A Meta-Analysis of Alternative Water Sources

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Senior Capstone Project
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Table of Contents

ABSTRACT

Roughly one half of the Earth's population suffers from shortage or lack of clean water. While many innovations and products have been created to address this Global Water Crisis, no comparisons have been done as to which innovations and products are the best overall choice for philanthropic investment. The crisis can be broken down into three specific crises including the transportation crisis, the access crisis, and the sanitation crisis. The study examined fifteen innovations and products, targeted to address the three crises to determine which innovation in each group is the overall smart investment. Pulse tool was used to create reports of data comparing the innovations and products to one another. Findings concluded that the Hippo Roller is the smart investment for transportation of water, the Treadle Pump is the smart investment for gaining access to water, and the Filtron and the Mobile MaxPure are the equally smart investments for sanitizing water. Therefore, for future development of social innovation comparison, it is recommended that an investor look at the overall benefits of an innovation before donating money to that cause.

INTRODUCTION

Nearly 3.5 billion people, or half the world's population, suffer from scarcity and/or contamination of fresh water. Roughly 1.2 billion people globally lack access to a sufficient water supply, which is defined by the United Nations as 20 liters per person, per day, at a maximum transportation distance of 1,000 meters (United Nations, 2011). This lack of access can be attributed to both the lack entirely of a sufficient water supply as well as the inability to transport it because of distance or terrain. Another 1.6 billion are faced with an economic water shortage; that is, they lack the necessary resources to take water from rivers, streams, or underground (United Nations, 2011). In addition, water use is growing at double the rate of population growth, which causes increasing scarcity. Some experts refer to water as the new oil, stating that it is increasingly difficult to gain access to and very expensive to transport to areas that need it most. By referring to water as new oil, experts could potentially be foreshadowing potential political conflicts over access to water. Some issues revolving around the global water scarcity crisis include not only getting access to a water source but also the quality of water, portability of water, and the costs associated with getting access, sanitation, and transportation.

Many organizations, including government organizations, not-for-profit organizations, investors, and social entrepreneurs have looked and continue to look for alternative ways to ensure that those in need are receiving clean and drinkable water. An alternative way is necessary for many people to get water, as the mainstream way includes polluted, disease-filled water and insufficient amounts of the resource. Many of these organizations have developed innovations, products and programs that have the potential to be highly effective in solving water accessibility, sanitation, and transportation problems. They all have the same purpose and goal of providing water for all those that have no access to it, yet are competing against each other for investors' and donors' attention. Some innovations and products that purify, transport, and/or sanitize water are much more expensive than others; some reach more people than others; some have a longer lifespan; some require more education to use and maintain than others, etc. So how does a donor choose which innovation is best to support? Current research, such as that from the United Nations and water.org, explains the extent of

the problem and the importance of the innovations and products and programs to combat the water crisis, but there is no expert or scholarly study that tells us which one is best or most successful. With so many different solutions to water problems, it is difficult to determine which option is the best choice for investment.

While everyone has the best intentions, it makes more sense logically to have fewer, successful solutions with a lot of investors than scattered investors with solutions that are not as effective. By working together toward this common good, the World Water Crisis could see its demise a lot sooner than expected.

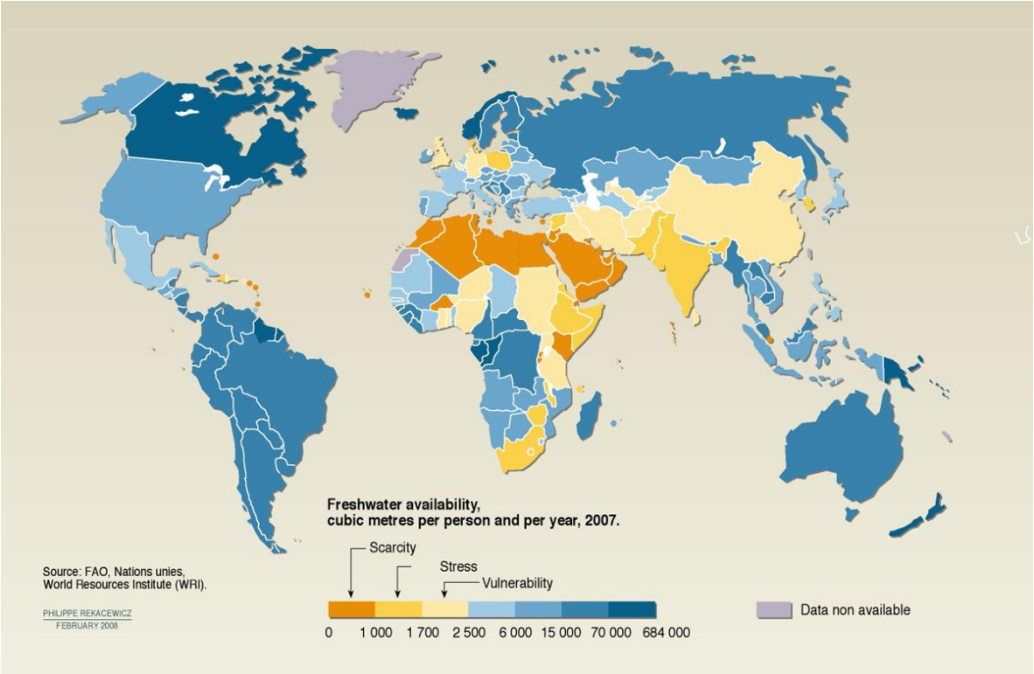
By analyzing a series of factors, including cost, upkeep, amount of water produced, and number of people able to receive clean water, an educated decision can be made as to which innovations and products should be invested in, in order to get clean water to the greatest number of people in the most efficient, safe, and cost effective way possible.

LITERATURE REVIEW

A lot of research has been done to determine the severity of the global issue of water supply and sanitation, specifically in developing nations. In addition, many solutions have been attempted and successful in increasing access to safe drinking water; however, these solutions have done so on a small scale in comparison to the global problem. While many of the innovations, products, campaigns, and resources that have been used have posted results about how effective they are and how much they have achieved, over 50% of all water projects fail within the first three to five years (Water Facts, 2010). In addition, there is no document that compares each of the solutions that have been proven effective and nowhere has formal research been done that suggests which innovation is the best choice to invest in to make significant improvement in solving the problem in the most efficient and cost effective ways possible. In the following sections, the current state of the global water supply and crisis will be explained and various innovations and products used to combat the crisis will be described.

The Global Water Supply

Roughly 4.5 trillion cubic meters of water are used per day globally, 14% of which is for domestic uses (cooking, cleaning, drinking, washing clothes). Roughly 70% is used for agriculture and the rest for commercial purposes (United Nations, 2011). As the global water use rate is growing at twice the pace of the rate of global population increase, scarcity and shortage continuously increase as well. By 2030, it is estimated that the global population will use 40% more water than the amount of accessible clean water on Earth (*Solving the Global Water Crisis*, 2012). The water will be consumed for both domestic and agricultural/commercial use. In addition, an unequal distribution of water resources globally makes shortages and scarcity that much more serious. There is enough freshwater on Earth for six billion people, but because of the unequal distribution a lot of this is wasted or polluted and therefore 3.5 billion people are still without enough water to live on (United Nations, 2011). For example, of the 1.2 billion people that suffer from water scarcity, 700 million come from 43 countries, the majority of which are in Sub-Saharan Africa (United Nations, 2011). Furthermore, water shortages and scarcity are most prevalent in developing nations. The lack of clean water leads to an increase of dehydration, disease, and poor living conditions. People in these countries often get their water from contaminated streams, rivers, or sometimes wells. Oftentimes, they must walk miles to get to the water source and carry it long distances through the heat. In many regions, the water collected for drinking and cooking is the same water used to bathe in. The map on the following page shows regions in which there are water scarcities, shortages, or threat of scarcity in the near future.



Source: Vital Water Graphics. UNEP

The Global Crisis: Three Parts

As previously mentioned, roughly half of the world's population suffers from water scarcity. It has become one of the world's biggest crises, as disease caused by lack of water or dirty water is one of the leading causes of death in our global community. While many scholars speak about the global water crisis as the world running out of fresh water, it can be broken down into smaller, separate crises (Lall et. al, 2008). For the purposes of this paper, the global water crisis will be categorized into three specific crises that will allow for individual attention to each. These three crises are the transportation crisis, the access crisis, and the sanitation crisis.

The Transportation Crisis

Transporting water is one part of the global water crisis. While there might be water close to a region, it usually is not close enough to a village or town to be conveniently accessed when needed. Therefore, women and children often spend hours of the day walking to and from a water resource. These resources can be miles away and could be a day's trip there and back. In sub-Saharan Africa alone, roughly 40 billion hours are wasted each year carrying water

(Living Water International, 2010). As a result, families and children don't usually receive the amount of water needed to remain healthy. In addition, they must spend much of their time fetching water rather than going to school or working to earn an income. This, in turn, contributes to higher poverty levels in developing nations.

In addition to the long distances that are traveled to find good water, it takes a vast amount of physical labor to transport water from a resource supply to a home. Women and girls, especially, must first walk these long distances that can take up to seven hours in time and then carry 20 liters of water back with them. This is most often carried by headloading and can be very demanding on the neck and back, causing health problems at an early age (Malloy-Good, 2008).

As this crisis becomes more and more known to scientists and researchers, social entrepreneurs and other organizations are creating ways to address the transportation crisis. Many innovations and products have been created to help cut down the time it takes to transport, to ease the physical labor required, and to carry more water than possible in the past without being too much work for the water fetchers.

The Access Crisis

Another part of the global water crisis is that of access to water. A serious contributor to the access crisis, in developing nations especially, is the unequal distribution of the resource. People living in slums, for example, pay up to ten times more per liter for water than the people living in the city. Because slum residents often do not have access to clean water and lack the money to buy a sufficient supply of water in the city, they must live with these conditions of water that is either dirty or an insufficient supply for the entire community to live off of (Water Facts, 2010). A person in a slum in India needs about 30 liters of water for their daily needs, while in America and other developed nations, a bathtub uses five times that amount in less than in an hour (Water Facts, 2010). This unequal distribution goes further, as in America and many parts of Europe, people have access not only to running water in their homes but to bottled water as well, and for a relatively cheap cost. Because of the portability

and availability of bottled water, people in these regions are consuming resources that could otherwise be exported to places with little or no access to water. In Fiji, for instance, exporting bottled water contributes 3% of the entire nation's GDP. Fiji water is the number one brand of imported water in the United States. While the country is regularly consuming dirty water as well as experiencing droughts year after year, relying on emergency water, Fiji is exporting 180 million bottles of clean freshwater overseas (Lenzer, 2009). This unequal distribution is a huge contributing factor to the access crisis. (Water Facts, 2010)

Approximately 1 billion people globally do not have a means or resource to obtain water. Of this number, 37% live in Sub-Saharan Africa. In Ethiopia, for instance, 50% of the 79 million citizens have no water (McCabe, 2011). In these regions, the water supply is inadequate to meet demands of the people living there (Lall et. al, 2008). While making the distribution of water more equal would easily help solve this problem, it is not quite feasible as bottled water has become a money making industry rather than a way to supply those who need it most with a clean water supply. As a result, many innovations and products such as rain harvesting, piping, pumps, etc. have been created to help improve access to water.

The Sanitation Crisis

The third crisis is the sanitation crisis. While a region might have access to water and a means to easily transport it, the water is often polluted, contaminated by chemicals, or filled with disease and infection causing bacteria. This is exacerbated when people defecate in rivers and open water which they also use as a water resource (World Health Organization, 2012). The Ganges river in India, for instance, has 1.1 million liters of raw sewage dumped into it per minute (World Health Organization, 2012). With 1.2 billion people without facilities for obtaining sanitary water, this polluted water is often the only accessible source of water (Water Facts, 2010). The regions with the lowest amount of access to basic sanitary water supplies are sub-Saharan Africa, southern Asia, and Oceania (World Health Organization, 2012). Over 3.5 million die each year from diseases relating to unsafe water or lack of water in some form. About 1.5 million of these are children under the age of five (United Nations, 2011). Diarrhea alone is responsible for 1.8 million deaths each year, 90%

of which are children under the age of five (Malloy-Good, 2008). This lack of sanitation is the world's biggest cause of infection and claims more lives than any war (United Nations, 2011).

The United Nations created Millennium Goals in 1990, one of which was to cut in half the proportion of people without access to safe water. In order to achieve this goal, roughly 260,000 people per day must get improved water sources from now until 2015 (World Water Council, 2010). By meeting this goal, 470,000 deaths in children under the age of five would be avoided each year. Many companies and organizations are looking to create innovations and products that will help people to sanitize their water so that even if the only water source is polluted, there is still an opportunity to obtain clean, safe drinking water.

Solutions

Many projects and innovations have been created to combat each of the three crises. However, over half of these attempted water projects fail within the first three-five years. Less than five percent of projects are visited regularly by its users and less than one percent of projects are monitored over a long-term period (Water Facts, 2010). In a study done by Diederik Rousseau and Tineke Hooijans (2010), the most important factors contributing to the failure of water projects are lack of detailed problem analysis prior to the introduction of a project/innovation, unclear or unrealistic objectives, ignoring stakeholders, choosing the wrong technology, and failing to follow up. One example of this failure is in Spain, where seven treatment plants were built to help people have access to sanitized water. However, there was opposition from the locals and five of the seven were abandoned, resulting in very little improvement (Rousseau and Hooijans, 2010).

On the other hand, successful projects can contribute greatly to economic growth. For every dollar that the invested in water projects that are successful after three years, for instance, $9 are made in return. For example, an investor that put $100 towards the Hippo Water Roller, which was very successful when introduced and is still used now, made $900 in return after three years (World Health Organization, 2012). Many of these government organizations are more successful than individuals in their investments because of the research they put into

deciding where to put their money. Unfortunately for this, most investors in water innovations, products, and projects are households. The ratio of household/individual investments to government investment in basic sanitation is 10 to 1, respectively (United Nations, 2011). While individual investments are helpful, governments have a lot more resources and time to invest for follow up and maintenance of the projects. If governments considered investing in basic sanitation and/or regulating upkeep of projects, the issue of water scarcity would decrease greatly, and could potentially result in meeting the Millennium goal for 2015 (United Nations, 2011).

A portion of the many innovations and products that have been created to address the three crises are described below. The innovations and products were chosen based both on popularity (i.e. which are most often brought up in scholarly articles researched) and availability of data on the effectiveness of the innovation or project (for comparison purposes).

Transportation

- *Hippo Water Roller:* The Hippo Water Roller is a tool that transports water easily in a roll-able drum, to help women and children to reduce the strain of transporting water. The drum holds 90 liters of water and feels like it only weighs about 10kg for the carrier that pushes it when it is full of water, compared to the typical 20 liter, 20kg bucket that is carried on one's head. Over 33,000 rollers have been distributed in the last 15 years, reaching a quarter of a million people (What is the Hippo Roller?, 2011).

- *Q-Drum*: The Q- Drum is a simple cylinder barrel with a hole down the center that holds 50 liters of water. It is used to help women and children to fill with water and then easily pull it by the rope to transport it. The hole in the center allows for a rope to be tied through it and act as a handle, making it easier to replace if the handle breaks. The drum is known for its durability, as it is made from a low-density polyethylene that can withstand many terrains and temperatures (Q Drum, 2011).

- *Aquaduct:* Although currently only a prototype, the Aquaduct is a pedal-powered vehicle used to transport water, while purifying it in the process. The purpose of the bike is to help prevent the need for women to carry heavy buckets of dirty water miles and miles each day. It contains two tanks, a storage tank and a clean water tank. The bike can purify water while being used as transportation or the clutch can be released and the bike can become stationary. It can hold 20 gallons of water at a time, which is enough to serve a family for one day (Ideo, 2008).

- *LifeSaver Systems Jerry Can:* Lifesaver Jerry Cans are primarily used with many military forces, but can also be adopted for use in regions lacking access to clean water as well. The can has a built in pump that sanitizes water within it. The can can be filled with water from any source and pumped a few times to sanitize it by moving it through the jerry can's micro filtration system. It is manufactured in England and comes with a backpack for easy transportation (*Lifesaver*, 2011).

Access

- *Fog Quest*: FogQuest is a Canadian non-profit that deploys fog collectors to regions that don't have access to water but that have high density or frequent fog. A mesh "catcher" is set up and the fog is pushed through it by the wind. Some droplets from the fog are deposited on the mesh and combine with others to form large droplets that then run down the mesh into gutters that flow into a storage tank (Ambio, 2012). The organization is run entirely by volunteers.

- *PlayPump:* PlayPump is a spinning playground piece on which children play on a merry-go-round like pump. While the children are spinning on the PlayPump, clean water is pumped from underground into a 2,500 liter tank. A simple tap is above the ground and the system can produce up to 1,400 liters of water per hour at a depth of 40 meters (How PlayPumps Works, 2009). This project failed after two years because the creators did not take into account the amount of ground water that would be consumed and because the demand for water was much greater than what the pump

could produce on a daily basis. Playing on the merry-go-round became like a job for many children and women who were trying to get water from a well that had run dry (Freschi, 2010).

- *Afridev Handpumps:* The Afridev Handpump that brings up water from 45-60 meters below the ground with a well. It is fairly simple to install and features a 225mm stroke length in the handle that discharges water. Since the original was created in the 1980s, the Afridev pump has undergone five revisions to make it more user-friendly (SK Companies, 2008). These pumps are sold in many countries throughout the world, including India, Kenya, Mozambique, and more, and are intended to bring water to regions that have no access to surface water sources (Afridev Handpump, 2009)

- *The Treadle Water Pump:* The Treadle pumps water from the ground from underground wells at a depth of seven meters. The device is like a stair climber; the up and down motion of the steps pumps water from the ground into a tank or through a hose. It is environmentally friendly, as it uses no fuel and costs significantly less than a fuel-powered pump. The pump is used often for irrigation as well as drinking water (DrDave, 2010).

- *Aakash Ganga:* Aakash Ganga is a rainwater harvesting system that delivers water daily to each person in a village. Rainwater is collected by participating villagers who receive a payment for excess water they collect that is not needed by their village. On average, about 30% of the water collected is needed for the village, and the other 70% is sold to villages nearby that do not have a system in place (WSJ, 2009).

- *The Global Rainwater Harvesting Collective:* The Global Rainwater Harvesting Collective is a collaboration between the Barefoot College and rural communities to develop self-sustaining rainwater harvesting systems. The community collects rainwater from rooftops in schools and community centers and stores it underground in tanks until needed. The project primarily supplies water to schools for drinking and for toilets. This helps keep children, especially girls, at school more often, as they

do not need to spend their days fetching water. This project has been especially successful in India and Afghanistan (Rainwater Harvesting Collective, 2011).

Sanitation

- *Innovative Water Technologies*: Innovative Water Technologies is a Colorado-based company that uses self-contained, solar-powered water purification systems. The systems can process water from rivers, creeks, lakes, and rainwater. They remove bacteria, viruses, etc. from the water, thus producing safe drinking water. The company currently has products in commercial, humanitarian, and disaster relief initiatives (Sunspring, 2011).

- *Filtron:* Designed by Potters for Peace, the Filtron is a low-tech, low-cost water purifier. The Filtron is made of clay and treats contaminated water by removing bacteria by passing water through tiny pores that are filled with colloidal silver, which renders the bacteria harmless for human consumption. The Filtron is created by local potters with local materials, which helps to keep the cost low (Architecture for Humanity, 2010).

- *Solar Watercones:* A Solar Watercone is a conical solar still that is made from polycarbonate and collects water by condensation, transforming it to drinking water. It has a screw cap spout and is very easy to use. A user puts the cone over a pan of salty water, damp ground, or floats it on top of a pool of water. The sun evaporates the water and it is distilled through a purification system (Markham, 2009).

- *Mobile MaxPure Systems:* A series of solar powered water purification systems, including freshwater, brackish water, and seawater purification systems. The systems are designed to pump, purify, and desalinate water without the use of any electricity. They are fairly mobile and have a long lifespan (Mobile MaxPure, 2010).

- *LifeStraw:* The LifeStraw is a portable water filter that purifies the water as it passes through the straw with microbiologic components. The straw prevents diarrheal

diseases as well as others. It is easily transportable for ready access to clean and safe water. In addition to the original LifeStraw, LifeStraw Family was created. It features a small jug with a hose that purifies the water as it passes through. LifeStraw Family can filter and store water for family use in the home (LifeStraw, 2010).

- *Solarball:* Invented by Jonathan Liow, the Solarball is a small, lightweight, and portable device that creates clean water using solar power to evaporate and condense water. It is very small, lightweight and easily transported. The original SolarBall is just coming out of prototype testing, and is currently getting redesigned to hold larger amounts of water for families to utilize (Coxworth, 2011).

- *Pee Totaler:* The Pee Totaler recycles urine into drinking water through a reverse osmosis filtration process. It has been tested in the United States after being created by NASA and has been used by astronauts at the International Space Station. Unfortunately, while it can purify up to 70 million gallons of water daily, it is very expensive to build the recycling system (Swaminathan, 2009).

Limited Research

Government programs and private and corporate donors invest in the various innovations and products to help solve the global water crisis. With so many different innovations and products, investors often choose the most appealing one to them, without really putting thought into which are successful and what is best based on the desires and needs of the local people effected (Novogratz, 2009). While donations are helpful, it is difficult for any one innovation or product to make a significant impact because the donations are spread among the many innovations and products, and is often wasted on failing projects. This could potentially be avoided if investors and donors had access to a ranking or metric of which innovations and products are recommended for certain goals.

While there is a vast amount of research on various solutions for each of the three aspects of the water crises, there is no literature that compares the solutions to one another. Without literature that has done a multiple comparison or meta-analysis, it is very difficult to

determine which innovations have a successful history. While many innovations and products have been created with the intention of solving the water crisis, over half of these projects fail in the first five years as previously mentioned. Current research explains the successes and failures of innovations and products and how they have the potential or failed to solve the water crisis, but no research was found that helps to determine if an innovation is a "smart" social investment, that is; one that will be successful, cost effective, and helpful to the region that is in need of that type of water resource.

By comparing and contrasting the various innovations and products, we can determine which are most cost effective. In the sections that follow, the various innovations and products that have been identified will be put through a systematic analysis using metrics of efficiency, effectiveness, cost, and durability to identify the best alternative water source.

METHOD

Procedure

Research produced a fairly lengthy list of alternative water resource innovations and products, whether they addressed the transportation, access, or sanitation crisis. A list of measurable data that would be sufficient to adequately compare innovations and products to each other was also determined. To obtain the actual data for this study, research was done via books, the web, and through phone calls and e-mails to various organizations. After the data was collected, it was organized and run through a web-based tool called Pulse, which provides various metrics that could in turn be used to determine the best innovation based on the investor's wants and needs as well as the needs of those in the region to be aided.

Apparatus

Pulse is a tool that is used to collect and manage various financial, operational, and social data. It is an application of SalesForce.com, and has been used often by the Acumen Fund to run metrics and comparisons of various projects that have a goal consisting of some aspect of positive social impact. Metrics data are collected and help to assess real-time impact of

certain projects (Acumen Fund, 2011). The Pulse tool is web-based and has various metrics as well as the option to create custom metrics for a project. For the purposes of this study, a custom metric set was created in order to compare and contrast innovations and products based on the list of measurable data. Pulse provides a standardized platform for each innovation, as each would be measured using the same set of metrics to enhance reliable results. Once the data was entered into Pulse, the program can produce reports, charts, and comparisons that enable ranking the innovations and products in terms of overall quality. The program can also prioritize certain metrics over others, allowing for an accurate ranking with the most important metrics having more influence than the lesser important metrics.

Measurement

With such a vast amount of data from organizations all over the world, accurate measurement is crucial to provide a consistent comparison. Each metric definition that was created was given a standardized unit and data was converted to fit this unit. When the reports are run against each other, this makes them easily comparable when displayed side by side or when compared and/or ranked against one another. The following list is the metric definition and the unit associated with that metric definition:

- Production/Installation Cost (USD): the cost to initially produce and install the product
- Cost per capita (USD/person): the cost per person to produce and install a product
- Cost of Upkeep (USD/year): the cost per year to maintain the product
- Lifespan (Years): the time before replacement of parts or product is required
- Amount of water transported/produced/cleaned (liters/hour): amount of water transported/produced/sanitized through use of the product
    - Please note: Liters/hour means when the innovation is in use- for example, if you use a hand pump for one hour, how many liters of water will be produced.
- Success rate after 1 year (%): percentage of products that are still intact and used after one year

- Weight of product full of water (kg): weight of product on the carrier when full of water (for transportation innovations and products only)

RESULTS

Innovations and Products for the Transportation Crisis

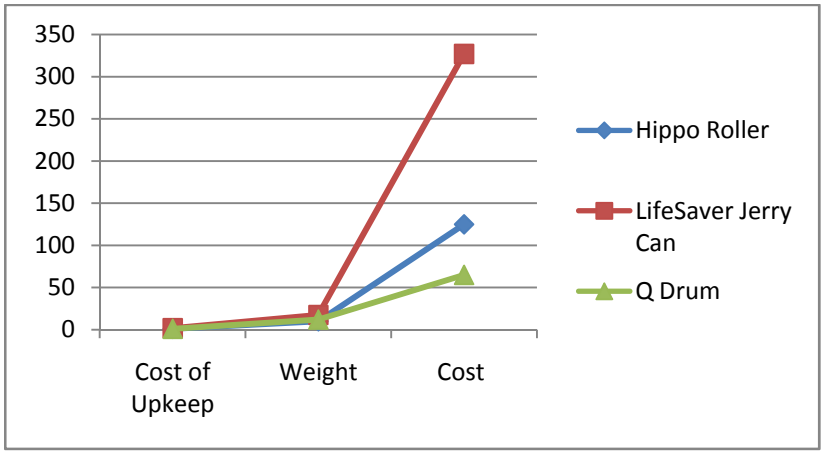


Figure 1- Transportation Innovation Comparison 1

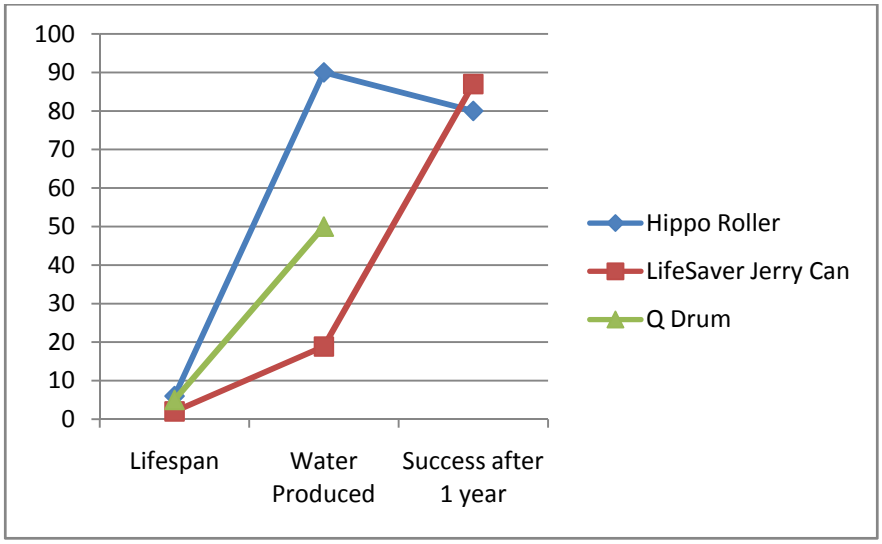


Figure 2- Transportation Innovation Comparison 2

The innovations and products for the transportation crisis were measured with six metrics: Cost (USD), Cost of upkeep (USD), weight (kg), lifespan (years), water produced (L), and success after 1 year (%). Tables of these individual results can be found in Appendix A.

Testing these metrics against each other occurred by means of two comparisons. The first was a comparison of cost, cost of upkeep, and weight, because a lower number is best. The second was a comparison of lifespan, water produced, and success after one year, because a higher number is best. Figure 1 and Figure 2 above demonstrate graphically how the numbers were run through the Pulse Tool. The Hippo Roller was determined of the three as the most cost effective, successful, overall smart investment.

Innovations and Products for the Access Crisis

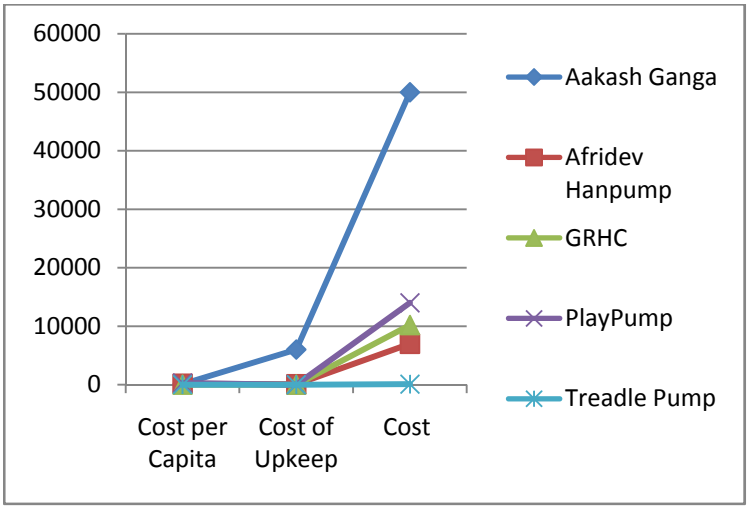


Figure 3- Access Innovation Comparison 1

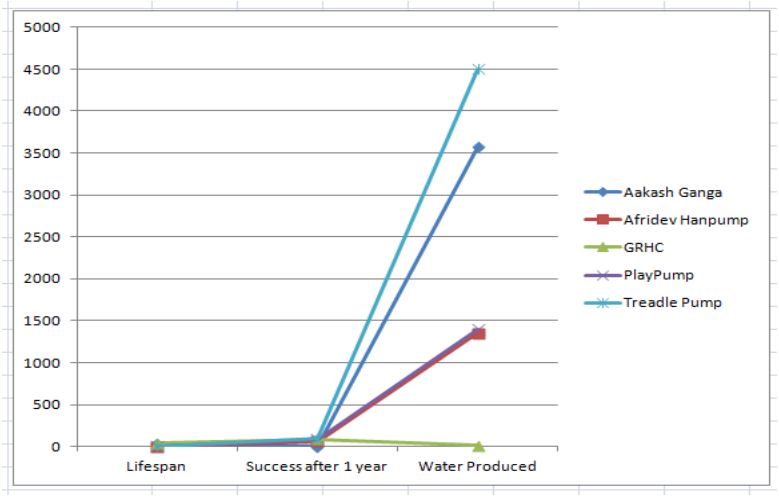


Figure 4- Access Innovation Comparison 2

The innovations and products for the crisis of access were measured with six metrics: Cost (USD), Cost per capita (USD), cost per (kg), lifespan (years), water produced (L), and success after 1 year (%). Tables of these individual results can be found in Appendix A. Analyzing these metrics against each other occurred by means of two comparisons. The first was a comparison of cost, cost per capita, and cost of upkeep, because a lower number is best. The second was a comparison of lifespan, water produced, and success after one year, because a higher number is best. Figure 3 and Figure 4 above demonstrate graphically how the numbers were run through the Pulse tool. The Treadle Pump was determined of the five as the most cost effective, successful, and overall smart investment.

Innovations and Products for the Sanitation Crisis

	Cost (USD)	Lifespan (yrs)	Water Produced (L/hr)
Biosand Filter	$ 70	30 yrs	60 L/hr
Filtron	$ 20	4 yrs	48 L/hr
LifeStraw	$ 6	1 yr	2.5 L/hr
Solarball PROTO	$ 52.55	3 yrs	16 L/hr
Solar Watercone	$ 59	25 yrs	62,459 L/hr
LifeStraw Family	$ 20		264,978,825 L/hr
Mobile MaxPure	$ 30,000	4 yrs	3 L/hr
Pee Totaler	$ 154,000,000		1.5 L/hr

Table 1- Sanitation Innovation Comparison

Due to insufficient data, the sanitation innovations and products were measured with three metrics: Cost (USD), lifespan (years), and water produced (L). Tables of these individual results can be found in Appendix A. Analyzing these metrics against each other occurred by means of two comparisons. The first was a comparison of cost because a lower number is best. The second was a comparison of lifespan and water produced because a higher number is better. Table 1 above demonstrates a side by side comparison of the numbers as run through the Pulse Tool. The Filtron was determined of the seven as the most cost effective, successful, overall smart investment of water production to meet the needs of a family of five or less people, and the Mobile MaxPure System was determined as the most cost effective, successful, overall smart investment of water production for communities.

DISCUSSION

The goal of this study was twofold. First, to apply a metric set to various social innovations and products and second, to compare these metrics to those of other innovations and products with the same goal in order to determine if one innovation stands out significantly above the rest. Together, the results offer a suggestion as to which innovations and products are smart investments, with regard to long-term success, costs associated throughout the process, and amount of drinkable water that is produced.

The Transportation Crisis

The first goal of the study was to determine the smart investment for the transportation crisis. Because the transportation crisis has a number of different options to address it, it is important to know which investment would be the smartest choice overall. While previous literature explains the use of each innovation and the success each has had individually, few involved a direct comparison of the innovations and products. Results from this study determined that the Hippo Roller has a significant and larger impact in successfully transporting water compared to the Q Drum and the LifeSaver Jerry Can. Furthermore, the study analyzes the data based on specific metrics so that an investor can purchase based on their needs as well as the needs of the users. For example, if looking for the innovation with the lowest weight, an investor could look at the tables and charts and determine that the Hippo Roller feels the lightest when pushed; feeling like it weighs 10kg. The significance of this ability to compare is worth noting and displays that the investor should consider the choice of the innovation should be based on the overall success and reliability of the innovation.

These findings are important for multiple reasons. First, as previously mentioned, these findings allow for smart investments. Investors can now select solutions for water transportation based upon a clear set of comparative data for the various alternatives. Secondly, it allows for comparisons between innovations and products that would otherwise seem to have very little difference. Take the Hippo Roller and the Q Drum, for instance. These products were very similar in design, but they have vast differences in overall quality and effectiveness. The Hippo Roller beat the Q Drum in four of six categories, and was very

close to the Q Drum in the others. Although the two may look and function similarly, one has a clear edge over the other which can be capitalized on to ensure success. Finally, these findings support that comparing innovations and products to one another can result in clear displays of one innovation over another and further research and investigation should therefore be conducted to expand the study.

The Access Crisis

Another goal of the study was to determine the smart investment for the water access crisis. Because the crisis has a number of different options to address it, it is important to know which investment would be the smartest choice overall. While previous literature explains the use of each innovation and the success each has had individually, few involved comparing them directly. Results from this study determined that the Treadle Pump has a significant and larger impact in successfully accessing water compared to the other innovations and products studied. Furthermore, the study analyzes the data based on specific metrics so that an investor can purchase based on their needs as well as the needs of the users. For example, if looking for the innovation with the highest lifespan, an investor could look at the tables and charts and determine that the Global Rainwater Harvesting Collection has the highest lifespan at 40 years. The significance of this ability to compare is worth noting and displays that the investor should consider that the innovation they choose should be due to the overall success and reliability of the innovation.

These findings are important for multiple reasons. First, as previously mentioned, these findings allow for smart investments. Secondly, it allows for a comparison across each specific aspect of innovations and products as well as the big picture. For instance, the Global Rainwater Harvesting Collective has double lifespan of others. However, it does not perform as well as the other innovations and products for nearly every other metric. While it may sound like a good idea and have an impressive lifespan, it is not the best option given the analyses metrics used. Finally, as with the transportation crisis, these findings support that comparing innovations and products to one another can result in clear displays of one

innovation over another and further research and investigation should therefore be conducted to expand the study.

The Sanitation Crisis

The final goal of the study was to determine the smart investment for the sanitation crisis. This crisis has perhaps the most options in terms of addressing it, making it both more complicated and more important to determine the overall best. In addition, it is much more difficult to get data for these innovations and products, as many have started very recently or are produced in other countries. Unfortunately, this reduces the amount of data available for analyses, but there is still sufficient data to identify a smart investment. While previous literature explains the use of each innovation and the success each has had individually, few involved comparing them directly. Results from this study were split into two different categories: sanitation innovations and products that produce a smaller amount of water for a family of 4-5 people and sanitation innovations and products that produce larger amounts of water for an entire community or village. The research determined that the Filtron has a significant and larger impact in a smaller amount (48L) when successfully sanitizing water compared to the other innovations and products studied, and the Mobile MaxPure System has a significant and larger impact when sanitizing large amounts (62,459L) of water compared to other innovations and products. This is a display of how the study breaks down the data based on certain metrics so that an investor can purchase based on their needs as well as the needs of the donation recipients.

These findings are important for multiple reasons. First, as mentioned previously, these findings allow for smart investments. Secondly, the findings allow for a clear split in data that helps when investing in innovations and products. If an investor wants to purchase products that would be distributed to individual families, a Filtron is suggested, but if an investor is looking to provide a central source of water for a community, the Mobile MaxPure system is suggested. Finally, these findings support the idea that comparing innovations and products to one another can result in clues and suggestions as to which water investment will best meet an investor's goals.

Limitations and Future Discussion

Although the present study was thorough and methodical as it attempted to determine the best choice for investors and donors to address the three water crises, there were four main areas of focus discovered that will need particular attention in future research. The first of these areas is the scope of the project in terms of the three crises. There are hundreds of innovations, products and programs that attempt to address the various water crises. Although this study addressed only those innovations and products that were most often discussed in literature and invested in, it is very possible that a less known innovation could, in fact, be more effective or more successful than those examined. Expanding the number of innovations and products in the comparison sets would help identify the top choices for investment in each category.

The second area that needs to be expanded on is the scope in things compared. While the innovations and products are a huge part of addressing the water crisis, there are also numerous programs, such as micro-lending, that are invested in and experimented with. Comparing these programs to one another, as well as to the many innovations and products, a better conclusion can be drawn as to whether innovations and products or incentive programs are more effective, or if there is a mix of both.

The third area that should be taken into consideration for future research is expanding the various metrics used. The metrics in this project included the very basic, quantitative characteristics of innovations and products. However, there are many other things that can be measured, especially qualitative characteristics. For instance, one thing that should be taken into consideration is region. Some water innovations and products thrive in one region and fail constantly in another. The climate, terrain, and culture can affect the success and use of an innovation in each place. In addition to region, other metrics such as time to educate people on use of innovation, success after three years, etc. could be analyzed and put into the metric.

The final area that needs further development is the means in which the data is analyzed. While the Pulse tool was very helpful in organizing data and drawing conclusions, it was difficult to treat each innovation as its own company in the system in order to analyze it. The

Pulse tool could still be used as a tool to directly compare quantitative data to draw conclusions. The Pulse tool would be best used to create reports that periodically track data for each innovation so that comparisons can be run on a regular basis. Had this study used year to year data, there would be a lot more information and results to work with that could be compared based on amount of rain that year, population, etc. Regardless of the amount of data, however, a variety of different metrics should be used to cross check the results and to create an overall comparison in addition to Pulse. A resource that can be utilized for this is the Double Bottom Line Project Report (Clark et. al, 2004). This catalog encompasses the many methods that can be used to assess social impact. By combining results from many different metrics together, a more accurate and well-rounded conclusion can be made.

CONCLUSION

Research examining smart investments for social causes is important if we want to be able to increase the effectiveness of our money. With the variety of innovations and products available to invest in, discovering which is more likely to be successful could help to drastically reduce the number of failed water projects. This study suggests that innovations and products addressing the water crisis, specifically split into the transportation crisis, the access crisis, and the sanitation crisis, can be compared among a set of metrics to suggest the overall smart investment for each category of crises. This study shows that the Hippo Water Roller is the smartest transportation innovation, the Treadle Pump is the smartest access innovation, and the Filtron (for family use) and Mobile MaxPure System (for community use) are the smartest sanitation crisis solutions. Practically, the findings help solve the water crisis more efficiently by determining which innovations and products are more successful when invested in. This research study is consistent with previous studies in terms of the description and goal of each innovation and the metric and measurement methods used. This study has chosen to compare the various metrics for each innovation and found some large differences in overall effectiveness of the innovations and products. Future studies should expand these findings by studying other innovations and products, developing better and a larger number of metrics, and incorporating both qualitative metrics and various metric sets to create a combined analysis.

APPENDICES

Appendix A- Figures of Data

Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Cost	Hippo Roller	Sum of Actual Data Record Count	125.00 1	125.00 1	
		Actual Data	125.00 1		Transportation
	LifeSaver Jerry Can	Sum of Actual Data Record Count	327.00 1	327.00 1	
		Actual Data	327.00 1		Transportation
	Q Drum	Sum of Actual Data Record Count	65.00 1	65.00 1	
		Actual Data	65.00 1		Transportation

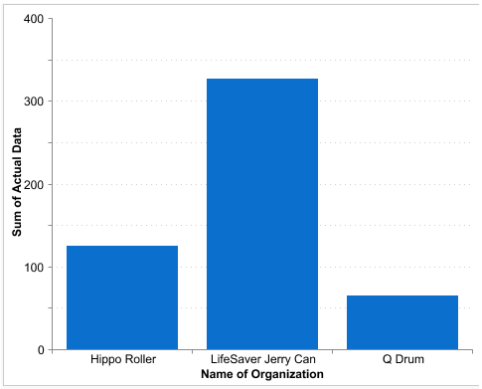


Figure 1- Transportation Innovation Cost (USD)

Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Cost of Upkeep	Hippo Roller	Sum of Actual Data Record Count	1.00 1	1.00 1	
		Actual Data	1.00 1		Transportation
	LifeSaver Jerry Can	Sum of Actual Data Record Count	1.83 1	1.83 1	
		Actual Data	1.83 1		Transportation
	Q Drum	Sum of Actual Data Record Count	1.00 1	1.00 1	
		Actual Data	1.00 1		Transportation

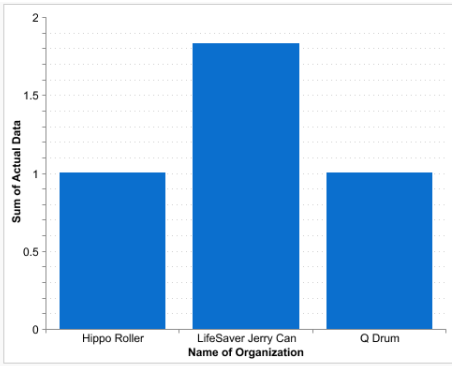


Figure 2- Transportation Innovation Cost of Upkeep ($/Year)

Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Weight	Hippo Roller	Sum of Actual Data Record Count	10.00 1	10.00 1	
		Actual Data	10.00 1		Transportation
	LifeSaver Jerry Can	Sum of Actual Data Record Count	17.50 1	17.50 1	
		Actual Data	17.50 1		Transportation
	Q Drum	Sum of Actual Data Record Count	12.00 1	12.00 1	
		Actual Data	12.00 1		Transportation

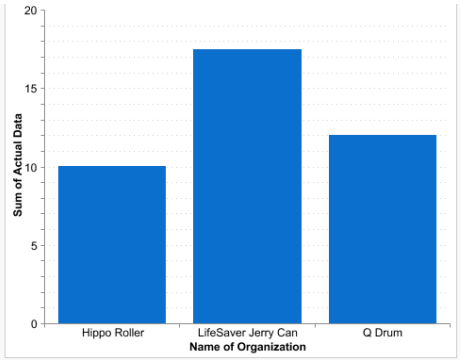


Figure 3- Transportation Innovation Weight on Transporter when Full (kg)

Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Lifespan	Hippo Roller	Sum of Actual Data Record Count	6.00 1	6.00 1	
		Actual Data	6.00 1		Transportation
	LifeSaver Jerry Can	Sum of Actual Data Record Count	2.00 1	2.00 1	
		Actual Data	2.00 1		Transportation
	Q Drum	Sum of Actual Data Record Count	5.00 1	5.00 1	
		Actual Data	5.00 1		Transportation

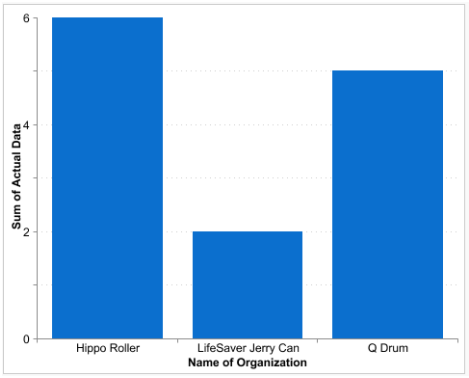


Figure 4- Transportation Innovation Lifespan (years)

Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Water Produced	Hippo Roller	Sum of Actual Data Record Count	90.00 1	90.00 1	
		Actual Data	90.00 1		Transportation
	LifeSaver Jerry Can	Sum of Actual Data Record Count	18.85 1	18.85 1	
		Actual Data	18.85 1		Transportation
	Q Drum	Sum of Actual Data Record Count	50.00 1	50.00 1	
		Actual Data	50.00 1		Transportation

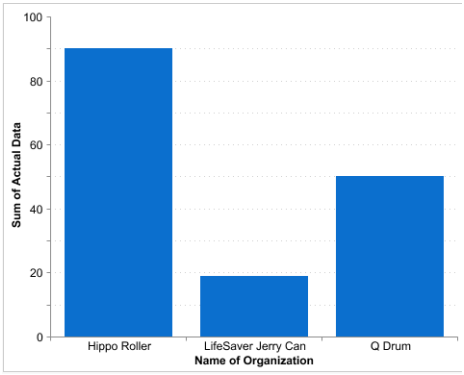


Figure 5- Transportation Innovation Water Transported (L)

Metric Definition: Metric Name	Name of Organization		-	CY2012		Crises
Success Rate (1 year)	Hippo Roller	Sum of Actual Data Record Count	0.00 0	80.00 1	80.00 1	
		Actual Data		80.00 1		Transportation
	LifeSaver Jerry Can	Sum of Actual Data Record Count	0.00 0	87.00 1	87.00 1	
		Actual Data		87.00 1		Transportation
	Q Drum	Sum of Actual Data Record Count	0.00 1	0.00 0	0.00 1	
		Actual Data	- 1			Transportation

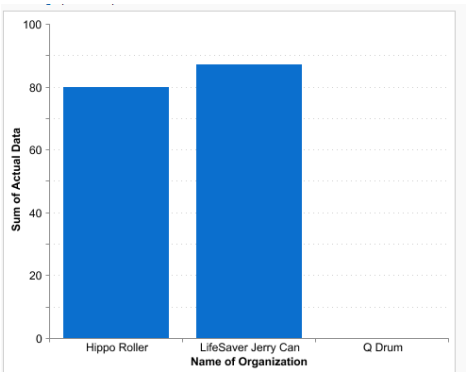


Figure 6- Transportation Innovation Success Rate after 1 Year (%)
[Please note: Success Rate for Q Drum not available]

Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Cost	Aakash Ganga	Sum of Actual Data Record Count	50,000.00 1	50,000.00 1	
		Actual Data	50,000.00 1		Access
	Afridev Handpumps	Sum of Actual Data Record Count	7,000.00 1	7,000.00 1	
		Actual Data	7,000.00 1		Access
	Global Rainwater Harvesting Collective	Sum of Actual Data Record Count	10,194.00 1	10,194.00 1	
		Actual Data	10,194.00 1		Access
	Play Pump	Sum of Actual Data Record Count	14,000.00 1	14,000.00 1	
		Actual Data	14,000.00 1		Access
	Treadle Pump	Sum of Actual Data Record Count	85.00 1	85.00 1	
		Actual Data	85.00 1		Access

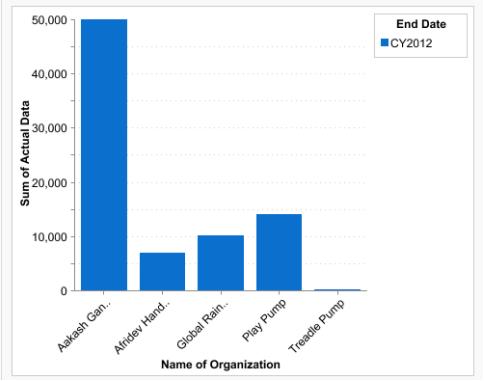


Figure 7- Access Innovations and Products Initial Cost (USD)

Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Cost per Capita	Aakash Ganga	Sum of Actual Data Record Count	91.25 1	91.25 1	
		Actual Data	91.25 1		Access
	Afridev Handpumps	Sum of Actual Data Record Count	156.00 1	156.00 1	
		Actual Data	156.00 1		Access
	Global Rainwater Harvesting Collective	Sum of Actual Data Record Count	0.04 1	0.04 1	
		Actual Data	0.04 1		Access
	Play Pump	Sum of Actual Data Record Count	297.87 1	297.87 1	
		Actual Data	297.87 1		Access
	Treadle Pump	Sum of Actual Data Record Count	0.57 1	0.57 1	
		Actual Data	0.57 1		Access

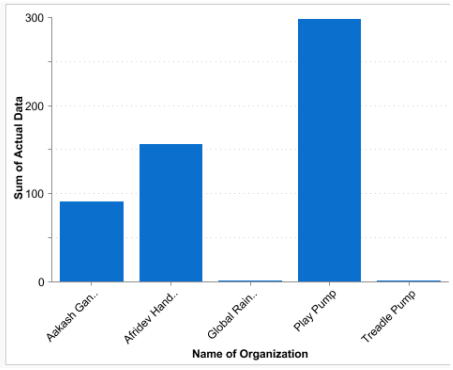


Figure 8- Access Innovations and Products Cost per Capita (USD)

Metric Definition: Metric Name	Name of Organization		-	CY2012		Crises
Cost of Upkeep	Aakash Ganga	Sum of Actual Data Record Count	0.00 0	6,000.00 1	6,000.00 1	
		Actual Data		6,000.00 1		Access
	Afridev Handpumps	Sum of Actual Data Record Count	0.00 0	60.00 1	60.00 1	
		Actual Data		60.00 1		Access
	Global Rainwater Harvesting Collective	Sum of Actual Data Record Count	0.00 0	7.40 1	7.40 1	
		Actual Data		7.40 1		Access
	Play Pump	Sum of Actual Data Record Count	0.00 1	0.00 0	0.00 1	
		Actual Data		- 1		Access
	Treadle Pump	Sum of Actual Data Record Count	0.00 0	1.00 1	1.00 1	
		Actual Data		1.00 1		Access

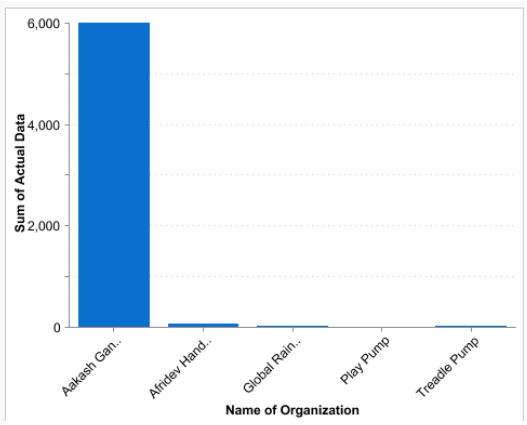
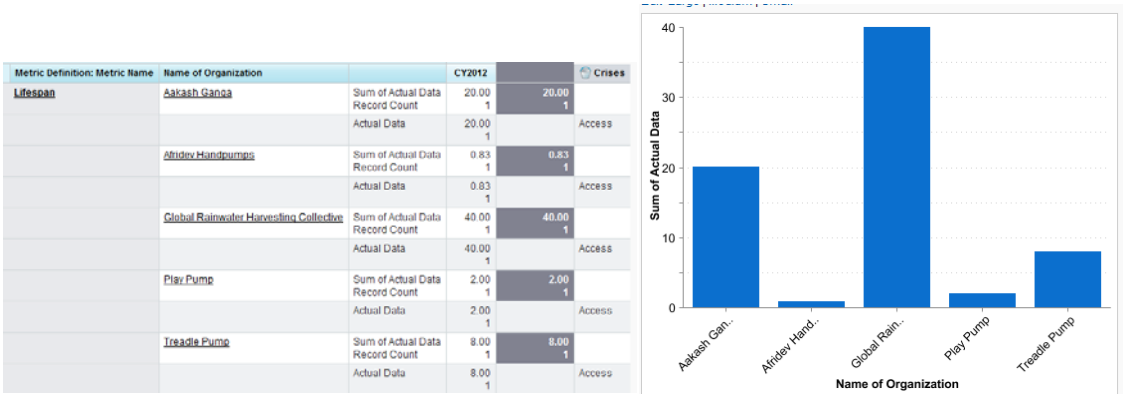
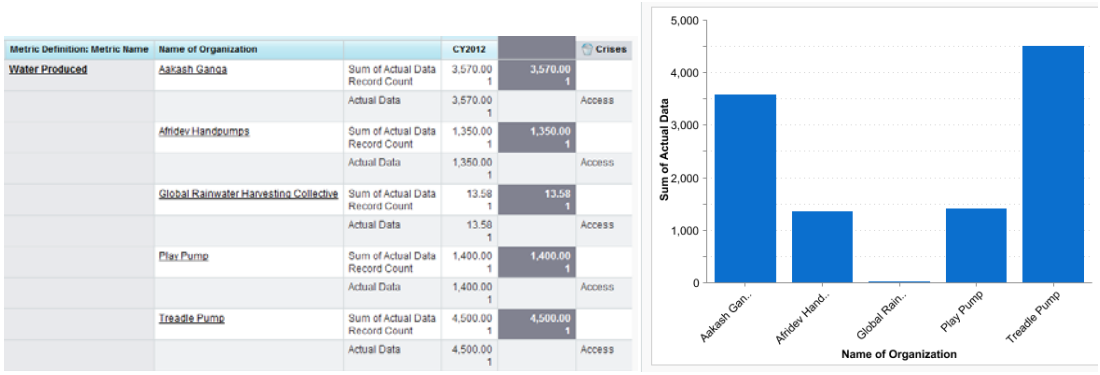


Figure 9- Access Innovations and Products Cost of Upkeep (USD/year)



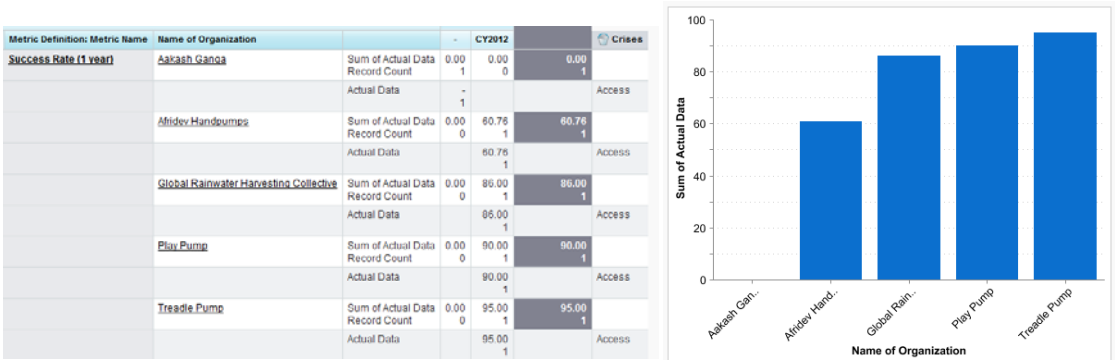
Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Lifespan	Aakash Ganga	Sum of Actual Data	20.00	20.00	
		Record Count	1	1	
		Actual Data	20.00		Access
			1		
	Afridev Handpumps	Sum of Actual Data	0.83	0.83	
		Record Count	1	1	
		Actual Data	0.83		Access
			1		
	Global Rainwater Harvesting Collective	Sum of Actual Data	40.00	40.00	
		Record Count	1	1	
		Actual Data	40.00		Access
			1		
	Play Pump	Sum of Actual Data	2.00	2.00	
		Record Count	1	1	
		Actual Data	2.00		Access
			1		
	Treadle Pump	Sum of Actual Data	8.00	8.00	
		Record Count	1	1	
		Actual Data	8.00		Access
			1		

Figure 10- Access Innovations and Products Lifespan



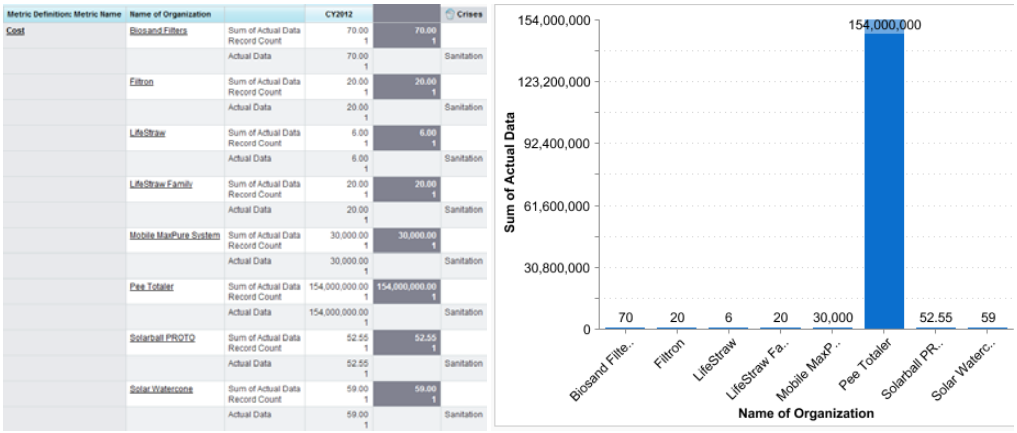
Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Water Produced	Aakash Ganga	Sum of Actual Data	3,570.00	3,570.00	
		Record Count	1	1	
		Actual Data	3,570.00		Access
			1		
	Afridev Handpumps	Sum of Actual Data	1,350.00	1,350.00	
		Record Count	1	1	
		Actual Data	1,350.00		Access
			1		
	Global Rainwater Harvesting Collective	Sum of Actual Data	13.58	13.58	
		Record Count	1	1	
		Actual Data	13.58		Access
			1		
	Play Pump	Sum of Actual Data	1,400.00	1,400.00	
		Record Count	1	1	
		Actual Data	1,400.00		Access
			1		
	Treadle Pump	Sum of Actual Data	4,500.00	4,500.00	
		Record Count	1	1	
		Actual Data	4,500.00		Access
			1		

Figure 11- Access Innovations and Products Water Produced (L/hour)



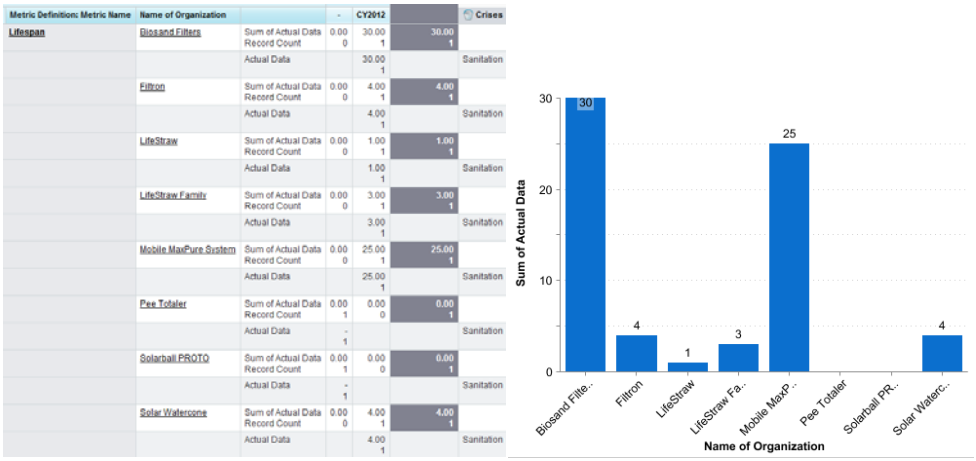
Metric Definition: Metric Name	Name of Organization		-	CY2012		Crises
Success Rate (1 year)	Aakash Ganga	Sum of Actual Data	0.00	0.00	0.00	
		Record Count	1	0	1	
		Actual Data	-			Access
			1			
	Afridev Handpumps	Sum of Actual Data	0.00	60.76	60.76	
		Record Count	0	1	1	
		Actual Data		60.76		Access
				1		
	Global Rainwater Harvesting Collective	Sum of Actual Data	0.00	86.00	86.00	
		Record Count	0	1	1	
		Actual Data		86.00		Access
				1		
	Play Pump	Sum of Actual Data	0.00	90.00	90.00	
		Record Count	0	1	1	
		Actual Data		90.00		Access
				1		
	Treadle Pump	Sum of Actual Data	0.00	95.00	95.00	
		Record Count	0	1	1	
		Actual Data		95.00		Access
				1		

Figure 12- Access Innovations and Products Success Rate after 1 Year (%)
[Please note: Success Rate for Aakash Ganga was not available]



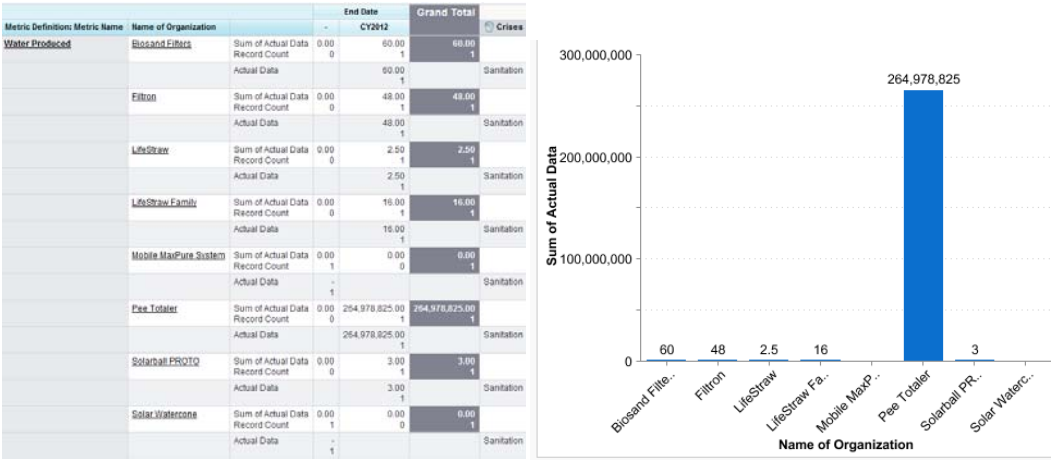
Metric Definition: Metric Name	Name of Organization		CY2012		Crises
Cost	Biosand Filters	Sum of Actual Data	70.00	70.00	
		Record Count	1	1	
		Actual Data	70.00		Sanitation
			1		
	Filtron	Sum of Actual Data	20.00	20.00	
		Record Count	1	1	
		Actual Data	20.00		Sanitation
			1		
	LifeStraw	Sum of Actual Data	6.00	6.00	
		Record Count	1	1	
		Actual Data	6.00		Sanitation
			1		
	LifeStraw Family	Sum of Actual Data	20.00	20.00	
		Record Count	1	1	
		Actual Data	20.00		Sanitation
			1		
	Mobile MaxPure System	Sum of Actual Data	30,000.00	30,000.00	
		Record Count	1	1	
		Actual Data	30,000.00		Sanitation
			1		
	Pee Totaler	Sum of Actual Data	154,000,000.00	154,000,000.00	
		Record Count	1	1	
		Actual Data	154,000,000.00		Sanitation
			1		
	Solarball PROTO	Sum of Actual Data	52.55	52.55	
		Record Count	1	1	
		Actual Data	52.55		Sanitation
			1		
	Solar Watercone	Sum of Actual Data	59.00	59.00	
		Record Count	1	1	
		Actual Data	59.00		Sanitation
			1		

Figure 13- Sanitation Innovations and Products Initial Cost (USD)



Metric Definition: Metric Name	Name of Organization		-	CY2012		Crises
Lifespan	Biosand Filters	Sum of Actual Data	0.00	30.00	30.00	
		Record Count	0	1	1	
		Actual Data		30.00		Sanitation
				1		
	Filtron	Sum of Actual Data	0.00	4.00	4.00	
		Record Count	0	1	1	
		Actual Data		4.00		Sanitation
				1		
	LifeStraw	Sum of Actual Data	0.00	1.00	1.00	
		Record Count	0	1	1	
		Actual Data		1.00		Sanitation
				1		
	LifeStraw Family	Sum of Actual Data	0.00	3.00	3.00	
		Record Count	0	1	1	
		Actual Data		3.00		Sanitation
				1		
	Mobile MaxPure System	Sum of Actual Data	0.00	25.00	25.00	
		Record Count	0	1	1	
		Actual Data		25.00		Sanitation
				1		
	Pee Totaler	Sum of Actual Data	0.00	0.00	0.00	
		Record Count	1	0	1	
		Actual Data	-			Sanitation
			1			
	Solarball PROTO	Sum of Actual Data	0.00	0.00	0.00	
		Record Count	1	0	1	
		Actual Data	-			Sanitation
			1			
	Solar Watercone	Sum of Actual Data	0.00	4.00	4.00	
		Record Count	0	1	1	
		Actual Data		4.00		Sanitation
				1		

Figure 14- Sanitation Innovations and Products Lifespan (years)



Metric Definition: Metric Name	Name of Organization		End Date -	End Date CY2012	Grand Total	Crises
Water Produced	Biosand Filters	Sum of Actual Data	0.00	60.00	60.00	
		Record Count	0	1	1	
		Actual Data		60.00		Sanitation
				1		
	Filtron	Sum of Actual Data	0.00	48.00	48.00	
		Record Count	0	1	1	
		Actual Data		48.00		Sanitation
				1		
	LifeStraw	Sum of Actual Data	0.00	2.50	2.50	
		Record Count	0	1	1	
		Actual Data		2.50		Sanitation
				1		
	LifeStraw Family	Sum of Actual Data	0.00	16.00	16.00	
		Record Count	0	1	1	
		Actual Data		16.00		Sanitation
				1		
	Mobile MaxPure System	Sum of Actual Data	0.00	0.00	0.00	
		Record Count	1	0	1	
		Actual Data	-			Sanitation
			1			
	Pee Totaler	Sum of Actual Data	0.00	264,978,825.00	264,978,825.00	
		Record Count	0	1	1	
		Actual Data		264,978,825.00		Sanitation
				1		
	Solarball PROTO	Sum of Actual Data	0.00	3.00	3.00	
		Record Count	0	1	1	
		Actual Data		3.00		Sanitation
				1		
	Solar Watercone	Sum of Actual Data	0.00	0.00	0.00	
		Record Count	1	0	1	
		Actual Data	-			Sanitation
			1			

Figure 15- Sanitation Innovations and Products Water Produced (L/hour)

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