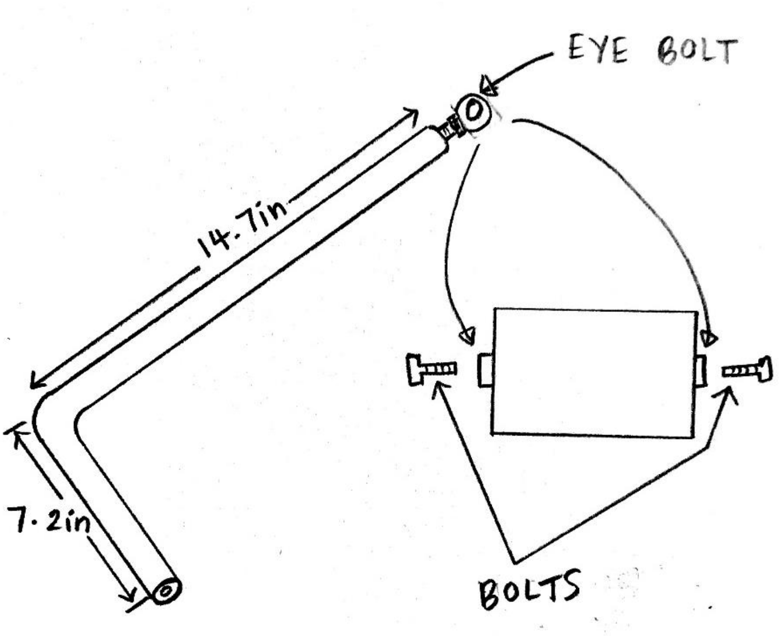
$$y_5 = \sqrt{r^2 + y_3^2} = \sqrt{6.4134^2 + 13.25^2} = 14.720537\ inches$$

$$W_s = W_b$$

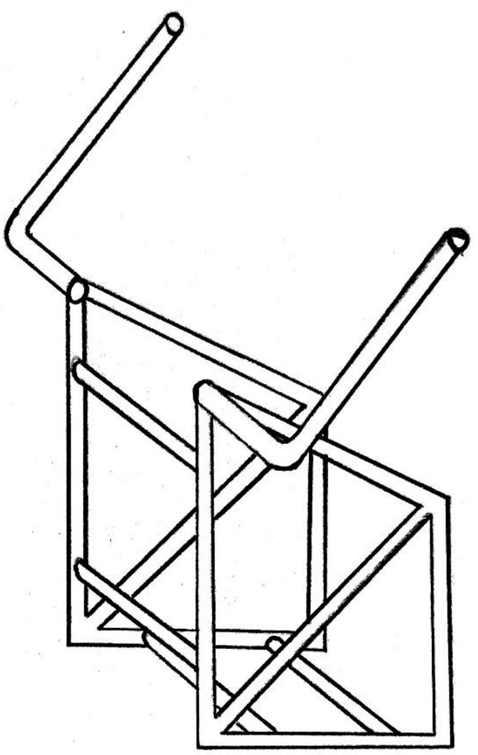
Ws is calculated as shown below:

$$W_s = (2 \times p) + c = (2 \times 4) + 1.85 = 9.85\ inches$$

11.2. Appendix B: Engineering drawings



Engineering Drawing 2. Explaining the drum handles and how they are attached to the washing drum



Engineering Drawing 1. Basic structure of the metal frame.

11.3. Appendix C: Conceptual cost analysis

Material that support the details provided in the Cost effective alternative section in Deliverables. This also includes tables for the conceptual cost analysis done for this project.

Table 8. The lengths of the components of The Green Machine

Component	Length of Component	Amount	Total number of same component
y1/in	26.5	2	53
y2/in	14.3	2	28.6
y3/in	13.3	2	26.6
y4/in	18.0	2	38.0
y5/in	14.7	2	29.4
x/in	18.8	2	37.6
W_s/in	9.9	2	19.8
W_b/in	9.9	2	19.8
d/in	7.2	2	14.4
Total length/in	267.2		
Total length/m	6.8		

Table 9. Estimating the price of an average washing machine in Cape York

Washing machine type from Bi-rate, Cape York	Highest price	Lowest price
Front load washing machines	$ 800.00	$ 449.00
Top load washing machines	$ 800.00	$ 449.00
Price of an average washing machine	$ 624.50	

Table 10. Estimating the price of The Green Machine

Price for galvanised steel per m/ AUD	$ 10.10
Total price for the frame (metal)/ AUD	$ 68.68
Price of stunt pegs	$ 17.65
Price for nuts and bolts	$ 10.00
60 litre plastic washing drum cost (AUD) - NEW	$ 90.00
Re-used bike (WeCycle Melbourne)/ AUD	$ 50.00
Welding costs for an hour/ AUD	$ 62.50
Total cost for The Green Machine/ AUD	$ 298.83
Average price for a normal washing machine	$ 700.00
The Green Machine as a % of the price of an average washing machine In cape York	42.69

These specific sources were used in order to set an upper limit for the price of this product. List of sources used for this conceptual cost analysis:

1) Bunnings Warehouse, Australia for galvanised steel (Bunnings Warehouse n.d.)
2) AdMerch, Australia for washing drum (AdMerch n.d.)
3) WeCycle, Australia for re-used bike (WeCycle n.d.)
4) Service Seeking, Australia for welding costs (Service Seeking 2019)
5) Bi-Rite Home Appliances, Cape York, Australia for the prices of washing machines (Bi-Rite Home Appliances 2019)
6) Amazon seller for stunt pegs (Amotor 2019)

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12. Team Reflection

As a team, we believe that participating in the Engineers Without Borders (EWB) challenge has provided us with a strong platform to build our lifelong teamwork skills, engineering skills, and knowledge, and we have gained invaluable experience which we will all use in the future as we continue our studies at the RMIT school of engineering. From a team perspective, we believe that at the beginning of the semester, our team performance was uncertain as we did face some challenges regarding our design and the loss of a team member. Despite this, as the semester progressed we became more consistent and confident with our teamwork. We all discovered the strengths of each team member, and we used these strengths to our advantage to maximise the skillset of the team as a collective for the remainder of the challenge.

We believe that one challenge we faced over the semester was that group meetings were not always attended by all members due to other commitments. Despite this, we all worked to the best of our abilities and put in a lot of hard work and effort into completing this challenge. We all communicated effectively and collaboratively to answer and explore any questions, queries, and concerns other team members had.

To improve our dynamic as a team, we should implement a schedule in which we have frequent team meetings and spread out the completion of the report over the semester so that we can balance this with our other commitments, and have the proper time to develop and analyse our work.