Miller Center for Social Entrepreneurship

solageo

Economic Resources and Restraints for Safe Water in Rwanda and Uganda

A Case Study of Willingness-To-Pay Analysis

Judi Li & Riley Casey

EXECUTIVE SUMMARY

We conducted market research to analyze customer behavior and the market landscape for Solageo to navigate the new product and geological markets.

We found that there is a large market for treated water and a strong demand for safe water but the setup cost exceeds residents' willingness to pay (WTP). Based on the cost structure of the two business models, Water Kiosk and Water Kit, we discovered that

1. the size of the community is the determining factor for the profitability of the Water Kiosk,
2. the profitability of the Water Kit is determined by the amount of water used by local residents.

We provided recommendations for increasing safe water to Rwandan communities and improving the operations of the two water dissemination models to better serve the local needs and constraints. Our recommendations will help Solageo provide more safe water to a greater number of communities and tailor the services to maximize the benefits for both community members and Solageo. The tools that we develop may inform future efforts to deliver solar-powered safe-water access to diverse communities from Africa to Southeast Asia.

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Table of Contents

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Introduction

To serve Solageo's mission and develop tools that allow social entrepreneurs to deliver solar-powered safe-water access we conducted market research in Rwanda and Uganda. Ultimately our recommendations may be applied to diverse markets from Africa to Southeast Asia.

We provide the following roadmap as an overview of our report. The first part of the report is our Customer Behavior Analysis. We used the data from the survey and interviews to analyze demographic information, customers' financial constraints, and their willingness to pay (WTP) for safe water. In the "Willingness-to-Pay Analysis," we depicted the demand curve of safe water and analyzed the relationship between the price and the demand. We found that the demand for safe water is inelastic, meaning that the increase in price has little impact on water demand. We recommend the price of a jerry can[1] of safe water to be 42.5 RWF (0.04 USD).

The second part is "Profitability analysis of Two Business Models." We incorporated the cost structure of two business models, the Water Kiosk and the Water Kit, to analyze the profitability of the models. We found that the size of the community is the determining factor of the success of the Water Kiosk model. With subsidies to cover half of the cost, a community with more than 350 households can pay off the setup cost within 12 months[2]. We provided three recommendations for the Water Kiosk model:

1. Finding the accurate number of households in the community,
2. Targeting communities with more than 250 households,
3. Selling both treated and untreated water at the water station.

Also in Part 2, the amount of water the community members are willing to buy from Water Kits determines the long-term benefit. The monthly revenue of selling 14 jerry cans of treated water per day can bridge the monthly PayGo payment of the Economy Water Kit without subsidy. However, it is challenging to bridge the monthly PayGo payment of the Solar Water Kit by solely relying on selling treated water without subsidy. We suggested the following for the Water Kit model:

1. Targeting store owners and small business owners who can sell treated water to their customers or neighborhoods, and
2. Targeting households that not only need treated water but also have a high willingness to pay for LED lights and solar panels.

Note:

1. A jerry can is a standardized plastic/steeled container to transport liquid. In Rwanda and Uganda. 20-liter jerry cans are widely used to fetch and contain water.
2. Paying back in 12 months is the goal of Solageo.

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In the third section, “Country Analysis,” we gathered data from the interviews that we situate in dialogue with other studies. We demonstrated the potential markets for Solageo to expand in Rwanda and Uganda by collecting statistical data on the offgrid population and lack-of-safe-water population, financial information, and the impact of climate change on local people.

In conclusion, we discovered that there is a large market for treated water. People acknowledge the value of safe water, but the WTP cannot easily match the setup cost of the water kiosk and water kit.

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Report Part 1: Customer Behavior Analysis

Demographics and Customer Behavior

In Kageyo, the average number of family members in households is 6 people, and the range varies from 1 to 10 people. We estimate the community size is 700-900 people. The daily consumption of drinking water is about 2 liters per capita per day. In our sample, 21.74% responded “unemployed.” Over two-fifths of respondents (43.48%) answered that they had no daily, weekly, or monthly income, which may be due to unemployment or an unstable income stream of self-employment (e.g., farming). Among 36 employed respondents, three were students, one was a teacher, and the rest were farmers. Over half of the respondents (56.52%) reported their income. The average monthly household income is 58,170 RWF.

Women and children are the main laborers fetching water. Usually, they fetch 100 liters of water and treat 20 liters. Most households in Kageyo do not have private water tanks to collect rainwater during the rainy season. They fetch water from the communal water spots and then pour water into the family water container to store. Many water spots use open-source water such as lakes and rivers, while some water spots are boreholes and wells using groundwater.

Out of our many options, people only chose boiling water or did not treat water. 76.91% of respondents boiled water and 30.43% did not treat water. Less than one-third of respondents (30.43%) did not spend money on treating water, two-thirds (65.22%) spent 500 RWF or less per day, and only 10.87% spent more than 500 RWF. Almost half of the respondents (45.65%) answered that someone in their family suffered from water-borne diseases in the last year. The majority (60.87%) of respondents rated very concerned (7 or more out of 10) about water safety, while 17.39% of respondents rated not concerned at all.

The residents saw the value of safe water by expressing their willingness to buy safe water from the Milk Collection Center (MCC) in the village. MCC bought solar water pumps from Solageo to extract groundwater and cool equipment. The water pumps can extract more water than MCC needs. MCC has the potential to become a new water spot for residents. Almost all respondents (97.83%) also believed that they would save time buying safe water from the MCC, meaning that they see this new solution as a benefit. Families with cattle went to MCC every morning to sell milk. They could buy water from MCC when they went back home. Over half of the respondents (60.87%) would increase their time doing agricultural work or farming if they could reduce the opportunity cost of treating water themselves. It also indicated that a large number of respondents understood the economic opportunities of saving time from fetching water. Almost all respondents (97.83%) of respondents replied that they have a mobile phone and mobile data to access mobile payment, making mobile payment possible.

In Eastern and Central Uganda, farmers pumped 10,000 liters of water per day to maintain their farms but only 60% is actually used, leaving a surplus available to be sold. BWM can bring them a business opportunity, selling the other 40% of water to people who do not have access to water. At the same time, Solageo needs to find out the current uses of water surplus to ensure its availability. Similar to Rwanda, the perception of safe water in Uganda is not comprehensive. Many people perceived water from deep wells was safe and from shallow wells was not. They saw clear water without physical particles as safe unless it gave a stomachache. Although local residents' immune system is getting tolerant of the toxins, parasites, and other microorganisms in water, these invisible contaminants accumulate stress on the immune system that contributes to shorter life expectancy and lower resistance to other diseases.

After analyzing their life routine, we found that the biggest challenge faced by residents was the long distance and long time required to fetch water. Residents spent 30 minutes to 2 hours a day fetching water, depending on how far they lived from the water spots and whether or not they had a bicycle. On the other hand, time spent on treating water was not a major issue. No respondent spent more than half an hour treating water. Almost half of the respondents (45.44%) spent less than 10 minutes per day. The majority (76.91%) of respondents boiled water as water treatment. We speculate that they may work on other activities when waiting for water to boil so they do not see much time spent on boiling water. The survey answer to this question indicates that time on treating water is not the pain point of customers but fetching water is.

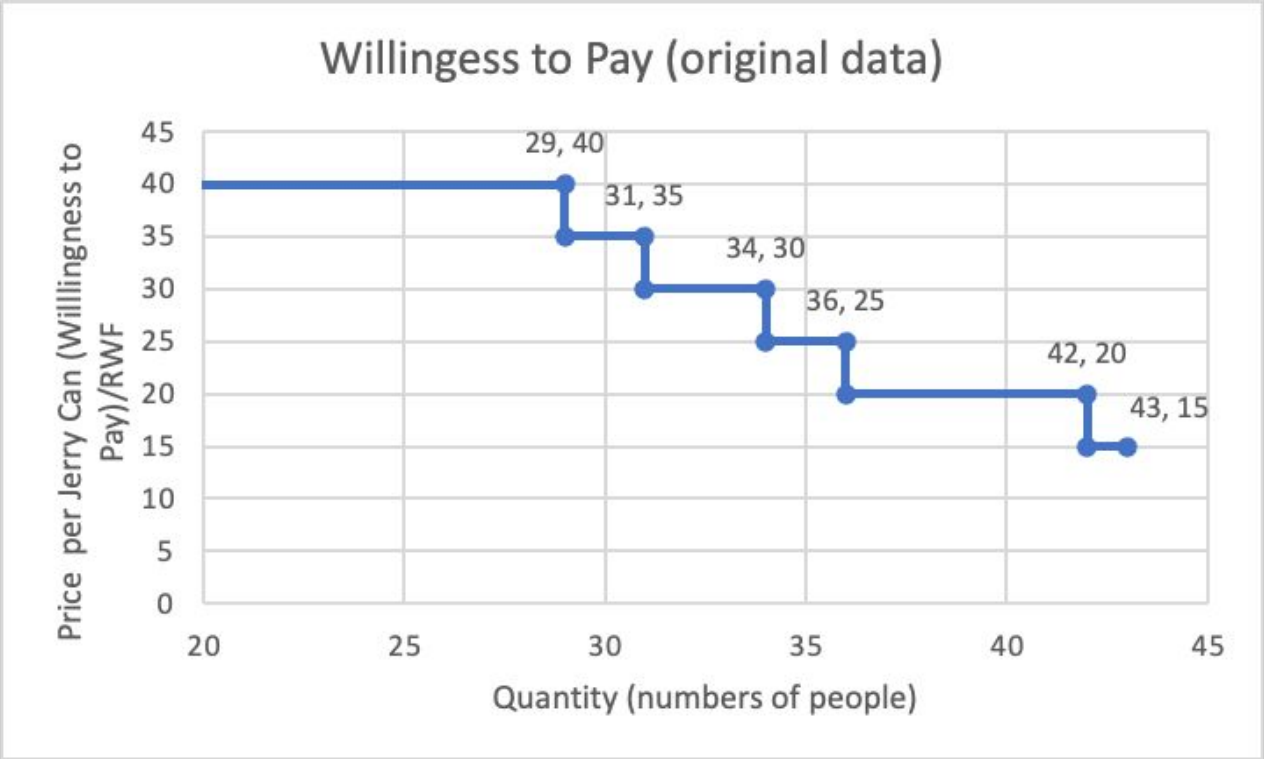
Data-Driven Recommendations

First, we suggest Solageo change the marketing strategy from focusing on saving time treating water to saving time fetching water by creating more water spots for local residents. To do this, Solageo can keep using the enterprise network to its advantage and cooperate with local businesses and enterprises. Together, they can use current resources and infrastructure (e.g., their water pumps and customer relationship) to build more water spots for the local communities.

Second, working in a two-tier franchise framework, Solageo can choose local enterprises with a deep understanding of their communities to be its partners. The two-tier franchise framework requires master franchisees to manage and distribute the products, and sub-franchisees buy products from the master franchisees and sell them to the customers. The consistent outreach and deep trust between the communities and the local enterprises enable the enterprise partners to be aware of the communities' specific needs. Their awareness and understanding of the communities can provide Solageo with new business opportunities. Solageo can better serve local enterprises and communities by tailoring the water treatment service and the operating model contextually. For example, MCC in Kageyo and the local enterprise in Central Uganda both noticed the entrepreneurial opportunities in their communities–the match between the demand for safe water and the excess capacity of solar water pumps. By partnering with them, Solageo can equip them to deliver tailored services, enlarging Solageo's impact and benefits.

Willingness-to-Pay Analysis

Based on the data gathered on WTP from the survey, we used the raw data from the survey to graph the following demand curve. Each dot represents the number of people who are willing to pay for a jerry can of safe water (20 liters) at each price level. For example, dot (29, 40) means 29 people are willing to pay 40 Rwandan Francs (RWF) for 20 liters of safe water.



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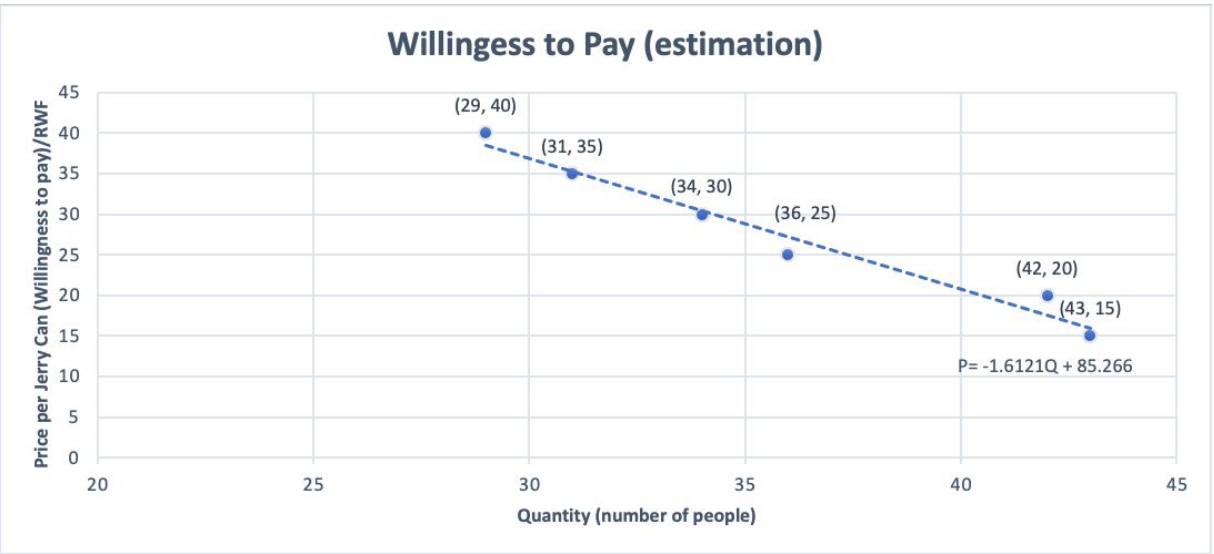
We chose 40 RWF as the starting price, doubled the current common price in the market (20 RWF), and deducted the price by 5 RWF each time until the respondent is willing to pay. We did not want the starting price to be too high, for which the respondents might lose patience and drop out of the survey. Looking at the raw data, we found that some respondents' WTP might be higher than 40 RWF. To solve this problem, we used the OLS method to draw the linear regression and estimate the number of customers at prices higher than 40 RWF. In hindsight, 50 RWF as the starting price may be better to capture the upper part of the demand curve.



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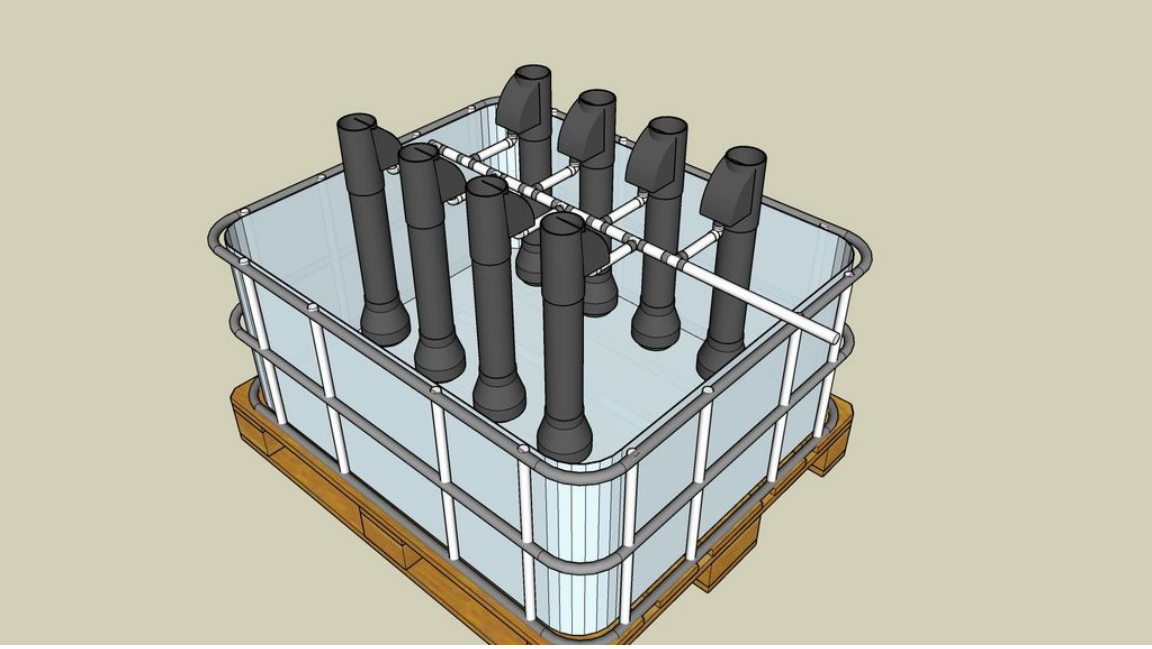
Given the demand curve equation, we can set the price which maximizes the profits. When the price equals 42.5 RWF, 60% of the households in the community will buy treated water every day, which maximizes profits. The revenue per day when the price is 42.5 RWF is 1127 RWF. (The calculation process is in Appendix A. Profit Maximization).

The elasticity of the water demand equals 0.5, which is smaller than 1, which means that the majority of people in Kageyo see treated water as a necessity. An increase in price has a relatively small effect on the quantity of demand (The calculation process is in Appendix A. Elasticity). However, we need to keep in mind that 30.43% of the respondents did not treat water and that people tend to appear better than they are in the survey (i.e., response bias). We should be *cautiously* optimistic about the conclusion that people see it as a necessity and that people have a higher willingness to pay than we expected.

Report Part 2: Profitability Analysis of Two Business Models

Water Kiosk

A water kiosk comprises 10 BWMs, a smart tap payment system, a water tank, and a piping system. It is a communal solution to safe and sustainable water access. The water kiosk can filter 10 liters of safe water per minute. The cost of a water kiosk varies depending on the infrastructure of the local communities.



Note:
3. Picture source: https://www.solageo.com/shop/solar-water-kiosk-90?page=2#attr=54

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We estimated that each household will buy one jerry can of treated water per day, and 150 households live in the community of Kageyo. The following table shows how the revenue and recoupment period change as the number of households in the community increases, setting the price of treated water per jerry can equals $0.04 (=42.5 RWF)[4].

Number of households in the community	Price ($) (60% of the households are willing to buy)	Revenue($) per month	($5000) Recoupment period in months	(with $2500 subsidy)[5] Recoupment period in months
150	0.04	108	46.3	23.1
200	0.04	144	34.7	17.4
250	0.04	180	27.8	13.9
300	0.04	216	23.1	11.6
350	0.04	252	19.8	9.9

Note:
4. The following calculation in this section does not include the cost of replacements such as carbon cartridges.
5. The subsidy comes from Solageo network. The information is provided by Solageo.

The following table sets the price of treated water equals $0.024 (=25 RWF) to compare how the change of price, and therefore the quantity of demand, influence the revenue and recoupment period.

Number of households in the community	Price ($) (84% of the households are willing to buy)	Revenue($) per month	($5000) Recoupment period in months	(with $2500 subsidy) Recoupment period in months
150	0.024	90.7	55.1	27.6
200	0.024	121.0	41.3	20.7
250	0.024	151.2	33.1	16.5
300	0.024	181.4	27.6	13.8
350	0.024	211.7	23.6	11.8

Data-Driven Recommendation

First, the size of the community is the key to the success of this model. The survey responses about the size of the village in Kageyo vary from 300-40,000. We recommend that Solageo obtain accurate data on the community size or the number of households in Kageyo to better estimate the number of potential customers. When Solageo replicates the research in other regions, collecting information on the community size is also an important indicator of the profitability of this model.

Second, we recommend that Solageo considers the communities with more than 250 households as potential markets. The recoupment period rapidly decreases as the number of households increases from 150 to 250. The size of the community can be smaller if the community has a better infrastructure that lowers the setup cost of the Water Kiosk. For example, building upon the infrastructure of MCC, the setup cost of Water Kiosk is about $1000. The recoupment period shortens to 9.2 months when the community size is 150 households.

Third, we recommend the new water spots sell both treated and untreated water to individual households in differentiated jerry cans. Households need treated water to drink and cook and untreated water for washing and cleaning. Usually, women and children fetch 100 liters of water and treat 20 liters. Since the time spent on fetching water is the biggest challenge for residents, providing both types of water can save them time from fetching untreated water separately. They will increase productivity by using the saved time for farming, chores, and homework according to our survey.

Water Kit

The two types of water kits, Economy Water Kit and Solar Water Kit, are designed to sell to remote individual households. The Economy Water Kit includes a 30W Power Bank, a 5W Solar Panel, a 3W LED Light, a cell Phone Charging Cable, and a BWM. The monthly cost to balance 80% over 11 months is $15.9. With subsidy to cover 50% of the cost, the cost becomes $7.95.

The following table demonstrates the relationship between the revenue the households can get and the amount of water they sell to the community. When the households can sell more than 7 jerry cans of water per day, their monthly revenue can match the subsidized monthly payment of PayGo. If they can sell more than 14 jerry cans every day, the revenue can cover the unsubsidized monthly payment. The recoupment period to cover the deposit cost varies, depending on how many more jerry cans they can sell.

water treated per hour (L)	hours of treating water (hr)	water sold per day (jerry can) (water production - personal use)	Price ($) per jerry can	Revenue from selling water per month ($)
50	2	4	$0.04	$4.80
50	3	6.5	$0.04	$7.80
50	4	9	$0.04	$10.80
50	5	11.5	$0.04	$13.80
50	6	14	$0.04	$16.80

The other type of the water kit, Solar Water Kit, includes an 80W Solar System, a LED Lights, a Cell Phone Charging Cable, and a BWM. The 80W solar system makes the Solar Water Kit more costly than the Economy Water Kit. The Economy Water Kit targets customers who need more electricity to power other utilities. The monthly regular price is $30.61. With subsidy, it will be $15.31. It is extremely difficult for local residents to pay off the monthly payment of PayGo by solely relying on revenue from selling treated water: the revenue of selling 21.5 jerry cans of water is $25.8, which is still $5 less than the monthly price ($30.61). However, with a 50% subsidy, the revenue from selling 14 jerry cans of treated water can cover the monthly payment of PayGo.

water treated per hour (L)	hours of treating water (hr)	water sold per day (jerry can) (water production - personal use)	Price ($) per jerry can	Revenue from selling water per month ($)
50	5	11.5	$0.04	$13.80
50	6	14	$0.04	$16.80
50	7	16.5	$0.04	$19.80
50	8	19	$0.04	$22.80
50	9	21.5	$0.04	$25.80

Data-Driven Recommendation:

First, the key determinant of this model is the amount of water the owners sell to their customers or neighbors. Therefore, we recommend that Solageo promote Water Kits to store owners or small business owners, equipping them with a new business opportunity of selling safe water.

Second, we recommend Solageo to target business owners with a strong desire for electricity (i.e., solar panels, and LED lights). These two items contribute to a higher WTP for the Solar Water Kit besides the potential revenue of selling extra treated water. They will be more likely to buy the Solar Water Kit.

Report Part 3: Country Analysis

In this section, we will analyze the demographics, off-grid population, clean energy access, and safe-water access in Rwanda and Uganda to demonstrate the characteristics of the macro market and the potential future regional markets in Rwanda and Uganda.

Rwanda

Rwanda is the most densely populated mainland African country located in east-central Africa. 13.28 million individuals populate Rwanda (Data Commons).

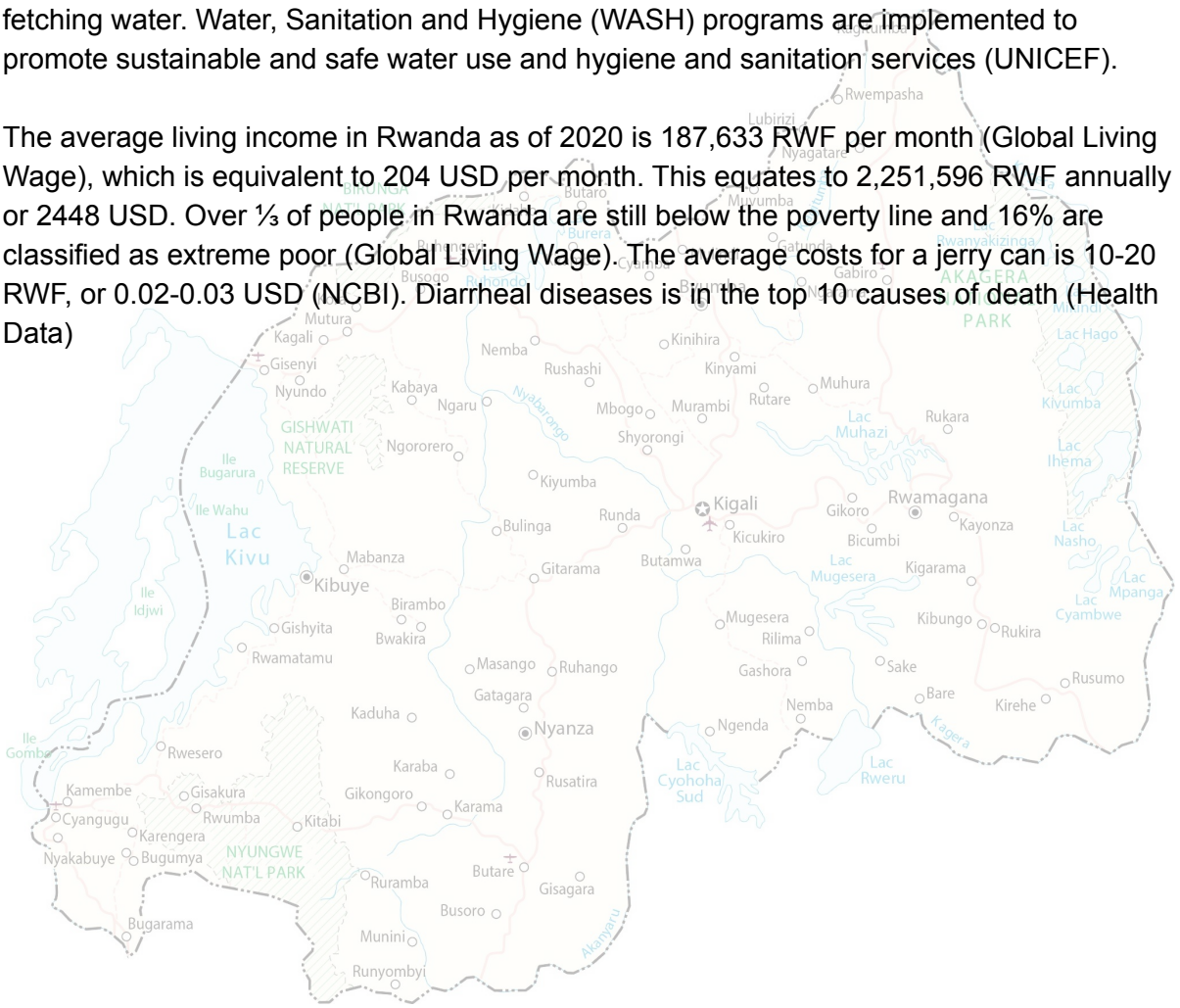
Geographically, Rwanda is bordered by Uganda, Tanzania, Burundi, and Zaire. The country is 26,338 km² (Nations Encyclopedia). Rwanda is divided into four provinces plus the capital city, Kigali, in the center of the country. The provinces include the North Providence, the East Province, the South Province, and the West Province. The provinces on the whole are further divided into 30 districts (gov.rw). Rwanda has 14,837 villages, each with local governments on a Village Executive Committee, comprised of 5 members: a village coordinator, a member in charge of social welfare and family relations, a member in charge of security, immigration and emigration, a member in charge of information and training, and a member in charge of development. The north region of Rwanda experiences water scarcity, causing a shortage of safe drinking water.

Note:
6. Map source: https://gisgeography.com/rwanda-map/

Rwanda experiences two rainy seasons from September to December and from March to June. Conversely, Rwanda experiences two dry seasons from January to March and July to August. Individuals often collect rainwater in tanks during the rainy season to prepare for the dry season.

60.41% of Rwanda's population is at least using basic drinking-water services (WHO). Only 57% of the population has drinking water that is within 30 minutes of their home (unicef). This disproportionately affects girls, who are often tasked with household chores, including fetching water. Water, Sanitation and Hygiene (WASH) programs are implemented to promote sustainable and safe water use and hygiene and sanitation services (UNICEF).

The average living income in Rwanda as of 2020 is 187,633 RWF per month (Global Living Wage), which is equivalent to 204 USD per month. This equates to 2,251,596 RWF annually or 2448 USD. Over ⅓ of people in Rwanda are still below the poverty line and 16% are classified as extreme poor (Global Living Wage). The average costs for a jerry can is 10-20 RWF, or 0.02-0.03 USD (NCBI). Diarrheal diseases is in the top 10 causes of death (Health Data)



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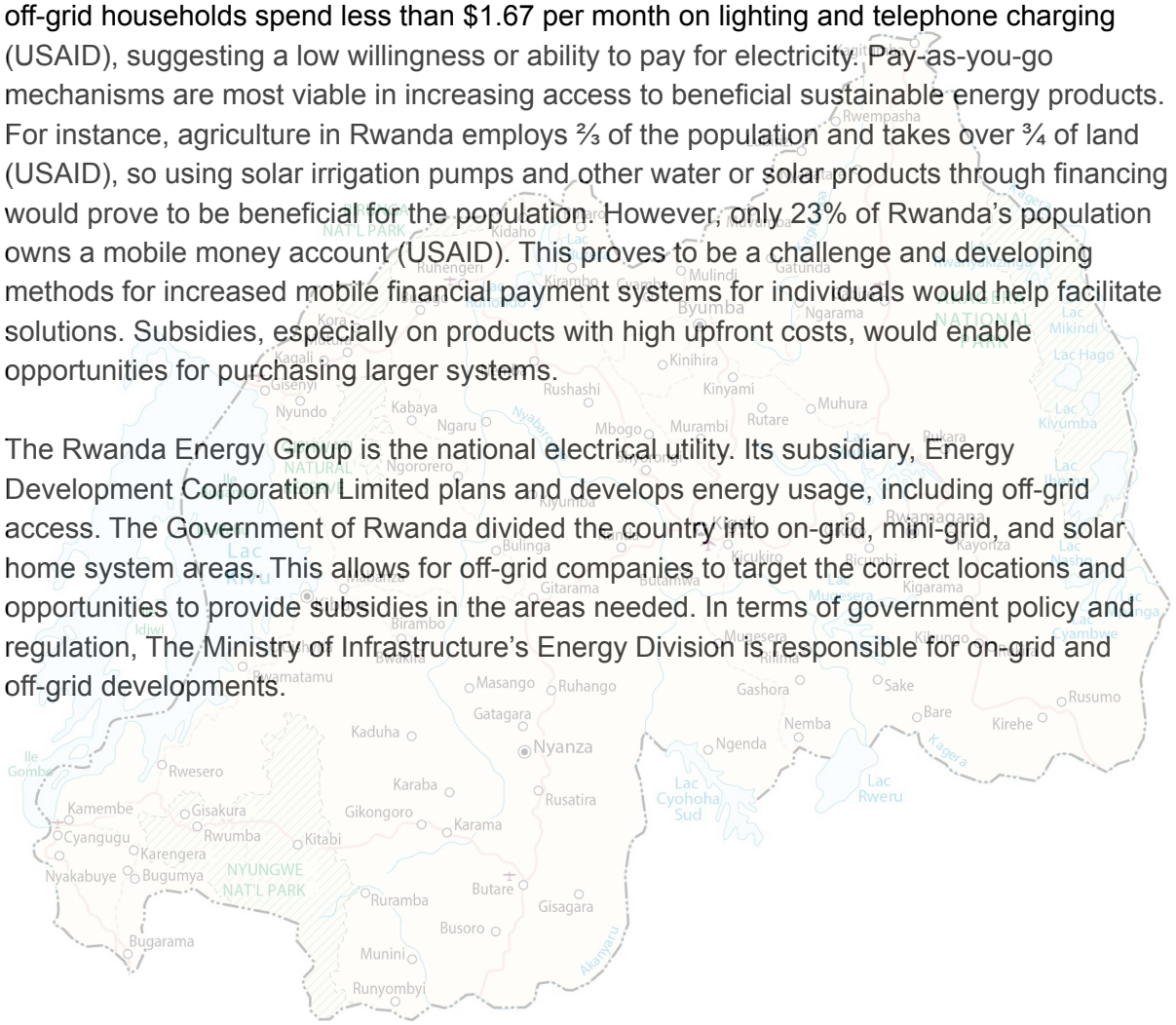
As of September 2022, 75.3% of Rwandan households have access to electricity, which includes 50.9% connected to the national grid and 23.6% accessing electricity through off-grid methods (REG). Government strive for targets achieving 100% of households to have access to electricity by 2024 (REG), 48% of these households using off-grid solutions (USAID). In order to achieve this goal, nearly all of the increase will come from off-grid installations. Solar home systems sold through the pay-as-you-go model are the most popular, although subsidies are commonly needed as the WTP has proven to be low. 75% of off-grid households spend less than $1.67 per month on lighting and telephone charging (USAID), suggesting a low willingness or ability to pay for electricity. Pay-as-you-go mechanisms are most viable in increasing access to beneficial sustainable energy products. For instance, agriculture in Rwanda employs ⅔ of the population and takes over ¾ of land (USAID), so using solar irrigation pumps and other water or solar products through financing would prove to be beneficial for the population. However, only 23% of Rwanda's population owns a mobile money account (USAID). This proves to be a challenge and developing methods for increased mobile financial payment systems for individuals would help facilitate solutions. Subsidies, especially on products with high upfront costs, would enable opportunities for purchasing larger systems.

The Rwanda Energy Group is the national electrical utility. Its subsidiary, Energy Development Corporation Limited plans and develops energy usage, including off-grid access. The Government of Rwanda divided the country into on-grid, mini-grid, and solar home system areas. This allows for off-grid companies to target the correct locations and opportunities to provide subsidies in the areas needed. In terms of government policy and regulation, The Ministry of Infrastructure's Energy Division is responsible for on-grid and off-grid developments.



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Uganda

Uganda is a landlocked country in east-central Africa, located north and northwest of lake Victoria. Around 18% of its total area is inland water. Its water body consists of five massive lakes, dozens of smaller lakes, and eight major rivers. The current population of Uganda is 49,655,286 (Worldometer).

The majority of Uganda is in tropical areas with two rainy seasons and two dry seasons. The rainy seasons are from March to May and from September to December, and the dry seasons are from January to March, and June to September. The northern region lies outside the tropical belt where it only has the rainy season from March to October. The rest of Uganda is in a humid equatorial climate zone. The rainfall patterns across the country change due to topography, prevailing winds, lakes, and rivers. (Climate Change Knowledge Portal). However, according to the interview data, climate change has made the dry and rainy seasons uneven. In the past summer, they experienced a long drought with abnormally high temperatures. The drought first started in Kenya and spread to Uganda. Eastern Uganda has relatively more rainfall but the drought in Southeastern Uganda was more severe, causing extremely high economic losses such as the death of cattle. People in Uganda learned about climate change from radio and school education. Most of the rural farmers have finished the 10th grade and have a basic understanding of climate change. The government shares information about climate change over the radio in different languages. Common people can also feel the impact of climate change through the higher commodity princess and the lower supply of agricultural products.

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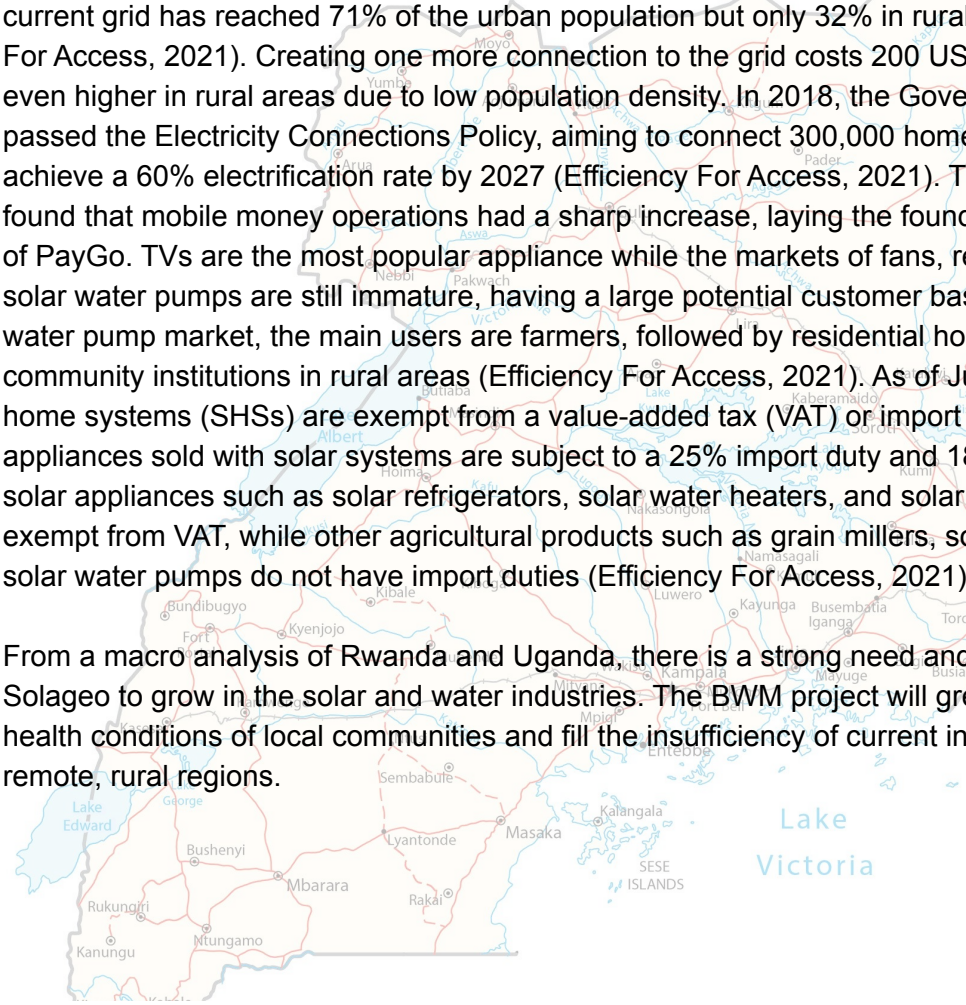
The average monthly income among rural Uganda farmers is 951,900 UGX (250 USD). The average price for a jerry can of safe water is 200 shillings ($0.053). The latest data (2016) showed that 34% of diarrhea cases and 6,506 diarrhea deaths are attributed to inadequate safe water. 451,590 years lost (disability-adjusted life years, DALYs) are due to diarrhea and inadequate safe water (World Health Organization). In 2020, 55.86% of the population had access to at least basic drinking water services, but only 16.65% of the population can access safely managed drinking water services (WHO).

59% of the population did not have access to electricity (Efficiency For Access, 2021). The current grid has reached 71% of the urban population but only 32% in rural areas (Efficiency For Access, 2021). Creating one more connection to the grid costs 200 USD, and the price is even higher in rural areas due to low population density. In 2018, the Government of Uganda passed the Electricity Connections Policy, aiming to connect 300,000 homesteads annually to achieve a 60% electrification rate by 2027 (Efficiency For Access, 2021). The report has found that mobile money operations had a sharp increase, laying the foundation for the use of PayGo. TVs are the most popular appliance while the markets of fans, refrigerators, and solar water pumps are still immature, having a large potential customer base. In the solar water pump market, the main users are farmers, followed by residential homes and community institutions in rural areas (Efficiency For Access, 2021). As of June 2019, solar home systems (SHSs) are exempt from a value-added tax (VAT) or import duty. Generally, appliances sold with solar systems are subject to a 25% import duty and 18% VAT. Some solar appliances such as solar refrigerators, solar water heaters, and solar cookers are exempt from VAT, while other agricultural products such as grain millers, solar irrigation, and solar water pumps do not have import duties (Efficiency For Access, 2021).

From a macro analysis of Rwanda and Uganda, there is a strong need and a large room for Solageo to grow in the solar and water industries. The BWM project will greatly improve the health conditions of local communities and fill the insufficiency of current infrastructure in the remote, rural regions.



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Conclusion

Our work has shown the challenges of accessing safe drinking water from several angles. The lack of access to clean water, as well as knowledge about drinking and using clean water are both issues that contribute to water-borne diseases and other health problems in East Africa. We acknowledged that local residents' perspective and information provided is valuable and informed our calculations and analysis. Our findings indicate that Solageo must address a knowledge gap between perceptions of water sanitation and scientific knowledge about how clean water mitigates disease, which is a gap between the wants and needs of using clean water and prioritizing it.

To summarize our findings, when virtually working with communities in East Africa, we considered the disparities that occur in obtaining clean water and the reasoning behind these methods. We recognized that cultural factors could potentially serve as barriers for individuals or communities to be willing to purchase the BWM. Societal factors influence decision-making processes, such as purchasing clean water rather than purchasing other assets that they may prioritize.

In the first part of the finding, Customer Behavior Analysis, we used the data from the survey and interviews to analyze demographic information, customers' financial constraints, and their WTP for safe water. In the "Willingness-to-Pay Analysis," we depicted the demand curve of safe water and analyzed the relationship between the price and the demand. We found that the demand for safe water is inelastic, meaning that the increase in price has little impact on water demand. We recommend the price of a jerry can of safe water to be 42.5 RWF (0.04 USD), which maximizes the revenue given the demand curve.

Note:
3. Picture source: https://www.solageo.com/shop/solar-water-kiosk-90?page=2#attr=54

In the second part “Profitability Analysis of Two Business Models,” we incorporated the cost structure of two business models, the Water Kiosk and the Water Kit, to analyze the profitability of the models. We found that the size of the community is the determining factor of the success of the Water Kiosk model. With a subsidy to cover half of the cost, a community with more than 350 households can pay off the setup cost within 12 months. We provided three recommendations for the Water Kiosk model:

1. Finding the accurate number of households in the community,
2. Targeting communities with more than 250 households,
3. Selling both treated and untreated water at the water stations.

Also in Part 2, the amount of water the community members are willing to buy from Water Kits determines the long-term benefit of the Water Kit. The monthly revenue of selling 14 jerry cans of treated water can match the monthly PayGo payment of the Economy Water Kit without subsidy. However, it is challenging to match the monthly PayGo payment of the Solar Water Kit by solely relying on selling treated water without subsidy. We suggested the following for the Water Kit model:

1. Targeting store owners and small business owners who can sell treated water to their customers or neighborhoods,
2. Targeting households that not only need treated water but also have a high WTP for LED lights and solar panels.

In conclusion, we discovered that although there is a large market for treated water, there are a number of challenges to be addressed. People acknowledge the value of safe water, but the WTP cannot easily cover the setup cost of the Water Kiosk and both Water Kits. As climate change has changed the climate pattern, people in East Africa need more reliable water access than ever before. Because each community’s current infrastructure conditions are different, we suggest Solageo tailor the services and calibrate costs to meet communities’ specific needs and adjust the operating models according to local contexts. By understanding the customer behaviors and community members’ life routines, Solageo can tailor the services to better serve the communities, lower the cost of operation, and maximize the benefits for both community and Solageo.

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Appendix A: Math Calculation

Profit Maximization:

Revenue = number of customers * price= -1.6121x^2+85.266x

To find the quantity that maximizes profits, we take the first derivative of the equation and set it equal to 0:

$$\frac{d}{dx}\left(-1.6121x^2 + 85.266x\right) = -3.2242x + 85.266$$

$$-3.2242x + 85.266 = 0 \quad : \quad x = \frac{85.266}{3.2242} \quad (\text{Decimal:} \quad x = 26.44562\ldots)$$

Price:

$$-1.6121 \cdot 26.5 + 85.266 = 42.54535$$

Revenue:

$$-1.6121 \cdot 26.5^2 + 85.266 \cdot 26.5 = 1127.451775$$

Given that the marginal cost of treated water is small, the profit is maximized when the revenue is maximized at price=42.5 RWF when 26~27 people among the 46 respondents in the community would buy treated water every day.

Elasticity of Water Demand:

Use two points (29,40) and (31,35) and the midpoint method to calculate the elasticity of water demand.

$$\text{Price elasticity of demand} = \frac{(Q_2 - Q_1)/[(Q_2 + Q_1)/2]}{(P_2 - P_1)/[(P_2 + P_1)/2]}$$

$$\frac{(29-31)}{30} \div \frac{(40-35)}{37.5} = -0.5$$

Appendix B: Survey Design

Hello! I am a researcher from the University of Rwanda working with a solar enterprise, Solageo. We are conducting market research for a solar-powered water filter system to understand its affordability. This system could be implemented at the Milk Collection Center in Kageyo. It could save time treating water, improve the water quality, and reduce water-borne diseases.

There are 27 questions in this survey that should take you 30 minutes. We would like to know whether you would fetch water from the MCC and how much you were willing to pay for the safe water. This survey is anonymous and your personal information is confidential. Do you want to take the survey?

(If they agree to take the survey) Thank you for your participation!

Survey Questions

(This survey aims to understand the market conditions for the Better Water Maker (BWM), UV Water Purifier, and then calculate the willingness to pay for clean/safe water, either through the purchase of the BWM directly or the purchase of water treated by the BWM. More specifically, the survey seeks to understand at what price members of different local communities would be willing to pay for clean/safe water services. The survey comprises 5 parts, background information, life routine + water value, opportunity cost of treating water, affordability, and willingness to pay.)

Background information

> *Rationale: This opens opportunities for identifying if specific demographics <are more likely to pay for safe water services> will perform better or benefit more from selling the BWM.*

1. (No need to ask) Is this survey taker a male or female?
    a. Male
    b. Female
2. How old are you?
    a. Under 20 years old
    b. 21-30 years old
    c. 31-40 years old
    d. 41 years old and above
3. What is your current work status?
    a. Employed full time
    b. Employed part-time
    c. Self-employed
    d. Unemployed
    e. Other: (please fill in)

4. **(Skip the question if they choose "d" in the previous question)** What is your current profession (optional)
    a. (Fill in blank)
        i. *To gather information on income*
5. Do you get paid daily, weekly or monthly?
    a. Daily
    b. Weekly
    c. Monthly

6. **(if they choose "a" in the previous question)** What is your daily household income:
    a. 1,000 RWF and below
    b. 1,001-3,000 RWF
    c. 3,001-5,000 RWF
    d. 5,001-7,000 RWF
    e. 7,001-9,000 RWF
    f. 9,001 RWF and above

7. **(if they choose "b" in the previous question)** What is your weekly household income:
    a. 5,000 RF and below
    b. 5,001-15,000 RF
    c. 15,001-25,000 RF
    d. 25,001-35,000 RF
    e. 35,001-45,000 RF
    f. 45,001 RF and above

8. **(if they choose "c" in the previous question)** What is your monthly household income:
    a. 20,000 RF and below
    b. 20,001-60,000 RF
    c. 60,001-100,000 RF
    d. 100,001-140,000 RF
    e. 140,001-180,000 RF
    f. 180,001 RF and above

        i. *Rationale: This specifically targets the willingness to pay aspect of<safe water services> the BWM. We have to be able to ensure the end users of the franchisee can afford the <safe water services> BWM. This data will help establish a foundational level that we can use to calculate willingness to pay.*
9. Do you have children? (optional)
    a. Have kids
    b. No kids

10. How many family members are in your household? (optional)
    a. (blank)
        i. *Rationale: This explicitly shows how much water is consumed, and therefore should be filtered, on a daily basis. As a commodity, water is very valuable and therefore the use of water daily shows both the value and accessibility of water.*
11. How do you normally treat water?
    a. I do not treat water
    b. Boiling
    c. Chlorine tablets
    d. Ceramic water filter
    e. Charcoal filter
    f. Straining through fine cloth
    g. Slow sand filtration
    h. Other: (please fill in)
        i. *Rationale: This provides insight as to how end users treat water normally, which could be time-consuming, unsustainable, or even expensive processes. Relating this to the advantages of the BMW could be a selling point and increase their willingness-to-pay*
12. How much time do you spend treating water daily?
    a. 10 mins or less
    b. 11 - 20 mins
    c. 21 - 30 mins
    d. 31 - 40 mins
    e. 41- 50 mins
    f. 51 mins and above
        i. *Rationale: This provides insight to how much water end users can normally filter with their current method. We can compare this to the BWM*

13. How much money do you spend on treating water daily?
    a. none
    b. 500 RWF and below
    c. 501 -1,000 RWF
    d. 1,000-1,500 RWF
    e. 1,500-20,000 RWF
    f. 20,000 and above RWF

14. Rank the following in terms of your desire to buy from most important to least important:
    a. Electricity
    b. Safe water
    c. Mobile phone (voice or data services)

    Rationale: This allows us to see how end users place value on safe water compared to other necessities. If it is lowly ranked, the willingness to pay may be lower since the demand will clearly be lower than other long-term or immediate purchases. These are all paid for and used in similar ways daily.

Opportunity cost of treating water

15. Are you willing to buy safe water from the Milk Collection Center (MCC)?
    a. Yes
    b. No
16. Do you believe you would save time if you bought safe water from the Milk Collection Center (MCC) daily?
    a. Yes
    b. No
        i. *Rationale: This conveys if the end users acknowledge and can conceptualize the value of the time saved by BWM. Not using the BWM presents an opportunity cost for end users which is vital for them to understand.*
17. Please choose the activities you or your household would do if you didn't have to fetch and treat water (check all that apply).
    a. Doing homework
    b. Spending more time in school
    c. Doing agricultural work/farming
    d. Picking up/chopping firewood
    e. Other: (please fill in)
        i. *Rationale: Building off the previous question, this question highlights the opportunity cost of using the BWM for community members. With the time freed from not treating water, end users would be able to attend more schools or conduct business, creating a better quality of life.*

Benefits of safe water

18. Did someone in your family suffer from water-borne diseases in the past year (e.g. diarrhea, cholera)?
    a. Yes
    b. No
        i. *Rationale: This plays into the advantage of having uncontaminated water. A byproduct of having contaminated water is the risk of water-borne diseases, which can be costly, timely, and even deadly. Avoiding water-borne diseases allows end users to avoid these consequences.*
19. **(If previous question answered "yes")** How many times did you and your family members get water-borne diseases in the past year in total?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
    f. 6 and above
        i. *Rationale: This follow up question identifies the amount of times a household faces water-borne diseases annually. Since each water-borne disease causes costly measure as well as physical and mental resources, we would be able to showcase the advantages of preventing disease through uncontaminated water.*

20. How much do you pay to treat water-borne disease on average?
(blank)

Willingness to pay

21. Do you have access to a mobile phones to make mobile money payments?
    a. Yes
    b. No
        i. r*ationale: This explicitly suggests how much end users are willing to pay for filtered water. This provides insight into the value placed on safe water, the expenses associated with it. If the answer is low, it conveys the demand is low for the BWM versus other forms of filtering water or simply filtering water in general. Conversely, if this is high, this is great for Solageo since it suggests they place a greater emphasis on safe water and are willing to pay for an efficient system to obtain it.*

22. Are you willing to pay 40 RWF for a 20L bottle of water?
    a. If not, are you willing to pay 35 RWF?
    b. If not, are you willing to pay 30 RWF?
    c. If not, are you willing to pay 25 RWF?
    d. If not, are you willing to pay 20 RWF?

Appendix C: General Interview Guide Design

Preliminary Interview Questions

This interview guide aims to understand 1. the qualifications of the potential franchisees–strengths, weaknesses, risks, and opportunities, and 2. the market they serve. It comprises two parts: franchisees' background/capabilities and local community knowledge. The local community knowledge part has a few similar questions to the survey.

Franchisees' background/capabilities:

Rationale: This provides background information on the franchisee. This opens opportunities for identifying if specific demographics will perform better or benefit more from selling the BWM.

1. What gender do you identify?
    i. *Rationale: Answers from males can differ from answers from females in their understanding of community members based on personal experience and background knowledge*
2. What language do you conduct business in?
3. How much schooling do you have? What is the highest level of degree you've earned? (optional)
    i. *Rationale: Using school as a screening mechanism.*

Franchisees' capabilities of distributing products

4. How many regions and communities are you currently serving? How many people or households in these communities?
    i. *Rationale: This question provides insight to an essential element to the franchisee criteria – the number of regions/communities served. Serving more communities could make the franchisee as a potential master franchisee.*
5. How long are these communities away from your enterprise?
    i. *Rationale: Learn about the distance between the communities and enterprise*
6. Can you use a few sentences to describe the communities you are serving?
    i. *Rationale: This provides insight on where the enterprise specifically works and therefore which communities, we should research for our market study.*
    b. (If they don't already mention which type of area) Are these communities off-grid, rural areas, or urban areas?
        1. *Rationale: Solageo's BWM targets rural communities so it's important to know if the communities served fit within these demographics.*
    c. Do the community members have mobile phones and cellular data to access mobile payments?

The selling model franchisees adopt

7. How many [one particular product] do you normally purchase from your suppliers annually?
8. How much available space do you have for importing and storing these products before selling them?
    i. *Rationale: These questions will help us understand what their import quantity normally is and the capacity they have – a critical criterion for evaluating the franchisee capabilities and an indicator of the magnitude of the cash flow.*

Experience/training

9. What is your prior experience (skills and products sold) in the solar sector?
    i. *Rationale: This provides information on previous experience, specifically in the solar sector, that may prove to be critical for franchisees to have before working with the BWM. Experience in the solar industry is of higher value in Joe's perspective. Having a background knowledge about how the product can work in cohesion with micro grids, mini grids, and solar home systems is an essential selling point,*
10. What is your prior experience (skills and products sold) in the water sector?
    i. *Rationale: This provides information on previous experience, specifically in the solar sector, that may prove to be critical for franchisees to have before working with the BWM. This experience is not weighted highly, but franchisees with this experience could possess some skills and knowledge that could leverage their ability to sell the BWM effectively.*
11. Do you normally need to receive third party funding for the projects you work on?
    i. *Rationale: As a social enterprise, Solageo cannot provide funding to the franchisees or other enterprises who it partners with. This question asks about that the franchisee has experience in the business world without being fully funded (for a nonprofit for instance).*
12. Can you describe the training process for the salesperson?
    a. What are some key things they need to know before they go to the field?
    b. How do you evaluate how much they learn from the training?

Net cash flow

13. Solageo could help you with access to the third-party financing, can you tell you what your annual sales revenue has been? You can provide us a range if you do not want to say a specific number.
    i. *Rationale: This is also an evaluation factor that Joe considers. It will be important to create levels based on net income to ensure the business is successful and that they are large enough to import products and maintain business operations.*

14. Do you use mobile payments? When do you use it (e.g., with community members? With other franchisees?)

The interpersonal relationship with the local community

15. How often do you visit the community you serve?
    i. *Rationale: This provides insight to the familiarity and connectedness the franchisee shares with the community they serve. If they visit the community often, this could be seen as a strength, given that they most likely have established connections there. Visiting the community often indicates they have a stong relationship with the communities. Not visiting the community often alludes to the fact that they do not have a strong connection to the community members.*
16. How would you rate your connection with the community you serve on a scale of 1-10 (1 being the community members are mostly strangers to you, 10 being you are very close friends with most people in the community)?
    i. *Rationale: This provides a self-described connection with community members. A close connection is important for business transactions. The closer they rate their connection, the franchisee can share the value of the BWM, and thus sell the BWM, with the audience more strategically.*
17. How would you describe an average client? Is there a main client base?
    i. *Rationale: This allows the franchisee to describe who they normally work with so we can gain more insight into the community. This could provide more information on demographics of current users specifically.*

<u>Local community knowledge:</u>

Affordability/financial situation of local families

18. How far away is your company away from the community in terms of distance and timing?
19. Based on your knowledge about the communities, what is community members' monthly income? (optional)
    a. Around 5000 RF
    b. Around 10,000 RF
    c. Around 20,000 RF
    d. Around 30,000 RF
    e. Around 40,000 RF
        i. *Rationale: This question provide us a basic understanding of local residents' financial resources. We have to be able to ensure the end users of the franchisee can afford the BWM.*

20. How much Rwanda Franc do people normally pay for a jerry-can (20L) of clean water per household?
    i. *Rationale: This will allow us to clearly compare how much people pay for 1L of water currently and what the BWM can provide. This plays into the value of the BWM.*
21. Who normally fetches and treats water in the family?
    i. *Rationale: This question asks about whom would benefit from saving time from fetching and treating water.*

The life routine of local families/social benefit

22. What activities could your clients do if they didn't have to fetch/treat water?
    i. *Rationale: This question highlights the opportunity cost of using the BWM for community members. Building upon the last question, with the time freed from not treating water, end users would be able to attend more school or conduct business, creating a better quality of life.*

Willingness to pay

23. How do you define safe water? (check all that apply)
    i. *Rationale: This question asks for the franchisees understand the value of the BWM for treating water. Want to know if more information is needed to understand the value of the BWM and clean water in the community. Need to understand clean water means that it doesn't involve unhealthy bacteria, viruses, and other dangerous or threatening qualities.*
24. What do you believe the benefits are of clean water?
    i. *Rationale: This is a knowledge-based question. If they understand the value of safe water and evading health risks for the communities they serve, they will be more likely to promote/market the BWM.*
25. How do people in the communities you serve normally treat water? (for instance, boiling water or using chlorine tablets)
    i. *Rationale: This provides insight as to how end users treat water normally, which could be time consuming, unsustainable, or even expensive processes. Relating this to the advantages of the BWM could be a selling point and increase their willingness to pay*
26. Do you believe contaminated water is a concern to community members?
    i. *Rationale: This also confirms that end users understand the importance and value of clean water. If they understand this, willingness to pay will increase because the value of obtaining clean water through the BWM will increase.*
        1. *If they do not understand this, education needs to be implemented through marketing.*

27. How would you rank BWM, boiling water, chlorine tablets, ceramic water filter, charcoal filter, straining through fine cloth, slow sand filtration, and/or other water treatments end users currently use from most to least valuable?

Water kiosk:

28. Based on your knowledge of the community, how much would your clients pay for a 10L bottle of safe water? (Our price is $0.1/bottle)

Appendix D: Survey Data Set Download

(Email judithli2023@outlook.com to access raw data.)

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