Economic Analysis of Free Waste Collection System in the City of Ouagadougou and Refined Business Plan

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Executive Summary

Problem statement: The goal of this project is to analyze the startup and maintenance costs of the proposed waste management system, as well as potential profits of products created from the waste in order to propose a refined business model that can be taken to the Embassy to file for a grant that will cover startup costs.

Background: The waste management system for the City of Ouagadougou, Burkina Faso is ineffective. Currently, households have to pay for waste collection services. However, many households cannot afford these services, and the service providers often participate in illegal waste dumping. Waste not properly disposed of leads to negative environmental, health, hygiene, and economic problems.

Proposed Solution: In order to mitigate the environmental harms of pollution, stimulate the local economy and improve quality of life, our client, a mandela fellow, working with RAID, African Network of Engineers for Development has proposed a free, city-wide, waste management system that converts the collected waste products into valuable items. The goal is for the items produced to offset the cost of maintaining and running the system.

Methodology: The following analysis tools were used throughout the course of our project.

1. Scoping Exercise
2. Stakeholders analysis
3. SWOT analysis
4. Economic analysis
    - LandGEM

Results Discussion: After an economic analysis of a free waste collection system for the city of Ouagadougou, we have determined that the system is economically feasible if a grant or other source of funding can convert the initial capital cost and first three years of running the system. After three years, the system will be economically sustainable and after nine years it will have generated enough income to cover the initial capital costs.

Recommendations: This group has completed all of the work it can do for this project, and it should not continue into D-lab two. The next step is for our client to conduct a small scale feasibility study in a section of Ouagadougou. He should take the findings from that study and the economics analysis we have provided him to the embassy in order to get a grant to cover the start-up costs of this system.

Introduction

The current economic model for the solid waste management system in Ouagadougou, Burkina Faso is too costly for many households to implement. This has resulted in illegal dumping and pollution that has detrimental effects to both humans and the environment. In order to mitigate the negative effects posed by this issue, a free waste management system is being proposed by the African Network of Engineers for Development (RAID). To ensure that this new system is sustainable, there needs to be a value generated from the waste that is collected. It is crucial for the profit return of the new system to, at a minimum, break even with the cost of and maintaining the system. The goal of this project is to analyze the startup and maintenance costs of the proposed system, as well as potential profits of products created from the waste in order to propose a refined business model that can be taken to the US Embassy to file for a grant that will cover startup costs.

Solid waste management is the one thing just about every city government provides for its residents. In capital of Burkina Faso, Ouagadougou, solid waste management is arguably the most important municipal service and serves as a prerequisite for other municipal action. Per research data provided by our client, average waste generation in the city region is around 0.85kg/capita/day and provided the city population of 2.5 million people totals to generation of around 2125 tons of waste a day. This volume is expected to increase as the population grows and the country develops further. In fact, waste generation rates expect to more than double over the next twenty years in lower income countries [1]. Therefore addressing the problem of solid waste management is an urgent priority.

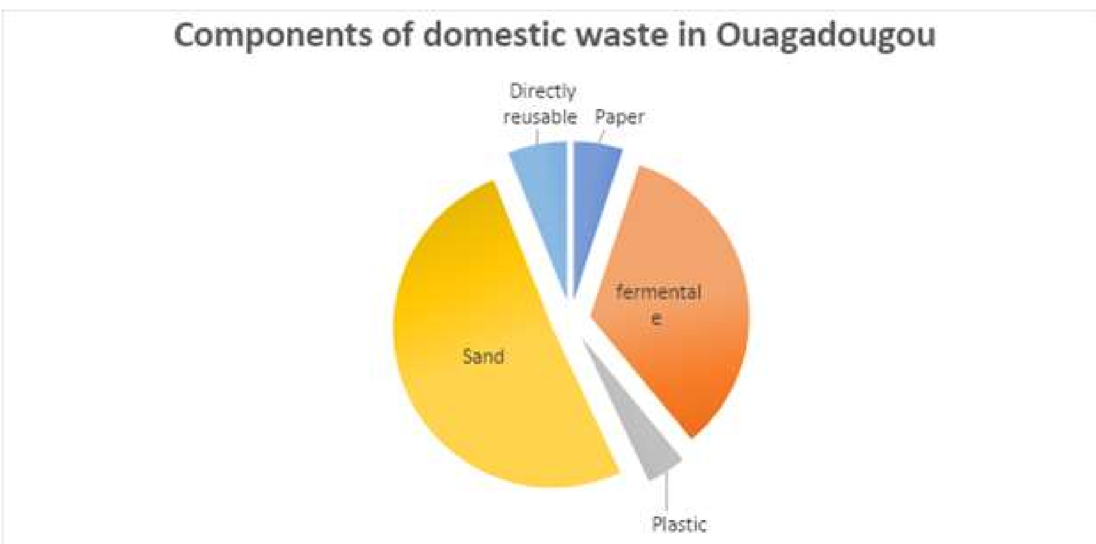

Figure 1 - Composition of typical domestic waste in Ouagadougou

The main contributors of plastic waste in sub-Saharan African countries come from plastic bags, bottles and some food packaging [2]. Despite its small composition of total waste, plastic pollution causes significant environmental damage and as a result has a negative impact on the people of Burkina Faso [3]. In addition to being an eyesore, littered plastics, by capturing stagnant water from rainfall, become breeding grounds for mosquitoes that carry potentially fatal diseases such as malaria [3]. Plastic also contaminates local waterways which creates a whole new set of health complications [4]. Potential uses for plastic waste that will generate a profit include bricks for construction composed entirely of recycled plastic as well as using PET fibers as a reinforcement for cement bricks. These materials can be used to build new classrooms for children, as well as improve roadways and other infrastructure within the city. Additionally, plastic waste may also be used as a new art medium. Littered plastic bags on the roads of Ouagadougou can be used to weave intricate patterns into tapestries, bags, hats, and other garments [5]. Weaving textiles on a traditional loom is both a part of the culture and source of income for many people in Burkina Faso [5]. By reusing plastic bags, the group is improving sanitation while also helping the women and youth who transform the materials to achieve a new source of income.

Many of these promising proposed solutions have been implemented on a small scale in Ouagadougou by private groups, but none have been implemented into a government sponsored system before. Based on the successful results of the small scale projects, we hypothesise that the project will generate enough profit to be feasible if approved for a startup grant. This system has the potential to improve the quality of life for the people living in Ouagadougou.

Methodology

The following analysis tools were used throughout the course of our project:

1. Scoping Exercise
2. Stakeholders analysis
3. SWOT analysis
4. Economic analysis
    - LandGEM

Scoping Exercise: The waste management system proposed by our client contains many parts. To decide what area of the project to focus on, we conducted a scoping exercise. As a team we discussed all of the various aspects involved with implementing and maintaining a free waste collection system. After listing out all of the aspects involved we met with our client and determined that our team should focus on analyzing the economic aspects of the system including start up costs and the cost of running and maintaining the system.

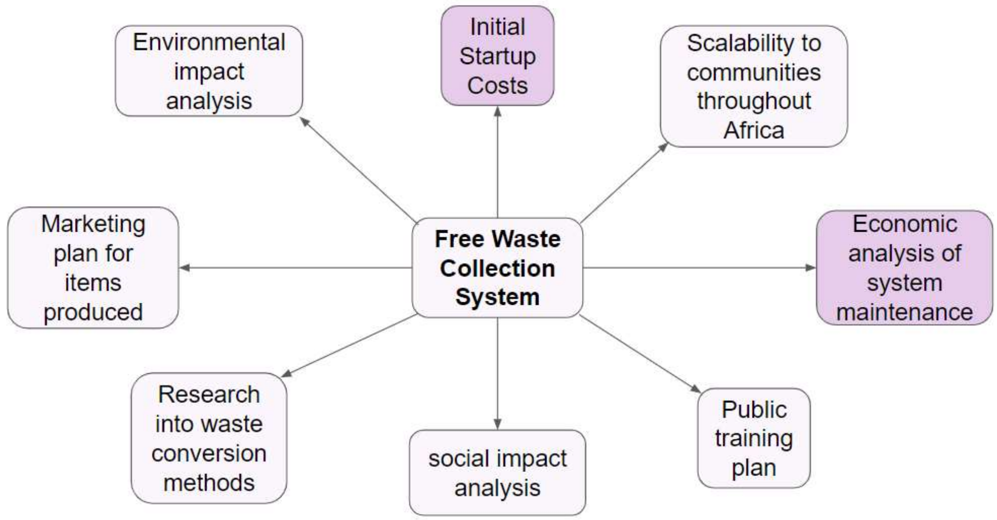

Figure 2: Scoping Exercise

Stakeholders Analysis: A stakeholders analysis, figure 2, is an important tool used to understand the various parties involved with a project and the influence they have. Working with our client, we have identified the stakeholder groups: the US embassy, the citizens of Ouagadougou, D-lab, RAID (African Network of Engineers for Development), the government of Burkina Faso, The Environmental Department of Ouagadougou, and current waste collectors. Identifying these groups will be crucial for our client to move forward with the project so he knows what steps to take to secure support both economically and with government policy.

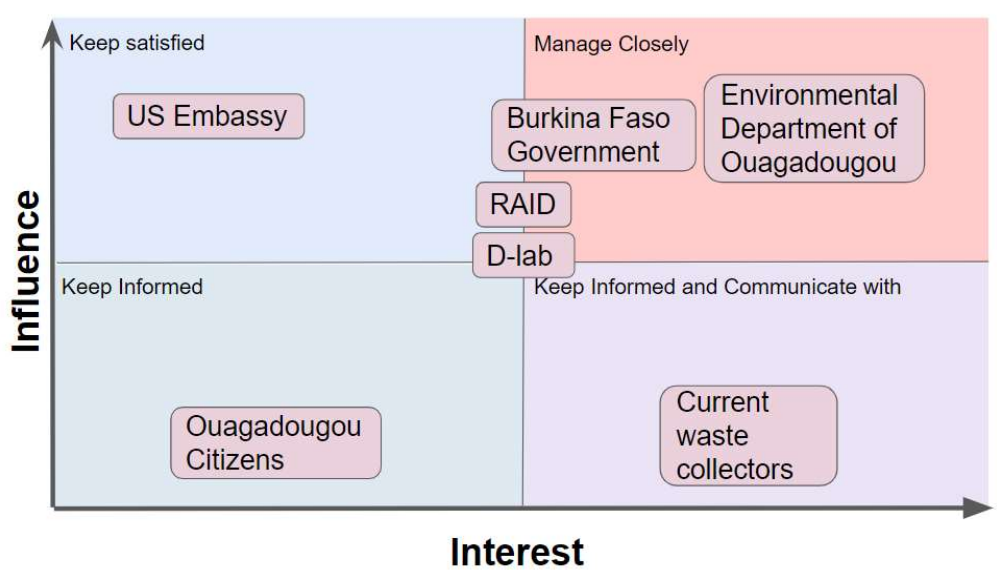

Figure 3: Stakeholders Analysis

SWOT Analysis: A SWOT analysis, figure 3, is used to identify the strengths, weaknesses, opportunities, and threats present in a project. By working with our client we were able to identify the areas both internal and external to the project that are helpful and harmful, we were able to gain a better understanding of the project and where we should be focusing our attention.

Strengths	**Weaknesses**
• Government connections • Client is educated with engineering background • Connections with US embassy as Mandela Fellow • Established NGO, RAID • Some established collection and sorting centers	• No secured source of funding • Lack completed infrastructure • Lack of public education and awareness about waste management • Lack of environmental policy
Opportunities	**Threats**
• Funding through US embassy • Current Waste collection companies operating illegally • Private sector already involved in waste collection • Regulation and permitting support • Poor electricity generation	• Current waste collection services • Community support • Unreliable electricity

Figure 4: SWOT Analysis

Through the use of both of these tools we were able to identify several factors that will be important for the success of the project:

- The head of the environmental department in Ouagadougou is a Humphrey fellow who was identified as a stakeholder with high interest and high power is pushing our client to provide a waste management solution to end the pollution of storm drain canals creating an strength for our project.
- The government of Burkina Faso spends thousands of dollars every year to clean waste clogged storm drain canals due to lack of a functional waste management system. This has provided the opportunity of government support through regulations and permitting.
- There are only a few current waste collection providers and most of these are operating illegally. To decrease costs they are cutting corners and dumping waste into drain canals instead of bringing it to designated dumping sites. Due to their illegal operations, our client is confident that these competitors will not cause difficulties with the implementation of a new waste management system.

Economic Analysis: In order to conduct a feasibility study of the proposed waste management system, our team created an economic analysis tool via comprehensive Excel-based tool to be utilized by our Client to further crystalize exact results using location specific data as the project goes into the implementation phase. Basic summaries of inputs have been presented in appendices of this paper. Through research and with the help of our client we identified the costs associated with the proposed waste management system and possible economic gain through transformation and reuse of collected materials. The tool takes these inputs to give an output of the projected overall economics of the system once implemented. Our client can easily update numbers in the spreadsheet and add additional, or delete current, inputs as his plan eveloves. This tool will allow our client to decide if the system is feasible and make adjustments accordingly.

- *LandGem:* In order to accurately account for the amount of methane that the fermentable waste can produce, we used LandGEM, an EPA tool. LandGEM is a precise modeling tool that provides the methane output from a location and climate-specific landfill gas collection system.

Results and Discussions

Upon analysis of available municipal waste value recovery avenues for Ouagadougou it was determined that the most viable and quantifiable options are landfill gas collection and converting it into electricity and production of plastic bricks. The client's original idea of generating biogas and distributing it in existing household cooking gas containers turned out to be technically unfeasible. This is because biogas is mostly composed of methane which is very different from propane, LPG, and cannot be distributed in common LPG tanks. In the absence of data about an existing natural gas pipeline system in the city of Ouagadougou, electricity generation potential has been chosen for evaluation as the most technically feasible option.

Electrical sector overview: The electrification rate in Burkina Faso is very low. Considerable investments have been done, but the system is insufficient to meet the rising demand in the country's two largest metropolitan areas, Ouagadougou and Bobo Dioulasso. The average connection rates have not improved for years and are 51% in urban areas and 1.5% for rural areas. Currently, 80% of total electricity generated in Burkina Faso comes from thermal-fossil fuels [6]. Hydropower is also a major contributor to generating electricity. Electrical grid reliability remains relatively low, with blackouts happening on a regular basis. The cost of electricity generation is one of the highest in the region at $0.22-0.25 USD/kWh while opportunities to increase generation capacity are being actively sought [6]. The climate in Burkina Faso is also very favorable for a landfill gas collection system. This combination of factors has created an opportunity for landfill gas production. The Government of Burkina Faso has set forth a bold national plan and has taken steps to introduce legislation to encourage private-sector investment and to liberalize electricity generation and distribution [6]. By providing additional capacity to the energy market there is an opportunity to contribute greatly not only to waste management development but also to electrical grid reliability and increased access to electricity.

To determine estimated capital expenses to set up a waste management system, we used a case study from *M. Dowling et al.* that evaluated landfill gas generation potential in Cape Town, South Africa [7]. Additionally, we validated our results by comparing to a similar system currently in operation in Sacramento, CA [16]. Based on location-specific and client-provided data on waste composition as well as generation rates prediction from World Bank, a hypothetical landfill model was evaluated to determine the feasibility of our particular landfill gas to energy project [1]. Exact LandGEM input parameters shown in Figure 5 below. And the results of the LandGEM simulation are presented in Figure 6.

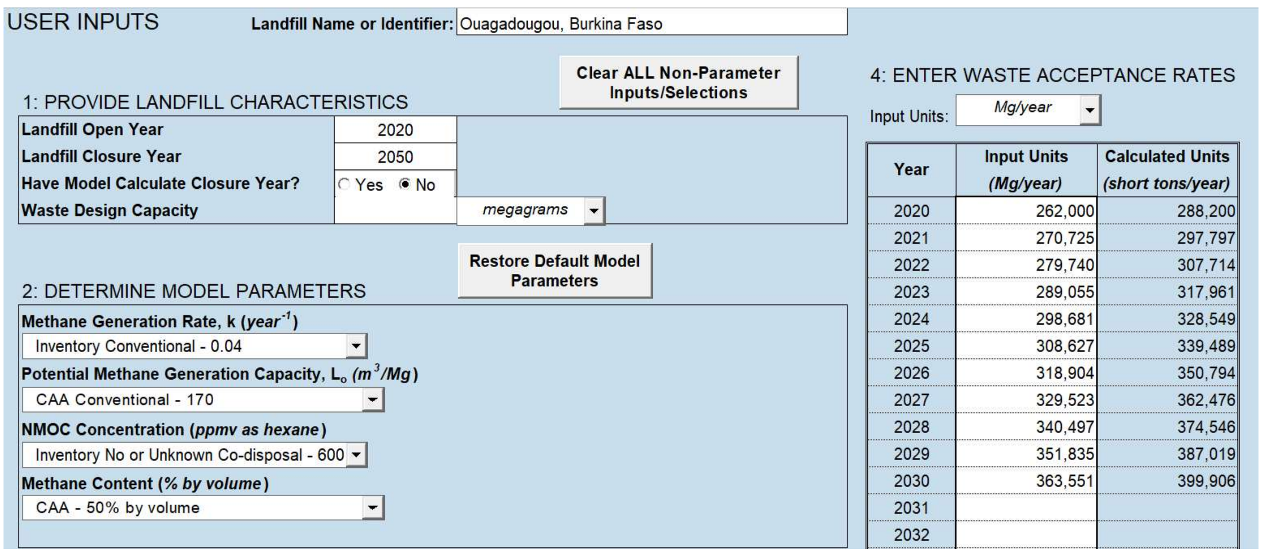

Figure 5: LandGEM Input Parameters

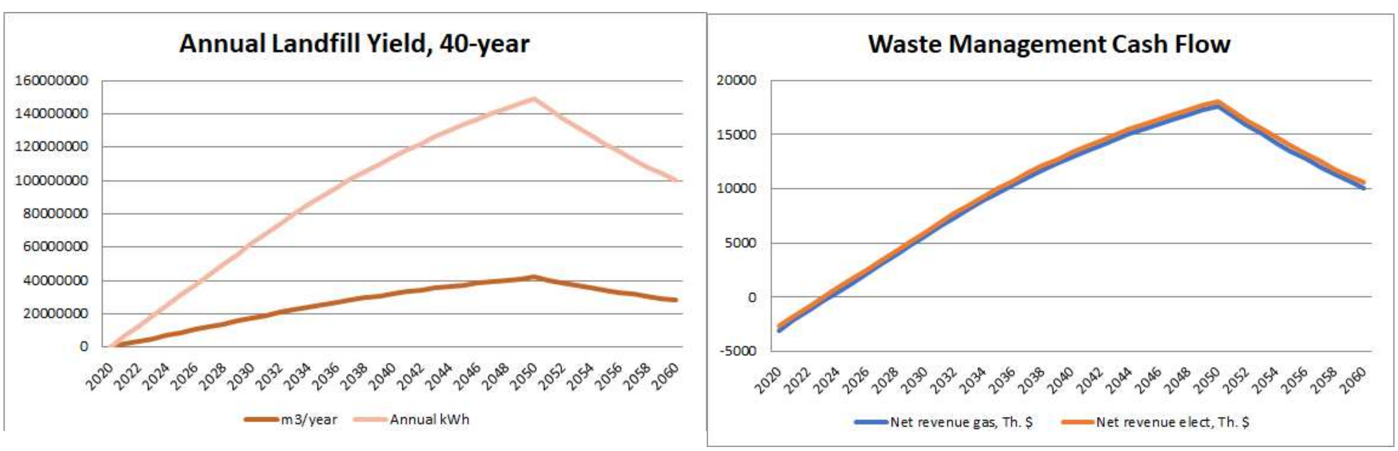

Figure 6: LandGEM Simulation Results

Several key assumptions were made during economic analysis:

- Electricity feed-in tariff assumed at $0.15/kWh [7]
- 75% of produced methane converted to electricity [7]
- The age of a landfill gas-to-energy project is assumed at conservative value of 10 years, with consequent 20 years of gas collection, maintaining and servicing the site [7].
- Waste management system employee salary considered at CFA 46,000/month, reasonably above country legal minimum wage [14]
- Capital Cost of providing households with containers for garbage collection assumed at $14 [10].
- Capital Cost of biogas-to-electricity turbine plant assumed at $859/kW [7].

LandGEM is used to estimate the amount of usable landfill gas that can be converted to electricity is defined by the EPA as between 75 - 85% of the produced methane in a landfill. The calorific value of methane (CH_4) is 4.5kWh/year [7].

$$\text{Electricity per year} = CH_4\text{/year} \times 75\% \times 4.5\text{kWh}$$

Waste collection modeling: Our client proposed using gasoline powered vehicles for waste collection. Additionally, we conducted a parallel evaluation of implementing all-electric collection vehicles for following reasons:

- Very low fuel cost and the possibility of charging the vehicles using electrical energy generated by landfill gas combustion [9].
- Much lower ongoing maintenance and potentially much higher longevity of the drivetrain [9].
- No tailpipe emissions and no noise associated with gasoline-powered vehicles [9].
- Much higher torque at 0 speed which is inherent for an electrical-motor powered drivetrain and will seamlessly benefit waste collection drive cycle over gasoline vehicle [9].

A comparison of the two options can be seen in Table 1 below.

Gasoline Waste Collection Vehicle [8] 	Electric Waste Collection Vehicle [9]  
Engine: 300cc 4-stroke	Motor: 2500W
Weight Capacity: 1200kg	Capacity: 2800L
Fuel: 12L gasoline tank	Battery: Lithium Iron Phosphate, 8640Wh
Advertised price: **$1400**	Advertised price: **$7000**

Table 1 - Comparative table of waste collection vehicles

Both vehicles evaluated possess similar operational characteristics and are comparable. Charging energy for electrical vehicles was modeled as a parasitic load on total energy generated by the waste management system. It should be noted that both vehicles present are examples and direct dialog with manufacturers should be facilitated to negotiate the price as electrical vehicle technology matures. We assumed maintenance value for those at $0.03 per kilometer, which is sufficient amount to fully replace the battery after about 7 years of operation [17].

Per our Client's research data, the city of Ouagadougou is divided by 55 sectors, with most of the sectors having designated intermediate waste collection locations. With that in mind, we included the cost of 1 heavy-duty roll-off truck as well as 1 dozer to manipulate the waste at the landfill site in the capital cost of which assumed at prices of $85,000 [11] and $75,000 [12] respectively. To estimate labor expenses required, the number of US employees in waste management sector was scaled for the population with hazardous waste removal and septic tank services employees excluded from consideration [15]. The rest of assumptions represented in Excel spreadsheet appendix.

As the end-result of our study, we developed several charts and identified key economic parameters to give our client a baseline for project implementation. The summary of capital costs as well as its breakdown is represented in figures 7 and 8 below.

Total cost of system implementation in Ouagadougou, millions $	**22.18**
Total cost of system implementation with electric transport, millions $	**23.42**
Difference in capital cost for Electric collection over Gasoline, %	**5.6**
System revenue over 30-year horizon, millions $	**283.0**
System revenue over 30-year horizon, with electric transport, millions $	**295.3**

Figure 7: Capital Cost Summary

Capital investment calculations excluded existing waste management facilities as well as country-specific landfill set up operational expenses such as setting up clay bed, etc. Additionally, profit generated from textiles produced was excluded from economic analysis due to lack of relevant economic data, and the profits would most likely be negligible compared to that of landfill gas and plastic bricks. Plastic brick production revenue was quantified at conservative value of $0.04 per unit due to insufficient economic data for the product market value [13].

As represented by figure 8, the two biggest contributors to capital cost are that of household bins and building a power generation plant.

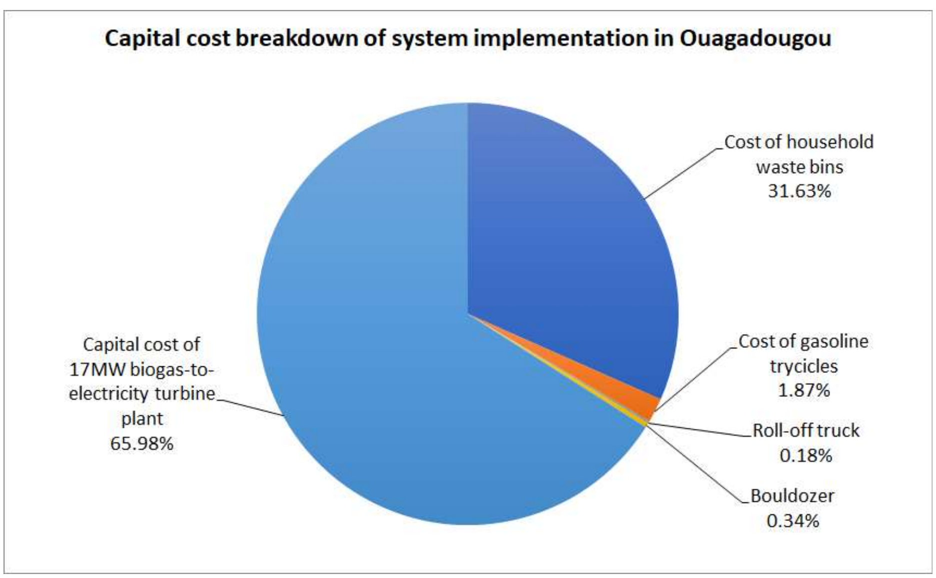

Figure 8: Capital Cost Breakdown

Upon finalizing our analysis, it was determined that there will be approximately $5.1M of negative cash flow for gasoline waste collection system and $4.1M negative cash flow for electric waste collection system in first 3 years of system operation. It is highly advisable, therefore, to account for those expenses as a part of capital expenses or recover those costs via low monthly collection fee of less than $1 a month per household in the first 3 years of operation. In comparison to current waste collection fees provided by our client, being in the range of $1.5-6 per month, this $1 per month could be a viable means of transitioning of the system. Both collection systems became profitable in the 4th year of landfill operation. And it took nine years to recover invested capital cost with electric waste collection and ten years to recover capital cost with gasoline waste collection. Annual cash flow is represented in table 2 below.

Year in operation	Net revenue gas, Th. $	Net revenue elect, Th. $
2020	-2606	-2263
2021	-1702	-1358
2022	-833	-486
2023	32	382
2024	893	1247
2025	1752	2110
2026	2611	2972
2027	3470	3834
2028	4330	4698
2029	5192	5564
2030	6059	6434
2031	6930	7309
2032	7766	8149
2033	8567	8954
2034	9335	9726
2035	10071	10466
2036	10777	11175
2037	11453	11856
2038	12101	12508
2039	12722	13133
2040	13317	13732
2041	13887	14306
2042	14432	14855
2043	14955	15382
2044	15455	15886
2045	15933	16369
2046	16391	16832
2047	16829	17274
2048	17248	17698
2049	17649	18103
2050	18032	18490

Table 2 - Waste Management Annual Cash Flow

Despite its small composition of total waste, plastic pollution causes significant environmental damage and as a result has a negative impact on the people of Burkina Faso [3]. In addition to being an eyesore, littered plastics, by capturing stagnant water from rainfall, become breeding grounds for mosquitoes that carry potentially fatal diseases such as malaria [2]. Plastic also contaminates local waterways which creates a whole new set of health complications [4]. Although there are labor and services costs associated with the proper recycling of plastic, RAID is hoping to be able to provide this service to the Ouagadougou citizens for free. In order for this model to be economically feasible, there must be a productive use of the recycled plastic that can generate revenue.

Recommendations

Starting a solid waste management system is a significant challenge, considering large capital costs and necessary expertise required to get the system going. Lower-income countries spend less on waste operations in absolute terms, but experience much more difficulty in recovering costs. On the other hand, significant improvement in greenhouse gas generation potential by implementing a waste management system in Burkina Faso definitely offers a potential to attract international capital aimed to mitigate climate change. Other unquantified benefits of improved waste management such as reduction in pollution of local water sources and positive health effects on the general population should be taken into account as well. Significant reduction of global warming potential will be achieved upon implementation of a waste management system in Burkina Faso. Additionally, creation of estimated 1270 full-time jobs will sure to positively impact the community and contribute to overall economic stability of Burkina Faso. On top of that, indispensable community benefits from reducing storm drain pollution and consequently, spread of diseases should be noted as another benefit of implementing a system. On a country level, governments saving steaming from not having to clean drain canals each year before rain season will surely add up.

While all assumed values presented in this study aim to reflect real-life conditions, additional research is commendable particularly in terms of market conditions for plastic bricks and textiles as well as further evaluation of electrical cogeneration details with local electrical utility. For detailed assumptions made for economic analysis as well as model of landfill site please refer to spreadsheets supplied with this paper.

Our group has completed all of the work it can do for this project, and it should not continue into D-lab two. The next step is for our client to conduct a small scale feasibility study in a section of Ouagadougou, and complete the market research as stated above. He should take the findings from that study and the economics analysis we have provided him to the embassy in order to get a grant to cover the start-up costs of this system.

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Appendix

Appendix legend:

Inputs	
Calculations	

Appendix A - Capital Cost Summary

Waste bins required, per household	2	Assuming 2-bin system
Cost of household waste collection bin, $	7	Aliexpress estimation [10]
Cost of a tricycle with added trailers, $	2000	Aliexpress + trailer estimation [8]
Cost of electric tricycle with added trailers, $	8000	Aliexpress + trailer estimation, suited vehicle [9]
Capital Cost for Electricity generation set-up, $/kW	859	M. Dowling et al [7]
Number of tricycles needed for waste collection in 55 sectors	207	
Number of households to collect waste from	500000	
Number of household waste collecion bins needed	1000000	
Cost of household waste bins	**7000000**	$
Cost of gasoline trycicles	**413194**	$
Roll-off truck	85000	[8]
Bouldozer	75000	[7]
Capital cost of 17MW biogas-to-electricity turbine plant	**14603000**	Capital cost for 17MW at 859/kW
Cost of electric trycicles	**1652778**	$
Total cost of system implementation in Ouagadougou, millions $	**22.18**	Estimation not accounitng for existing waste management assets
Total cost of system implementation with electric transport, millions $	**23.42**	Estimation not accounitng for existing waste management assets
Difference in capital cost for Electric collection over Gasoline, %	**5.6**	
System revenue over 30-year horizon, millions $	**283.0**	
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