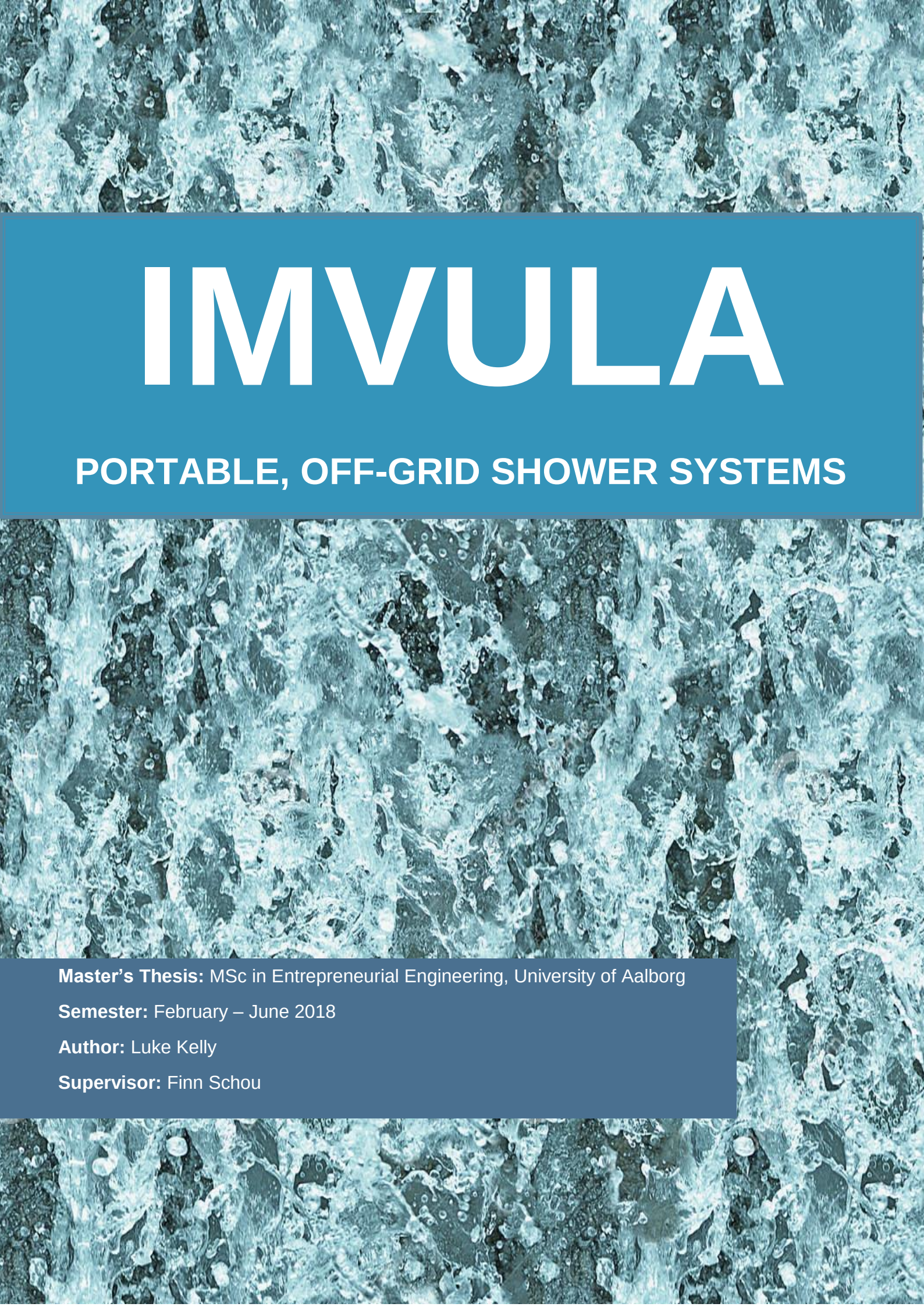

IMVULA

PORTABLE, OFF-GRID SHOWER SYSTEMS

Master's Thesis: MSc in Entrepreneurial Engineering, University of Aalborg

Semester: February – June 2018

Author: Luke Kelly

Supervisor: Finn Schou

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STUDENT REPORT

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Synopsis:

As a Masters dissertation, this paper outlines the work, thinking and processes undertaken to develop a portable off grid shower and associated business as a solution to the water scarcity experienced in Cape Town, South Africa.

Using design thinking, rapid prototyping methods and user testing, the Imvula Micro Shower was designed as a low-cost solution to those without access to a pressurized water supply.

The business model was found to be feasible with relatively low prototyping and production costs and high profitability at scale.

Moving forward, this project will require building a team and thoroughly engaging with customers during product development to ensure success.

Title: *Imvula – Portable, off-grid shower systems*

Semester: 12th Semester

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By signing this document, each member of the group confirms participation on equal terms in the process of writing the project. Thus, each member of the group is responsible for the all contents in the project.

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READING GUIDE

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Figures and tables are identified with the caption of “FIGURE” or “TABLE” followed by a number and a description of the contents. Information used to inform this project came from countless sources through formal and informal means, and not all information used as assumptions in this project should be considered as empirical fact.

ACKNOWLEDGEMENTS

Thanks to my family for their support and encouragement. Thank you Formlabs for allowing me to use your printers freely. Thanks to all the kind people working at SEAD who provided their insights on the concept during interviews. Thank you, Finn, for your input and guidance. Thank you Carina for putting up with everything and being so supportive.

PROBLEM STATEMENT

“Can a product and business be developed to provide people with off-grid water pressure? “

PERSONAL LEARNING OBJECTIVES:

In addition to the learning objectives outlined by AAU, personal learning objectives were set

- Develop a deeper understanding and attain further experience of 3D printing
- Develop further experience and skills associated to 3D modelling and rendering.
- Develop the skills to create functional prototypes for product concepts.
- Develop a further understanding of manufacturing techniques and processes.
- Develop a real working solution to a problem.
- Create a clear pathway to further business development based on this work.
- Have a working proof-of concept for the exam.
- Create a pitch deck for the Exam and general send-out.
- Treat this as a real business rather than a university project and fully commit.

LIMITATIONS AND RISKS

Designing for a crisis - Off Grid vs On Grid Systems

The Cape Town water crisis is a highly unlikely event. The Day Zero is an even more unlikely scenario and is increasingly being pushed back, initially estimated to be on 11th April 2018 and now postponed into 2019. With winter rains and supplementary water supply infrastructure under fast track construction, there remains a fair chance that Cape Town will never actually face Day Zero. In this case, an off-grid solution may not have any relevance.

Developing a system too late

Unfortunately, looking into this problem from my side only began on the 26th January 2018. The people of Cape Town have been in somewhat of a panic mode and are already investing in solutions on the quickly growing market of “water profiteers”. There is a high risk that any new products will take too long and will arrive after the problem as a whole has been fixed or at least after everyone has invested in their own crisis avoidance systems.

Doing this alone

A decision was made from the start to try and do undertake this project independently. The lack of a team would force more learning but likely stifle progress and make things more difficult for myself.

INTRODUCTION

This thesis details the thinking behind developing Imvula, a portable off-grid shower, as a Masters Dissertation project for an MSc in Entrepreneurial Engineering at the University of Aalborg.

Imvula was born out of looking for solutions to Cape Town, South Africa's unprecedented water shortage. In January 2018, Cape Towns four million citizens faced the looming "Day Zero"" date, wherein all household water supplies would be cut off and people would be required to collect their allocated 25l of potable water from one of the 2000 water dispensaries established throughout the city.

Realizing that people are used to easy access to free-flowing pressurized water from a tap, the question arose as to how people would cope with such a situation, and whether new coping mechanisms could be developed to alleviate the potential pains which would come about due to not having access to a water supply.

A concept was developed for an off-grid human powered water pressure device which uses a foot pump and a modified water bottle closure to pressurize and spray water, giving users access to a continuous, hands free water supply when they lose access to one.

After researching the situation and the measures set to be implemented in Cape Town, competition and similar products were investigated to assess whether there is adequate space for a new product.

Finding that a better solution to what is available could be developed, the components of the shower system were then designed using materials and supplies readily available online or in hardware stores, and 3D printing.

After two months of Ideation and Prototyping, "Day-Zero" was postponed to 2019, resulting in the initial customer base for this idea fading away. Attention was then placed onto the millions of people who never had a household water connection, asking the question of whether they could sufficiently benefit from this solution to make their lives easier.

A visit was then made to Cape Town, to live in the context of such water restrictions, to uncover some of the subtler coping mechanisms people employ, to investigate costs, methods and feasibility of operating a business to manufacture these devices in Cape Town, and speaking to potential users.

After conducting interviews and a focus group in Cape Town, it was found that Imvula was not suited to low income houses, due to the tried and tested "bucket system" being considered better fit for purpose.

This resulted in pivots in the product concept to add value to such users, but after experimenting with new bucket systems and filtration, it was found that it would be difficult to serve these users, especially when starting the business.

Having continued prototyping, and tested numerous iterations, the business models and opportunities were assessed, considering costs and production scales, finding that selling to businesses will be the best market entry strategy, followed by direct to customer and finally, once the business has matured and developed a proven track record, to cater to the humanitarian and disaster relief market.

Imvula now stands as a business concept with an accumulation of easily implementable and innovative solutions aimed at providing an off-grid human powered pressurized water stream to increase the utility value a water supply. Many ideas have proven resilient, many have failed, many have transitioned and pivoted to other concepts and many remain completely unexplored. However, what remains clear is that development of this concept is worth pursuing, due to the low cost of product development and the innovative solutions it has to offer to a world increasingly concerned with water scarcity.

FIGURE 1 - THE IMVULA MICRO SHOWER

BUSINESS OVERVIEW

Pain
Water scarcity and access to pressurized water supply

Cure
A compact and portable device which transforms a water bottle into an off-grid human powered portable shower, allowing you to function as if you had a pressurized water supply when you don't, and save water when you do.

Profit
€2 million + per 50,000 units

Business Model
We develop and manufacture the products, making small modifications to existing low cost products, assembling and shipping to customers anywhere. B2B sales offering followed by B2C launch and ultimately to serve humanitarian market.

Market Size
1 Billion + users who do not have access to pressurized water and Growing due to effects of global water crisis.

Customer Segments
B2B – Schools and Universities, Offices, Restaurants, Hotels, Guest Houses, Eco Lodges, Public buildings, Museums, Shopping Malls, Events, Hospitals, Public Facilities

B2C – Middle Income Households, Outdoor Enthusiasts, Campers

Key Product Features

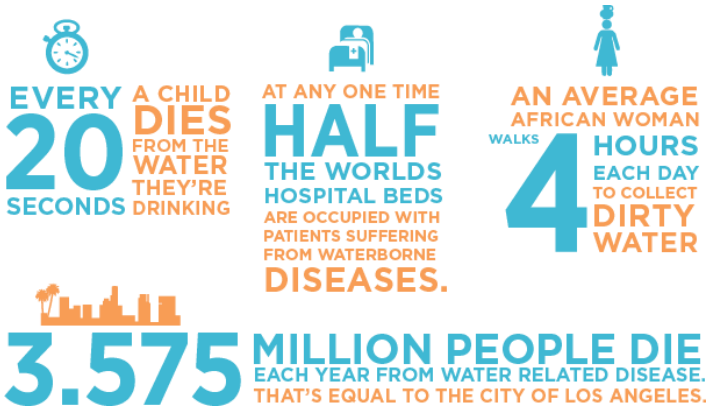
- Smallest, Cheapest, Most Portable and lightest weight pressurized shower on the market
- Requires no electricity or batteries
- Highly efficient water use
- Allows you to recycle used water bottles
- Hands-Free Showering
- Indoor/Outdoor Use
- Powerful Waterjet Action

FIGURE 2 - IMVULA FITS MOST WATER BOTTLES

THE PROBLEM – THE PAIN

Global Water Scarcity

According to the UNHDP, Water scarcity affects more than 40 percent of people around the world, an alarming figure that is projected to increase with the rise of global temperatures because of climate change. Dwindling supplies of safe drinking water is a major problem impacting every continent. 844 million people, (1 in 9, lack access to water (Water.org, 2018) and “By 2050, it is projected that at least one in four people will be affected by recurring water shortages.” (Elrha.org, 2017) (WHO, 2017) (Imperative, 2017)



To fight the Global Water Scarcity crises, the United Nations aims to coordinate international efforts to eradicating water scarcity by establishing *Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all.* This puts water scarcity on the world stage, high on the agenda of governments and international organizations.

FIGURE 3 - SOME STANDOUT NUMBERS ASSOCIATED TO WATER SHORTAGE (WATER.ORG, 2018)

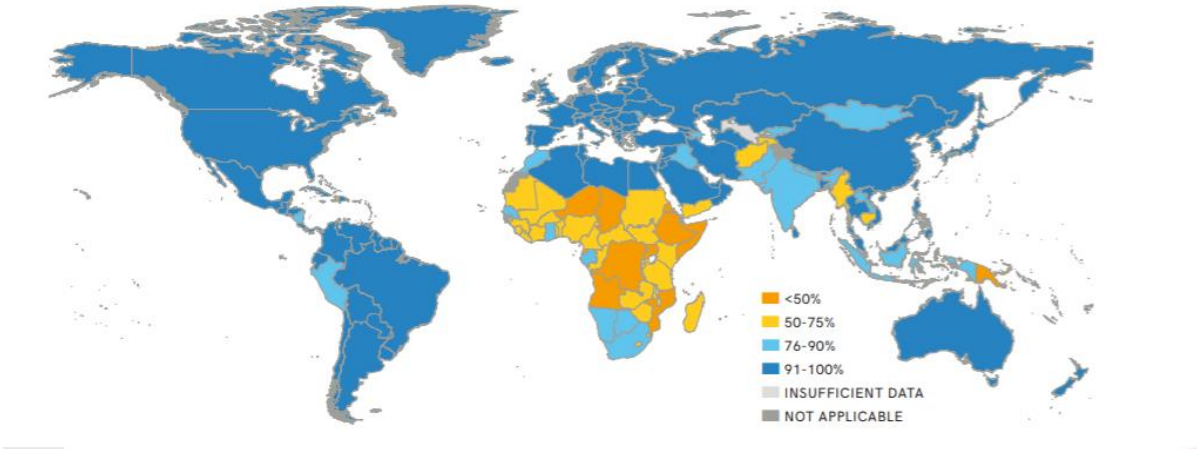


FIGURE 4 - PERCENTAGE OF POPULATION WITH ACCESS TO CLEAN DRINKING WATER. (WHO, 2017)

Considering population growth, rapid urbanization and climate change, the situation is only projected to worsen unless serious initiatives are undertaken on a global scale to develop solutions to the problems occurred due to water shortage. To this end, whilst some solutions are better than others, any efforts into developing solutions are actively encouraged throughout the world.

Billions of dollars are allocated to alleviating the problem every year. The problem is huge, incredibly complex and has its own sub-context of sub-problems for every community. It therefore does not serve well to aim to completely alleviate the crises with one solution, but rather, to continue to attempt to develop new solutions which contribute to alleviating this world-wide pain.

Cape Town Water Shortage – Urban Global Water Scarcity

In the beggining of 2018, Cape Town, South Africa was facing one of the worst droughts it ever experienced. The city of 4 million people imposed increasing water restrictions on its citizens over the previous two years in an effort to reduce water consumption with methods including public awareness campaigns, increased water tariffs and installation of flow control water meters on high consumption users. Whilst the citizens reduced the cities overall consumption as a result of these initiatives, the situation remains a major threat to the future of Cape Town and restrictions are currently at 50l per person per day with the looming threat of “Day Zero”.

Day Zero

“Day Zero” is the scenario in which the City of Cape Town will cut off all residential water supply due to the depletion of the water supply. People will then have to collect water everyday from one of the 2000 water collection points allocated across the city, where they will cue to be given their allocated 25l of water per day. Day Zero was initailly planned for April 4 2018. However, this date has now been postponed into 2019.

This situation generated a degree of hysteria, with citizens stocking up on water supplies, and investing in a wide range of products to conserve, store, treat, use and reuse water (Ramphele, 2018). Besides the international media attention and daily local news articles, the most apparent indication of the community concern for crisis was the establishment of a Facebook page titled “Water Shedding Western Cape” which has grown to a community of more than 160,000 members. This group is actively engaged with people sharing their ideas, solutions they have found, fears they have, and attitudes towards the entire situation of water shortage and “Day-Zero. Another indication from this channel was how people were interested in products related to water shortage.

One of the most obvious points was that when the water cuts, people would not have a pressurized water supply. The citizens are very familiar with turning a tap to get water, but how do they cope when they suddenly only have a 25l bottle of water to shower, use the toilet, cook and clean and drink.

Under the assumption that people would wish to keep things as close to how they always were, and would require coping mechanisms to deal with not having a pressurized water supply, the idea for an off-grid shower came about, whereby the user screws a bottle of water into a lid, and pumps a foot pump to shower.

Important to note is that whilst Cape Town received much attention on this, there remain scores of cities in South Africa, and thousands throughout the world who face intermittent water supply, cut-offs are lack of access altogether.

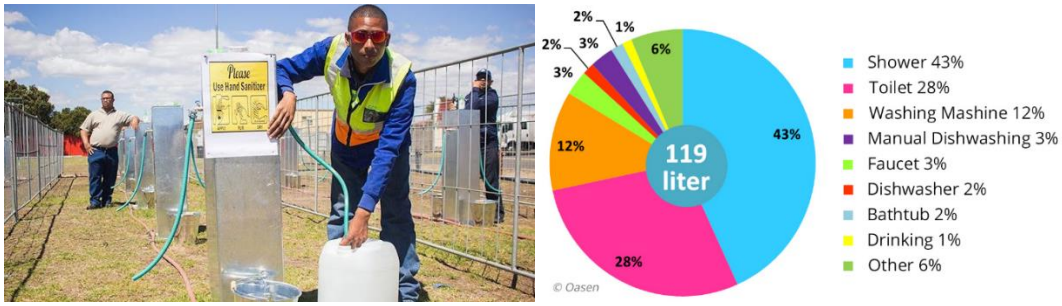


FIGURE 5 - EXAMPLE OF THE WATER COLLECTION POINTS PLANNED FOR DAY ZERO AND BREAKDOWN OF AVERAGE HOUSEHOLD WATER USAGE (WHO, 2017)

THE SOLUTION – THE PRODUCT – THE CURE

Imvula Micro Shower

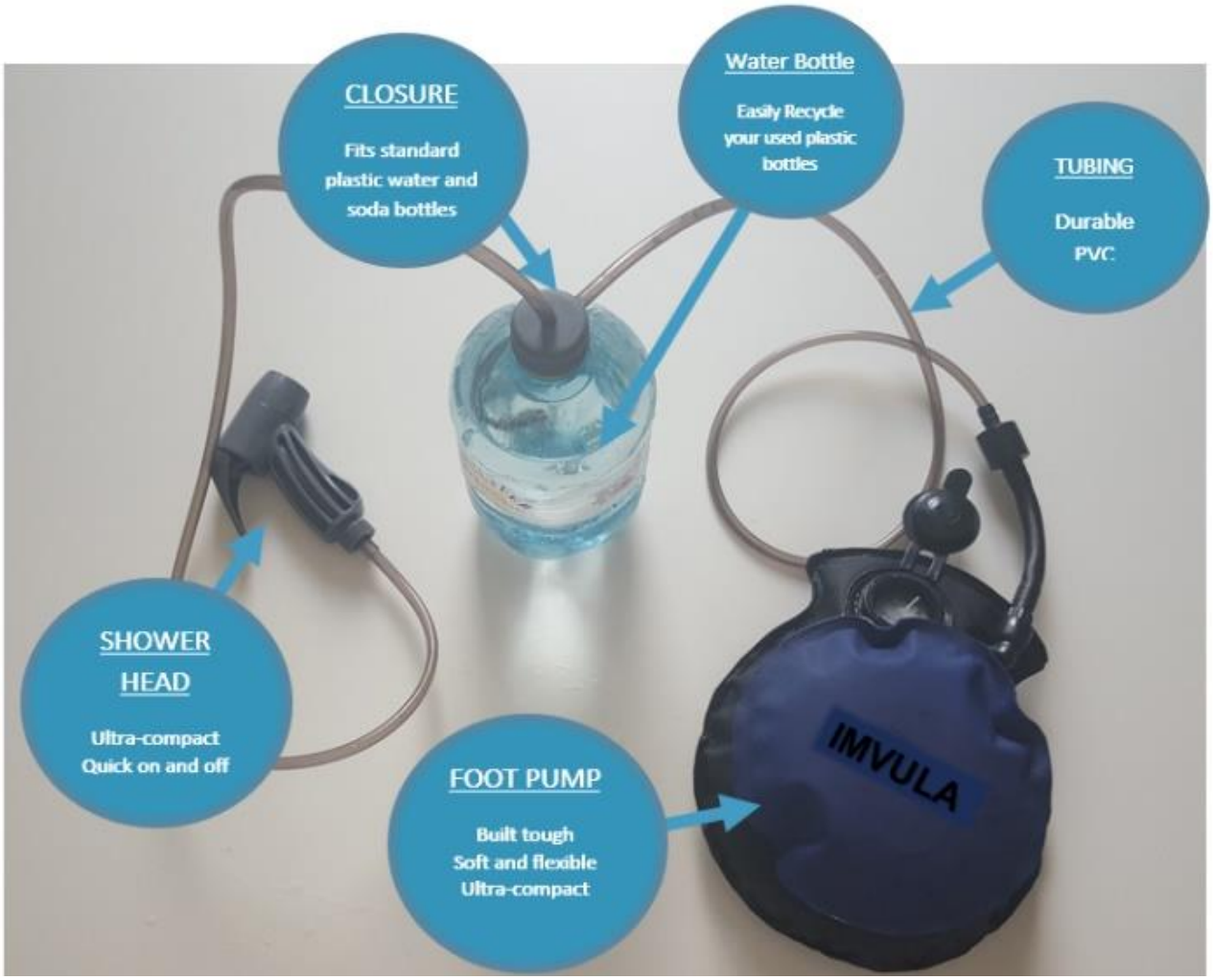


FIGURE 6 - COMPONENTS OF THE MICRO-SHOWER

Aimed at helping people use water more efficiently, and provide those without access to running water with a pressurized off-grid supply, the Imvula micro-shower is an off-grid, air powered shower and water efficiency device which provides users with a controlled and pressurized water stream, anywhere they need.

Imvula, is an isiXhosa word for "The Rain ", and provides just that.

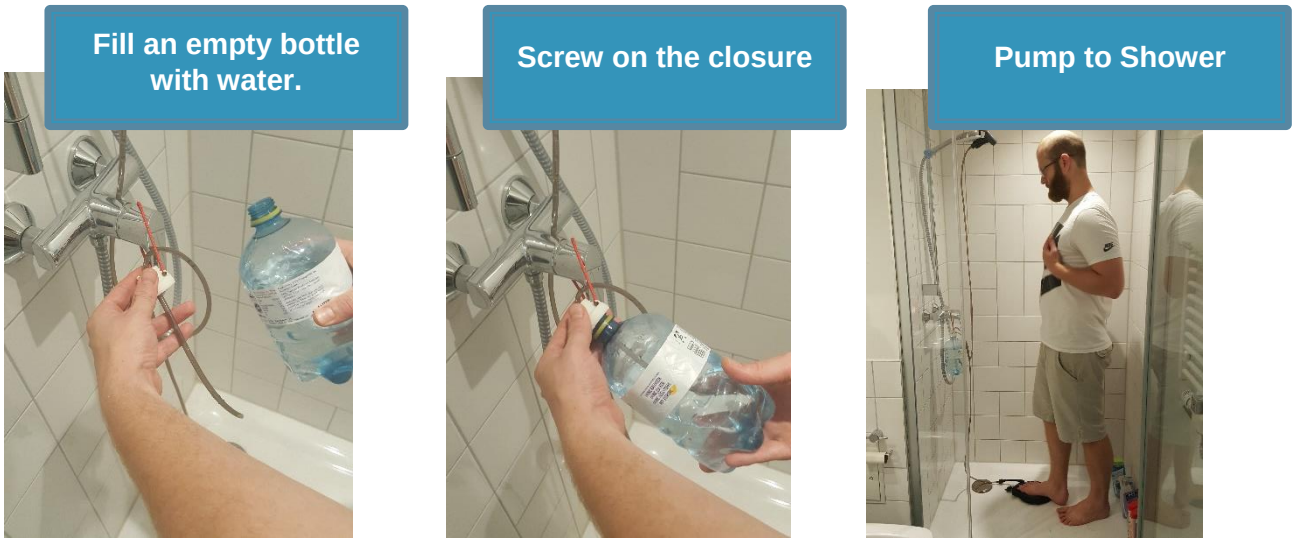


FIGURE 7 - USING THE SHOWER

The Imvula Micro transforms a water bottle into a portable shower, efficiently dispensing a spray with the same pressure as a regular shower, providing a 2 minutes of spray time with as little as 1 liter of water and can fit most bottles from 0.5-5l in size, making it easy to adjust to different uses and get up to 10 minutes of constant spray from a 5l container.

The underlying principle of Imvula, is to use a foot pump to pressurize a bottle of water, forcing the water up the tube, through the closure and out of a shower head for a controlled spray, almost instantly after stepping on the pump.

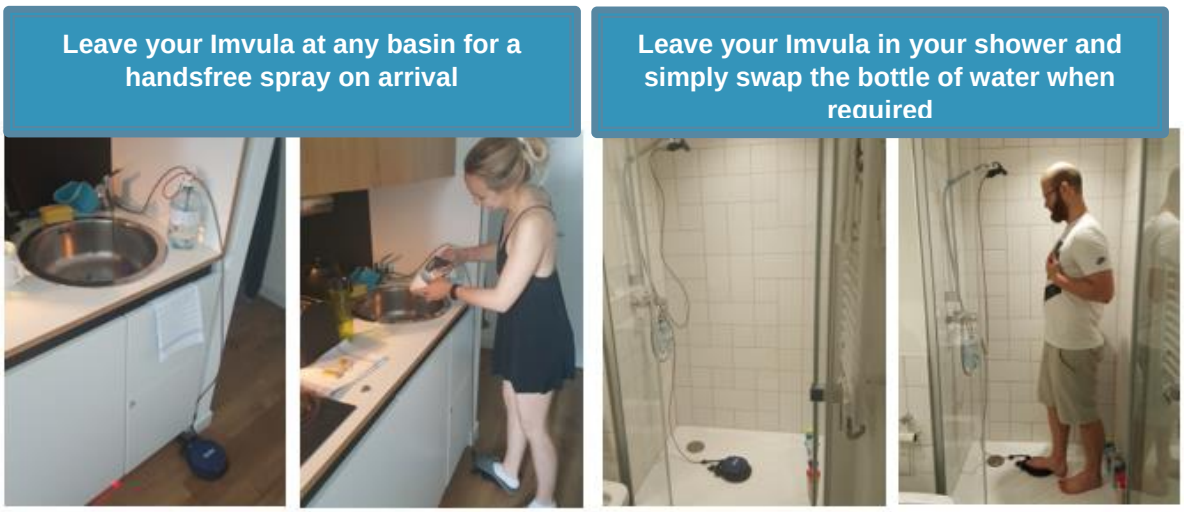


FIGURE 8 - HOUSEHOLD USES OF THE IMVULA SYSTEM

Leaving the small shower head and closures at water faucets, and the small pump on the ground in front of a basin, it is easy to wash hands, dishes or vegetables, and allows the user to get a hands-free water supply, without even turning the tap. Designed to be as small and hassle free as possible, there is no complicated plumbing or installation required to have pressurized water, and the device can be left at a sink or basin without getting in the way of everything else.

With rising water bills, the shower could also be used for anyone looking to cut their water bill. A family of 4 recovers the cost of Imvula in less than a month, making it a great tool for anyone looking to be more efficient with their water use or cut their water bills.

Imvula is an effective solution in dealing with a water crisis, as it is in line with reducing the demand on the limited water supply. B encouraging more efficient use of water it is lower in cost and has more immediate impact on reducing the rate of depletion of the water supply than building supplementary water supply systems.

The Imvula micro is not bound indoors however, and can be used by campers, hikers, outdoor enthusiasts and back-packers to provide a shower of water to clean yourself, your gear or your dishes. Being ultra-compact, the Imvula Micro may be the worlds' smallest shower, and can be easily tucked into your pack or cubby-hole for those times when you need to clean up or water is limited.

FIGURE 9 - OUTDOOR USES OF THE IMVULA SYSTEM

In designing the shower, many additional concepts have been developed including water recirculation and filtration, however, numerous uncertainties exist and these should be addressed after perfecting the Imvula Micro.

FIGURE 10 - THE SPLASH BOARD AND INLINE FILTRATION

The Splash-Board, a concept of using the passive shifting of weight in the shower to pressurize the water has also proven promising and major innovations in the form of entirely new shower experiences lie in the pipeline.

THE PROCESS OF DEVELOPING IMVULA

With an idea in mind, and attempting to taking inspiration from existing off-grid, portable and camping showers, potential competitions products were analyzed and tested to identify strengths and weaknesses, (see competitor comparison table in Appendix 2). Imvula is a combination of existing products (such as pre-manufactured foot pumps), which are modified, reassembled with new custom parts which we manufacture and repackaged as a new product.

With validation from my supervisor that this concept was worth exploring, prototyping came to constitute the majority of time and thinking allocated to this project. Whilst it was clear that it is an unrealistic expectation to hope to build a manufacturing ready prototype in the four months allocated to this project, the intention was to get things as close to this as possible. This resulted in a complete immersion in the project for the four-month process.

Although trying to build the product myself as opposed to getting the design work and manufacturing outsourced is not necessarily the best business decision considering my lack of experience, the fact that this was a learning activity stood paramount. The objective was to build up capabilities and knowledge by experiencing the process rather than just accepting what might be told to me by a manufacturer. This likely slowed progress considerably as time was spent learning what to learn, and making more mistakes than may have been necessary, but proved an enriching and enjoyable experience.

The following chapter outlines some of the thinking behind the product development process and highlights some of the most standout learning associated to this project specifically, and to prototyping in general. Due to time constraints, it would not be possible to document the entire process and learning gained through this project, so rather a brief overview of the planning and most important events are listed in chronological order, followed by an explanation of some of the thinking processes which shaped this project.

Project Plan

A rough plan was drawn up in the beginning phases of the project, however, when comparing this to where focus was directed, as can be seen in the table below, it is quite clear that things did not go according to plan. The cancellation of Day-Zero, failed attempts at developing concepts for rural and informal households kept the idea in discovery for most of the period of the project, looking for new solutions. Prototyping also required far more time than originally estimated. It’s worth noting that whilst Business Development was identified as a separate task, in many ways work in this area was regularly being done, as feasibility and cost informed many design decisions.

TABLE 1 - PLANNED AND ACTUAL PROJECT PLAN

Planned Project Development																		
Week Commencing	5-Feb	12-Feb	19-Feb	26-Feb	5-Mar	12-Mar	19-Mar	26-Mar	2-Apr	9-Apr	16-Apr	23-Apr	30-Apr	7-May	14-May	21-May	28-May	1-Jun
						Cape Town Visit												
Product/Business Discovery																		
Proto Development																		
User Testing																		
Content Development																		
Business Development																		
1st Draft of Thesis																		
Final Draft of Thesis																		
Hand-In																		
Actual Project Development																		
Week Commencing	5-Feb	12-Feb	19-Feb	26-Feb	5-Mar	12-Mar	19-Mar	26-Mar	2-Apr	9-Apr	16-Apr	23-Apr	30-Apr	7-May	14-May	21-May	28-May	1-Jun
						Cape Town Visit												
Product/Business Discovery																		
Proto Development																		
User Testing																		
Content Development																		
Business Development																		
1st Draft of Thesis																		
Final Draft of Thesis																		
Hand-In																		

The following events were considered to be most significant and outline what happened through the process of developing Imvula to where it is today:

1. **Time was put into conceptualizing a solution for Day-Zero**
2. **Imvula Shower concept and prototypes developed for middle income households**
3. **Day Zero was cancelled**
4. **Shifted focus of Imvula to rural and low-income houses**
5. **Interviews and Focus group with informants of low-income housing**
6. **Imvula found not to be needed in rural and informal settlements**
7. **Filtration explored to serve these users**

8. **Filtration tested and found not effective enough to be both a shower and a drinking water filter**
9. **Humanitarian market explored and found that quick solutions do not have lasting impact and are not preferred methods of alleviating crises. Also, participating in this market requires a proven track record, and is thus difficult to succeed in initially.**
10. **Attention was put back into serving middle income consumers whose households do not have access to pressurize water due to the prevalence of this problem and the likely chances that another Day-Zero may occur somewhere else.**

Decision Making – Discovery and Ideation

Decision making in the product was mainly guided by prototyping, and testing ideas and concepts to see what works and what doesn't from experience.

Effort was put into developing as many concepts as possible, to have a selection of opportunities to take forward, with multiple applications for these ideas. This is in line with idea discovery, as taught by (Hyland, 2013) through the DIA Model.

The DIA Model, (Discovery-Incubation-Acceleration) says that new businesses move from Discovery, where new opportunities are investigated, to Incubation, where uncertainties are eliminated, and finally into acceleration where the business is launched and scaled up.

Although (Hyland, 2013), developed the DIA model with corporate entrepreneurship in mind, the concepts are no less relevant to startups. The idea is that a concept moves from major uncertainty regarding the technical, market, resource and organizational components of a business (TMRO Uncertainties), which are systematically eliminated by making assumptions and validating them through testing and experimentation. The objective is to remove uncertainty and the associated risk, to have a validated business.

It is also worth noting that common talk of "Are you out of Discovery yet?" and "Are we ready for acceleration?", are often uninformed and misleading ways of looking at the conceptual nature of the DIA framework. Well established businesses can still be in discovery if they are still identifying new ways of shaping their core value, whilst newly formed businesses can be dealing with many typicaly acceleration type tasks.

The DIA framework was used to inform the idea development and to prompt more critical questions relevant to the idea, but it was not used so much as a project management tool. This semester has been spent primarily in discovery, with the intention of developiong an "opportunity Pipeline", and multiple options to explore moving forward, ensuring that success is not dependent on just one part or feature of Imvula.

Another important message from (Hyland, 2013) when referring to idea discovery is that "Customers do not buy technologies—they buy solutions.". This can be paraphrased to say that, people don't really care how its done, they just care that it works. This project has the danger of trying to be fancy and innovative, but with customers not being interested in the final product as it may be another technology but not a solution to any problem they actually face.

The following recommendations from (Hyland, 2013) were tabulated to illustrate what actions and thinking have been undertaken to develop Imvula during Discovery.

TABLE 2 - RECOMMENDATIONS AND ASSOCIATED ACTIONS DURING DISCOVERY

Recommendation	Action
Understanding the underlying science	Fluid Mechanics. Water Filtration. Valves and pumps. How would it work inside? Whats involved? Water
Uncovering technical insights, recognizing opportunities, and articulating their value	Developing prototypes, making assumptions and evaluating potential opportunity of that idea
About **possibilities,** not probabilities. A conceptual process, divergent thinking, developing questions rather than answers.	Getting too concerned with results and hard numbers would stifle creativity.
A match between **a need** in the marketplace (hidden or explicit) and a **product or service** offering that fills that need	There is a need for running water supply in most mid-income homes which have had a water supply. The loss of access creates a for a product such as Imvula which allows people to cope and maintain their familiar habits.
Planting a **business vision** of what could be	Imvula has multiple markets it can serve, from office buildings to households, impacting many people's lives by giving them access to a pressurized and efficient water supply.
Creating an **opportunity pipeline** for innovation Find alternate applications	Work to ensure that the success of the idea does not rest on just one technology/capability – Opportunities may have many different applications Many unexplored concepts remain such as enclosures recirculators and recollectors as well as new pumps and shower heads, electric versions and uses in agriculture, hospitality and events.

Imvula still remains in discovery with unexplored concepts, and will likely remain in discovery for another 3 months before the exploration, and finding alternate applications associated to the concept are largely covered.

Design Thinking

Design thinking is a creative solution development methodology based on focusing on the needs and sentiments of the user. (Dam, 2018)

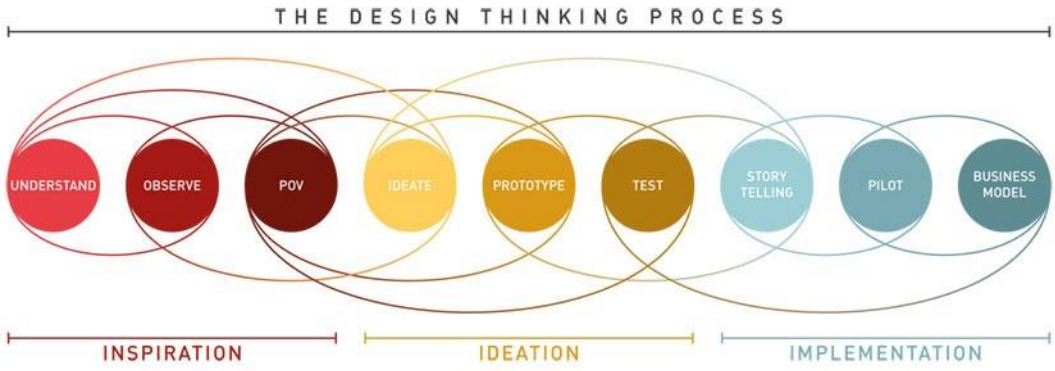


FIGURE 11 - THE DESIGN THINKING PROCESS, (DAM, 2018)

Design thinking informed the process of developing solutions for this project, by emphasizing understanding the customer to understand their pains, and then working with them to develop and test solutions to create a product and business which serves their needs on a fundamental level (Linke, 2017).

The relevancy of design thinking became particularly apparent through a focus-group with users, wherein it was pointed out that the concept of taking a shower has no value in most informal settlements or rural households which are not connected to the water grid, and offering them an off-grid shower will not necessarily be an ideal solution as they use buckets to clean. This informed product development and business model thinking as the assumption that the micro-shower would add value to such users was proven inaccurate, resulting in searching for alternate solutions such as water filtration.

Also important to note in this process as illustrated in the figure above is that Business Model consideratoins should only be made after prototyping and testing with users, mutiple times. Whilst prototyping is largely done, no pilot tests or user testing have been conducted, meaning that we don't know if this solution actually serves their needs and whether the business will offer them any value.

Design Guiding Principles

In starting the project, some guiding principles were established to reflect on when conflicted with a design direction to follow.

1. Keep things simple - As few moving parts as possible
2. No electricity
3. Keep things quick
4. Design for manufacture
5. Create the best user experience

These initial rules proved helpful, especially when looking for complicated rules and reiterating keeping things simple.

Testing Prototypes / Being the User

Testing Prototypes

The resounding message in product development is to test with the user and have the user engage with the product and the activity as much as possible (Dam, 2018). However, when starting from nothing, there are immediate shortcomings to a product which are obvious. There remain many problems to Imvula which need to be overcome before user testing can begin, but there has been no need in asking them to test a product which does not work.

By using the shower myself, and by placing myself in the context of the user, I could identify many immediate shortcomings which would be disturbances to the experience we would hope to provide the user, and get their opinion on. Small examples of problems identified by putting on the eyes and perspective of the user include the following:

- Larger diameter tubing is too stiff, reducing flexibility, making things unstable and dificult to manuevre - Use as small tubing as possible
- Smaller Bottles have bad balance - a Stand or holder is required
- Moving and Pumping can be slippery - Traction is required
- Screwing in the bottle can be difficult - Supprt for the screw is beneficial
- Repacking in a box can be time consuming and difficult – The packing/unpacking process needs to be simple

There are fair arguments to say that this project has not engaged the user enough right from the start, and that customers should have tested the product by now, or at least given their opinion on whether they would use it. However, this argument is countered by the fact that four months is still early for product development and new possibilities and ideas are still being discovered. If “Day-Zero” was not postponed, time would have been far more critical and customers would likely be testing products by now. However, adding a filter and looking for means to serve impoverished households shifted the product development focus to include filtration and reticulation, adding complexity and prototyping time before testing the product with users.

Living in the Context

Visiting Cape Town and living with a 50l per day water restriction for 3 weeks exposed me to how people deal with the problem and some of the easy solutions people employ which were not considered when not being there and expected to live every day with a water restriction. In visiting different households, it was found that different households have their own solutions but common examples included the following:

- Re-using greywater is a big focus and is often used to refill toilet cisterns.
- Filling buckets with water from the warming up of the shower saved a lot.
- People have stocked water

User Reviews of Competition

Many videos exist of the unboxing and testing of competitors products. Watching these helps to highlight the biggest strengths and weaknesses of products, the general look and feel as well as the users experience. This proved very informative. An example of key feedback which can be found in an online product reviews from customers is indicated by the comment that “There needs to be some sort of strain relief on the water tubing as it comes out of the water container. This tubing kinks as you move the shower head around. “. Reading such a review from a customer is equally informative as having them test a productive of our own as it highlights how the connections need to be loose for them not to irritate the user. The full review from this user can be found in Appendix 8.

Considering User and Maneuverability

Some people may have a frame which is too big to fit onto the splashboard, or some people may not have the balance. Some people may be too light to get the right pressure, and some people may not be able to bend over.

The tables below were developed to help assist with understanding the sizing the foot pump for Imvula, considering what pressures and volumes are possible for people and pumps of different sizes.

TABLE 3 - IDENTIFYING THE MAXIMUM PRESSURE ACHIEVABLE CONSIDERING SOMEONE’S WEIGHT AND THE SIZE OF THE FOOT PUMP

Pump Dimensions		Weight of User (KG)											
Radius	Area	20.0	30.0	40.0	45.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0
(cm)	(cm2)	Maximum Pressure (Bar)											
3.0	28.3	0.7	1.1	1.4	1.6	1.8	2.1	2.5	2.8	3.2	3.5	3.9	4.2
4.0	50.3	0.4	0.6	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
4.5	63.6	0.3	0.5	0.6	0.7	0.8	0.9	1.1	1.3	1.4	1.6	1.7	1.9
5.0	78.6	0.3	0.4	0.5	0.6	0.6	0.8	0.9	1.0	1.1	1.3	1.4	1.5
6.0	113.1	0.2	0.3	0.4	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1
7.0	154.0	0.1	0.2	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.8
8.0	201.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6
9.0	254.5	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5
10.0	314.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4
11.0	380.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3
12.0	452.4	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3

TABLE 4 -IDENTIFYING THE VOLUME PER PUMP FOR DIFFERENT PUMP SIZES

Pump Dimensions		Height of the Pump (cm)								
Radius	Area	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0
(cm)	(cm2)	Volume of the pump (ml)								
3.0	28.3	282.8	254.5	226.2	197.9	169.7	141.4	113.1	84.8	56.6
4.0	50.3	502.7	452.4	402.2	351.9	301.6	251.4	201.1	150.8	100.5
4.5	63.6	636.3	572.6	509.0	445.4	381.8	318.1	254.5	190.9	127.3
5.0	78.6	785.5	707.0	628.4	549.9	471.3	392.8	314.2	235.7	157.1
6.0	113.1	1131.1	1018.0	904.9	791.8	678.7	565.6	452.4	339.3	226.2
7.0	154.0	1539.6	1385.6	1231.7	1077.7	923.7	769.8	615.8	461.9	307.9
8.0	201.1	2010.9	1809.8	1608.7	1407.6	1206.5	1005.4	804.4	603.3	402.2
9.0	254.5	2545.0	2290.5	2036.0	1781.5	1527.0	1272.5	1018.0	763.5	509.0
10.0	314.2	3142.0	2827.8	2513.6	2199.4	1885.2	1571.0	1256.8	942.6	628.4
11.0	380.2	3801.8	3421.6	3041.5	2661.3	2281.1	1900.9	1520.7	1140.5	760.4

12.0	**452.4**	4524.5	4072.0	3619.6	3167.1	2714.7	2262.2	1809.8	1357.3	904.9

Working in a Print Farm

In my pursuit to learn more about 3D printing and get access to high end 3D printers, I was fortunate to get a part time job in the Formlabs Print Farm. The Print Farm constitutes dozens of Formlabs high end desktop SLA printers, which are continuously printing new sample parts for customers.

Much of the job entailed the packaging of sample parts to send to customers. Doing this and being involved in the manufacture, processing, packaging and shipping of products was invaluable in that I learned how simple the operations of small scale production can be, how teams can be structured and how task management can work in a print farm. If using 3D printing the operations in small scale production of Imvula would likely be the same.

Being able to print freely on high end 3D printers is a rare opportunity for someone trying to develop a product, and it was seized on by to do my project. This has made it possible to make high quality finishes using many engineering resins, saved considerable prototyping costs and allowed me to undertake 1-2 prints per week, depending on how often I would work there, whether there were printers available or whether I had been able to test and improve a component before the next week.

The general process of making a 3D printed component would be as follows:

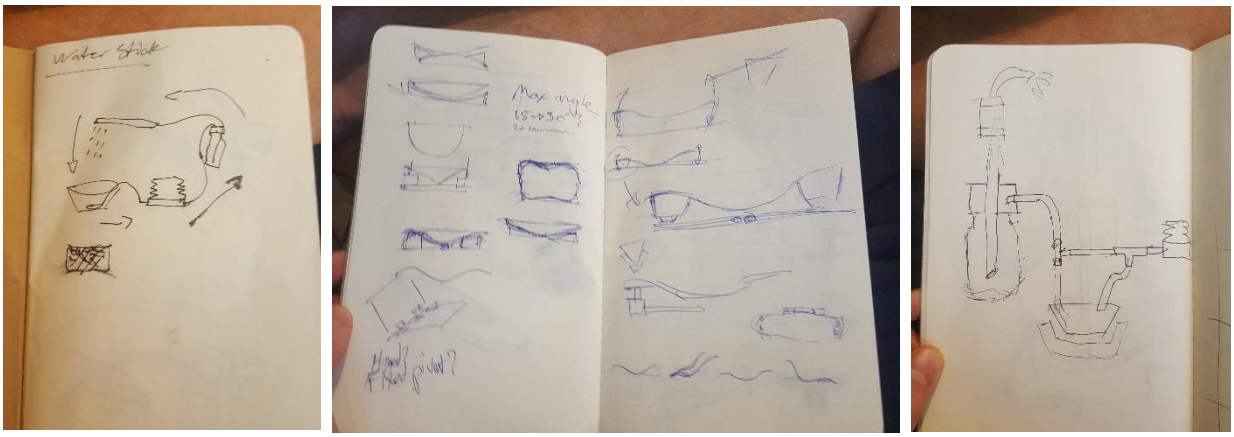
- Design Component
- Setup Print
- Print – (and post process by washing, curing removing supports and then filing down)
- Testing Component
- Identifying strengths and weaknesses
- Coming up with new solutions and improvements
- Making new component or improvement
- Make multiple similar versions with slightly adjusted parameters
- Setup Print
- Repeat process

This experience taught me a great deal about materials, post processing and craftmanship. It also improved my knowledge of the tools and methods used in manufacturing 3D printed objects to people, as well as how packaging and brochures are really what bring out a product, especially when done well.

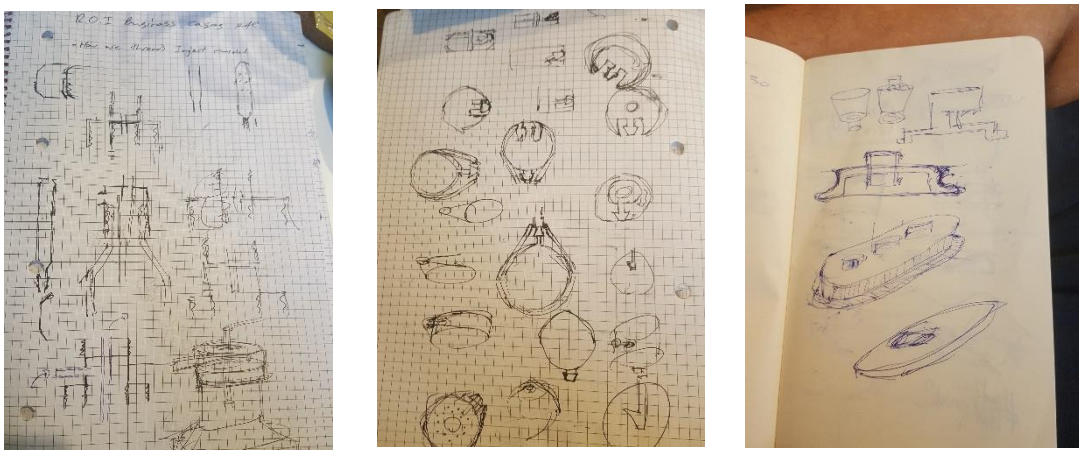
Designing the System – Sketch to 3D print

Using examples from this project, the development of an idea to a component is shown below.

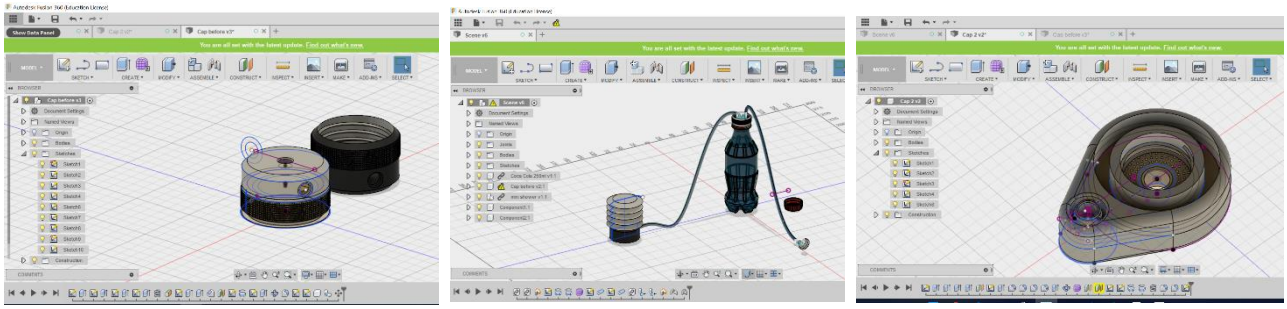
1. **Ideas start as a rough sketch of the concept**.



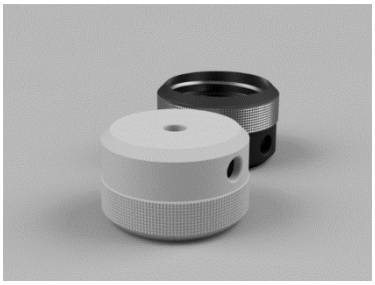
2. **More refined sketches are made, considering the dimensions and how it could be modeled.**

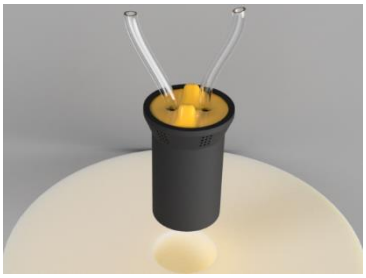


3. **A 3D model is developed**.



4. **The Model can be rendered to give a life like depiction of the product or component.**





5. **The part is 3D printed, and used as required.**


PROTOTYPING

A personal learning objective for this project was to learn how to design, prototype and manufacture a product. Without a formal training in product design or engineering prototyping, work has not been as fast as it could be, and has resulted in prototyping and testing accounting for the bulk of the work and time spent on this project.

Various parts and pieces were purchased along the course of the project development with costs in the region of EUR200. Considering the amount of tools and materials which can still be used, and the progress that has been made over 4 months, this is satisfactory. Although a lot of time was wasted on looking for the cheapest options, postponing buying decisions and not getting what is required to test properly.

3D printing was also thuruoughly used to develop new components, and sub-components, such as the pump, and the valves or bellows for the pump. Bonding and sealing proved difficult and required many attempts from simple adhesives to thermal pressing to concede that Radio Frequency welding machines are required to produce a satisfactory pump, requiring and investment of EUR5000 for the purchase of such a machine, or to get a contract manufacturer to produce a new design, which is the most sensible decision due to the lack of expertise in the field.

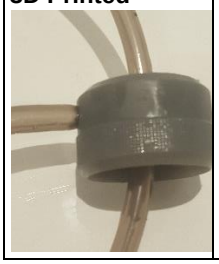
Through multiple iterations, the product has slowly become more defined, resilient, predictable and effective, but 3-6 months remain of prototyping before a manufacturer should be seriously engaged.

For further insight into some of the prototyping work, see Appendix 3-6.

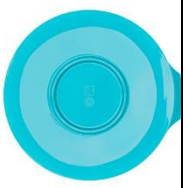
Imvula Shower Components

While entire reports could be written on each component of the shower system, for brevity, the components developed through prototyping were tabulated and assessed based on their strengths and weaknesses, and the key learning associated to the component. For further details see Appendix

TABLE 5 - COMPONENTS OF IMVULA SYSTEMS

Component	Strengths	Weaknesses	Risks and Challenges	Key Learning	Cost
Bellows Pump 	Tough Material Very cheap High Pressure Compact Low dev time	Inconsistent Too light Metal spring rusts	**Low Risk** Requires bulk orders but still very cheap. Not visually appealing and gives a “cheap” aesthetic	Best low budget option. Adjustments can be made and superior valves and a custom base plate can be retro-fitted.	0.5-3
Foam Pump 	Tough Material High Pressure Compact Light and soft Easy to use Stable	Difficult to source Potentially expensive Some leakage	**Medium Risk** Expensive and requires bulk orders. Requires custom design.	Can be reshaped to fit new applications	10-15
Closure: Holes 	Very Cheap Self-manufactured Easy to source	Look cheap Potentially leak	**Low Risk** Can be bought cheaply enough to test thoroughly	Very easy to put together but requires a drill press for a clean finish. Difficult to fit 2 tubes through the top of a 28mm cap	0.1-0.5
Closure: 3D Printed 	Intricate Design Customizable Quick lead time	Limited material strengths Slow process – 20/day/machine	**Low Risk** Have access to free 3D printing for low volume.	Possible to make a good quality prototype for user testing but likely not durable enough for mass sales	0-8

Closure: Injection Moulded 	High quality materials Cheap at mass production	High upfront costs High Dev Time High risk Cannot change design	**High Risk** Requires upfront investment. Risk can be lowered once product is sufficiently validated by customers through 3D printed versions	Many services available such as ProtoLabs which simplify this process significantly.	3,000-20,000
Tubing – PVC 	Durable Inert Cheap Easily Available Low dev time	Thick tube section Stiff	**Low Risk** The material is very cheap and can be easily sourced.	Tubing has a big effect on the ease of use of the product. Tubing needs to be easy to manage, pack and unpack and should be as if it was never there	0.5-1
Shower Head: 3D Printed 	Intricate Design Customizable Quick lead time Can print a cavity	Durability Good Design Shut-off valve Slow manufacture	**Low Risk** Have access to free 3D printing for low volume. Self-designed may never be superior to manufactured version	Many 3D prints were attempted, however, the right design	0-1
Shower Head: Supplier 	Cheap Flow Control Usability Durable materials Low dev time	Bulk Orders required High flow rate Medium Risk	**Medium Risk** To source affordably it is required to buy more than 500 units resulting in the danger of buying stock and not being able to sell it	A wholesale purchase from a manufacturer will provide a well-designed and reliable shower head.	0.5-1
Filter 	Most effective Lower Cost Portable High flow rate Comes with accessories	Bulk Orders required Low pressure at outflow Limited lifespan Fouling Cannot filter everything	**High Risk** Regulation could be an issue. If you are to offer someone a filter, it must work as you say. Backwashing and clogging still cause problems.	Many Chinese manufacturers produce at low prices. The common price point is 20 EUR Imvula could price the entire shower system similarly, offering superior value and features to	5-10

				just a standard filter.	
Recollector 	Reduces wastage Reduces spillage Protects feet from dirt Allows one to conserve water in outdoor environments	Bulky Can be a hassle Doesn't contain all water Inflatables puncture	**Medium Risk** Cheap and easy to source. Not a core element and have reverse attributes, making the product appear worse than it would be without the recollector	Needs to be foldable for storage. Flexible and inflatable options are available and relatively inexpensive. Many inflatable or	1-5
Recirculator 	Recirculates water to create a full shower loop. Allows for longer showers	Needs design and development time Blockages Ensuring a low point	**Low Risk** Prototyping can be done for free Added benefit could be a very attractive feature	Uses water pressure rather than suction to recirculate. Concept3D printed prototypes	0-2
Enclosure 	Provides Privacy Contains all water Provides shower head support structure Self-Erecting Multi direction spray	Large size Unstable in wind	**High Risk** Difficult to customize design Cheap and tacky appearance Fairly large, requiring higher shipping prices and more space for storage	This is not imperative but is an easily added extra feature or add on purchase. New experiences with side spray	5-20
Splash-Board 	Provides higher pressure Makes pumping easier Fun experience Recollects Water All in one device Multiple manufacturers	Big size – Not easily portable Requires further customization Unstable and difficult to use Increases prices	**Medium Risk** Prototype is under development and could be done cheaper Added benefit could be a very attractive feature	New concepts will be tested. Many attempts indicated that bonding material to balance boards is difficult. Attaching existing pumps to an existing balance board is easy The right size needs to be found	4-6

Designing for a loop

Because each component has an affect on the other, and that the ideal system is a loop, there was a lot of back and forthing between design decisions. Every part needs to function well with the other parts for the loop to work. Therefore, whilst it would be ideal to develop a plan where one focuses on developing each component to a sufficient degree before moving onto the next, this required shifting focus based on where weaknesses in the system occurred, and where solutions came about.

Using Existing Products

Buying existing plastic products from discount stores can often be the cheapest way of acquiring basic components to shape to test concepts. Examples include:

- Kitchen equipment – (containers, chopping boards etc.)
- Gardening Equipment
- Exercise Equipment
- Camping Equipment
- DIY and Hardware accessories
- Water Bottles and Bottle Caps

Using such materials helps to keep prototyping costs low whilst still being able to test concepts.

Materials

Looking at the uses, and the expectation of Imvula to be waterproof, durable, chemically inert and resistant to grease to name a few, the required material characteristics for Imvula were considered and then used to identify which materials would be most applicable using tables such as shown below. Two materials experts were also consulted who validated that thermoplastics such as PVC, PP, PE and ABS are the most suitable due to them being able to bond easier, and TPU may be the best flexible material option.

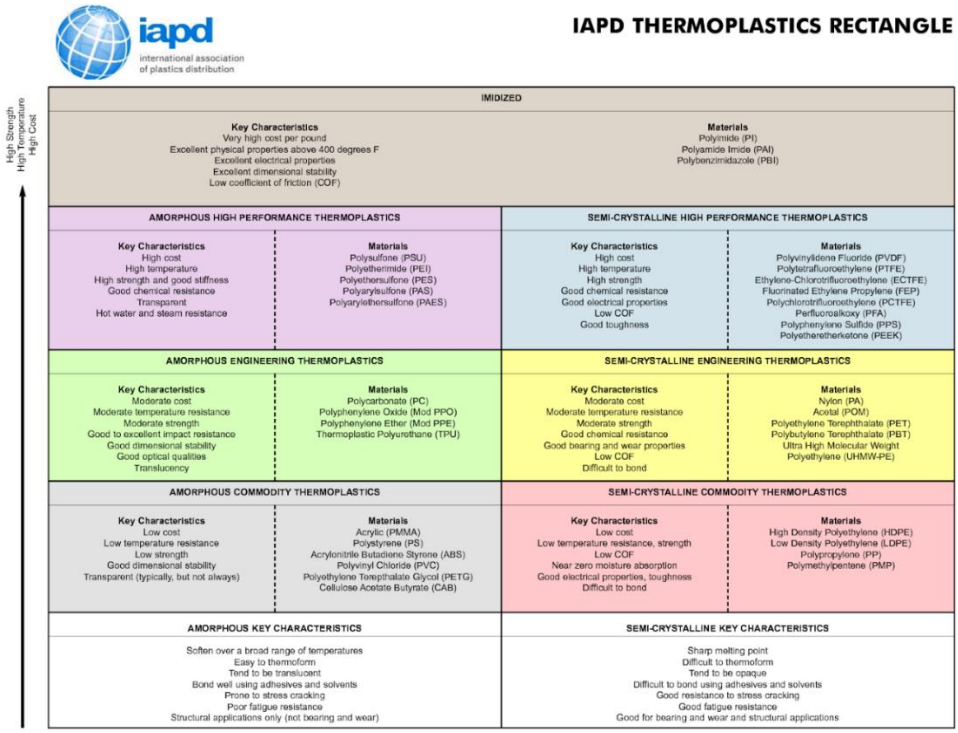


FIGURE 12 - TABLE TO INDICATE THE KEY CHARACTERICTICS OF CERTAIN PLASTICS TO IDENTIFY WHICH MIGHT BE SUITABLE FOR CERTAIN APPLICATIONS. (IAPD, 2015)

Considering that pressure and waterproofing is required, the way materials are bonded to ensure that no leaks develop with use becomes particularly important. Many adhesives and mechanical bonding techniques were attempted, from using simple household acrylic glues and epoxies and glue guns to strapping stapling and thermal bonding.

A Hot Gun was the best and only real option easily available at a relativley low cost but still has high consumable costs when using high quality hot adhesives. The extruder in the hot gun could be removed in refitted to a machanised dispenser, costing $3 but is still a messy dispensing technique and not the most economical.

Thermal bonding was found to be the most effective and preferred bonding method, which is confirmed by the fact that almost all inflatables are manufactured through thermal bonding rather than adhesives.

A heat gun and an iron were used to heat different PVC sheets in attempts to bond them. The iron worked well when a strip of teflon was placed in between it and the plastic, although it required some time. Handling the heat gun severley limits the dexterity of the operator and will not be easily done. A mount should be developed for holding the heat gun and moving the plastic past the mounted heat source to free up the operators hands. Or a thermal wedge welding machine could be bought for aprox. $3000.

Best option for complex geometry - RF Welding press. Cost is approximately $3000. If we were to manufacture our own parts/Pumps are mold any thermoplastics, an RF plastic welding machine would be the best option based on the quality and consistency of the weld, the rate of production would mean it is worth it and maybe the only option if making our own pumps.

Patents

While there is no immediate intention of patenting this device, consideration needs to be made as to which patents it may infringe upon to avoid infringement.

An expert at AAU was contacted regarding patent searches, and whilst he was not able to give specific advice, it was pointed out that if an invention serves a new need or application then it is probably not infringing on an existing patent. Which provided some assurance. However, a proper search was required.

The preferred method used was to search for patents using google patents as a starting point.

Linking to the EPO – Espace, and opening the Global Dossier, one can see the entire filing history of all documents related to that patent. The claims and responses to these claims are thoroughly informative in explaining the reasoning for patent application rejection referencing previous patents with similar claims.

Searches were made for competitors, (LifeStraw, Nemo Equipment, MSR, Sawyer Products, Katadyn, etc.) Searching competitor patent applications, the most pertinent results came from LifeStraw for water filtration and Nemo Equipment Inc. for the foot pump and portable shower.

Searches for terms such as “portable shower”, “portable filter”, “off-grid shower” and “foot pump shower “were made, yielding similar results to searching for competitors and outlying the IP landscape for such products.

LifeStraw hold patents for many of their devices (Frandsen, 2009), (Scharstuhl, 1996), (Hill, 2015), (Frandsen, 2014). However, these are generally design patents and are not a major threat considering Imvulas proposed design.

Nemo Equipment have attempted to patent many of their products with mixed success. The Helio portable shower and foam shower pump have been rejected for utility patent applications (Brensinger, 2008), (Brensinger, 2006), with the patent assessor referencing previous and now expired patents (Haller, 1998) (Pinkwater, 1961). Nemo does however hold a design patent for the water container used in their shower (Brensinger, 2015).

Innova water has been the most aggressive in pursuing patent infringement cases against other water companies including Brita water, and Sawyer Products, however, many of their patents are now expired or inapplicable to Imvula (Wqpmag.com, 2000).

Overall, the patent search had a positive outcome, proving educational and providing inspiration from expired patents to use in Imvula designs, and offering some comfort in not needing to be overly concerned with patent infringement with Imvula.

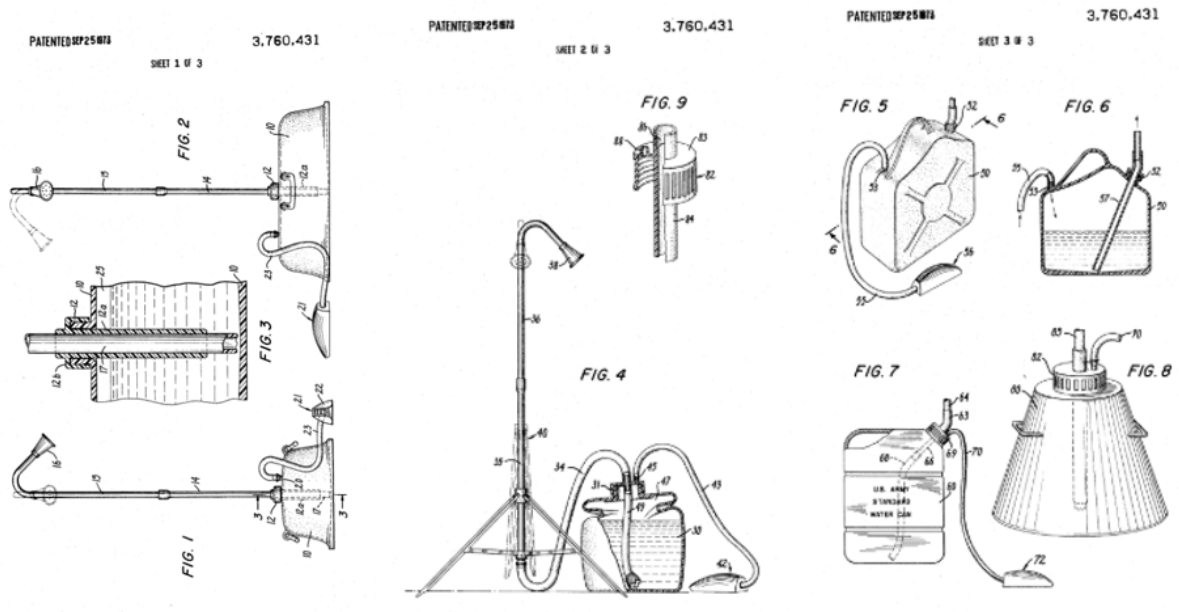


FIGURE 13 - AN ILLUSTRATION FROM A PORTABLE SHOWER PATENTED IN 1970 (SCHWIBNER, 1970)

Quality Management and Testing:

This product is likely to bare some scrutiny from critics. As soon as claims that water can be filtered, flow rate can be reduced, water can be pressurised or water efficiency can be increased, it is likely that these claims will need to be validated through extensive testing, and proof needs to exist that these claims are true.

Further to this, there exists a big difference between making a working prototype in a workshop and producing 5000 units for customers to use every day. Once a final product is developed it will be required to undergo testing, to ensure they are being consistently well manufactured before it can be sold to a customer

One way of testing products is through a testing agency such as TUV Sud. Tuv Sud is a global technical testing agency which is well recognised by consumers as a global standards leader. By passing Tuv Sud standards, manufacturers attain quality marks, which can help set a product apart as being superior. These tests are not a requirement and associated costs can be high, however, it is an effective way to market a product as being of a good quality.

When sourcing components for Imvula, buying products which are already certified through testing agencies makes things easier as there is proof of precompliance in the logistics stream.

Navigating this field is complex and best left to those with experience if wanting to save time. QiP-QM is a quality management company who I have engaged with before and charge EUR115 per hour. They could further help with manufacture sourcing, assist with project management of testing and specifications, and would require approximatley 10 hours of work, totalling EUR1150.

Field Trip - Cape Town

3 weeks were spent in Cape Town with the aim of further understanding the context of the water shortage problem, of investigating the options and potential of starting a business in South Africa and of speaking to potential customers.

One week before arriving in Cape Town, “Day-Zero” was postponed into 2019. This meant that the need for the product no longer existed and ideation was required to come up with a new concept or find a new market.

MakerSpaces and Manufacturing Spaces

Makerspaces were contacted and the most promosing lead was visited to check the facilities available there. The management was helpful and friendly and indicated that they would be willing and able to connect with manufacturers for plastic injection moulding should the need be required.

Labor and Employment

It was found that there are many skilled tradesmen who wait outside hardware stores for temporary contract work in Cape Town. These people could be hired on a one-off basis to manufacture a batch of products and would likely be good with their hands and up for the work. A satisfactory wage for such workers would be in the range of EUR3-5 per hour.

Hardware Stores

Local chain hardware stores were visited to assess the material costs and availability proved to have the required basic eqiupment at affordable rates. PVC tubing, Pond Lining and adequate power tools could be purchased here very cheaply.

Manufacturers

Manufacturers of reticulated foam, plastic wares and rubber molding were contacted and found to be able to offer very affordable materials. Most manufacturers require a company VAT number and it would thus be required to be a registered business before purchasing, but this is not a major obstacle.

Property Rental

Property is very affordable for light manufacturing. Initially, garages or rooms from friends or family will be used for the first run of production eliminating the of rent for the first production run. Light manufacturing space is widely available can be rented for as little as EUR5 per m2 per month, with an initial space requirement of 20-40m2, and a cost of around EUR200 per month.

Partnerships and Assistance

South Africa does not have the sophisticated and well-funded start-up support structure that one might find in wealthy countries. However, there are some initiatives for SME’s and start-up funding which could support this.

The Cape Craft and Design Institute (CCDI) is an initiative to help new business in design and product development as well as connecting entrepreneurs to markets and manufacturers. In visiting their facilities, it was indicated that they would be able to support many aspects of the project.

Acquiring User Perspectives

In line with design thinking, this product is designed with the user in mind, trying to ensure that it actually serves a fundamental need of the customer. To gain insight, interviews and a focus group were conducted while in Cape Town.

Participants had grown up or been thoroughly exposed to life in rural and informal settlements and came from countries including South Africa, Gambia, Malawi and Zimbabwe, giving a wide range of viewpoints. These participants were formally educated professionals working in the fields of monitoring and evaluation, and their perspectives and points of view were thus considered to be well informed.

Focus Group:

Three people participated in a focus group to get their perspectives on Imvula. To start with, they were shown a video of a device being used in the shower. Asking them whether they could imagine this being used in low income houses without a water connection, the general response was negative.

The group pointed out that such households do not have a segregated showering area, and simply use a bucket and a towel to wash with. The context of replacing a shower had no relevancy to them, as this was not their normal behavior, and using an Imvula shower would be more of an inconvenience than added value.

Interviews:

Using a similar method of showing a video of the device in action and the discussing the idea and whether they would use it, 4 people were interviewed.

Interviewees shared a similar sentiment to the focus group, indicating that the bucket system is a “no brainer” and would be difficult to do away with as people are so familiar with such a system which costs them nothing. It was also indicated that hygiene is not a top priority.

The findings from the interviews and focus group were that this device would not serve much value in low income houses as it would be ineffective considering that people do not have a shower and place to spray water. Due to space and lack of drainage, washing is confined to a small shared plastic bucket, and the method of dipping a cloth or sponge into this to clean oneself is simpler and produces less splash than using a device such as Imvula.

These user discussions informed the direction of the product considerably and after attempting to develop a pressuriseable bucket like those commonly used by such households, and investigating the potential of adding filtration, it was realized that Imvula is not able to add sufficient value to such users based on their feedback, and lead to refocusing the product back onto consumers who seek an off-grid shower for urban and adventure purposes.

Facebook Community

The “Water Shedding Western Cape” Facebook group gained more than 160,000 members all sharing their ideas and solutions. This is a very active page, and has been very informative and passively observing the solutions being developed and how people deal with the situation. This platform is a great testing ground and it would be very easy to find test users for Imvula and through this platform.

THE BUSINESS

Before discussing the business behind Imvula, it must be noted that there remain many uncertainties and decisions to be made regarding the product which would greatly affect the business case.

Considering the process of design thinking, the business model should only really be addressed once engaging with customers and is generally the last step of the process when developing a new product.

As a result, less attention has been put into in depth business analysis as was planned from the beginning of the project.

However, it was found that the business could be effectively scaled, and started with as little as EUR2000 to get first production.

The Customer – A brief look at a Customer Persona

There are many customer segments which Imvula serves, serving all with the same need of access to a pressurized water source and efficient water use.

The household user segment persona is expressed in the Daniels family. They use a simple garden sprayer to shower, and can shower the family of three with as little as 5 liters. They are very proud of their solution, which cost R200 (€15), and have cut their water bill by 50% and their electricity bill by 60% as they no longer use a geyser (DUVAL, 2018). The Daniels family is a typical middle-class family in South Africa. For them, saving money is very important, and they are willing to embrace new solutions given the extent of the water crises, even if it means some extra effort.

FIGURE 14 - QANITA AND LABIEQ DANIELS BECAME LOCAL HEROES AND THEIR GARDEN SPRAY SHOWER GAINED NATIONAL ATTENTION FROM NEWS AGENCIES. (DUVAL, 2018)

However, this customer segment will be addressed after focusing on opportunities selling direct to businesses with multiple water users.

The Numbers

To determine the best go to market strategy, the costs of various product packages was determined, based on quotations received from multiple suppliers.
A model was developed to investigate the costs, profitability, pricing and required investment for various production scales.

Costing Model

The tables below illustrate how costs were modelled, considering the bare bones scenario of Imvula Micro, and the scenario of attempting to sell all Imvula concepts:

TABLE 6 - IDENTIFYING COSTS AND REQUIRED SELLING PRICES FOR PROFITABILITY AT VARIOUS PRODUCTION RATES

Micro Shower	**Quantity of Products Manufactured**						
	10	100	500	1000	5000	10000	50000
Component	**Cost (€)**						
Pump	2	1.5	1	0.8	0.5	0.5	0.3
Closure	1	1	1	1	1	0.5	0.1
Shower Head	2	1.5	1	0.8	0.6	0.5	0.4
Tubing	0.5	0.2	0.2	0.2	0.2	0.2	0.2
Labour/Unit	*0*	*1*	*0.8*	*0.6*	*0.5*	*0.4*	*0.4*
Rent	*0*	*0*	*200*	*200*	*200*	*800*	*800*
Machinery	*400*	*500*	*10000*	*10000*	*15000*	*20000*	*50000*
Cost/Unit	**45.5**	**10.2**	**24.4**	**13.6**	**5.84**	**4.18**	**2.416**
Imports and Taxes	*75.53*	*16.932*	*40.504*	*22.576*	*9.6944*	*6.9388*	*4.01056*
Cost/Batch	**755.3**	**1693.2**	**20252**	**22576**	**48472**	**69388**	**200528**

	Quantity of Products Manufactured						
Quantity	*10*	*100*	*500*	*1000*	*5000*	*10000*	*50000*
Selling Price (€)	**Profit/Loss for Batch based on Selling Price (€)**						
5	-705.3	-1193.2	-17752	-17576	-23472	-19388	49472
10	-655.3	-693.2	-15252	-12576	1528	30612	299472
15	-605.3	-193.2	-12752	-7576	26528	80612	549472
20	-555.3	306.8	-10252	-2576	51528	130612	799472
25	-505.3	806.8	-7752	2424	76528	180612	1049472
30	-455.3	1306.8	-5252	7424	101528	230612	1299472
35	-405.3	1806.8	-2752	12424	126528	280612	1549472
40	-355.3	2306.8	-252	17424	151528	330612	1799472
45	-305.3	2806.8	2248	22424	176528	380612	2049472
50	-255.3	3306.8	4748	27424	201528	430612	2299472

All Products	**Quantity of Products Manufactured**						
	10	100	500	1000	5000	10000	50000
Component	**Cost (€)**						
Pump	2	1.5	1	0.8	0.5	0.5	0.3
Closure	1	1	1	1	1	0.5	0.1
Shower Head	2	1.5	1	0.8	0.6	0.5	0.4
Tubing	0.5	0.2	0.2	0.2	0.2	0.2	0.2
Filter	7	7	7	6	5	5	5
Recollector	3	2.5	2	2	1.5	1	1
Recirculator	2	1	0.8	0.5	0.4	0.3	0.25
Enclosure	20	15	10	8	7	5	5
Splash-Board	10	7	6	5	4	3	3
Labour/Unit	*0*	*1*	*0.8*	*0.6*	*0.5*	*0.4*	*0.3*
Rent	*0*	*0*	*200*	*200*	*200*	*800*	*800*
Machinery	*400*	*500*	*10000*	*10000*	*10000*	*20000*	*30000*
Cost/Unit	**87.5**	**42.7**	**50.2**	**35.1**	**22.74**	**18.48**	**16.166**
Imports and Taxes	*145.25*	*70.882*	*83.332*	*58.266*	*37.7484*	*30.6768*	*26.83556*
Cost/Batch	**1452.5**	**7088.2**	**41666**	**58266**	**188742**	**306768**	**1341778**

	Quantity of Products Manufactured						
Quantity	*10*	*100*	*500*	*1000*	*5000*	*10000*	*50000*
Selling Price (€)	Profit/Loss for Batch based on Selling Price (€)						
5	-1402.5	-6588.2	-39166	-53266	-163742	-256768	-1091778
10	-1352.5	-6088.2	-36666	-48266	-138742	-206768	-841778
15	-1302.5	-5588.2	-34166	-43266	-113742	-156768	-591778
20	-1252.5	-5088.2	-31666	-38266	-88742	-106768	-341778
25	-1202.5	-4588.2	-29166	-33266	-63742	-56768	-91778
30	-1152.5	-4088.2	-26666	-28266	-38742	-6768	158222
35	-1102.5	-3588.2	-24166	-23266	-13742	43232	408222
40	-1052.5	-3088.2	-21666	-18266	11258	93232	658222
45	-1002.5	-2588.2	-19166	-13266	36258	143232	908222
50	-952.5	-2088.2	-16666	-8266	61258	193232	1158222

Observations on Costing Model

Even when making quite large variations to the input costs of the model, the general trends remain much the same indicating that profitability really starts at 10,000 units and that producing and selling more than 50,000 units will yield high profits even at small margins and at a price point far lower than competitors.

Prototyping and user testing would account for the first 10-100 Units and cost in the region of EUR2000 to develop to a point where the design is ready for mass manufacture. If this phase proves successful, then it may be possible to acquire funding or an investment. Approximately EUR70,000 would be required to ramp up production above 10,000 units, allowing for

substantial profits. Although this is riskier than funding lower production scales, 10,000 units is almost twice as profitable at half the cost of 5000 units and may be worth the risk.

These cost estimates are based on the acquisition of machinery. Repeat batches will thus be drastically cheaper.

Payback

The time required to pay back the cost of Imvula due to water savings was estimated.

Considering the costs of Imvula, and the water tariffs in Cape Town, the savings were calculated, assuming that people shower with 50 liters per day, that Imvula uses 2 liters, and that people shower once per day.

TABLE 7 - WATER TARIFFS AND SAVINGS ASSOCIATED WITH USING THE IMVULA SHOWER

Water Consumption (litres)	Price ZAR	Price (€)	Cost/l	Cost per shower 47 litres	Savings per year (€)	Savings per year for Family of 4 (€)
6000	179.58	11.972	0.00199533	0.09378067	34.2299433	136.9197733
10500	415.56	27.704	0.00263848	0.12400838	45.263059	181.0522362
20000	1555.56	103.704	0.0051852	0.2437044	88.952106	355.808424
35000	6685.56	445.704	0.0127344	0.5985168	218.458632	873.834528
50000	20365.56	1357.704	0.02715408	1.27624176	465.828242	1863.31297

Market Trends

Assessing the markets allows one to determine whether there is sufficient interest and investment.

Unfortunately, portable off-grid showers are niche products and market reports are not compiled to gain easy insight into the market size and potential. However, thinking more broadly, competitors tend to fall into the outdoor and apparel market or the household water saving devices market.

Given that water filtration was a promising prospect, the market was also considered, indicating that moving into water filtration once perfecting the basic concept may yield rewards.

As this device was designed to mitigate the effects of a water crises, marketing to disaster management organizations is possible, however this requires a maturity of product and a preparedness to deliver instantly. This market is an opportunity but not possible to start with.

As this device was developed with the citizens of Cape Town in mind, one could say that the market size of people facing a pain would be 3.8 million. However, this is a gross underestimation of the total amount.

In general, considering the impact of the global water crises, trends indicate that there is a substantial and growing market for water use related products, and this has been considered sufficient validation to continue exploring the idea (UNStats, 2017).

Outdoor Apparel Market

As indicated in an Industry report on Hiking and Outdoor Equipment Sales (IbisWorld, 2018), Global Outdoor apparel is a $50B + with 20% growth in China. But is competitive and dominated by conglomerates who buy up smaller innovative companies. Brick and Mortar sales continue to shift online, but remain the number one sales channel as users can test and try gear in store. This report further cites how a good reputation, good technical product knowledge and the ability innovate and bring new products and services to market changes are the most important characteristics of successful companies in this market. Apart from price, design, and quality, consumers look for the sustainability of products (Prnewswire.com, 2016).

Further insights in this market come from (Phelps, 2016), indicating that “There is a rising consumer interest in outdoor recreation and camping activities. One of the key drivers spurring the market’s growth is the increasing demand for lightweight equipment. The need for modern equipment has encouraged the introduction and adoption of smart and compact products over conventional products.

Portable Water Filter Market

The portable water filter market is showing strong growth especially in Asia, with replacement water filter cartridges projecting to be the most lucrative business (Technavio, 2018).

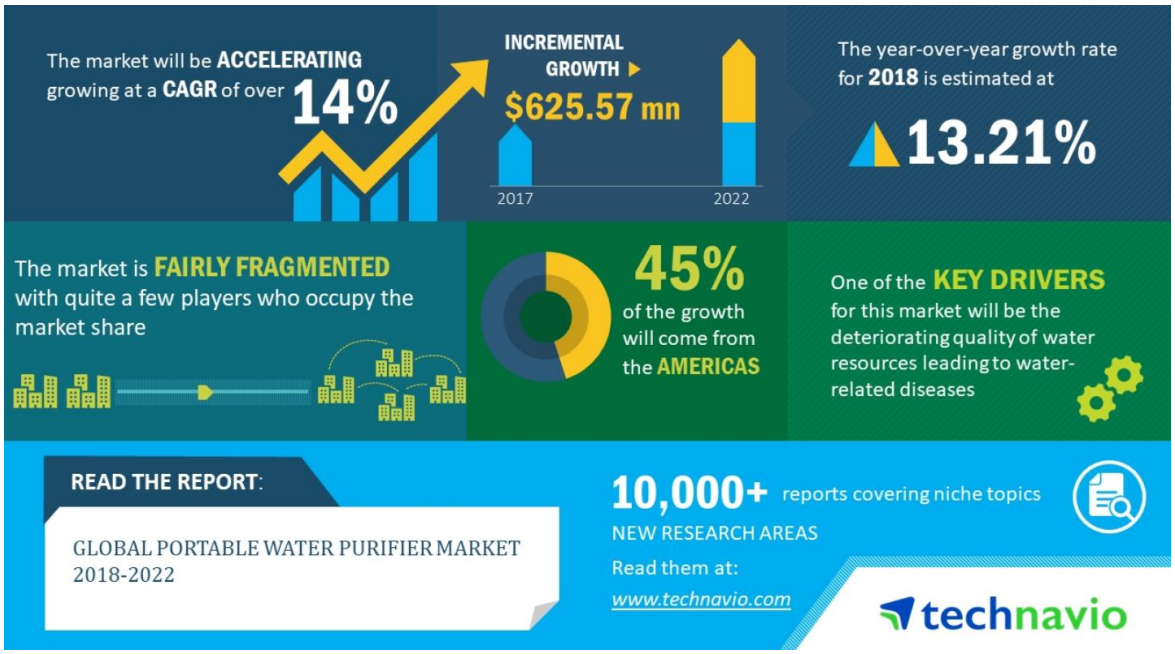


FIGURE 15 WATER FILTRATION MARKET REPORT (TECHNAVIO, 2018)

Market Entry Strategy

1. Create Online Presence

The reality is regardless of the market to serve, much work needs to be done in creating channels for people to get information and buy the product.

Establishing a website with product pictures and videos, testimonials, and key information will be required for all markets.

2. Aim for Businesses (B2B)

With a strong online presence, businesses will then be contacted to start a pilot run or sell bulk orders. The benefit of this is that it simplifies shipping and could generate more total sales as opposed to individual customer purchases. Taking pre-orders and establishing that there may be a lead time, it may be possible to source the business establishment costs this way. An overview of the business is provided in the business model canvas for a B2B situation.

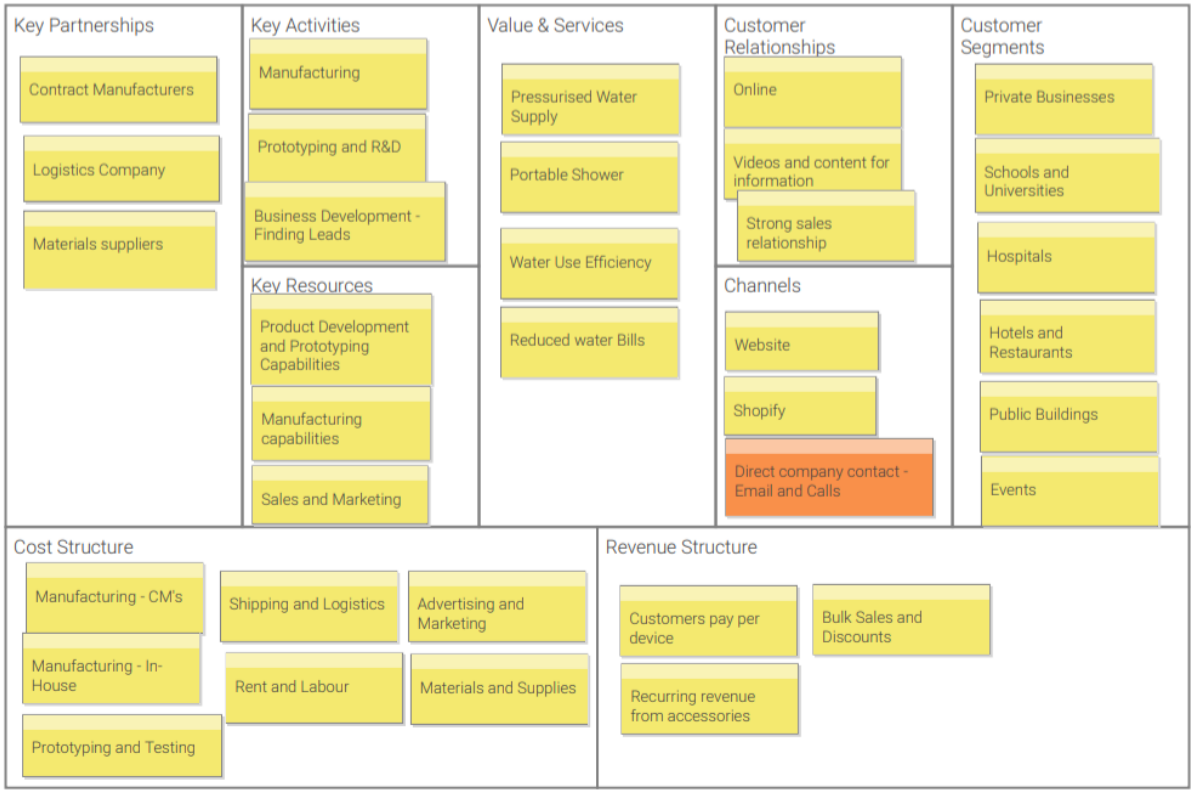


FIGURE 16 - IMVULA MICRO B2B BUSINESS MODEL CANVAS

An elaboration of some of the B2B opportunities for Imvula are below.

Office Buildings and Facilities

Schools, hospitals and public facilities, hotels, gyms, restaurants and airports all face substantial water tariff increases. Many of these facilities have cleaners who tend regularly to the bathroom. Many such places also cut-off the faucet water supply, keeping only one open for public use.

Imvula systems could easily be installed, with the users being able to clean their hands with one or two-foot sprays and the attendant ensuring the water bottles are full. This will be a highly water efficient way of people getting sufficient water to wash their hands.

The hospitality industry suffers a lot from lack of water, and a hotel could easily put an Imvula micro shower in each room instead of not being able to offer their guests water at all.

Schools could also drive the initiative in their public restrooms, improving hygiene.

It is believed that considering the awareness of the problem, it will be possible to get at least one business or institution to sign up for a pilot test, with their staff or students trying this solution. This will require the product to be effective and reliable and requires a better pump.

CSR

Corporate Social Responsibility, and Corporate Giving, account for more than $50 Billion from the Forbes Fortune 500 companies alone (Mahabubur Rahman, 2017). Many corporations use CSR as a marketing tool, and there is opportunity to present companies with an alternate way of giving back. An example of such an approach is to offer our product as a service and opportunity for companies to be eco conscious as “using our products reduces water usage “.

This is a huge market with more leads than time to contact. Sending proposals to company CSR or HR managers with a clear product and purchase strategy will be easy once the product is further developed and press packages are compiled for mass send out.

3. Aim for Consumers (B2C)

After starting in the B2B market, a shift will be made to aiming at customers. By this point we would have engaged with users somewhat already, and would have an idea of who exactly we are marketing to. Facebook, and other online platforms offer very targeted marketing services which are easy to use.

The issues with B2C is that we would be dealing with many more individuals than B2C, resulting in more individual orders and greater shipping complexity as well as the public scrutiny and requirement to always be there and serving the customer. Whilst it is never a good idea to bank on hype or viral campaigns, the relevancy of this solution may garner media attention. This means that we would need to be very well prepared for a B2C product launch, and more prepared than a B2B launch, making B2C the second option.

A business model canvas depicting a B2C business model is indicated below with the key differences to the B2B offer in orange. Marketing becomes more important and expensive with increased need for customer support. Important to note is that the B2B customers and operations would still be maintained after encompassing B2C components into the business model.

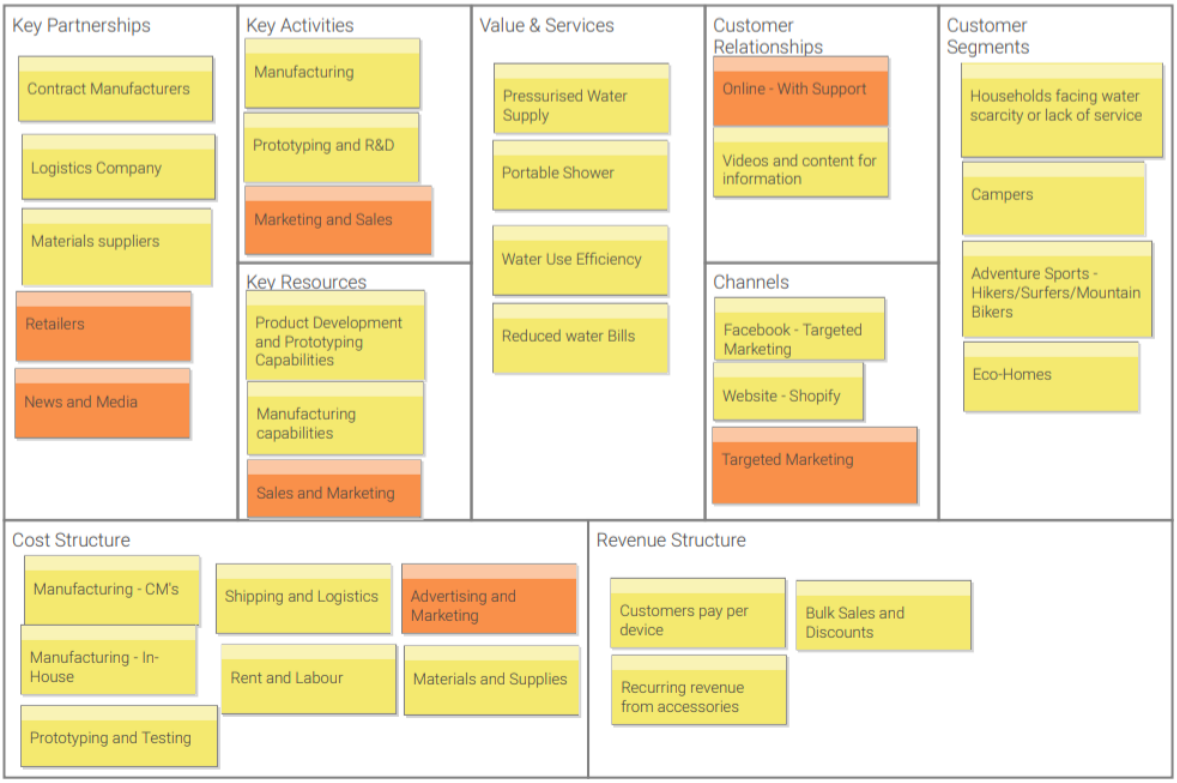


FIGURE 17 - IMVULA MICRO B2C BUSINESS MODEL CANVAS

4. Aim for Humanitarian and Disaster Relief

Once the product is mature and Imvula has a strong track record, then it will be possible to aim at these markets. The business model shifts substantially, but was not analyzed to the detail of B2B and B2C business models as the Humanitarian and Disaster relief strategy are too far on the horizon.

Billions of dollars are allocated each year from charities, foundations, governments, humanitarian organisations, and philanthropists towards alleviating water scarcity problems and achieving Sustainable Development Goal 6 – Access to clean safe water for all.

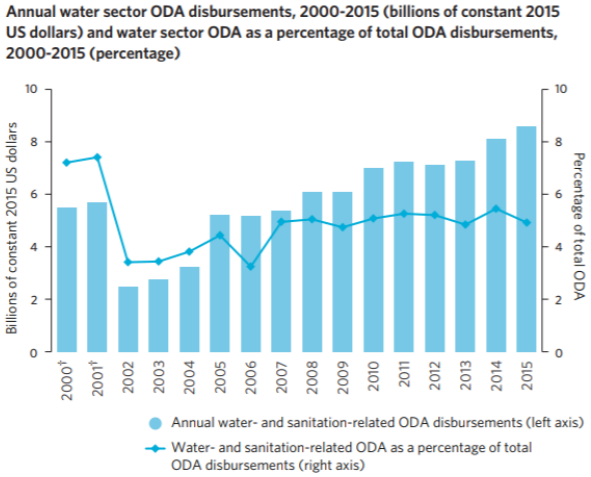
Whilst this is promising, after discussing the concept with some such organisations, there are some barriers to entry in this market.

One observation made is that when attempting to deal with UN funds there exists a portal called the United Nations Global Market Place (UNGMP). This platform aims to help companies to provide humanitarian focused products where they are needed by posting grants and tender contracts for companies to apply for. The problem with this is that qualification is required. To really stand a chance of being awarded a contract, a company needs a good history. This is very much a barrier to entry and the UN is unlikely to engage with a new Startup without a proven track record associated to the product they sell.

Many organisations which work in the field of providing people in poverty with access to water, point out from experience that quick inventions are not a sustainable long-term solution.

Wateraid.org has stated how short time inventions are not the most effective solution stating the following. “Charitable distribution of inventions – such as filters, pumps, purifiers, water condensation units, rolling water butts or similar – has been tried many times in the past, but

only ever achieves limited short-term impact. Instead, the crisis is largely a management problem – one where government and the local private sector are desperately lacking finances, skills, coordination and dedicated institutions to provide water and sanitation services to citizens. “ (WaterAid, 2018)



Further barriers to entry in this market also exist with getting one’s product tested and qualified to be meet a certain standard. The WHO developed a scheme for assessing the efficacy of existing products, which can be done for free but requires more time and a more refined product (WHO, 2017) .

FIGURE 18 - THE AMOUNT OF WATER SECTOR OFFICIAL DEVELOPMENT ASSISTANCE (ODA) GIVEN FROM THE US (UNSTATS, 2017)

Competition

A focus has been placed on the competition since this project began, with a tabulated overview of the most common off-grid shower products on the market being compiled to see what products are being made, their strengths, weaknesses and costs (Appendix 2).

Competition comes from the following markets.

- Portable and Off-Grid Showers
- Water Saving and Water Efficiency Devices

As water filtration was at one point considered imperative to the success of Imvula, the portable water filtration was also assessed which can be found in appendix

Whilst competition comes from many angles, the most obvious come in the form of the market leaders in outdoor equipment and apparel.

The strongest competition have standards, products and business models which we would be proud to produce ourselves. They make very high quality products, serve multiple sets of needs, have a wide ranging catalogue of atractively designed and user focused products and a proven reputation.

Portable / Off-Grid Showers

Nemo Equipment Inc.

Nemo invented the Helio, which appears to be the best human powered shower on the market. However, at EUR100 their products are expensive and likely not going to be commonly bought in South Africa by someone looking for a quick solution. They put a lot of thought into their products, and have tried to patent their ideas unsuccessfully.

Nemo specializes in tent manufacture and their camping shower is not their primary product, that being their airframe tents. They have won multiple design and product awards and are recognized as best in class. Because of their reputation for quality, and the expensive materials they use, it would be difficult to compete with them in the premium segment they now command. However, the high cost of their products might be a drawback and customers could be drawn more to Imvula if it is able to offer similar functionality at a much lower cost.

FIGURE 21 - NEMO SHOWERS

FIGURE 20 - NEMO HELIOPOLIS

FIGURE 19 - XL VERSION

Their total shower solution, the Heliopolis, costs an extra $150, and their floor mat costs an extra $20, making their products expensive, but well-built and well designed. It lacks a recollector and water filter, but patent applications indicate that they have considered it.

Pump n Spray

FIGURE 22 - THE PUMP 'N SPRAY

Pump n Spray is a product developed in Jamaica, as a consequence to water cuts which occur in Jamaican cities, and operates much the same as Imvula. This product is considered as the lowest cost and easiest option that could be produced. Although Pump N Spray offers a very similar product to Imvula their reach is limited mainly to Jamaica and they are not considered as competitors to be worried about. The objective is to develop a much better version of Pump N Spray and sell it for cheaper. The Micro concept using smaller bottles, and better foot pump make Imvula superior.

Chinese Manufacturers

When searching online there are many options from Chinese manufacturers, including for replicas of the Helio shower, electric versions and gravity driven versions. These however are not heavily market in South Africa, and those people who do sell them are sold out, despite the high markup on the products. Such manufacturers are considered a risk in competition, but there appears to be no retailers actively marketing these solutions.

FIGURE 23 - ELECTRIC OFF GRID SHOWERS

Garden Spray

The garden sprayer received much media attention and is widely sold in department and hardware stores as an off-grid shower. These are sold in the region of EUR15-30 and can build up a high pressure. However, users are required to stop and pump up the vessel when the water pressure recedes, whereas with the Imvula shower, one receives a continuous, hands free-spray using a foot pump. It needs to be tested whether users find a foot pump adds enough value to be superior to the highly functional garden sprayer. Whilst no company stands out as the most popular producer, the availability of products like this nationwide put it is as one of the most threatening competitors.

FIGURE 24 - GARDEN SPRAYER

Manufacturing

Manufacturing a new product generally comes with high upfront costs which act as a barrier to entry. The fact that one would have to pay tens of thousands of Euros for machinery, and then make and sell tens of thousands of products just to cover the costs makes manufacturing risky. However, if done right, it can also reap great rewards.

Manufacturing also relies on hiring a labor force, which comes with its own set of complexities. Contract Manufacturing (CM) hands all the work over to the manufacture, and simplifies the business model significantly. Another reason for not manufacturing ourselves is the testing process. Every product would need to be tested to ensure it works adequately. This work can be done by CM's.

ProtoLabs is a company which has proven to be a strong lead and which will be engaged with once the design is ready. ProtoLabs has a wealth of resources and regarding designing for manufacturing, as well as automated assessment of designs and improvements to be made.

The idea initially is to buy as many components from manufacturers as possible, to reduce the costs and risks of manufacturing ourselves. All parts except for the closure will be bought from Original Equipment Suppliers (OEM), who manufacture the same product for multiple companies and allow design changes and printing custom logos on these products. OEM's are easy to find using Alibaba, and have a lead time of 30-60 days for a custom product. Unfortunately, custom colours and logos usually require a high minimum order quantity

exceeding 1000 units. However, these suppliers to provide samples, and it is possible to develop a final product with smaller orders.

Light Manufacturing

Given the high initial costs of injection moulding, and the time required to make sure the designs are perfect, it is prefered to start with as many predesigned/premanufactured components as possible and to assemble or make minor modifications to existing products.

FIGURE 25 - THE PUMP 'N SPRAY MANUFACTURING SPACE. VERY SIMPLE AND CHEAP TO ESTABLISH AND OPERATE

The jobs required are very simple. Drilling extra holes, cutting lengths of tubing, glueing or melting together components, pushing tubing through holes and repackaging of items are all examples of the types of simple tasks which could be done with cheap and basic machinery, and a low cost, low skill labour force, making manufacturing of this device very feasible.

An example, is the closure. The fastest and most cost-effective way of making closures initially is to buy bottle closures from a manufacturer and drill two holes into them, then pull the tubing through the holes. Whilst this will not appear as high tech as custom injected part, it is certainly sufficient for the task, and allows production of 100 units for EUR20 and up to 5000 closures to cost as little as EUR100.

FIGURE 28 - RF WELDER

FIGURE 26 - DRILL PRESS

FIGURE 27 - HEAT PRESS

FIGURE 29 - DESKTOP INJECTION MOLDER

A bit about 3D printing

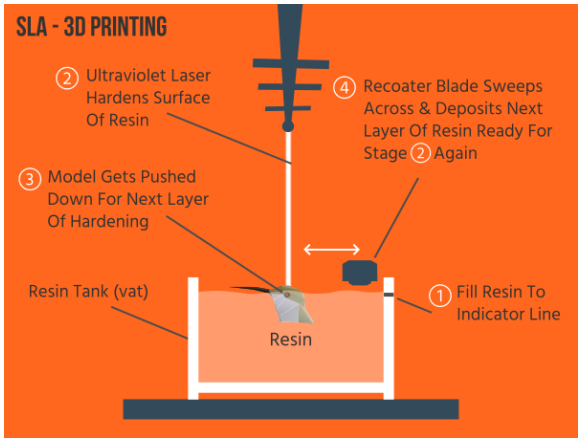


FIGURE 31 -SLA PRINTING METHOD

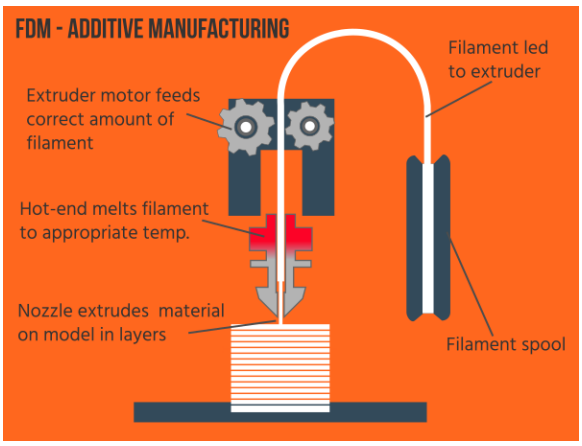


FIGURE 30 - FDM PRINTING METHOD

The most affordable and hassle-free method of 3D printing is Fused Deposition Modeling (FDM), which is some motors essentially tracing a picture out of melted plastic through a small nozzle. These machines can be bought for as little as 100EUR.

Using an FDM printer will be the easiest process to manage and the cheapest method of starting. EUR1000 will get a reliable printer and filament can be bought for as little as EUR12 per kg.

SLA printing will provide very high-quality parts; however, the cost and extra processing time are cons. Desktop SLA printers start at EUR300 and resins cost 150-300 EUR per liter, rendering the process quite expensive for production scale.

3D printing is not suited for large scale manufacturing however, and will only be beneficial in prototyping and pilot testing type production sizes.

Outsourcing 3D Printing

Many companies such as Shapeways, Materialise and Sculpteo operate as manufacturers of 3D printed parts. These companies have a wide range of machines using different 3D methods and can produce high end parts which could be shipped to a customer. However, Imvula parts will cost more than EUR8 using these services and therefore not economical.

Injection Molding

Desktop injection molding machines can be purchased for less than 2000EUR and molds manufactured for 200-500EUR, achieving maximum production rates of around 50 units/hour. However, these can only manufacture small parts and are best suited to prototyping or low scale production. The advantage of a desktop injection molder is that it can be purchased for less than the cost of a mold for a large machine, and allows changes to part designs at many times cheaper than large scale injection molds. However, it remains questionable whether using such a machine would offer any value in comparison to 3D printing.

Large scale injection molding machines can achieve incredibly high rates. Plastic bottle caps as an example can be produced at the rate of thousands per hour, and can produce very efficient economies of scale. However, this process requires the outsourcing of production. Comparing multiple quotations from reputed high-end Injection Molding companies such as ProtoLabs and Xometry as well as the low-cost options manufactured in China, a mold similar in size and complexity to the Imvula closure would cost in the region of 2,000-6,000EUR.

In attending a presentation by the CEO of a company which manufactures products in Germany, it was mentioned that German Injection Molding manufacturers can often be cheaper and of superior quality to what one might find in China. This is due to the high level of automation in the process and the fact many of the world's biggest Injection Molding Machinery manufacturers such as Arburg, are German.

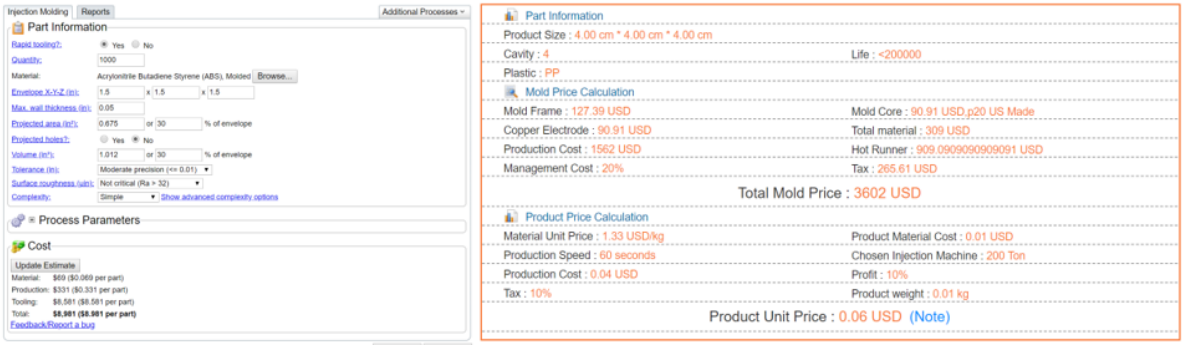


FIGURE 32 - QUOTATIONS RECEIVED FOR AN IMVULA PART

Urethane Mold Casting:

3D printed molds can be SLA printed to generate high precision pieces. These can be used for injection molding on desktop injection molders or used for casting hard setting resins such as urethane. These allow superior finish, consistency and material properties to 3D printing. A vacuum chamber is required for degassing the mold, costing 200-300 EUR. Resins are affordable and one could produce 100 Imvula closures for approximately 100EUR. However, this process is more complicated and expensive than simply 3D printing, and therefore will not be pursued.

FIGURE 33 - MOLD CASTING AND A DEGASSING MACHINE

OBSTACLES MOVING FORWARD

The biggest product development obstacles are listed below:

Market Validation

The product is at the point where people could indicate whether they see value in it or would buy it. Without validated interest in the Imvula product, it would be too risky to spend on developing and manufacturing the product.

A good pump

Out of the 10 different pumps purchased and tested, none were good enough for the job. Either a new pump needs to be developed or effective modifications need to be designed for existing pumps to ensure high pressures and prevent leakage in the system. Considering that an effective pump is an expectation of the customer, without a pump that is highly resilient to use, this idea may not be worth pursuing. A good pump is priority number one.

A good Shower Head

The shower head remains incredibly basic and under designed. Using phenomenon such as the Venturri effect and atomization, the experience can be enhanced. Whilst shower heads using the Venturri effect usually consist of multiple parts to assemble the final product, it may be possible to create such a shower head from a single 3D printed model.

A flow control valve and different flow rate settings needs to be explored.

A hook or way of securing the shower head and the ease of control of the spray direction needs to be explored, but this can likely be achieved with a ball and socket joint.

Team and Co-Founders

At this point, this project could seriously benefit from additional input and expertise, especially regarding product design. Without help, this project will not see significant improvement.

- Industrial / Product Designer
- Graphic Designer - Logo Design, Branding, Brochures, Packaging, Reports, Pitch Deck
- Marketing Guru
- Opportunity Scout - Identify New Leads for manufacturing, new customers, funding opportunities etc.

PLAN MOVING FORWARD

The intensity will lower after the completion of this paper, but a gradual prototyping will continue.

An experienced industrial designer will be sought. If it is possible to find co-founders, the likely development path would take approximately 6-12 months, roughly following the below schedule:

- Product Development: 3-6 Months
- User Testing and Expert Advice: 1-3 Months
- Design and Branding: 1-Month
- Website and Establishment: 1-Month
- Pitch deck and Videos: 1-Month
- Launch B2B drive: 1 Month

CONCLUSIONS

The problem statement for this paper asked “Can a product and business be developed to provide people with off-grid water pressure? “.

The results of the work undertaken indicate that yes, a product can be developed, however, there remains some uncertainty as to whether a sustainable business can be built from this product. Customers need to be engaged and pilot tests need to be undertaken to assess whether this solution adds value.

Because of the increasing effects of Global Water Scarcity, the market for Imvula is growing and even if was found that there is no immediate need for the product, it is worth developing considering water trends.

Imvula will not be able to provide people with long term water treatment, and should initially focus on the micro-shower. It remains to be seen how effectively these filters will work long term, as fouling and clogging may occur quickly due to using dirty water with many dissolved solids, resulting in the system being a gimmick which worked a few times but becomes a hassle and effectively useless by the user.

Recirculation and the splash-board appear to be ways to truly differentiate Imvula and bring something fresh to the market.

The business is feasible to operate with light manufacturing and assembly being an achievable method should fund for contract manufacturing not be available.

Pursuing this business remains low risk, with low costs and high potential rewards if achieving high sales numbers. However, regardless of the potential, at least EUR2,000 will be required to complete prototyping, user testing and pilot studies before starting to scale manufacture.

As it is such a simple business and concept and product, it is easy for someone to replicate. Should a business with significant resources become interested in pursuing this idea, Imvula could easily be drowned by new competition.

REFLECTIONS

As reflections vary in their subject matter, they are noted below as simple anecdotes:

Developing a business is just as much about making decisions as it is about coming up with ideas, and the decision making is often the most difficult part of the process.

Unfortunately, while not all mentioned, this project has concluded with more unanswered questions than it started with.”

To some extent I avoided dealing with customers too much as I did not want to show an incomplete product. The desire to have everything perfect to show the user is counter intuitive to creating a product which they want.

The time constraints of the semester prevented many important and interesting areas of business development from being considered. Four months is simply not enough time to develop a sustainable business able to stand up to intense scrutiny, especially when basing

this off an invention. Whilst this short period was a great motivator to push and see how far things could be taken in a defined space of time, it resulted in things spreading widely, but not necessarily deeply enough and much needs to be done before it could be presented as a final concept. This project would have been excellently suited to a one-year time span.

It would have been better to follow a Kano type model to develop the project from the start as it appears to be very interesting and informative. It would have also forced earlier customer engagement.

This project was quite a challenge for me. Not being familiar with product development and Industrial Design, much was new, and much was probably done the wrong or long way. This kind of project is normally done in a team, and considering my skills and background, I would not normally be tasked with the design of the product. It was decided in discussion with my supervisor that I should try do this alone, however, I imagine the product would be much further along if an Industrial Designer was focused on the product, and me on the business. Although doing this alone forced me to learn new things, it is time for someone to join.

It appears I am more interested in product development than business development. I really had to fight myself to stop working on prototyping and focus on the business components of this product.
Despite trying, a disciplined project management approach does not help me too much as I seem to constantly find new things to focus on.
There is an argument to focusing all the time and energy on finding customers, and simply outsourcing all manufacturing to the point of this being a drop shipping company. However, a personal interest in manufacturing steers to the direction of being a manufacturer. Whether this is the best business decision remains to be seen, but it does beg the question of when it is appropriate to make decisions on your business model based on your feelings and what you want the business to be rather than modeling and analytics. Does every business decision have to be based on which is most profitable or simplest, or can some decisions be made because that is what you want to do, even though it won't be as profitable and will require more effort?

I am not sure how much people could actually learn from this work, but believe that this could be an effective departure point for a product and business developer to pursue. However, I believe this paper gives significant insights into the thinking and methodologies of product and business development, and thus contributes to the knowledge field.

The drawing point to undertaking an MSc in Entrepreneurial Engineering at the University of Aalborg was the tag line of "learning how to bring ideas into reality, from thought to action". Whilst much of the content dealt with business and idea generation, one field remained unattended, that being rapid prototyping. I desired to develop the skillset required to build functioning prototypes of ideas for physical products. I therefore endeavored to focus my time and learning on how to make good prototypes. Unfortunately, I have not had a formal education in this so learning was somewhat slower as I had to find my way to solutions which may have been obvious to those "familiar-in-the-art". I now feel quite confident that, given the resources, I could develop someone's idea into reality, and thus have achieved my objective in pursuing this degree.

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Appendix 1 – Global Water Shortage Facts and Figures

Key Water + Sanitation Facts | for use in 2018

- 844 million people — 1 in 9 — lack access to water.
- 2.3 billion people — 1 in 3 — lack access to a toilet.
- Almost 6x the population of the United States lives without a household water connection.
- More people have a mobile phone than a toilet.
- Every 90 seconds a child dies from a water-related disease.
- Diarrhea is one of the top 3 leading cause of child death, a majority of which are water-related.
- Water, sanitation and hygiene-related disease kills nearly 1 million people each year.
- Women and children bear the primary responsibility for water collection.
- Women and children spend 258 million hours every day collecting water. This is time spent not working, caring for family members or attending school.
- Women and girls spend up to 6 hours every day collecting water.
- Women and girls living without a toilet spend 266 million hours every day finding a place to go.
- Reductions in time spent collecting water increase school attendance.
- Globally, 1/3 of all schools lack access to basic water and sanitation.
- Involving women can make water projects 6 to 7 times more effective.
- Every $1 invested in water and sanitation provides a $4 economic return.
- Every $1 invested in water and sanitation provides a $5 return in health benefits.
- $260 billion is lost globally each year due to lack of basic water and sanitation.
- Universal access to basic water and sanitation would result in $32 billion in economic benefits each year from reductions in health care costs and increased productivity from reduced illness.
- Annual aid for water and sanitation amounts to only US $8 billion – far short of the $1 trillion needed to solve this crisis and maintain access long term.
- Access to credit plays a significant role in triggering household sanitation investments, increasing health and providing families the dignity of a toilet.
- The water crisis is the #1 global risk based on impact to society as a measure of devastation, announced by the World Economic Forum in January 2015.

(Water.org, 2018)

See Also:

https://www.csreurope.org/sites/default/files/FS_WP_Sustainable%20Development%20Goals_05112017_RD_0.pdf

The Sustainable Development Goals (SDGs): The Value for Europe A Whitepaper by Frost & Sullivan and GlobeScan on behalf of CSR Europe

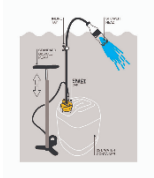
https://washdata.org/sites/default/files/documents/reports/2018-01/JMP-2017-report-final.pdf

Wash SDG assessment

Appendix 2 – Existing Systems

Existing Systems:

Below is a list of the water efficiency shower systems currently available. Not all are sold in South Africa, but those that are being sold are done so at very high profit margins. These different devices were looked into for inspiration, design guidance and comparing features to search for some blue ocean opportunities for a new system.

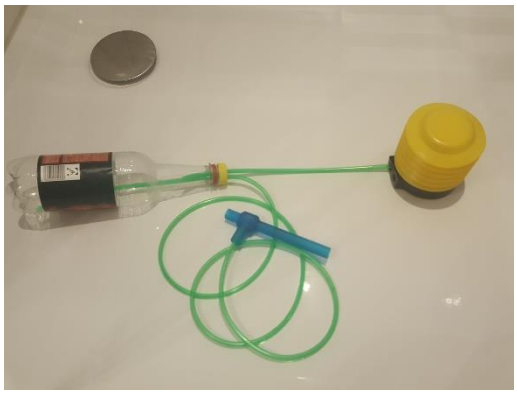
System	Features	Pros	Cons	Cost $
Pump and Spray 	Self powered off the grid shower Water bottle connection Foot Pump Pipes Shower Head	Simple Easy to manufacture Cheap Fair pressure	Bad shower head Looks cheap No reuse	28 Parts can be bought from Alibaba for $2
Garden Spray 	Self powered off the grid shower Using a garden sprayer	All in one system Can be used for garden Can get high pressures Good spray nozzle	Bad user experience Only one size of water No reuse	20
Ekasi Water Cap  	Propriety cap which fits onto a 25l bottle and is pressurised by a bicycle pump	Cheap Simple Small	Could be more simple Bad user experience Only for 25l bottles No reuse	-
Aerator Nozzles 	Nozzles fitted onto tap heads to add air and reduce flow rate, increasing efficiency	Fairly easy to install Easily available Long term solution Static/Passive solution (the user does not have to do anything more after installing the nozzles)	Can be overpriced Only fits to taps No reuse	1-20
Water Saving Kits 	Propriety kit with different devices to install around the house Tap Aerators Efficiency Shower Heads Cistern Block etc.	Covers multiple parts of water useage	Difficult to install More of an investment	-
Shower Collector 	Water containers channel and recollect shower water to be used for watering plants	Covers the base Easy to install Effective reuese	Not so easy to use? Does not affect useage	

Portable Electric Shower 	Submersible pump and shower head can be placed in a bucket. Can be rechargeable battery	Simple to use Highly portable	Overpriced Bad shower head	15-50 Alibaba - 7
Camping Shower 	Gravity driven shower using solar heat for warmth	Cheap and Easy Portable	Requires somewhere to hang Bad shower head	10 Alibaba = 2
Pressure Camping Shower 	Pressurised by foam foot pump and placed in sun for heat	Nice Pressure Easy to store	Overpriced Cannot lift thewater for more water head Shower head?	50-150 Alibaba = 12
Shower Loop 	A special full shower system installed in ones home	Full reuse and filtration	Expensive Extensive work Too specialised	1000+

Appendix 3 – 1st Prototype

New System:

A proposed system works in a similar way to the Pump ‘n Spray and Nemo Helios camping shower shown above, but is differentiated by water reuse to make a closed loop, water filtration and a finer misting spray nozzle to slow the litres per minute.



How does it Work:

1. Water is filled into a bottle
2. The bottle is connected to the cap
3. Air is pumped through footpump into bottle, creating pressure and displacing water through the spray nozzle

4. A plug can be fitted to capture the water which can be connected to the pump to circulate the water back into the system

5. Multiple bottles can be fitted in series to include filtration, water treatment or even aromatherapy modules

Appendix 4 – Components Elaborated

Pump

The pump has proven itself to be the most important and most difficult component of the system. The pump adds utility to the system, by generating pressure and needs to be highly reliable and effective. However, a highly reliable, foot pump suited to this purpose remains to be found, with even the best having leaks and weaknesses.

The foam pump concept illustrated by Nemo's Helios Shower is preferred however, it has not been possible to get a manufacturer to sell just the pumps. This therefore would require increased complexity and the pump would need to be designed and a manufactured by experts. Manufacturers of Inflatable Boats, Jumping Castles, Waterproof Clothing and Apparel and Tents are some examples are manufacturers who could be approached to manufacture this. However, engaging with a contract manufacturer will require substantial initial costs and would be risky, relying on large production numbers to make a profit. Whilst some manufacturers were approached, no strong leads have developed, mainly since the design remains incomplete.

It appears unlikely that I will be able to develop a good enough pump, and therefore would need to engage with contract manufacturers, or a product development service to take things further.

The plastic bellows pump is very cheap option but it has proven very cheap and unreliable. More attempts will be made to get these to work.

It is likely that without a best in class pump, the entire concept will not work and this needs to be the focus taking this idea forward.

All pumps were shown to be much more powerful in outflow, as the suction due to the internal spring mechanism is very weak. The pump needs be used in this way, rather than trying to make the suction better, flow can be manipulated just with outflow pressure to move the water around, and recirculate it.

Tubing

PVC tubing has been the material of choice thus far due to easy accessibility from hardware stores and pet shops. It was found that thick tubing tended to act rigidly, affecting the stability and ease of movement in the system. Additionally, considering that objective of keeping the system as small and cost effective as possible, efforts were made to make the tubing diameter as to a minimal whilst ensuring appropriate pressure and flow rates could be built up. However, smaller diameter tubes result in lower pressures so this needs to be finely balanced.

Tubing with a 4mm internal diameter was sufficient for the system. Better materials including PP and silicone straws and tubing with section thicknesses of 0.2-0.5 mm exist, further reducing the volume of the product. These will be incorporated into further iterations.

Filter

When considering efficacy in removing water contaminants, the most effective, readily available solution stands out as the portable microfiltration device.

These filters are becoming increasingly cost effective, while they are prone to shortcomings including limited shelf life and filtration capacity, they stand as the most obvious solution when trying to remove contaminants from the water.

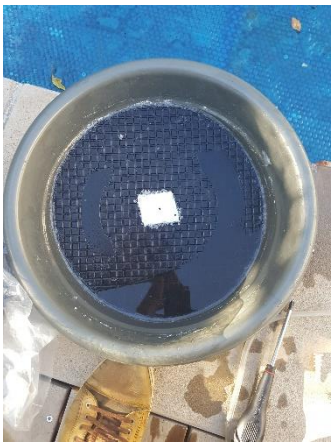
Recollector

If people intend on reusing their water, a recollector acts as a wide basin to prevent spillage and allow reuse. The thinking behind this device was mainly driven by findings from a focus group which indicated that people in informal settlements use buckets as their shower and bath. 3 Recollectors were prototyped.

Bucket Recollector

Attempts were made to develop a bucket type pressuriseable recollecter. Whilst this was an interesting concept, it was too much of a spin-off from the original concept.





Inflatable Recollector

Could be compact in storage and create interesting experiences but would be susceptible to punctures.

An inflatable baby bath was purchased as an example to test.




Foam Collector

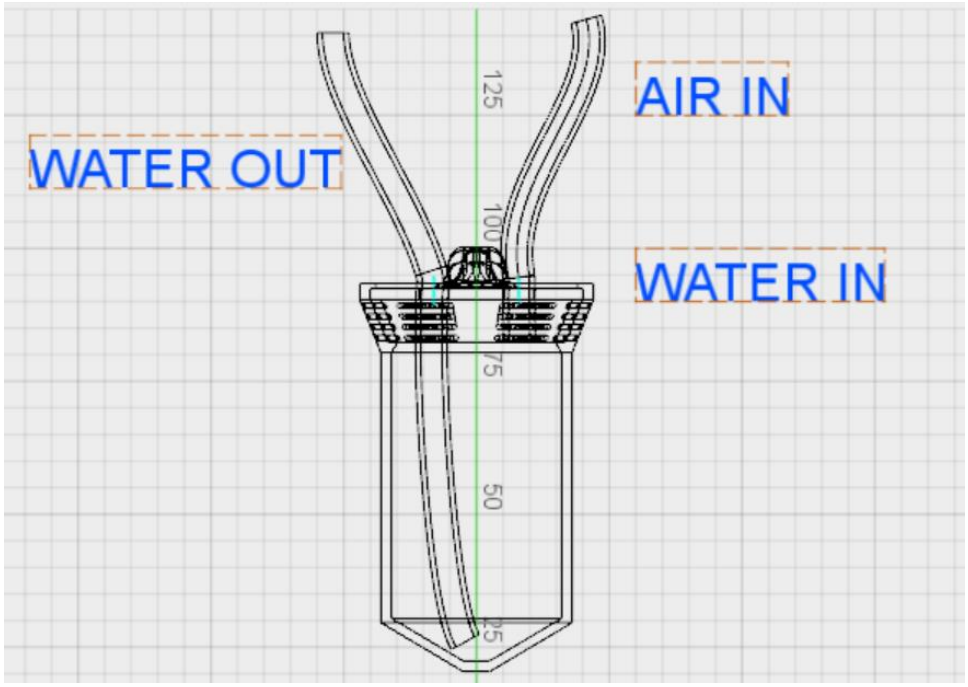
A simple circular cutout of foam covered in a pvc coating to direct water into the lowest point. Can be easily manufactured and a concept was developed as can be seen in the figures above.




Recirulation

The recirculator is an integral part of the system and what turns the flow line into a complete loop.
Design of this component remains largely unattended to as the functioning relies on a well working pump. In introducing dirty water to the system, the recirculator acts as a pre-filter, preventing large particles and hair from being pumped.
It needs to have a well-designed lowest point from which water and air are suctioned into the pump to ensure that the least water is wasted.
By setting it a bit above the bottom of the shower, sand and matter can settle acting as another means of filtration.
The suction tube needs to be large enough to ensure an effective flow rate considering that the pump re-inflates slower with smaller tubes.
The tube needs to be flexible enough that it does not transfer forces between the pump and reciurculator when being used.
It needs to by weighty as it was found that the foot pump naturally moves a bit which in turn pushes the plug around in the shower.
If used in a basin, the recirculator could also help with grey water recollection as a natural siphon would be created after one or two pumps, allowing gravity to drive the water into a container below the sink.

A concept for a recirculator which fits into a standard basin was designed and illustrated below.



Enclosure

The purpose of an enclosure is to contain the splashing water, to help with reticulation, to provide privacy and to point from which to hang the shower head. This provides a full shower experience. The shower experience could be enhanced by leading the water lines up the tent structure to have 360-degree horizontal spray.

Existing shower enclosures use solid steel poles which are hefty but solid.

Self-erecting pop-up tents are affordable and can serve the purpose. They are compact and lightweight and designed to be folded into 10-centimeter discs approximately half a meter in diameter. However, because they are so light they can be flimsy and are susceptible to moving/toppling in the wind when erected.

Inflatable structures have been developed, but are not marketed in the portable shower market. These could be more lightweight and compact than a pop-up shower tent, and could be inflated by the foot-pump. With time, this could be developed to the point of the user erecting the structure around them as they pump. The air pressure of the structure could be used to pressurize the water. However, an inflatable structure is of course susceptible to

punctures. The structure would also likely require a considerable amount of pumping to fully inflate and may become tedious to the user. Flimsiness would also be an issue as it may easily blow over.

Regardless, it will be possible to develop a basic prototype of this concept through basic materials such as PVC piping and tubing, costing less than EUR50, and this idea will be experimented with once the foot-pump is good enough.

Water Bottle

The water can add extra value to the customer. From stainless steel to incorporated water filters, to foldable bottles.
After investigating the price and potential of various options, it was decided that the basic foldable water bottle which comes with most portable filters will be adequate.
The intention for the most part of this design is to get people to use existing water bottles. However, there is concern that these could leach chemicals into the water if old. A clear weakness in using smaller volume water bottles is that pressure can build and dissipate far quicker in smaller and stiffer vessels. This means that bottles of smaller 1.5 liters in volume require constant pumping to get a constant shower stream whereas bigger and more flexible vessels can store more pressurized air, and thus do not require continual pumping.

Stainless steel for $5
Aluminium vaccum flask for $1-2 with custom printing
Foldable silicone bottles - $1-2
With water filter - $1.75
2.7l Nice finish - $5

Packaging

Packaging ties the product together. Initially this will be kept as cheap as possible using simple cardboard or plastic film packaging.
Worth considering is the fact that there is likely to be some residual water on the product when packing it away after use. Packaging made of cardboard or paper is likely to be damaged by water ingress and it is thus better to use a plastic.

Packhelp allows one to design and purchase small numbers of custom printed packaging, to full scale production of packaging. To get a high quality prototyped packaging Packhelp services will be used. It is assssumed based on their online price generator that packaging EUR2 per item for 30 pieces.

Unexplored Possibilities

a. Shower Board
b. Vortexs
c. Filtration
d. Aromatherapy
e. Chemical Treatment
f. Electronic Version
g. UV
h. Manufacturing Aids
i. Modular Workshops
j. Mobile Worskhops
k. Recycling

Appendix 5 – Making a new pump

The Pump

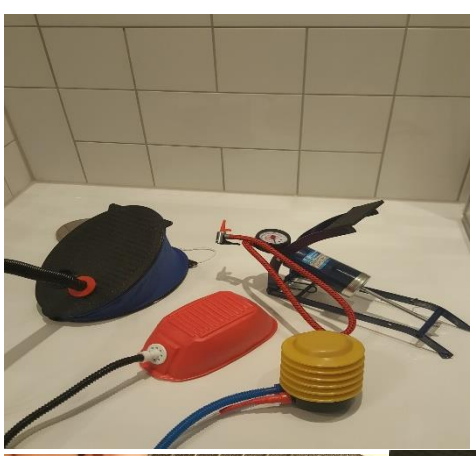
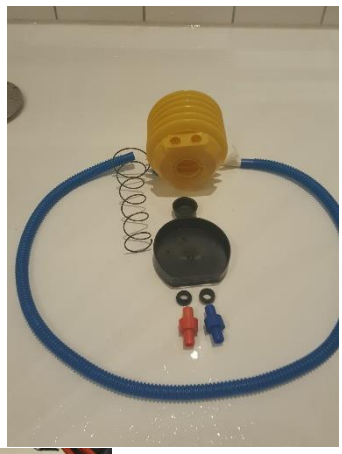
The pump has much room for innovation. It was decided to use a foot pump rather than a hand pump as it frees up the users hands. The following pumps are the cheapest options available on the market and were purchased and tested to compare their design functions and efficiency.

	Cost $	Pros	Cons
Plastic Bellows Pump 	5	Cheapest. Achieved Highest Pressure. Simple manufacture and assembly. Can get in all colours	Quality varies between manufacturer (2nd pump was bad)
Fabric Bellows 	12	Large volume	Too big Inconvenient movement
Bag Pump 	7	Small	Bad pressure Leaks quickly Pressure energy lost due to elasticity of material
Piston Pump 	15	Pressure Gauge Bicycle fiting	Too many moving parts Does not get very high pressure Metal and will rust Poor quality construction Too big
Foam Pump 	35	Simple Construction Effective pressure Uses reticulated open cell foam as a spring	Too small? Not easily available

Testing Existing Pumps

Existing foot pumps are cheap and easily available. The different kinds were purachased and tested to see which is best suited.

The plastic bellows pump had superior performance and given its low cost was selected as the best option. Manufacturers were contacted in China and these can be bought for as little as $0.5 and can be made any numerous colour options, including all white.


The above images indicate the pumps tested and taken apart to see how they work etc.

It was not possible to test the nemoid foam pump as they are not sold without the entire shower system but remained an interesting concept to look into. Reticulated open cell foam of two different densities (10PPI and 30PPI) was thus purchased to test.

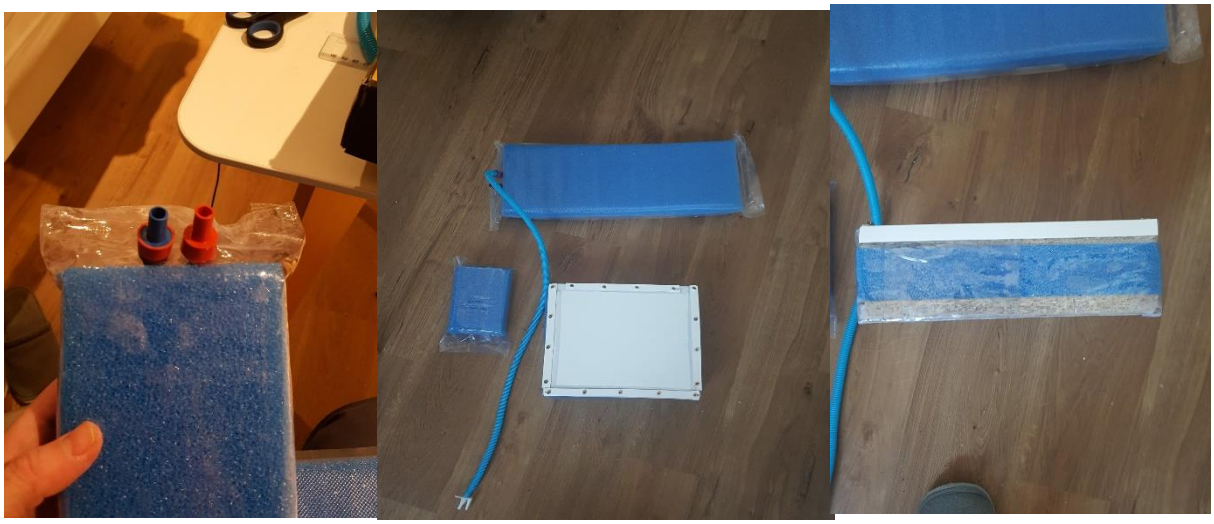
The advantage of using this foam is as follows:

1. It can be easily cut to size and stacked, thus changing the spring action as well as the size of the pump.
2. It can be used for water filtration

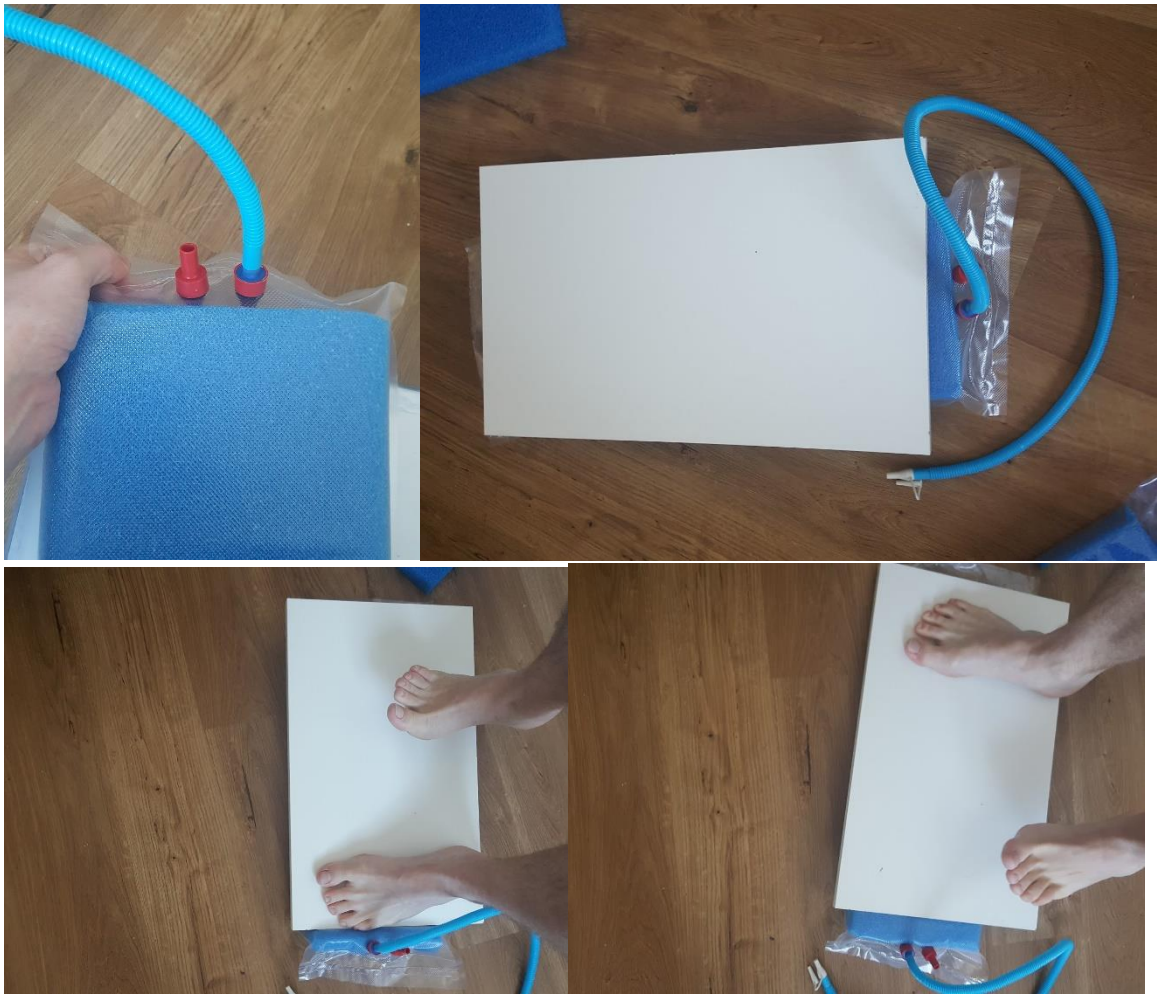
Developing a new pump

Time was spent in the shower, thinking about how one moves around and trying to use a foot pump to get water. A small foot pump is more convenient than a hand pump but the user is still required to stop what they are doing to some extent and aim their foot on the small pump. It was then realised that there is somewhat of a natural swaying and moving that occurs when showering. Could this movement not be used to create pressure? How far can we take this? Can it be an exercise device? Can it be a fun sport? Could one ride the pump like a surfboard, simply shifting their centre of gravity to induce pressure?

After creating various smaller prototypes and getting an understanding of how easy it is to seal and join parts together, an effective pump was developed by heat sealing a piece of foam with in inlet and outlet valve into a plastic sleeve used for food packaging.



The above picture indicates first attempts at making a foam pump. It was observed that if using a stiff platform to push down on, far less foam is required to induce pressure and.

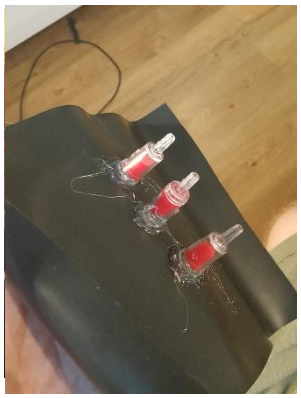


The above figures illustrate the idea of a pump board which creates air pressure by shiting ones weight from left to right.



The above picture illustrates the idea of a 500mmx500mm piece of foam which if sealed with check valves, compresses and creates air pressure by stepping on it.

Below are examples of pump concept tested over this project.












Appendix 6 – Making a new connection and head

Developing the Shower Head

A fine mist will be the most water efficient type of spray. However, this requires significant and consistent pressure.

Interesting concepts to test included

Venturri valves - Some parts were 3D printed by the noice induced was too loud and the lack of high pressure deemed venturri valves not possible

Vortex Valves - Yet to be tested but may be able to create high turbulance or implosion which will be interesting.

Spray Nozzles - Spray nozzle design is somewhat straightforward.

The idea of the shower head would be to make it small (the size of a pen) with 3 or 4 well engineered orifices to spray the water.



Above are some examples of parts which have been 3D printed to test the efficacy. These parts were simple downloaded from thingiverse.com

Developing the Connections

The simplest connection is 2 holes. However, sealing rings will be required for higher pressures. Thus far, the wholes in the top of PET bottles have proven to seal surprisingly well, however, barbed outlets may be required. The below images illustrate some closures designed.










Appendix 7 - Product Problems

Requires people to change a lot of their behaviours? It is not the easiest option.

Two lids as a concept is nice but spray doesnt come out well from the top.
The pipes are still too thick
The pump is too light
The valve should point upwards
Still some air leackages
Will the pipe come out? Is a protruding barb required?
The spring in the bellows pump is not strong enough to recollect water and/or vacuum
The bellows pump can rust
The foam pump can punture
Tubing thickness and material can be changed for more flexibilty
Thread can be optimised
Size can be reduced
Patterns/Aesthetic

It is difficult to pour water into the bottle without spilling, wider mouth required.

Difficult to hold the shower head in place.

There may be a reason people don’t make foot pump filters. Not as easy etc.

Appendix 8 – Amazon Review

*1.0 out of 5 stars*Fantastic Idea but Poor Design Execution for this Generation -- Can't wait to see how they fix it!
ByM. Schwartzon October 7, 2017
Color: Black/Apple GreenVerified Purchase
First my credentials to write this review. I'm a 30 year old biomedical engineer with about 8 years of design experience for plastic injected molded parts, adhesives for plastics creating chemical bonds, designing of tubing and cabling, waterproofing electronic parts and creating water tight seals.

The good: This was a fantastic idea and worked amazingly well for about 4 uses.
The bad: The adhesive seal near the fill port failed to the point there the product failed to work anymore. There are some important design flaws that need to be addressed in the next design iteration or gen 2 or 3 of this product.

1) The adhesive seal that I'm talking about perhaps needs more overlap on seal surface, use of different materials or adhesive to properly chemically bond the two plastics. The use of a mechanical seal would be ideal for this as this product has constant pressure and temperature changes against the seal.

2) “There needs to be some sort of strain relief on the water tubing as it comes out of the water container. This tubing kinks as you move the shower head around. “

3) A shoulder strap for transport the 50lbs of water that you'll be filling this up with.

4) The base of the unit needs to be reinforced somebody to hold up 50lbs of weight on a consistent basis.

5) Some sort of plastic handle should be placed in the center of the handle strap for easier weight distribution in the handle.

Again, this is a great product idea, but lacks in proper design principles that make this generation of the product great for a few uses, but will not last. Even if this lasts for a few months or a year, these bonds will eventually fail rendering the product unusable.

Appendix 9 – Water Filtration

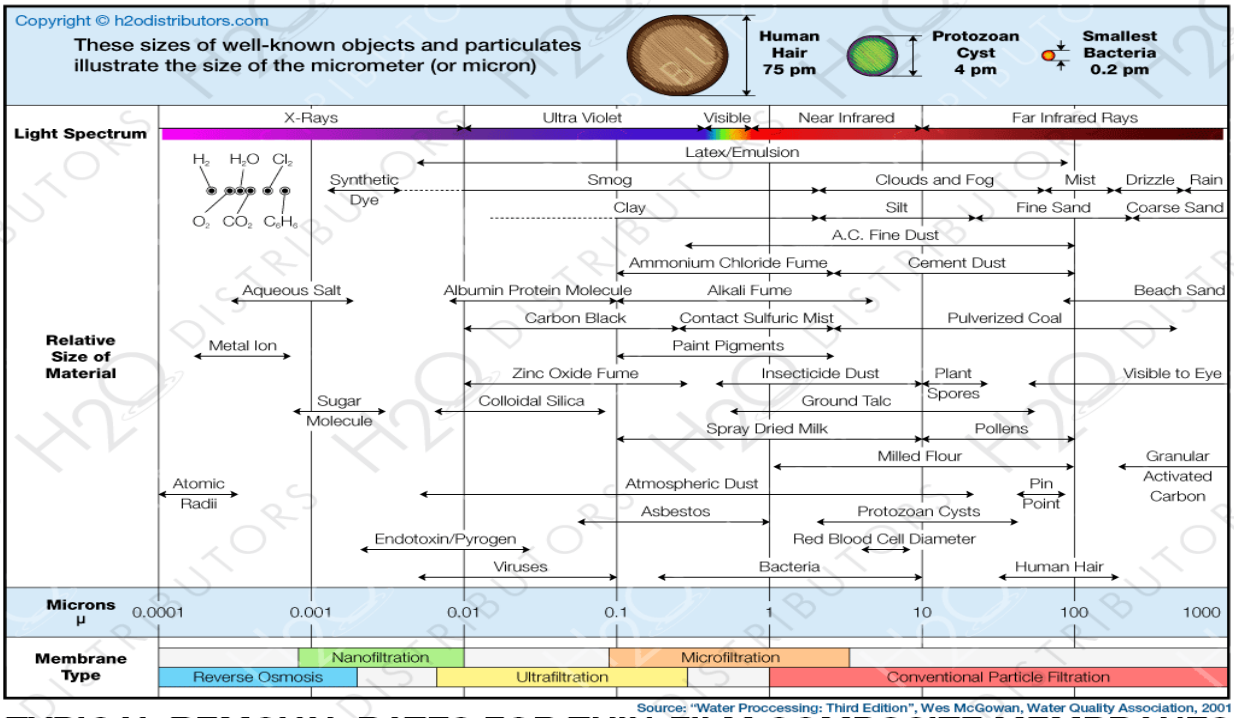
Filtration

Boiling water is the most effective means of treatment – But uses coal and takes time.

HHWT brings water treatment closer to the end user. While this limits the opportunities for recontamination, it also places the burden of water treatment on vulnerable individuals. http://www.elrha.org/wp-content/uploads/2016/01/Water-Treatment-WASH-Problem-Exploration-Report.pdf

The idea behind water treatment is to remove all the unwanted particles in a water source. Filtration works by screening out particles which are bigger than a certain filters pore size. Therefore, if a filter has maximum pores of 0.1 micro meters, then no particles bigger than this will be found in the effluent. The diagram below illustrates the pore sizes and what conventional filtration methods can remove from water.

As can be seen, portable ultrafiltration filters still leave some metal ions, viruses and salt in the water. This means that they are not able to deal with all water contaminants but are essentially the most effective readily available consumer product, given that nanofiltration remains expensive and not heavily used in consumer products.



At this stage, the simplest way to move forward is to buy filters from another manufacturer. Manufacturing our own filters would require large initial capital expenditure for machines and space, extensive R&D, employing experts and big investment just to be able to start trying to develop a prototype for a new filter which is more effective than what is currently on the market

and so considering new filter development is not on the horizon until our products are selling well and there is clear need for something better.

The range of technologies for water treatment vary from simply leaving water to settle in the sun, to enormous desalination plants boiling and purifying water.

A solution was sought, considering the following attributes to be the most important:

- Efficacy – What can be effectively removed with the filter
- Size – The smaller the better, as compact as possible, easier for the user to carry and easier to ship if smaller.
- Cost – Of filter and replacement components
- Lifespan – How long can these operate without maintenance or breakage
- Flow Rate and Pressure Drop– How fast can the water flow and water pressure can be built up on the output side of the filter

The stand out solution came to be the compact mini water filtration straws popularized by Sawyer and LifeStraw. These are very simple devices, able to filter out most harmful bacteria, viruses and water contaminants. These offer better filtration then some much larger water filters and can last in the region of a few hundred to a few thousand liters per filter.

UF membranes are prone to fouling and depending on the turbidity of the water can have a range of lifespans. However, they are often used for emergency response, and for numerous humanitarian initiatives aimed at giving people access to improved water sources.

These filters do not filter everything but can prevent many viruses.

They can be purchased from Chinese manufacturers for approximately $5 per unit with a minimum order of 500 units and sell on Amazon for approximately $20.

Water Filtration Competitors

Judging by the way these products are marketed by competitors, it appears customers are heavily concerned with the numbers and specifications of their filters, and Imvula would have to stand up to such scrutiny. Therefore, there wouldn't be much point in investing in the marketing of these devices to the outdoor market unless.

This is a saturated market with a lot of big and small players.

Lifestraw - "We make contaminated water safe to drink."- LifeStraw

1. Sawyer - $50,000 per month on Amazon
2. MSR
3. Cheap imitations

Most of the big players have a humanitarian angle, with initiatives which donate money for every purchase you make. From LifeStraws promise that when you buy a lifestraw you buy a child in Africa clean water for a year, to REI's Grab a product, Help a Park" pledge that 5% of your purchase will be donated to National Parks, most successful companies in these markets make a point of their social angle.

Expensive high quality materials are used and most products often contain soft touch plastics and overmolded parts, which are expensive to manufacture, especially at lower scale.

Most have a strong story, related to outdoor, adventure or change making.

Whilst they may offer variations and other differentiated products, the business model remains the same for most of these companies.

Existing Products Similar to Imvula Filtration

Interestingly, none of the leading companies use foot pumps to filter water. This is likely from user input and it is easier to hand pump than lay a foot pump on the floor etc. This begs the question of whether a filter should be added at all. Customers need to be engaged with to inform whether a foot pump is more of a hassle, but my immediate predictions are that they would prefer a system such as below.

PORTABLE WATER BOTTLE FILTERS:

PURITII VS. THE COMPETITION

Which bottle filter is the best? You be the judge!

PURITII BRITA CAMELBAK Water-to-Go LifeStraw ecoflo KATADYN

	Puritii	Brita	CamelBak	WaterToGo	LifeStraw	EcoFlo	Katadyn
Product Name	Filter/Bottle	Brita Bottle	Groove .5L	Go! Filter	LifeStraw Go	Flip Top	My Bottle
Made In	USA	Mexico	China	China	China	USA	Switzerland
Testing Standards	EPA, NSF 53 & 42	NSF 42	NSF 42	NSF 53 & 42	EPA	NSF 53 & 42	EPA
Technology	Electropositive Attraction, Carbon/Zeolite filtration	Carbon	Carbon	Nano Alumina, Electropositive Attraction	Hollow fiber Micro-filtration membrane	Ionic Adsorption, Micro-Filtration	Glass Fiber, Iodine, Carbon
Requires Backflushing	No	Yes	Yes	No	Yes	No	Yes
Bacteria Removal	>99.9999%	No	No	>99.9999%	99.9999%	99.1%	99.9999%
Virus Removal	99.95%	No	No	>99.9998%	No	No	99.99%
Parasite Removal	>99.997%	No	No	>99.99%	99.9%	99.9%	99.9%
Heavy Metals & Particulates Removal	Significantly reduced	Reduced	Reduced	Significantly reduced	No	Significantly reduced	Significantly reduced
Pharmaceutical & Pesticide Removal	Significantly reduced	Reduced	Reduced	Reduced	No	No	Reduced
VOC Removal	Significantly reduced	No	No	Significantly reduced	No	Significantly reduced	Significantly reduced
Inorganics Removal	Significantly reduced	No	No	Significantly reduced	Slightly reduced	Reduced	Significantly reduced
Filter Capacity	60 gallons	40 gallons	48 Gallons	34 Gallons	Not published	100 Gallons	26 Gallons

(Ariix, 2015)

Membrane Fouling

Fouling in hollow fiber membrane microfilters used for household water treatment Anna Murray, Mario Goeb, Barbara Stewart, Catherine Hopper, Jamin Peck, Carolyn Meub, Ayse Asatekin and Daniele Lantagne

Shortcomings of Point of Use Water Filters

Whilst UF membrane filters help in emergency situations, they are not feasible long-term solutions. These filters are prone to fouling, reduced flow rates, damages and lost parts. In a study undertaken on a Sawyer Products filter, it was found that after 2 years most filters were unusable. (Murray, 2015)

Murray, A., Goeb, M., Stewart, B., Hopper, C., Peck, J., & Meub, C. et al. (2015). Fouling in hollow fiber membrane microfilters used for household water treatment. *Journal of Water, Sanitation and Hygiene for Development* , *5* (2), 220-228. doi: 10.2166 / washdev.2015.206

Prototyping a filter

Two competitor filters were purchased and tested. The Sawyer mini was purchased based on it being a compact and having a fast flow rate with a long lifespan of 100,000 gallons of filtration. A cheap Chinese filter was also bought to compare the performance.

Observations:

Both have same components and are packaged with a straw, backwashing syringe and drinking caps.

Flow rate is higher with the Sawyer filter

The filters require a pre-filter to block sedimentation building up quickly.

It is not possible to build up sufficient pressure on the effluent side of the pump for more than 2 liters. A good pre-filter would be required. Due to the thin diameter of the tubing, sedimentation buildup will affect flow rate very quickly and so a fast flowing prefilter needs to trap as much particulate matter as possible from entering the system. This can be 3D printed.

Self-backwashing systems exist, such as the Village Pump 5000, but would require much more intricacy.





Appendix 10 – NGO and Foundation Contacts

The below list is a collection of potential contacts if wishing to tap into humanitarian and water aid foundations.

Partnerships / Foundations / NGO's
https://www.borderstep.de/foerdermittel-und-auftraggeber/ - Apply for funding from their partners
https://p4gpartnerships.org/#are-you-a-do-er - Partnerships - Funding, Facilitation, Recognition
https://simavi.org/ - WASH Programmes
http://aquaforall.org/about-us/innovation-tracks/# - Incubator and Assistance in water/sanitation
http://switzerland.masschallenge.org/ - Mass Challenge Accelerator
Nelisa.kente@tia.org.za
https://vc4a.com/
https://www.fundingconnection.co.za/funding-agencies-in-south-africa
https://sdg-investments.com/en/projects/project-overview/ - Danish SGD fund
https://impactalpha.com/the-accelerator-selection-tool/ - Accelerator database
http://pipelineh2o.org
http://www.climate-kic.org/programmes/entrepreneurship/accelerator/
Online Resources and Learning:
https://www.nonprofitready.org/course-categories?tid=24
https://www.disasterready.org/