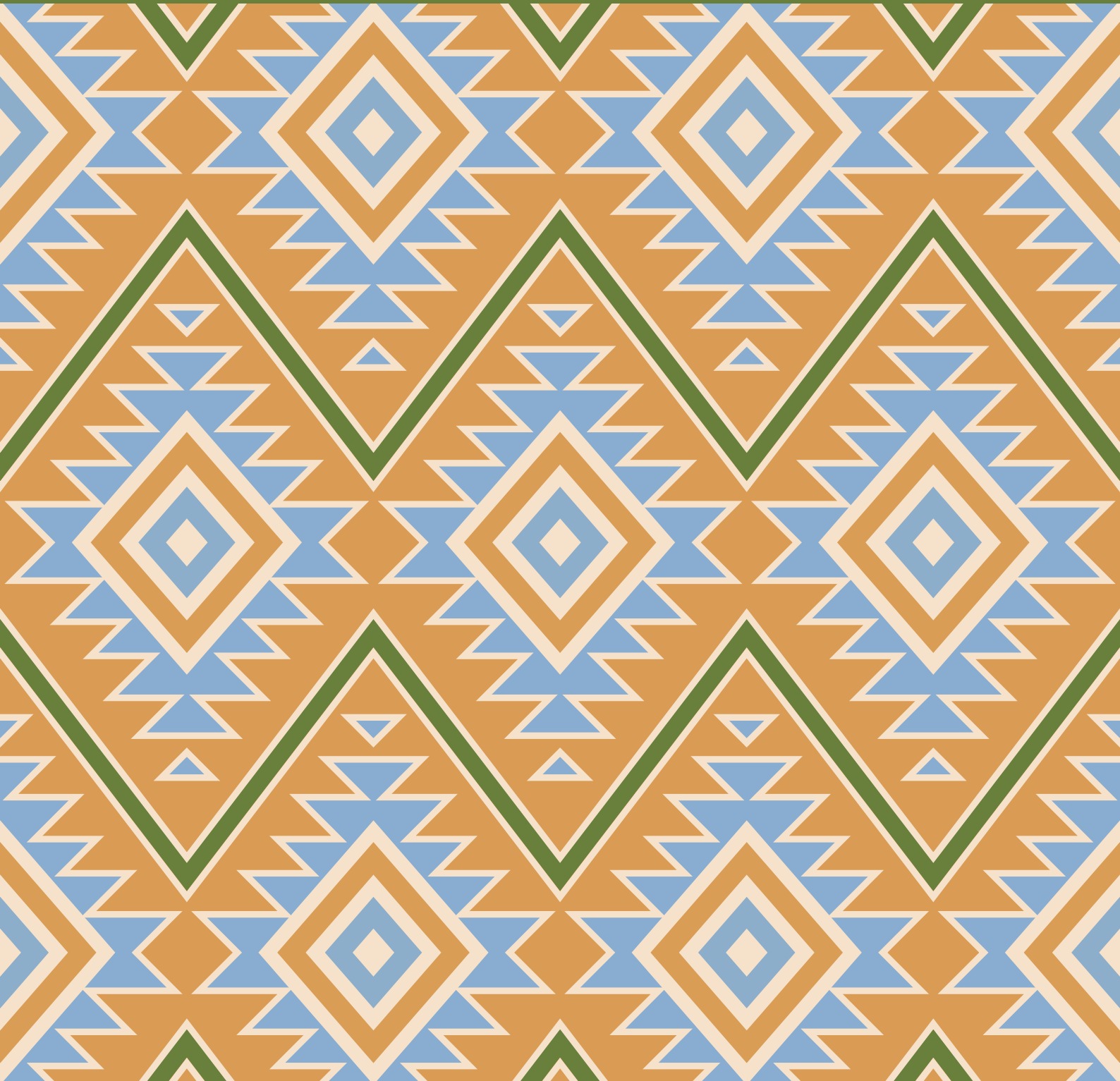


Development of a Sustainable Business Model for Recycling Plastic Waste in Sierra Leone

Nicolai Fürstnow | Master's Thesis | July 2023



Abstract

The world is facing a global environmental catastrophe in the shape of a plastic pollution crisis. Globally, more and more plastic is produced with limited measures in place to manage the waste materials. Overexploitation, greed, and a lack of waste management traditions cause plastic waste accumulation and significant environmental and social challenges, especially in marginalised third-world countries. A global movement is developing where national states, NGOs, and industrial front runners seek to fight the problems by creating circular economy value chains.

This thesis describes the development of a sustainable business model for recycling plastic waste in Sierra Leone, West Africa. The research results include work from the author's internship at Engineers Without Borders Denmark, with three months of work on-site in the capital of Freetown, working with local partners on the specific challenges. The business model was created through desk and field research and applying theoretical frameworks for solution development and implementation.

An initial investigation of the plastic waste challenges was performed, including a root cause analysis to clarify the interlinked issues. The investigation illustrated how the lack of a waste management system is further complicated by multiple social, economic, and technical challenges such as social marginalisation, inefficient infrastructure, unstable power supply, and repeated flooding of the city during the rainy seasons.

To navigate the complex nature of the situation and focus the thesis's work, the primary research question was defined as:

"How can a business model be devised for recycling plastic waste, focusing on developing a waste management infrastructure?"

Supplemented by the underlying questions:

"How can the model be implemented and performed with the management of stakeholders?" and "How can the associated risks be mitigated?"

Opportunities for recycling plastic were explored based on perspectives from the concepts of circular economy and platform thinking, along with a screening of available plastic recycling technologies on the market today. A solution space could then be defined by investigating possible options within waste sourcing, transportation, collection and sorting sites, processes, and the offsetting channels. By evaluating and combining these options, a comprehensive business model was derived where the collected plastic waste is separated according to type, condition, and contamination degree. A vital contribution to the economic model is the attainment of international plastic credits. The business model was finally assessed concerning its strengths, weaknesses, and risks.

An implementation plan was derived for waste sourcing, collection, sorting, and offsetting recycled plastic waste. For this, different implementation perspectives were used to identify areas of high importance for success. Stakeholder management was identified as critical and local partners are utilised to a high degree to ensure a sustainable and empowered business model.

Concerns and limitations that affect the business model are discussed in the thesis, highlighting areas with room for improvement to be further investigated. The project serves as a case study from which learnings can be applied broadly in developing business models. The thesis outlines these learnings, including inputs to local partnerships, sustainability focus, and legislative frameworks.

The thesis is completed by a summary of the research results and a proposed business model including points of interest for future work.

Approval

This thesis has been prepared over five months at the Department of Management at the Technical University of Denmark for the master's degree in Industrial Engineering and Management, MSc.

The thesis was complemented by the author's internship at Engineers Without Borders Denmark in Sierra Leone during the spring of 2023.

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Abbreviations

ACEA	African Circular Economy Alliance
API	Application Programming Interface
B2B	Business to Business
B2C	Business to Customer
CE	Circular Economy
CSO	Civil Society Organisation
CISU	Civilsamfund i Udvikling
DIS	Dansk Ingeniør Service
DRS	Deposit Refund System
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
EWB-DK	Engineers Without Borders Denmark
FCC	Freetown City Council
FWT	Freetown Waste Transformers
GNI	Gross National Income
HDPE	High Density Polyethylene
LCA	Life Cycle Assessment
LDPE	Low Density Polyethylene
MoU	Memorandum of Understanding
NGO	Non-governmental Organisation
OEM	Original Equipment Manufacturer
OPF	Ocean Plastic Forum
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl Chloride
RIC	Resin Identification Codes
SBMC	Sustainable Business Model Canvas
SDG	Sustainable Development Goal
SCS	Seven Clean Seas
SLE	Sierra Leonean Leones
UNICEF	United Nations Children's Fund
WCMA	Waste Collection Management Association
WHI	World Hope International
WPU	Waste Plastic Upcycling

Thesis Design

The layout is made by the author.

The colour palette is chosen to match the one of Engineers Without Borders Denmark.

The cover image print is interpreted and designed by the author based on the traditional Sierra Leonean printing style.

The illustrations are made by the author unless otherwise stated.

The photos are captured by the author unless otherwise stated.

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Introduction

A brief introduction to the Plastic Pollution Crisis and what it has to do with Sierra Leone and Engineers Without Borders Denmark



1 Introduction

In the following, the foundation for the thesis is set by a description of how critical plastic pollution is for Sierra Leone and how Engineers Without Borders Denmark seeks solutions to solve it.

1.1 The Plastic Pollution Crisis

The plastic pollution crisis is a global environmental catastrophe of alarming magnitude. With over 359 million tons of plastic produced annually, our ecosystems are drowning in plastic waste. Its persistence in the environment for hundreds of years causes severe harm to nature, humans, and wildlife. The crisis disproportionately impacts marginalized communities, exacerbating social and environmental inequalities. These communities often bear the brunt of plastic pollution due to their proximity to waste disposal sites, limited access to proper waste management infrastructure, and reliance on contaminated water sources. It threatens their health and well-being, as they are more likely to suffer from waterborne diseases, respiratory issues, and other adverse health effects caused by plastic pollution.

Additionally, marginalized communities heavily dependent on fishing or agriculture face economic losses due to plastic contamination of their livelihoods. Lack of resources and political power further limits their ability to address and mitigate the crisis. Environmental justice concerns arise as marginalized communities experience a disproportionate burden of plastic waste while having less influence over decision-making processes. Urgent action is needed to reduce plastic production, improve waste management, promote sustainable alternatives, and raise awareness through education and policy changes. Collective efforts can mitigate the crisis and pave the way for a sustainable, plastic-free future.

In recent years, there has been an increasing focus on recycling the plastic waste as a crucial step in addressing the plastic pollution crisis. This focus stems from the recognition that recycling can help reduce the reliance on single-use plastics, promote resource efficiency, and mitigate the environmental impacts of plastic production. On a global scale, governments and industries are investing in infrastructure and programs to improve plastic waste

recycling rates and ensure proper waste management. Innovations such as chemical recycling and advanced sorting technologies are expanding the possibilities for recycling a broader range of plastics. This heightened focus on recycling is essential for building a more sustainable future and preserving our planet for future generations (Alliance To End Plastic Waste, 2021).

1.2 Engineers Without Borders Denmark

Engineers Without Borders Denmark (EWB-DK) is a technical, humanitarian non-governmental organisation (NGO) established in 2001. It comprises 1,400 members, of which about 250 are actively engaged in the organisation's work. EWB-DK is financed by contributions from members and generous donations from private and public donors.

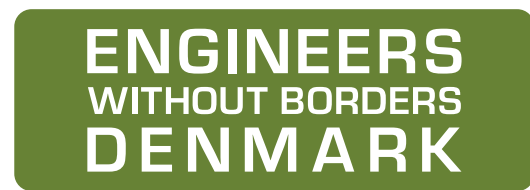


Figure 1: Logo of EWB-DK

The organisation seeks to improve the livelihood of impoverished people in close collaboration with local and international aid organisations. Through the donation of time, skills, and experience, the volunteers develop global partnerships, create sustainable solutions, and improve living conditions in some of the poorest communities in the world. Their work covers four strategic focus areas: WASH (Water, Sanitation, and Hygiene), Environment (Sustainable Energy, Waste Management, Environmental Planning), Food Security, and Disaster Relief and Preparedness (EWB-DK, 2023).

1.3 Sierra Leone

The Republic of Sierra Leone is located on the southwestern coast of Africa, bordering Liberia and Guinea. It is characterised by a tropical climate with diverse environments ranging from savanna to rainforest. The total population consists of 8 million people with English as the national official language, though strongly influenced by local dialects (Globalis, 2019).

Although Sierra Leone is abundant with resources, the country is one of the poorest countries in the world with a poverty rate of 56.8%. On the Global Human Development Index, the country ranks 181 out of 195 countries in 2021 (UNDP, 2022), and according to the World Food Programme, nearly 30% of the population suffers from chronic hunger (WFP, 2023). As if that was not enough, the country faces numerous challenges. This includes weak governance, a high infrastructure deficit, low human capacity, high youth unemployment, a vulnerable private sector, and a lack of economic diversification. These factors are primary drivers of the country's fragility; hence a multi-faceted approach to strengthening the waste management challenges is needed.

According to The African Development Bank, civil society organisations (CSOs) are paramount for addressing fragility in a multi-dimensional context and encouraging more inclusive and resilient growth trajectories, as often CSOs are closer to the population and comprehend the local dynamics driving the social, economic, and environmental issues. Because of this, it must be an essential strategy for any project to support civil society and engage the local communities in all parts of the project definition, development, and implementation (African Development Bank, 2014).

1.3.1 A Nation of Freed Slaves

To understand the current society, it is important to understand its history. In 1772 slavery was proclaimed illegal in Great Britain, and in 1787, the *Province of Freedom*, which later became *Freetown*, was founded as a British colony. Also, the territory held a naval base to patrol the area against illegal slave ships. In the following years, freed slaves from Nova Scotia in Canada crossed the Atlantic Ocean and joined the original settlers, the Maroons, who had been exiled from Jamaica following the Maroon War.

In 1808, Sierra Leone became an official British crown colony, after which virtually all new settlers were slaves rescued from slave ships and emancipated by the Royal Navy. The re-captive slaves mixed with the existing community and formed the Krio culture and language with Christianity as its base. In the following years, Sierra Leone became a place of great importance for missionary activities and the center of education in West Africa. In particular, Freetown was of great prosperity and



Figure 2: Map of Sierra Leone

was known as the “Athens of West Africa”.

In 1961, Sierra Leone gained independence from the United Kingdom and became a Commonwealth realm at the same time. In the decades to come, the country experienced increased political activities with widespread turmoil and humanitarian and socio-economic crises. This led to the Civil War in 1991, which would devastate the young nation (BlackPast, 2009).

1.3.2 Civil War, Ebola and Covid

When a rebel group, the *Revolutionary United Front*, attempted to overthrow the government in 1991, the country fell into a civil war. It resulted in over 50,000 deaths and was characterized by acts of extreme brutality. Also, it led to the internal displacement of over two million people, and another half million were forced to seek refuge in neighbouring countries. When UN Peacekeeping and later the British military intervened, the civil war ended in January 2002. Since Sierra Leone has made tremendous progress in establishing good governance and consolidating peace and security, it is often cited as a success story in peacebuilding.

Until the outbreak of Ebola in 2014, Sierra Leone attempted to achieve middle-income status by 2035, but severe post-conflict attributes such as corruption, high unemployment, and weak governance affected the country. Also, the country faces the immense challenge of facilitating transparency in managing its natural resources and establishing fiscal room for development. Despite

groundbreaking reforms and initiatives, problems such as fragile infrastructure and widespread rural and urban impoverishment persist (The World Bank, 2023).

Like many other African countries, Sierra Leone has been exceptionally severely affected financially by the COVID-19 pandemic and the Russian invasion of Ukraine. In a macroeconomic context, the post-pandemic recovery was disrupted by coinciding domestic and external forces, which worsened the existing macro-fiscal vulnerabilities. It has boosted the ongoing inflation, and as of the start of 2023, the inflation rate peaked at 40%. Likewise, the exchange rate depreciated, depressing economic activity and squandering living costs. The prices of beef, tomatoes, rice, and onion have been increasing by 50% whereas fuel and palm oil prices are roughly doubling (Trading Economics, 2023). Due to the national depreciation, the central bank of Sierra Leone has removed three zeroes from its bank notes as of mid-2022. By doing so, they hope to evade rapid inflation, restore confidence in the currency, and reduce the amount of paper-based money in circulation (The New York Times, 2022).

1.3.3 Freetown

The capital city of Freetown is located in the west on the shores of the Atlantic Ocean (see figure 2). It is situated on a mountainous peninsula and is one of the most densely populated cities in West Africa, with approximately 1.25 million residents; however, locals believe the actual number is threefold. Over the past 30 years, the population has doubled due to the Civil War, which caused a migration of people from rural areas to the capital in search of better economic opportunities. Due to the expanding population, the city has sprawled beyond municipal boundaries adding settlements in places such as along the coast and on the hillside. This land reclamation has led to deforestation with severe weather vulnerability. The relentless urban development has left Freetown City Council (FCC) struggling to sustain effective waste management throughout the city.

In 2017, the world's deadliest natural disaster occurred in Freetown after three successive days of intense and heavy rainfall. A massive landslide took place on the outskirts of Freetown, developing into a debris flow that traveled six kilometers through the city towards the ocean (see figure 3 - credits:



Figure 3: Landslide in 2017



Figure 4: Flooding in Freetown

ARUP). It killed thousands of people and displaced even more. However, the infamous landslide is not a unique case. Annually, a heavy rainy season hits from May to September, creating small landslides and severe flooding throughout the city (see figure 4 - credits: The Freetown Society). According to locals, climate changes have worsened the powerful weather phenomena in the last 20 years to an unbearable degree. This is further intensified by the lack of waste management, causing waterway and drainage blockage, leading to a city left in complete deterioration (UN Sierra Leone, 2017).

Project Description

Presentation of the purpose, aim and goal of the project as well as the overall framework for the execution



2 Project Description

The project is based on a preliminary study by EWB-DK volunteers in 2021. In connection with other projects concerning climate action and sanitation in Freetown, the team identified a potential to develop waste management and plastic recycling in Freetown, Sierra Leone. The project is split into three sub-projects. All three play an essential part in the bigger picture, and they are highly interlinked. Due to the project's size, EWB-DK hired two interns for the spring of 2023, and the author was one of them. To roothold the project, EWB-DK partnered up with the local organisations; *World Hope International* (WHI) and *Skill Pool* (SP).

1. The first sub-project consists of the design, construction and placement of a floating barrier in the Freetown Lagoon below the Aberdeen Bridge to block plastic waste from entering the ocean and make it collectable (see figure 5 and 6). The barrier is developed in close cooperation between representatives from *Dansk Ingeniør Service* (DIS) and Peter Lindhøj Tuxen - the second intern. During the spring of 2023, a prototype was developed and brought to the designated site in Freetown for testing (see figure 7).
2. The second sub-project consists of establishing a waste collection and sorting site near the floating barrier. The objective is to ensure an adequate plastic waste collection infrastructure to facilitate local plastic recycling. The hope is that the centre will showcase how waste management and recycling can be done. To run the site, communities must be engaged to anchor the operations locally.
3. The third sub-project consists of the development of a sustainable business model for selling recycled plastic waste and sustaining the operations. In collaboration with local partners, it is the objective to build a waste-based value chain with the sale of plastic as a commercial product that will form part of a circular economy.

The primary focus of this paper is on the third sub-project, while the other sub-projects are included to provide the context of the bigger picture. To outline the scope of the paper, the purpose, aim, and goal are described in the following.

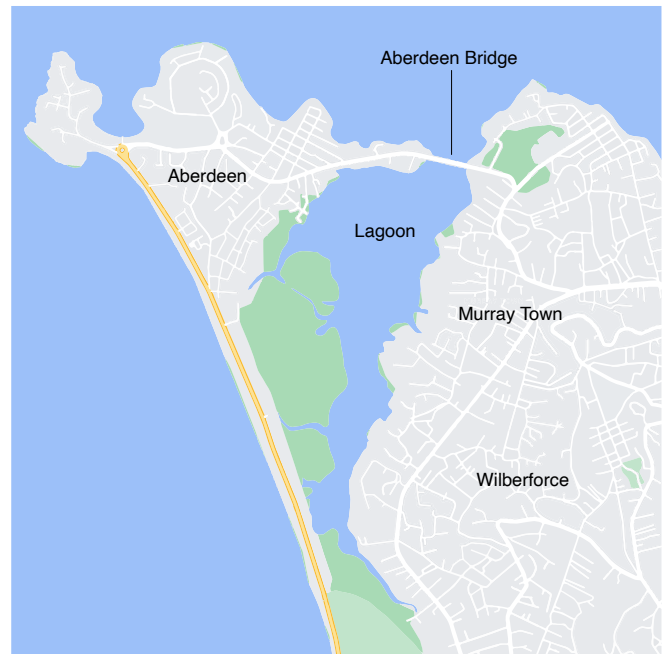


Figure 5: Map of Western Freetown



Figure 6: The lagoon

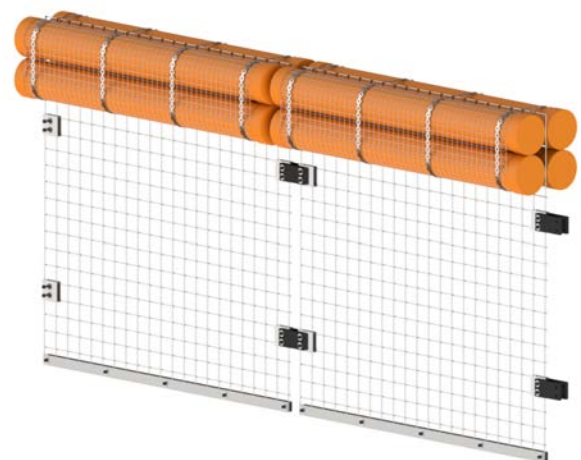


Figure 7: Floating barrier prototype

2.1 Purpose, Aim and Goal

The *purpose* of the project is to establish a socially, financially, and environmentally sustainable value chain for plastic waste in Freetown. This involves the development of a sustainable business model, and creating plans for collecting, sorting, processing, and offsetting plastic waste. The commercial objective is to transform plastic waste into a valuable commodity and build a network of collectors, sorters, and processors. This will facilitate innovative recycling expertise and technology while enabling access to the global market. The project is designed collaboratively, incorporating local needs and knowledge as a foundation for long-term, locally owned and managed solutions that benefit marginalized citizens.

The *aim* of the project is to establish locally-led sustainable plastic waste recycling in Freetown. This includes collecting, sorting, transporting, processing, and offsetting mismanaged plastic waste. By implementing these activities, the project intends to generate local income for marginalized citizens, reduce pollution in the city, and protect its water-based ecosystem. The project takes a holistic and engaging approach and serves as a proof of concept by showcasing the potential of plastic waste recycling and aims to stimulate interest in establishing, developing, and expanding recycling efforts.

The *goal* of the project is to establish a sustainable value chain for plastic waste, encompassing collection, recycling, and the permanent removal of plastic waste from the marine environment. It aims to demonstrate scalability and replicability, building trust in reliable access to plastic waste in Freetown to foster interest in expanding recycling initiatives. The project adopts a comprehensive and engaging approach that aligns with Freetown's waste management strategy and planned activities. It seeks to raise awareness and understanding of the opportunities presented by plastic waste among stakeholders such as authorities, communities, and plastic manufacturer companies, among others. By employing a co-creative and collaborative approach, the project aims to establish a locally owned and managed system that garners strong community support, particularly benefiting marginalized citizens in Freetown.

2.2 Internship at EWB-DK

Concurrent with the master's thesis period, the author interned at EWB-DK, where three months were spent in Freetown, Sierra Leone, from March until May 2023. To synchronise the internship with the master's thesis, the objectives were synchronised as best as possible. During the dispatch, the author was based at WHI's headquarters and the research activities were conducted primarily in Western Freetown in collaboration with WHI and SP. The main research activities were completed upon returning to Denmark, and a handover was conducted with the local partners. To ensure safety abroad, EWB-DK provided a security briefing before the dispatch, delivered by Bischoff Advisory on February 6, 2023.

2.3 Project Funding

To fund the project Ocean Plastic Forum (OPF) and Dansk Ingeniør Service (DIS) financed the construction of the floating barrier with 150,000 DKK and 200,000 DKK, respectively.

For the rest of the project, EWB-DK and WHI applied for 499,978 DKK from *Civilsamfund i Udvikling* (CISU), denoting the project as a citizen participation intervention. CISU administers *The Civil Society Fund* on *Danida's* behalf and has previously funded EWB-DK projects. The application was sent in mid-April, and approval was received in mid-May 2023, whereafter the project was launched.

2.4 Sustainable Development

The project is based on the principles of "Sustainable development", defined by the Brundtland Commission, which links social, ecological, and economic sustainability. It recognizes the interdependence of these dimensions to meet present needs without compromising future generations (Brundtland, 1987). As outlined in figure 8, the interlinkage forms the foundation for creating livable, fair, and viable societies by promoting human well-being, equity, and economic prosperity concurrently with responsibly managing resources and preserving the environment.

In 2015, the Sustainable Development Goals (SDGs) were adopted to reinforce the connection further, encompassing 17 goals and 169 targets addressing poverty, education, climate change, and more. They build upon the concept put forward by the Brundtland Commission, providing a framework and specific targets to guide global action

towards a more sustainable and equitable future. The goals and targets of the SDGs reflect the interconnectedness of social, ecological, and economic dimensions and highlight the need for integrated approaches to address global challenges (United Nations, 2023).



Figure 8: Sustainable Development

The project aims to affect aspects covered by eight SDGs (see figure 9), which are elaborated in the following.



Figure 9: Sustainable Development Goals

Partnership Sustainability

Goal 17 - Partnership for goals is the foremost important SDG as the project’s most prominent objective is to strengthen the means of implementation and revitalise the global partnership for sustainable development. It serves as a cross-cutting goal that supports the achievement of the other SDGs, highlighting the importance of fostering global cooperation, partnerships, and capacity-building.

Economic Sustainability

Goal 12 - Responsible consumption and production is affected as the project aims to establish a sustainable business by recycling materials to ensure sustainable consumption. Also, it will encourage sustainable production patterns by including thought within platform thinking.

Social Sustainability

Goal 3 - Good health and well-being is touched as the project aims to improve waste management and ensure cleaner habitation and healthy lives. Also, it will promote well-being across social groups due to a focus on marginalised communities.

Goal 11 - Sustainable cities and communities is affected as the project aims to target the challenges posed by rapid urbanization and develop a sustainable, inclusive city with enhanced resilience to disasters and climate change.

Ecological Sustainability

Goal 6 - Clean water and sanitation is touched as the project aims to clean the lagoon and thereby ensure the availability and sustainable management of water and sanitation in Freetown.

Goal 13 - Climate action is touched as urgent action is taken to combat the pressing climate changes and its impacts that especially hit Sierra Leone.

Goal 14 - Life below water is touched as cleaning the lagoon entails conservation and encourages sustainable use of marine resources for sustainable development. This includes the mangroves that have been in regression due to infected waters.

Goal 15 - Life on land is touched as the project aims to facilitate the restoration and protection of terrestrial ecosystems in Freetown. For many years they have been exposed to exploitation, leading to desertification, land degradation and biodiversity loss.

Methodology

Description of the research methods employed to assess the current state of Freetown, Sierra Leone, developing a solution and planning the implementation



3 Methodology

The performed research follows a *System-Oriented Problem Solving* approach introduced by Rainer Züst and Peter Troxler in their work on innovation and organizational development (Züst and Troxler, 2006). The approach emphasizes the need to consider the underlying systems and their interdependencies to address complex problems and challenges. The method is different from traditional problem-solving approaches, which focus more on linearly isolating and solving individual problems. However, many real-world challenges, not least the current ones, are complex and interconnected, involving multiple stakeholders, variables, and feedback loops. *System-Oriented Problem Solving* is therefore applied to capture the actual complexity and develop holistic solutions. For carrying out the project, several theoretical frameworks are applied for the various parts of the project. These will be presented in the following.

3.1 Desk Research

The study has involved desk research of secondary data found in publications, industry and policy reports, journals, newspapers, local government sites and records. The most profound findings are presented in the paper and quoted accordingly.

3.2 Field Research

In performing field research, primary qualitative data collection methods have been used to interact with and understand people in a natural environment. Here, direct observation has been applied to observe people from a distance to understand how they behave in a social environment and react to situations around them. The researcher does not interfere with the behaviour or outcome of a situation by which contextual data on people management, interactions, situations and the surroundings were obtained. Through site visits at locations of interest in Freetown, including local communities, dumpsites, companies etc., data was collected through photos and interviews of locals and served as primary sources. Here, ethnography was applied to understand the entire communities' social settings by objectively observing social perspectives and cultural values. By becoming familiar with the surroundings and the involved communities, participant observations were performed by participat-

ing in discussions and moulding its direction to fit the topic. Concurrently, qualitative interviews were performed to centre the conversation around the research subjects with a mix of informal, conversational, semi-structured, standardized and open-ended interviews.

3.2.1 Interviews and talks

Several interviews and talks with plastic industry leaders, local companies, citizens, authorities etc., were carried out to attain insights into the local issue with plastic waste, proven industrial mitigation measures and emerging technologies on the global market. This was primarily done to identify the problem, set the scope, and investigate potential solutions. Below, all of the interviews and talks are listed together with the topic of the discussions:

- *Kidus Asfaw, CEO of Kubik* on their business and potential overlap between our ventures.
- *Lotte Rosenberg, Co-CEO of Waste Plastic Upcycling* on their operations and global plastic waste management tendencies.
- *Anders Peter Hansen, CEO of Classdiving Co. Ltd.* on their operation and finding of plastic in the Lagoon.
- *Hassan Hijazie, CEO of AH&M Ltd.* on their operation and the prospects of incorporating recycled plastics in their production.
- *Walid Bahnsoon, CEO of Enviro Premier Solutions* on their operation and the prospects of incorporating recycled plastics in their production.
- *Ocean Plastic Forum* on the partnership.
- *Makeen Energy* on the prospects of implementing pyrolysis technology in Sierra Leone.
- *Rostock University* on the partnership and learnings from their site in Kumasi, Ghana.
- *Chief Heat Officer at Freetown City Council* on the prospects of using Lumley Transfer Station as a collection and sorting site.
- *Chief Environmental and Social Officer at Freetown City Council* on the permission to test the floating barrier prototype below Aberdeen Bridge.
- *Executive director from Skill Pool - Alie Swazie Bangura* on truck and tricycle acquisition or rental expenses.
- *Michael Langlo from DIS* on plastic recycling technologies and application in Sierra Leone.
- *Manfred Pearce from Propel Organization* on their operations, knowledge sharing and potential fu-

ture collaboration.

- *Almami from Propel Organization* on the temporary barrier they have mounted in a river.
- Notifying the following authorities to have permission for testing the floating barrier: *Ministry of Local Government, Ministry of Environment, Ministry of Tourism and Cultural Affairs, Ministry of Marine Resources, Office of National Security, National Disaster Management Agency, Environment Protection Agency, Freetown City Council.*
- *Informal waste collector at Kingtom dumpsite* on his undertaking and the waste management system at the site.
- *Formal waste collector in Douda Town, Kenema* on his job and the waste management system in Kenema.
- *The leader of the youth in Pottor community - Michael* on the recent flooding of the community.
- *Community members at Pottor* on collecting plastic waste and potential buyers.
- *"Kip Am Klin" truck operator* on the truck's operation.
- *Alpha Massaquoi, a citizen of Freetown* on his waste management and the city's plastic recycling.
- *Suleiman, a plastic trader* on the ongoing trading of plastic waste and shipment to Guinea.

3.2.2 Conferences

During the project, the author participated in two conferences at the City Hall in Freetown, Sierra Leone. These provided valuable insight into the situation and laid the foundation for collaboration with key players in the industry.

- The conference *Empowering Young Women* shed light on the current low political involvement among women and led to the formation of trajectories for future advancement. The speakers underlined the importance of involving young women in projects as they are often marginalised, March 21-22, 2023.
- The conference *Official Launch of First-Ever Waste App* arranged by Freetown Waste Transformers. The purpose was to launch the mobile application, raise awareness and call for potential collaboration partners in waste management on May 17, 2023.

3.3 Frameworks for Solution Development

In solution development, various frameworks have been used to assess the different project perspectives and lead the solutions in a sustainable direction. This includes models such as *The Waste Hierarchy*, *Value Proposition Canvas*, *Sustainable Business Model Canvas*, *Circular Economy* and *Platform Thinking*.

3.3.1 The Waste Hierarchy

While developing a business for waste, it is essential to consider *The Waste Hierarchy*, which was outlined by the European Union in 2008 as part of the *Waste Framework Directive* (European Commission, 2008). It is a valuable tool in evaluating waste treatment processes alongside environment protection considerations (shown in figure 10).



Figure 10: The Waste Hierarchy

The hierarchy outlines five different action methods to reduce and manage waste from most favourable to least favourable. This represents the latter part of the life cycle for each product and considers resource and energy consumption based on the degree of sustainability. Herein lies the principle that waste management cannot be solved solely by applying technical end-of-pipe solutions, but an integrated approach is necessary. The five methods presented in figure 10 are elaborated in the order of most to least favoured option.

Reduce Waste is the foremost preferred method that builds on the approach to minimise the amount of waste produced. Waste is reduced at the source and can be achieved by taking actions in designing, manufacturing, purchasing or using materials or products differently. This will reduce the amount of waste generated in the first place and the amount of waste that enters the system. To be effective, the approach requires interventions in the lifecycle of products before they are scrapped.

Reuse Waste is the second favoured option where a material is used repeatedly in its current form for its original purpose or an alternative one. With this approach, some or all of the energy and materials that go into making an item are preserved.

Recycle Waste is the middle point in the hierarchy, converting waste materials into new materials and objects. A material's recyclability depends on its ability to reacquire the properties it had in its original state. The derived recycled materials are substitutes for raw materials that can be increasingly scarce natural resources or poison the environment to extract.

Recover Energy is a method that can be applied if waste creation cannot be prevented and reuse and recycling are found impossible. The energy stored in the waste can be recovered by utilising advanced technologies. This approach is usually better than land-filling, but the circumstances must be considered. In this case, the European Union has developed a 'waste-to-energy' initiative to improve energy recovery in the incineration of waste.

Dispose Waste is the least favoured option in managing waste. It is equivalent to what is currently done in Freetown, where the citizens dump waste at the dumpsites. This is regardless of the site's legitimacy, as the waste is not treated in any way.

When exploring possible solutions, the options will be placed on different levels in the waste hierarchy. In this case, it is essential to remember that one must seek to identify the final solutions as high as possible. Further investigation is needed to understand the methods used in the different levels of waste treatment and the individual environmental effects. A technology screening was required to define which waste handling technology would be the optimum for the challenges in Freetown. The results can be found in section 6.2.

3.3.2 Value Proposition Canvas

To understand the customers' needs and expectations and to develop a product or service in accordance, the Value Proposition Canvas developed by *Strategyzer* is applied (Strategyzer, 2020b). The canvas facilitates alignment and ensures a product-market fit to avoid creating something nobody wants.

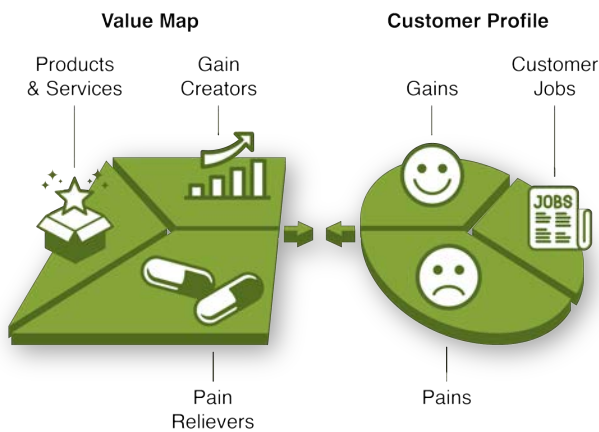


Figure 11: Value Proposition Canvas

As seen in figure 11, the canvas consists of five essential components distributed in two main sections; the Customer Profile and the Value Map. The results of the *Value Proposition Canvas* can be found in section 6.1.

Customer Profile

Customer Jobs defines the task(s) that the customers are trying to perform and the needs that must be satisfied. For this point, it is important to notice the frequency and importance of the job, the different roles the customers play, and in what contexts.

Pains encompasses the things that irritate the customers while they are performing their *customer jobs*. This includes negative experiences, emotions, challenges, risks, financial costs, mistakes, consequences etc. Hereto, it is also relevant to be aware of the frequency and severity of the pain.

Gains describes the benefits that the customers wish and expect that have a positive outcome, whether functional, social, emotional or financial. The gains can be anything that amuses the customers and makes their lives easier, more pleasant or more successful. Again, this can be ranked concerning frequency and relevance.

Value Map

Products and Services specify the products and services one delivers to the customers. Here it is relevant to evaluate if it accomplishes the *customer jobs* and in what way it is, whether functionally, socially, emotionally etc. Also, it is valuable to consider the solution's relevance and how often the customers would use it.

Gain Creators involve the factors why the product or service offers the customers added value. Here the benefits of using the solution are listed and evaluated in terms of alignment with the customers' expectations. Likewise, for the other components in the canvas, the gains must be ranked according to relevance and frequency.

Pain Relievers describes how the product or service relieves the customers' pains. This includes cost reduction, negative feelings, efforts, risks, negative consequences etc. The pains must be ranked according to intensity to understand how the product or service helps the customers (Strategyzer, 2020b).

3.3.3 Sustainable Business Model Canvas

In formulating the business model, the Business Model Canvas developed by *Strategyzer* is applied to create an overview of the project's workings, customers, cost, revenue streams and much more (Strategyzer, 2020a). The canvas visually represents a business model where all key strategic factors are highlighted holistically. It is a strategic management tool to ensure no vital factors are neglected. Figure 12 shows that the canvas consists of nine essential components elaborated in the following. The results of the *Sustainable Business Model Canvas* can be found in section 6.7.

Key Partners describe the most important partnerships essential for long-term survivability. Here the common and primary partnerships that one typically needs to consider are distributors, coopetition, suppliers and existing customers. As the business grows, this will be subject to change due to discontinued partnership needs and unknown alterations.

Key Activities determine what needs to be done to produce the value propositions and make the business model effective and successfully connected with customers. Such activities can include initial investments through funding, marketing,

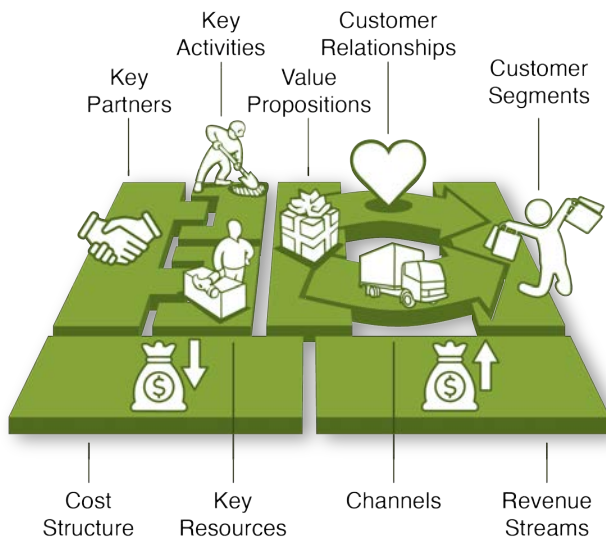


Figure 12: Business Model Canvas

and advertising to generate that initial awareness. All actions should be considered, including each impact on the overall business, to fully grasp the absolute essentials and recommended activities.

Key Resources deal with the resources and essential assets the business runs on and provide value to customers. This can be present in many forms, such as human resources, financial, physical, and intellectual property.

Value Propositions refer to the sum of the various products or services that uniquely stand out amongst the competition. One could ask; what is the unique factor(s) that make this business better than another?

Customer Relationships revolves around creating, maintaining, and growing customer relationships. Initially, the customers must discover the business, then return and support fostering a good reputation to grow the audience. In this case, factors such as personal assistance, automation, self-service, and communities are relevant to bear in mind.

Channels enlighten how the business and the customers interact. Once the product and customers are defined, the interaction can be devised. This is, in particular, important to consider regarding availability and convenience.

Customer Segments determine the people or organisations that buy the product, use the service, or are otherwise essential in creating profit. The constellation can be Business to Business (B2B)

or Business to Customer (B2C). Still, it is essential to focus on the core customers first before less critical or potential future clients. The canvas should assess current and future needs, general demographics, likes, dislikes, pain points, and relations with different segments.

Cost Structure define all the potential costs that exist with both existing and future costs taken into account. This entitles expenses such as fixed and variable costs and economic principles such as economies of scale and scope. These aspects are important to include to attain a realistic view of costs and where the business aims to be short.

Revenue Streams deals with how to turn a profit and the various channels with which income can be generated. Expected revenue streams are asset or goods sales, subscription, licensing, white labeling, and advertising. It is essential to remember that these streams are not set in stone. They must adapt and evolve as the market changes regarding options and pricing (Strategyzer, 2020a).

Sustainability extension

To incorporate sustainability in the Business Model Canvas, the framework is extended with the aspects; *Eco-Social Costs* and *Eco-Social Benefits* (see figure 13). The extension exists in many formats, but the one by Case Knowledge Alliance is used for this paper, outlining the Sustainable Business Model Canvas (SBMC).

By directing the focus toward the ecological and social implications of the business activity, sustainability is woven into the fundamental aspects of the business, ensuring that it operates in a manner that is beneficial for society and the environment.

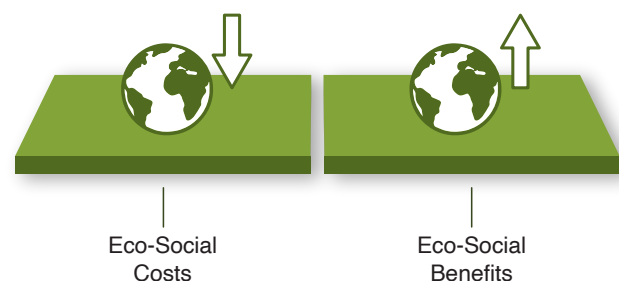


Figure 13: Sustainability extension

Eco-Social Costs encompass the adverse consequences a business model may have on the environment and society. These costs can include environmental degradation, resource depletion,

social inequality, health and safety risks, cultural erosion, and other negative impacts. Recognizing and addressing these costs is crucial for businesses to operate responsibly and sustainably.

Eco-Social Benefits refer to the positive environmental and social outcomes resulting from a sustainable business model. These benefits include environmental conservation, resource efficiency, community empowerment, social inclusion, job creation, poverty alleviation, and cultural preservation. By incorporating eco-social benefits into the business model, business operations can contribute to the planet's and society's well-being (CASE Knowledge Alliance, 2023).

3.3.4 Circular Economy

In the current economy, materials are taken from the Earth, made into products and eventually thrown away as waste. This is known as a linear process with significant disadvantages regarding sustainability. By contrast, a *Circular Economy* (CE) entails markets that provide incentives to reuse products rather than scrap them and then extract new resources. In this case, all forms of waste are returned to the economy or used more efficiently. This protects the environment and develops new sectors, creating jobs and blossoming communities with newly gained capabilities (Ellen Macarthur Foundation, 2023). In the following, different schools of thought for CE are presented with principles illustrating the flow of materials.

Cradle-to-Cradle

German chemist Michael Braungart and US architect William McDonough introduced this concept. They present an integration of design and science that provides lasting societal benefits from safe materials, energy and water in circular economies. Ultimately it eliminates the concept of waste and argues that the waste must be re-utilised as raw materials for other production processes and that biological materials should be reinserted into natural environments. Rather than thriving to minimise the harm one inflicts, the concept of Cradle-to-Cradle reframes design as a positive and regenerative strength that produces imprints to delight in (McDonough and Braungart, 2002).

Performance Economy

This concept advocates selling services rather than goods within circular economic systems. The theory aims to extend the product and material lifecycle by combining system design with technical and commercial innovation. While based on regional economies, it has the outcome of new local jobs and prevention of waste creation. The objectives introduced by this school of thought are resource productivity, nature conservation, toxicity limitation and lastly, social as well as cultural ecology (Weetman, 2016).

Regenerative Design

This is arguably among the most influential schools of thought behind the circular economy and has laid the initial framework. It underlines the importance of restoring, revitalising, and renewing materials, resources, and energy. In short, it describes the methods needed to regenerate and sustain systems (Ellen Macarthur Foundation, 2023). The analysis results for circular economy potential can be found in section 6.3.

3.3.5 Platform Thinking

The concept of *Platform Thinking* refers to a strategic approach in ecosystems that emphasises the creation, management, and utilisation of platforms to drive collaboration, innovation, and value creation. This entails adopting a holistic perspective beyond individual products or services and focusing on building and orchestrating interconnected systems. At its core, *Platform Thinking* recognises that platforms act as a foundation that enables multiple actors, organisations, or communities to interact and co-create value. In this way, a product or service can gain global applicability and accommodate various use situations. The concept has gained significant traction in multiple domains, including technology, business, and public sectors. By adopting the approach, organisations can utilise the power of ecosystems, harness network effects, plus foster innovation and collaboration. For the project, the methodology can be applied in different ways, either in the shape of a product or service. The analysis results for platform thinking can be found in section 6.4.

3.3.6 SWOT Analysis

The concept of the *SWOT Analysis* is a popular framework used to evaluate a company's competitive position and to develop strategic planning. It was developed by Albert Humphrey, an American business and management consultant, during his work at the Stanford Research Institute in 1960-1970.



Figure 14: SWOT Analysis

The method is used to evaluate the Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T) that are involved in a business case (see figure 14). By making so, risky assumptions about the organisation's performance are challenged by which dangerous blindspots might be uncovered (Humphrey, 2005). The results of the SWOT analysis can be found in section 6.9.

3.4 Frameworks for Implementation

For the implementation of a solution, various concepts are to be applied. These include the concepts of *The Golden Circle*, *Push and Pull*, *The Power of Default Bias* and *Persistence of the change*. They are presented and briefly described below. The perspectives of the implementation framework can be found in section 7.2.

3.4.1 The Golden Circle

In communicating the project's vision, the concept of *The Golden Circle* by Simon Sinek is introduced. It outlines the essential points to consider when doing projects and engaging stakeholders.

The concept is seen in figure 15 and consist of three different definition levels. While most corporations work from the outside towards the inside, defining *What* as the start - Sinek argues that the greatest ventures happen when working inside out. Articulating the organisation's *Why* is a very effective way to communicate, define particular value propositions and inspire people to act. By doing so, the sender taps into the part of

the listener's brain that influences behaviour and ensures the best possible dissemination of the project.

Firstly, the *Why* is defined and communicated to the stakeholders. It describes the project's existence and the team's work on the specific matter. Then, *How* is defined and disseminated, outlining how the problem is solved, how the project aids in tackling the problem and what sets it apart from other initiatives. Lastly, *What* is defined. This describes the specific product or service offered to address the problem. It outlines what is precisely done on the ground (Sinek, 2011).

The concept of *The Golden Circle* is considered very important to incorporate in developing an implementation strategy. It provides a valuable structure for communicating the project's vision and engaging the stakeholders properly. Therefore, the concept will form the overall design of the implementation plan and contribute to the insurance of a good hand-over.

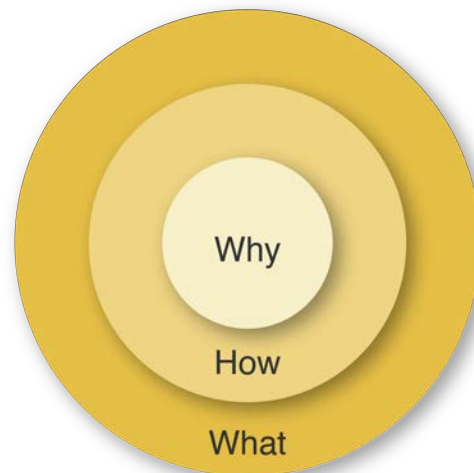


Figure 15: The Golden Circle

3.4.2 Push and Pull strategies

Sociologist Kurt Lewin introduced the so-called *Force-Field theory* in 1951, arguing that organisations are balanced between forces for change and resistance to change. It introduces the concept of driving and restraining forces that affect a change positively or negatively (Lewin, 1952). With this comes the adaption called the *Push and Pull strategies* that outlines the contradiction of push and pull when implementing a change (see figure 16).

In general, strategies that induce individuals to move away from something are called push strategies. While they can help initiate change, they often become counterproductive afterward. When pushed, people naturally resist and strive to move in the opposite direction. On the other hand, there is the alternative of pull strategies. In pull strategies, one positions oneself before the person, enticing and motivating them to move forward. By employing subtle psychological techniques, individuals can be persuaded to own their future fully and subsequently change their initiative.

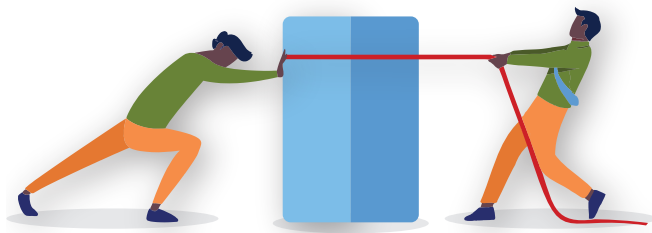


Figure 16: Push and Pull strategies

Concerning projects, it is essential to distinguish between push and pull strategies and choose the best fit. This way, the solution's implementation will be strengthened and most successful.

3.4.3 The Power of Default Bias

The concept of *Default Bias* is a behavioural principle attributed to Cass R. Sunstein, an American legal scholar and behavioural economist. It describes that when people are presented with pre-set courses of action or so-called defaults, they tend to accept what is shown. People prefer behaving as they always have, even when the circumstances that influence their decisions change. Repeating choices often become automatic as default choices do not involve a lot of cognitive effort. Intuitively, one usually just *go with the flow*, behaving without considering other options and simply accepting what has been chosen (Sunstein, 2013).

Situation Analysis

Investigation of the project's internal and external environments in Freetown, Sierra Leone, with the identification of opportunities and challenges



4 Situation Analysis

This section aims to provide an immediate analysis of the situation in Freetown, Sierra Leone. This encompasses, among other things, an introduction to plastic waste, plastic waste management practices, the country’s governance structure, power infrastructure and the identification of stakeholders.

4.1 Plastic

The world of polymers offers undreamt-of amounts of variations. However, seven various plastic types are the most popular and commonly used. These are listed from 1 to 7 with appertaining plastic resin identification codes (RIC) as seen in figure 17. The seven plastic types are to be described with common uses, properties, recycling opportunities, and adverse health effects included.



Figure 17: Common plastic types

Type 1 is a tough and transparent polymer called polyethylene terephthalate (PET). It is often used in water bottles, soft drinks, containers, and biscuit trays and is known for being one of the most recyclable polymers. PET has the potential to be fully recycled or made into alternative things such as sleeping bags, pillow filling, and building insulation. When consumed by humans due to unconscious handling, it can cause carcinogens, vomiting, and diarrhoea.

Type 2 is hard to semi-flexible polymer called high-density polyethylene (HDPE). It is resistant to chemicals and moisture and has an opaque surface

that can be coloured easily. The polymer is commonly used for shopping bags, buckets, shampoo and milk containers, pipes, crates, and chemical bottles. It is often recycled into bins of different kinds. If digested, HDPE can cause stomach ulcers.

Type 3 is called polyvinyl chloride (PVC). It can take different shapes: strong, tough, flexible, clear, and elastic. In both cases, it can be solvent welded. PVC is often used for plumbing pipes and fittings, cosmetic containers, shoe soles, electrical conduct, and roof sheeting. The recycling of PVC is complicated and hardly done. If ingested, PVC can interfere with hormonal development and be difficult to extract.

Type 4 is a soft, flexible, and translucent polymer that often has a wavy surface. Low-density polyethylene (LDPE) is often used for garbage bags, irrigation tubings, and cling wraps. Cases of recycling have shown that it can be recycled into bin liners and pallet sheets.

Type 5 is a hard, versatile, and translucent polymer called polypropylene (PP). It is often used for lunch boxes, garden furniture, kettles, potato chip bags, and straws. In some cases, the polymer has been recycled into bins and pipes.

Type 6 is called polystyrene (PS). It is characterized as a semi-tough and glossy shine, mainly used for CD cases, cutlery, cups, and packaging. Studies have shown that this polymer, in particular, takes thousands of years to degrade.

Type 7 is denoted as "Other" and includes all resins and multi-materials as laminates, for example. It has different properties depending on the combination of plastics. This polymer is often used in automotive and appliance components, computer electronics, and packaging. Due to the diverse characteristics, health effects are hard to determine. Though, some cases have shown that this type of plastic cause obesity, cancer, and endocrine problems in fetuses and children (Singh, Solanki, and Singh, 2023).

Though plastic products are often made of one type of plastic, composites also exist where the types are blended or combined in layers.

Plastic purity

In theory, all polymers are technologically 100% recyclable. Certain plastics even possess a cradle-to-cradle lifecycle, allowing them to be repeatedly utilized in producing the same goods. In contrast, other plastics can be directly reused by shredding objects into flakes, melting them, and using them again. Although recycled plastics may exhibit slightly lower mechanical properties than virgin plastics due to the degradation of polymeric chains during melting and processing, these properties can be restored by incorporating additives or mixing with virgin plastic. Successful examples of industrial recycling include PET (polyethylene terephthalate), commonly employed for manufacturing soft drink bottles, and polystyrene (Alliance To End Plastic Waste, 2021).

4.2 Plastic Waste

The amount of plastic waste produced globally is genuinely devastating. As described previously, over 359 million tons of plastic products are produced annually, belonging to many different industries. However, one industry is dominant regarding the prevalence of plastic waste in the environment: the packaging industry. Plastic has emerged as the preferred packaging material for many products in the past five decades. Its popularity stems from several factors: durability, lightweight nature, flexibility in moulding into various shapes, and suitability for marketing purposes. Plastic also provides effective barrier properties, sealing out oxygen and contaminants, and is a cost-effective option. It has become the dominant material for single-use food and beverage packaging, carry-out shopping bags, and to-go containers and cutlery used in restaurants and cafeterias. As a result, the five most common sources of plastic pollution fall within the packaging industry and are characterized by the following products:

1. Food wrappers and containers hold 31.14% of environmental pollution by unit count. Although these items may easily break down in sunlight and water, the resulting tiny plastic particles persist and pose a threat. Animals mistake these particles for food and ingest them, unknowingly filling their bellies with toxic and non-digestible plastic.
2. Bottle and container caps account for 15.5% of marine pollution. Caps often go unnoticed and receive little consideration when disposing of a plastic bottle. The focus primarily rests on the

bottle itself. However, caps pose a significant environmental concern as they float on the water's surface, resembling enticing morsels to birds and other wildlife.

3. Plastic bags are responsible for 11.18% and have a remarkable persistence, with a mere 3 per cent being recycled. They become entangled in trees and waterways and are often ingested by marine animals such as sea otters, turtles, seals, birds, and fish. Tragically, these plastics can give animals a false sense of fullness, leading to starvation.
4. Straws and stirrers hold 8.13%, caused by the fact that no form of recovery system exists for them. Given the staggering quantity of straws used daily, an alarming number of straws are disposed of in landfills and end up in our oceans yearly. In the United States alone, 500 million straws are used daily, which is incomprehensible.
5. Beverage bottles account for 7.27% even though they generally exhibit a relatively high recycling rate of up to 74%, depending on the type of plastic. However, many bottles in the environment have not been successfully directed to recycling facilities (5 Gyres Institute, UPSTREAM, and Clean Production Action, 2017).

4.3 Global Plastic Waste Management

Globally, efforts are being made to tackle the induced issues due to the lack of plastic waste management. Some countries implement plastic bag bans or taxes to discourage their use, while others invest in recycling programs and technologies that can turn plastic waste into new products.

Recycling plastics

The global demand for recycled plastics and the concept of plastic circularity have rapidly gained momentum in the past years. Over 80 global companies in the consumer packaged goods, packaging, and retail sectors have pledged to incorporate 15 to 50% recycled content in their packaging by 2025. Some companies have even publicly announced that they are willing to pay higher prices for materials with recycled content. In the United States alone, it is anticipated that the volume of recycled plastic waste will double or triple by 2030 to fulfil the commitments made by individual brand owners and industry alliances. Alongside increasing customer demand, there is a growing trend of regulatory mea-

asures worldwide that specifically address issues such as single-use plastics, Extended Producer Responsibility (EPR) regulations, and requirements for recycled content.

Access to sorted plastic-waste feedstock is a major obstacle to scaling up recycling efforts. Studies have shown that globally, only 16% of plastic waste was collected for recycling in 2016. A change in consumer behaviour, infrastructure development, and recycling capacity investments are needed to increase this amount. The economic factors of recycling depend on various aspects, such as the location of waste generation, the kind of plastic waste, and the recycling process. Generally speaking, there are two types of recycling methods, mechanical and chemical, each with unique advantages and disadvantages. Mechanical recycling is optimal for circular plastic production but requires well-sorted and high-quality waste feedstock. Chemical recycling is suitable for challenging and commingled plastic waste that is difficult to recycle. As a result, it produces recycled plastics of high performance that are of the same quality as virgin plastics (McKinsey & Company, 2022).

Holistic approach

According to the interviewed individuals from the plastic recycling industry, there is a growing tendency to take a holistic approach where companies offer complete solutions, including power generation, waste management, etc. The interviews shed light on current trends in the industry where symbiosis plastic processing networks are established where plants are connected to take advantage of sharing shortages and surpluses of, for example, heat. This way, less energy is spilt, and the processes become even greener. For example, biogas plants can be co-located with pyrolysis plants. The excess fibre material generated in the biogas plant can be utilised to feed the pyrolysis process, which can be performed relatively simply but requires a stable energy source. An example of such a solution is in Kalundborg, Denmark, made by the company *Symbiosis*, where large industrial companies across sectors work together to share excess energy, water, and materials so that less goes to waste. One company's surplus of resources adds value to another and creates a symbiosis of resource exchange, adding more resilience and profit to the partners (Symbiosis, 2023).

Sustainability certifications

Furthermore, the interviews revealed that sustainability certifications are becoming increasingly crucial for companies looking to demonstrate their commitment to sustainability. These certifications are designed to ensure that businesses operate environmentally responsibly while also considering their operations' social and economic impacts. One such certification is the International Sustainability and Carbon Certification (ISCC), recognized globally as a leading sustainability certification for biofuels, food, feed, and chemicals. The certification requires companies to follow strict criteria related to sustainability, including reducing greenhouse gas emissions, minimizing water consumption, protecting biodiversity, and promoting fair labour practices. In addition to meeting these criteria, companies must also undergo regular audits to ensure they maintain their certification status (ISCC System GmbH, 2023).

In addition to the ISCC, there are a variety of other sustainability certifications available to companies, depending on their industry and specific sustainability goals. By obtaining a sustainability certification, companies can differentiate themselves in the marketplace by demonstrating their commitment to sustainability. In this way, they can attract new customers, investors, and business partners who prioritize sustainable practices.

4.4 African Plastic Waste Management

African countries have been making efforts to address the issue of waste management, concerning plastic in particular, although the progress varies among different nations. Some countries have implemented measures to regulate and manage plastic waste effectively, while others are still in the early stages of developing comprehensive strategies. In figure 18, an overview is provided to display the progress made by some of the African nations. The following statistics relate to the information displayed here.

Studies show that, likewise, globally, the plastic packaging industry significantly contributes to pollution in Africa. It represents the most significant amount of poorly managed plastic waste and has been identified as a focal point (Singh, Solanki, and Singh, 2023). Among Africa's 54 states, 34 have taken action toward the prohibition of plastics by

either passing legislation and putting it into effect or passing legislation with the aim of implementation. Of those, 16 have entirely or partially banned plastic bags without establishing regulations to enforce these bans (Greenpeace Africa, 2020). Compared to Europe, where just 18 countries out of 44 have banned plastic bags, the continent of Africa is in advance (Euronews, 2023). In the case of partial bans, the legislation is determined by the thickness of the bags measured in microns or micrometres. Mutual for all countries is that the policies restrict all parts of the plastic bags' life cycle, including manufacturing, sale, use, and disposal. However, according to multiple sources, most policies are yet to be enforced. They have been written on paper but have not seen daylight yet (Singh, Solanki, and Singh, 2023).

The solid waste collection rate in African countries ranges between 40-70%, while the recycling rate varies between 1-20% (see figure 18). In several cases, the recycling efficiency of plastic waste could not be ascertained due to uncertainties and lack of transparency. In general, the practice of source separation is rarely observed. When it does occur, it is limited to small areas and specific locations within a few major cities, such as Dar-es-Salaam in Tanzania. Unfortunately, these isolated instances do not significantly improve the recovery of recyclable materials throughout the rest of the country. Also, the value of recyclable waste, especially plastics, is negatively affected by high contamination levels. Suppose any food residue or non-plastic materials like paper, metal, or glass are mixed in; manual intervention becomes necessary to sort the waste, leading to increased costs and decreased economic feasibility of recycling. Additionally, the low efficiency of waste collection in African nations results in a substantial loss of the valuable portion of plastic waste (Singh, Solanki, and Singh, 2023).

Pioneering countries

Rwanda stands as a pioneer in the fight against plastic pollution and has a unique take on the legislative framework. The capital of Kigali has been named one of the ten cleanest cities in a UN ranking. The Rwandan government banned plastic bags in 2008, which includes all parts of the bags' lifecycle; manufacturing, import, use, and sale. Any illegal use of plastic bags will lead to fines of up to 500,000 Rwandan francs or 12 months of imprisonment. Similarly, states like Kenya,

Senegal, Tanzania, and South Africa have shaped their legislation around strict punitive measures, including fines and prison sentences. In the case of Kenya, the directives also mention a Deposit Refund System (DRS) to promote the reuse, refill, and recycling of plastic waste. Boldly, Kenya is making great leaps towards a circular system, similar to the Danish "pant system".

In South Africa, a strong plastic recycling market with expertise in PET plastics is flourishing. The largest PET recycling company in Africa, *PETCO*, operates as a non-profit organization and is recognized as the industry body responsible for managing PET plastic recycling within the country. *PETCO*'s primary focus is on collecting, recycling, and recovering post-consumer PET plastic bottles. In 2022, the company recycled 83,967 tonnes of post-consumer PET bottles, which accounts for a 69% recycling rate of South Africa's annual consumption. The company collaborates with stakeholders, including government bodies, businesses, recyclers, and consumer groups, to create a sustainable and circular economy for PET plastics. Due to its success, *PETCO* has expanded to Swaziland, Namibia, Botswana, and Zambia and is looking to expand further (*PETCO*, 2023).

Standing behind these pioneering countries are some 20 African states that lack the establishment of a proper waste management system. Some of these have policies implemented, but they only regulate plastic disposal at the national level. This includes countries such as Equatorial Guinea, Guinea, Somalia and Southern Sudan (Afrik21, 2019).

African Circular Economy Alliance

In 2017, Rwanda, South Africa and Nigeria founded the African Circular Economy Alliance (ACEA) to establish momentum for circular economy engagement and foster continental and regional partnerships. The Ministry of Foreign Affairs of Denmark, Danida, and the World Economic Forum support the alliance. ACEA is a collaborative platform that brings together various stakeholders, governments, businesses, civil society organizations, and academic institutions, intending to advance the circular economy in Africa. The alliance plays a vital role in advocating for policy changes, raising awareness, and building partnerships to drive the continent's transition towards a more sustainable and circular future. Since its

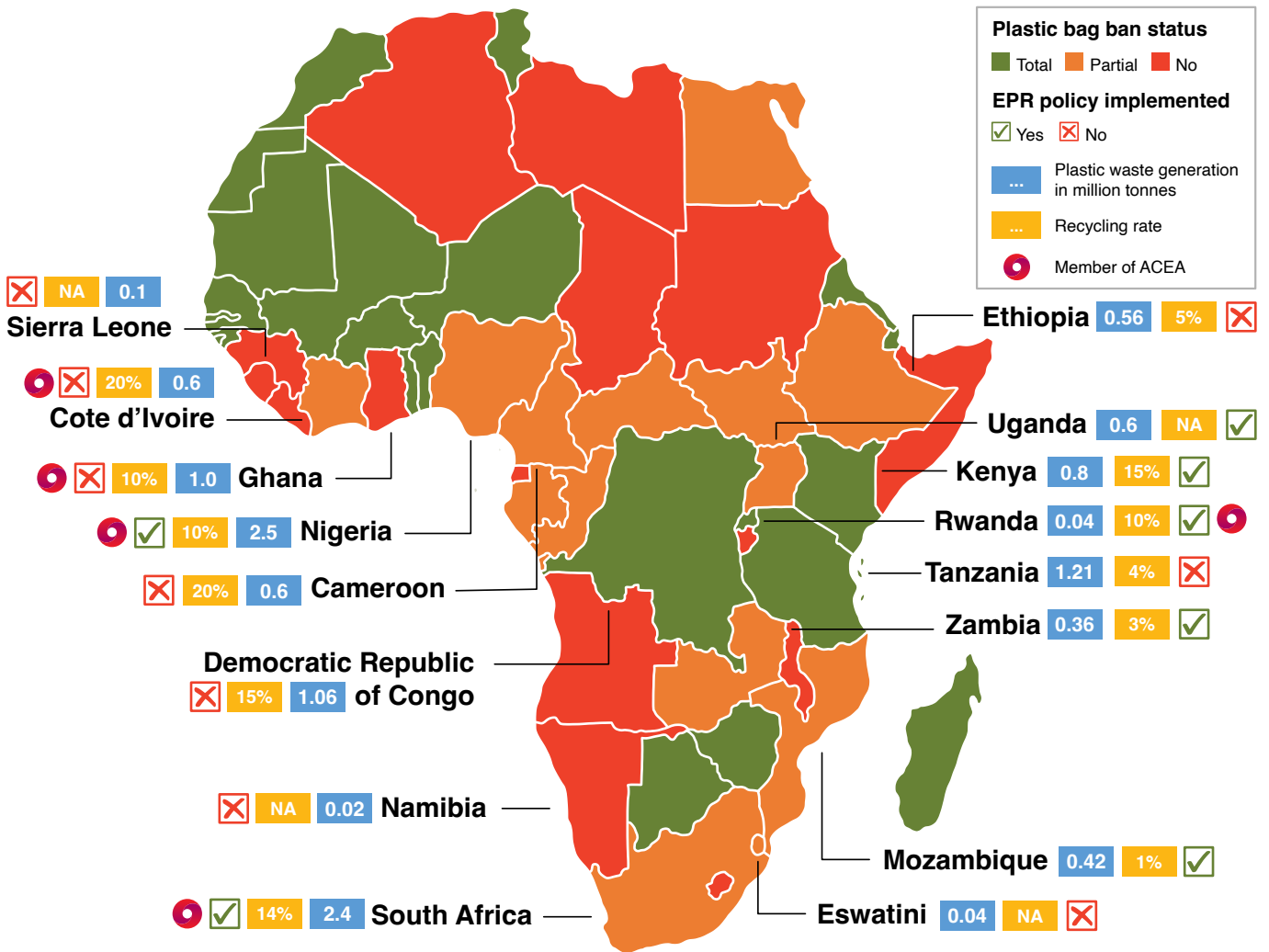


Figure 18: African Plastic Waste Management

establishment, Ghana, the Ivory Coast, Benin, Burkina Faso, and Sudan have joined the Alliance (see markings in figure 18) (ACEA, 2023).

Extended Producer Responsibility

As seen in figure 18 many African countries have imposed Extended Producer Responsibility (EPR) schemes to invoke the principle of "the polluter pays". The modalities of the EPR schemes vary a lot, while some focus on the design recyclability of plastic packaging, and others place the emphasis differently. Also, most EPR policies are voluntary schemes and are not mandated by directives, limiting the transition towards circularity (Singh, Solanki, and Singh, 2023).

Building classrooms of recycled plastic bricks

Organisations like the United Nations Children’s Fund (UNICEF) have begun targeting plastic waste issues. In Ivory Coast, UNICEF has carried out a large-scale project to build 500 recycled plastic brick classrooms in collaboration with the Colombian company *Conceptos Plasticos*. A manufacturing plant has been built in Abidjan, the capital of Ivory Coast, to convert locally sourced plastic waste to bricks. The project’s obtaining is threefold; more classrooms for schoolchildren are built, plastic waste is removed from the environment, and additional income sources are created for the population (Afrik21, 2019). Since the launch of UNICEF’s project, the Kenyan startup company Kubik has been founded to commercialise and deploy the concept continent-wide. The author talked to Kubik during the project, exploring the concept and its potential.

4.5 Plastic Waste in Freetown

Waste is highly dominating in Freetown and is seen anywhere you go. Studies show an estimated 550 tonnes of solid waste are generated daily in Freetown. Around 30% of the waste reaches the official dumpsites, while the remaining 70% is dumped elsewhere. The distribution of waste is 66% organic waste, and 16% plastics, while the remaining is a mix of paper, metal and others (see figure 19) (Freetown City Council, 2021). For many people in Freetown, waste is a source of livelihood. By scavenging through organic material, plastic, metal, and toxic material, sorters collect reusable waste for selling. In sorting the waste, open burning is a common practice that increases exposure to respiratory infections. Also, leachates from dump sites contain heavy metals that contaminate the soil, groundwater, drinking and food reserves.

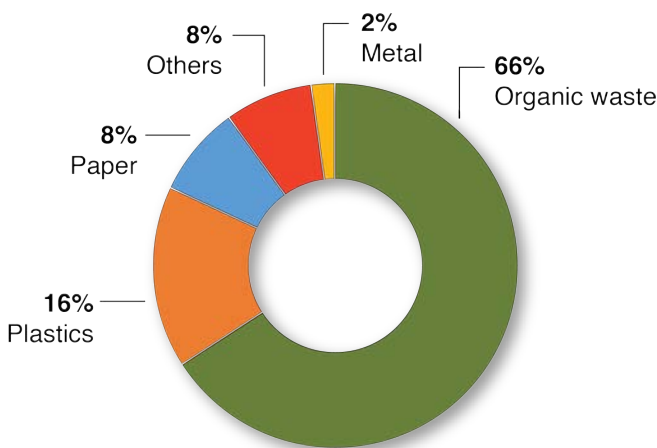


Figure 19: Waste distribution

Within the informal settlements, vicious cycles of risk accumulation and traps are daily due to poor waste management. These settlements are often high-density and are located on the coast near official dumpsites. Here, waste accumulation is often higher due to the low collection frequency, which forces the residents to dump waste by alternative means, such as in the nearby water bodies. Without an inclusive waste collection system, rivers function as unofficial pathways for the flow of waste from informal settlements. Consequently, large amounts of waste accumulate around coastal settlements or flow to the sea. This worsens the extent of flooding, increases water contamination and exposes residents to infectious diseases such as malaria, typhoid, diarrhoea, and cholera (Kumar et al., 2022). As a result of waste obstructing the waterways,

flooding destroys settlements which cause annual exodus. Due to the subsequent rebuilding, an estimated eight million USD is lost annually. This is deemed to form 2% of the country’s Gross Domestic Product (GDP) that could be of great value spent otherwise.

Exposure to hazards in terms of health, flooding, and livelihood, in general, is progressively ingrained in the daily lives of low-income Freetown residents. It deteriorates their socioeconomic capacity, erodes the change of coping, obstructs any form of recovery, and contributes to the inevitable reproduction and continuation of perfdy risk cycles. Poor waste management is blamed for spatial vulnerabilities and socioeconomic marginalization (Smith et al., 2019).

Plastic waste samples

According to locals, the use of plastic has tripled over the past years in Freetown (Sierra Leone Economic Diversification Project, 2020). Based on observations in various parts of town, large quantities of plastic bottles and water sachets are found (as seen in figure 20a-c). Water sachets are not so common in the Western world, so some explanation is needed. Plastic sachets containing water diffuse among the population as an affordable source of potable water due to an inadequate public drinking water infrastructure. While the sachets have proven a great solution, used water sachets are thrown into the streets and pose severe environmental risks. The sachets are made of thin PE, just like normal plastic bags. According to Almami at Propel Organization, a system exists for recycling water sachets. They are sent to Conakry, Guinea, to be recycled by an unknown company (see Appendix A.1.8). No system for recycling plastic bottles seems to exist, which is why they are the most prevalent in the townscape.



(a) Sample 1



(b) Sample 2



(c) Sample 3

Figure 20: Plastic waste samples

Current waste flow

When observing the locals' waste management behaviour, the city's waste flow pattern transpires. The current waste flow in Freetown follows a routine illustrated in figure 21 with an appertaining description.

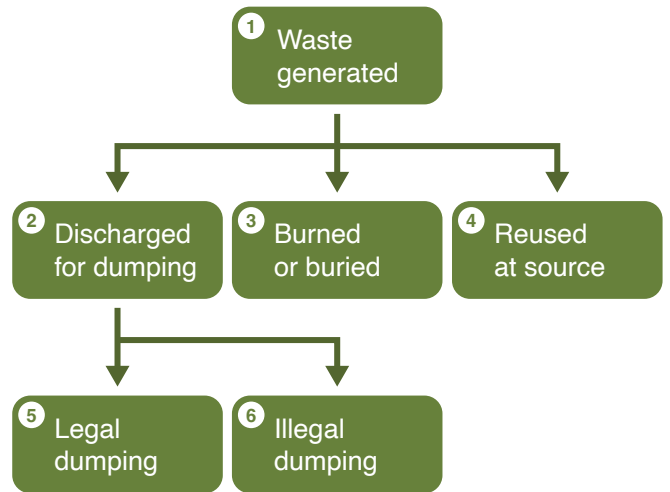


Figure 21: Current waste flow

1. Waste is generated at houses, offices, shops, restaurants, etc.
2. Waste is dumped
3. Waste is burned or buried at the source
4. Waste is reused at the source
5. Waste is dumped at a legal dumpsite
6. Waste is dumped at an illegal dumpsite

As seen from the waste flow, no official waste management service is provided to the citizens of Freetown. Simply put, it is up to the individual to manage the waste without any guidance. The waste is mostly discharged for dumping and dumped in illegal dumpsites, but waste is often burned or buried near the source. Some businesses take responsibility for their dumping and use legal dumpsites as directed by the FCC. In rare cases, the waste is reused at the source - for example, plastic bottles are used as honey containers in many homes.

Current waste management infrastructure

Two major legal dumpsites, Kissy in the east and Kingtom in the west, are designated by the government but have reached their maximum capacity. However, as mentioned, much of the generated waste does not reach these dumpsites (Aminu et al., 2020).

The *Kissy dumpsite* is the oldest open dumpsite in Freetown and covers an area of approximately 20,000 m² (approximated with Google Maps) It is located in the eastern part of town at the neck of the estuary of Granville Brook and accessible from the main highway connecting the city with the rest of the country. The dump site has pushed beyond its limits and is now in the centre of the city, surrounded by many settlements, including one of the largest and poorest slums in Freetown (see figure 22 - credits: Awoko Publications).

The *Kingtom dumpsite* is the largest and most popular dumpsite covering a sheer size of approximately 70,000 m² (approximated with Google Maps). It is located in the western part of Freetown, bordering the official cemetery. Around the dumpsite, settlements have emerged that scavenge waste for a living. According to locals, the dumpsite has a tarnished reputation as bodies were disposed of at the dumpsite during the Ebola outbreak in 2014.



Figure 22: Kissy dumpsite

Illegal dump sites are scattered all around Freetown where the locals dump their household waste if they cannot afford waste management services. Studies performed by the FCC show that 46 major and 500 smaller illegal dumpsites are scattered around the city (Aminu et al., 2020 and Freetown City Council, 2021). The sites are often located in proximity to communities, and they are rarely cleared. Over time organic waste has vanished while predominantly plastic waste remains.

The FCC plans to establish a new sanitation landfill, as the current dumpsites have been unstable and dangerously overloaded for decades. The new site will not be an open dumpsite but sealed off to minimize health hazards. Though, FCC faces challenges in identifying sites as landowners in the surrounding villages and towns are unwilling to give up their lands. Due to this, no official opening day



Figure 23: Lumley Transfer Station

has been announced yet (Freetown City Council, 2021).

Seven transfer stations have been constructed throughout the city by the FCC to serve as temporary holding centres for waste collection (see figure 23). The purpose is that waste collectors can dump the collected waste at the stations, reduce travel time going to the legal dumpsites and thereby collect more waste from households and businesses. Besides improving waste management and creating sanitation improvements, the aim is also to create jobs for the local communities. Despite the good intentions, the transfer stations remain inoperational months after their inauguration, and no commencing actions are in sight.

4.6 Governance of Sierra Leone

Reliable governance is critical in creating a new waste management system. The following presents the different levels of governance in Sierra Leone. The country follows a standard order with national and municipal administration, though the inclusion of ward and community governance is distinctive.

4.6.1 National

Sierra Leone is governed as a constitutional republic with a directly elected president and a unicameral system based on the 1991 *Sierra Leone Constitution*. It has a dominant unitary central government headed by the president, with extensive powers and influence. The president is the head of state, the government director, and the Sierra Leone Armed Forces commander-in-chief. Since the establishment of the republic, two major

political parties have held the majority of the votes at the general elections. These are *Sierra Leone People's Party* and *All People's Congress* that have been dominant except in times of war. Between them, the presidency has been alternating, and the constant fight has created a stop block for the persistence of changes.

Currently, the former military junta, H.E. Julius Maada Bio, is the president of Sierra Leone (see figure 24 - credits: The State House of Sierra Leone, 2023). He has been in command since 2018 as the leader of the *Sierra Leone People's Party* and is seeking to win his second term in the presidential election of 2023.



Figure 24: President H.E. Julius Maada Bio

Since the president's inauguration, several governmental waste management initiatives have been launched, including a monthly clean-up day. Every first Saturday of every month, all citizens must take part in cleaning the city. However, studies show that the waste collected has not been dealt with properly and has been chiefly burned in open fires (Smith et al., 2019).

4.6.2 Freetown

The current Mayor of Freetown is Yvonne Aki-Sawyerr, who was inaugurated in May 2018 (see figure 25 - credits: Mayors Migration Council, 2023). Aki-Sawyerr has a background in finance with over two decades of experience in strategic planning, project management, and risk management in the public and private sectors, both locally and internationally. She has campaigned against the "blood diamonds" trade and advocated strongly for ending the civil war. In 2014-2016 during the Ebola crisis in West Africa, Aki-Sawyerr was a National Ebola Response Centre planning officer. In recognition of her well-known work and contribution

to the Ebola response efforts, she was awarded an Officer of the Order of the British Empire by Queen Elizabeth II in 2016. Since then, Aki-Sawyerr has been highly reputed and has the uppermost support from the people.



Figure 25: Mayor Yvonne Aki-Sawyerr

One of Aki-Sawyerr's rallying calls is a transformation plan focusing on resilience, human development, healthy cities, and urban mobility features. A heightened level of transparency, accountability, and data-driven decision-making supports this. In light of the increased deforestation in Freetown, she launched the project *FreeTown Tree Town* in 2018. With this, she committed to planting one million trees throughout the city by the end of her term to mitigate the effects of climate change (Freetown City Council, 2023a). Studies show that she keeps her word and the project is well en route.

The Mayor strongly supports the *Global Green New Deal*, which was established at the *C40 World Mayors Summit* in Copenhagen, 2020. *C40* is a global network of nearly 100 mayors from all around the world collaborating to take urgent action and confront the climate crisis as a joint venture (C40, 2023). Following joining the C40 network, Freetown's first climate action strategy was made in 2022. It highlights the importance of local action and pinpoints focus areas to be kept in focus until 2030 (United Nations, 2020).

4.6.3 Ward and Community

Freetown municipality is politically divided into three regions: East End, Central, and West End. Furthermore, the city is subdivided into 47 Wards where a councillor is appointed for each one. The councillors supervise their authority areas and must

be consulted whenever projects are to be launched. Before the project’s launch, it was decided to occur primarily within two specific wards; Ward 441, where Mariatu Kamara is the councillor (see figure 26a), and Ward 446, where Pastor Abdul Karim Turay is the councillor (see figure 27a).

In addition, the Wards are divided into communities governed by community leaders that, based on gender, are either called *Chief* or *Chairlady*. Similarly to the councillors, the leaders must be consulted whenever the communities are to be involved. Sometimes, visitors must also ask the community leader for permission to enter the community.

Within Ward 441 and 446, the two communities, Gemata and Pottor, are in focus. Gemata, where the floating barrier is to be placed, is governed by the Chairlady, Rookie (see figure 26b) and Pottor is governed by the Chief, Sally Sesay (see figure 27b).



(a) The Councillor - Mariatu Kamara



(b) The Chairlady - Rookie

Figure 26: Ward 441 and Gemata community



(a) The Councillor - Pastor Abdul Karim Turay



(b) The Chief - Sally Sesay

Figure 27: Ward 446 and Pottor community

4.7 Waste Management Initiatives

In recent years, the mayors of Freetown have realized the need for waste management in the city. Through several reigns, they have launched initiatives to combat waste pollution issues, and the current rule has been advocated strongly. In 2018, the FCC proposed a strategy to mitigate waste and sanitation problems. It is called *Transform Freetown* and includes the following fundamental targets (Freetown City Council, 2021):

1. Ensure that 60% of Freetown’s solid and liquid waste is safely collected, managed and disposed of by 2022.
2. Ensure that 40% of Freetown’s plastic waste is recycled by 2022.

As of 2023, the goals have not been met, but steps have been taken towards the targets. In 2022, six new waste management laws were imposed to form the city’s legislative waste framework:

1. Every household must have a waste containment facility.
2. All waste generated must be cleared and deposited into the containment facility.
3. All households must make arrangements with a waste collection contractor (Push Cart/Tricycle or alternative waste collection contractor) for the collection of their waste from the containment facility daily.
4. All containment facilities must be kept clean after every collection exercise.
5. Every household must have a standard toilet facility with a septic tank to be used by all occupants.
6. Every household must immediately ensure the desludging of their septic tank when full for desludging.

If the laws are violated, individuals can be reported for a criminal offence which will be punished by a fine of 500 Sierra Leonean Leones (SLE) or six months imprisonment (Freetown City Council, 2022). Although the legislative framework is well-defined, actual enforcement is not present (Smith et al., 2019).

Concurrently, several initiatives have been started on both governmental and local levels. An excerpt of the most prominent is described in the following.

Cleanest Zone Competition

In 2018, the *Cleanest Zone Competition* was launched by the FCC to encourage community participation in waste management. The initiative is supported financially by C40 and awards the zone that had been cleaning its area the most with four sponsored improvements: 10 solar-powered street lights, 500 meters of paved road, one 10,000-liter water tank/point, and ten education scholarships. The competition runs for six months, twice a year, after which the winning community is announced through a live show celebrating the extraordinary efforts of the five best-performing communities. The initiative has proved very effective in engaging the communities in waste management, enlightening the mutual responsibility that the citizens of Freetown hold. However, the competition seems to have vanished after the second time is no longer organised (Smith et al., 2019).

Geo-tube dewatering system

In 2019, a geo-tube dewatering system was installed at the *Kingtom dumpsite* for faecal sludge treatment (see figure 28). It replaces the existing infrastructure of gravel-lined drying beds and lined polders and ensures that untreated faecal sludge is not discharged into the sea. The geo-tubes dewater the sludge, which can then be used as compost (GOAL, 2022). However, locals say the compost is currently dumped next to the facility without being utilized.



Figure 28: Geo-tube dewatering system

Shipment of waste to Guinea

On numerous occasions, locals told the author that certain factions of plastic waste were collected and shipped to Guinea for recycling. At the *Kingtom dumpsite*, the author interviewed an informal waste collector who was collecting plastic waste and selling it to a company in Conakry, Guinea (see Appendix A.1.1). The narrative correlated with the

plastic trader Suleiman whom the author encountered in the Gemata community (see figure 29). He was weighing and buying the community's plastic waste that he would sell in Conakry. He underlined that the company only wanted to purchase used water sachets and thin plastic bags. For one kilogram of plastic waste, he pays five SLE and then sells it for ten SLE in Conakry (see Appendix A.1.13). According to scientific publications, the *Freetown Waste Management Company (FWMC)* undertook the city's waste management in 2018 and introduced shipment of waste to Guinea for recycling (Smith et al., 2019). However, additional information is nowhere to be found, and the locals did not know about the FWMC. Though, the system seems to be going on all over Freetown, wherefore the water sachets are less prevalent than ordinary plastic bottles in the city's waste accumulation.



Figure 29: The plastic trader Suleiman

Waste containers

All around Freetown, in busy junctions and near markets, waste containers are located like the one in figure 30. According to locals, many more were scattered around the city previously but were removed due to health concerns. Initially, the containers served as intermediate collection sites from where the waste was brought to the dumpsites by trucks. However, the locals say that no one collects the waste, why it is burned when the containers' limit is reached.

Waste Collection Management Association

Private groups of youths are currently providing waste management services on a small scale. They drive tricycles, pick up waste at private households



Figure 30: Waste containers

or businesses for a small fee, and bring it to the legal dumpsites (see figure 31). To sustain the operations, the FCC has been supporting financially and showing support by donating additional tricycles for expansion.

In 2022, Yvonne Aki-Sawyer launched an initiative where several tricycle groups joined forces in an umbrella organisation to support the growth of their businesses and ensure the sustainability of household waste collection in Freetown. The formation was named the *Waste Collection Management Association (WCMA)* and encompasses around 80 tricycles and 800 trained personnel and serves around 50,000 households and public spaces (Sierraloaded, 2022).



Figure 31: Tricycle waste pick-up

Waste management in Kenema

In Kenema, the third largest city in Sierra Leone, located a five-hour drive from Freetown, the author encountered a waste truck collecting domestic waste. As seen in figure 32, the truck resembles those used in Denmark; however, they are nowhere to be found in Freetown. The driver, a waste worker, elaborated on how Kenema was predominantly advanced concerning waste management. He explained that Kenema has a controlled dumpsite on the city’s outskirts and that the Kenema City Council provides regular waste pick-up service to the citizens (see Appendix A.1.4). Based on his statement, Kenema seems far more advanced regarding waste management. Confirmation of the waste worker’s statements was not obtained, but it is worth investigating.



Figure 32: Waste truck in Kenema

Propel Organization

A local NGO called *Propel Organization* is organising clean-ups on beaches and rivers in Freetown. The author met and spoke to two employees who described the organisation and its activities (see Appendix A.1.8 and A.1.8). Beach clean-ups were often held in the spring of 2023 and were well documented on their Facebook page. Approximately ten volunteers gathered and collected waste each time and brought it to the *Kingtom dumpsite* afterwards. As seen in figure 33 (credits: Propel Organization), the organisation has set up a net in a river to collect waste. Substantial amounts aggregate and are collected by the organisation at each clean-up event. The initiative is supported by the Ministry of Tourism, the National Tourism Board, the Marine Foundation and other partners. Propel’s vision is to encourage volun-

teers to assess plastic usage in their community and consider modifying their behaviour based on first-hand experience with plastic collection. Also, they hope that volunteers will raise awareness of plastic pollution by discussing the issue with friends, family etc. (Propel Organization, 2023).



(a) Beach clean-up



(b) River net

Figure 33: Propel Organization

Africell's "Kip Am Klin"

At Lumley Beach in Freetown, the author encountered a truck driving back and forth. It belonged to Africell, one of the largest mobile service providers in Sierra Leone, which has gotten involved in cleaning the beaches around Freetown. From talking with the operator, it was found that they do clean-ups on Lumley Beach multiple times a week. The truck has a rake that collects the waste and sorts the sand (see figure 34). Subsequently, the waste is loaded onto a lorry and brought to the *Kingtom dumpsite* (see Appendix A.1.11).



Figure 34: "Kip Am Klin" truck

Community collection

On several field trips around Freetown, the author met and talked with community members managing misplaced waste in their communities. In general, the communities were collecting waste to store it in a fixed location and did not have a plan. In the case of figure 35, the Pottor community has started to collect water sachets to keep the local square clear. The locals say they do it primarily to keep the area tidy and avoid the sachets wandering. At the moment, they do not have any agreement with any buyers of plastic waste, though a trader had once been there to buy some plastics. Sadly, an acquaintance of the trader's doings and contact information were not attainable (see Appendix A.1.9).



Figure 35: Community collection

Waste-to-Energy plant

In Western Freetown, a company called *Freetown Waste Transformers* has installed a waste-to-energy plant to supply power to the Aberdeen Women’s Center (see figure 36). According to the signage, the facility creates energy, heat, and fertiliser from organic waste. However, over three months, the author did not witness any activity around the facility.

DortiBox Waste Management Application

On May 17, 2023, the author participated in a conference at the FCC, arranged by *Freetown Waste Transformers* where their new waste management application, DortiBox, was launched (see figure 36b). Through the application, the WCMA is connected digitally with businesses and citizens that can schedule pickups of all kinds of waste for a small fee by which the waste is brought to the legal dumpsites.



(a) Waste-to-Energy plant



(b) DortiBox Waste Management Application

Figure 36: Freetown Waste Transformers

4.8 Power Infrastructure

Sierra Leone has one of the lowest energy access rates globally. Estimates show that 76% of the population does not have access to electricity. Even the capital city of Freetown is highly affected by the insufficient power supply. It is known by some as the darkest city on the planet for its lack of electricity. The main grid relies solely on temporary solutions or power from neighbouring countries, leading to the mass use of diesel generators (GSMA, 2022). When the author was dispatched, petrol prices increased incrementally, resulting in very few operational generators. Due to this, the author only had power available 25% of the time in Freetown.

Located in central Freetown is the *Kingtom Power Station* that runs on diesel with a capacity of 50 MW (see figure 37a). However, due to consistent diesel theft and fluctuation in the reliability of the plant, it has been shut down. Also, recently the pier leading to the power station collapsed, making fuel deliverance impossible (see figure 37b). The reason behind the havoc is unknown, and no reconstruction seems to be underway. Multiple solar and hydropower projects are being installed around the country, though they do not have the equivalent stable capacity as the power station. For example, the major hydropower facility, *Bumbuna Dam*, has a peak capacity of 50MW during the rainy season but a reduced output of 8MW in the dry season. Given this, the country, as a whole, lacks a stable and reliable public power source, and the domestic demand remains significantly unmet.

In 2018, the government of Sierra Leone signed the first deal with the Istanbul-based company *Karpowership* to deploy a powership, called *Karadeniz Powership Dogan Bey*, with a capacity of 50 MW, for five years in the harbour of Freetown (see figure 37c). Since then, a second ship, *Karadeniz Powership Göktay Bey*, has been installed, and together the two powership are now providing 80% of the total national energy need, though only 15% of the population has access to electricity. Both powerships are dual-fuel powered using liquefied natural gas or heavy fuel oil, delivered regularly from Turkey (Karpowership, 2023).



(a) Kingtom Power Station



(b) Broken pier



(c) Karadeniz Powership Dogan Bey

Figure 37: Freetown’s energy infrastructure

Implementing powerships in Africa to supply electricity to state power utilities is not rare. Likewise, a solution has been implemented in the Gambian capital Banjul and seven other African

countries (Reuters, 2021). While the powerships are paramount in securing the stability of Sierra Leone’s national grid, the solution is undoubtedly short-term in fulfilling the country’s power needs. The dependency on a single source of electricity is found to be highly risky, and prolonged blackouts are common. While the author was in Freetown, power breakouts happened regularly and often multiple times during the day. On rare occasions, major blackouts happen, as in November 2021 when the state faced a 50 million USD debt to *Karpowership*. Power was missing for several days until an agreement on the debt payment was derived (Sierraloaded, 2021). How the government managed to settle the debt dispute is unknown.

The current energy infrastructure in Freetown points to the fact that any business to be established must predominantly be power self-sufficient. Possibilities in operating without the use of power can be investigated in the case that a privately owned diesel generator cannot be in possession or operation. Also, the study indicates that alternative ways of energy production could prove valuable to implement.

4.9 Identification of Stakeholders

Partnering with other organisations with expertise in different areas can significantly contribute to the project’s success. Especially in the context of foreign countries, partners are critical actors in the planning, development and execution of projects. Various potential local partners have been identified, capable of taking part in different areas, including local institutions, plastic producer companies, and general waste companies. Regarding the waste-based value chain, they are the leading firms that can drive the chain regarding value addition and distribution. They hold the power to manage the chain and the strength to make changes.

4.9.1 Current Partners

Before and during the initial part of the project, EWB-DK is teaming up with multiple local and international partners. These are shown in figure 38a-38f and described in the following.

World Hope International (WHI) is a Christian relief and development organisation that works with vulnerable and exploited communities to soothe poverty, suffering, and injustice. They are active in

Sierra Leone and have multiple ongoing projects across different sectors (World Hope International, 2023). Regarding the current project, WHI is a key partner in developing a solution for the management of plastics and supports it with both technical and societal knowledge while hosting the author.

Dansk Ingeniør Service (DIS) is a global consulting engineering company headquartered in Skanderborg, Denmark. They provide knowledge within various industries, from wind to amusement (Danish Engineering Service, 2023). For the current project, DIS sponsors person-hours from in-house personnel and 200,000 DKK to construct and implement the floating waste collection barrier.

Ocean Plastic Forum (OPF) is a network of companies aiming to combat the plastic pollution of the global marine environment. By connecting key actors in the plastic industry, they develop value chains and business models for plastic waste collection, management, and upcycling (Ocean Plastic Forum, 2023). For the current project, OPF has sponsored 150,000 DKK to construct and implement the floating waste collection barrier. Also, they will support with knowledge within the field of plastics and through the accessibility to their members and its network.

Skill Pool is a local NGO funded as a development initiative in Sierra Leone that comprises a small group of young people. They have solid experience in raising awareness, ecological advocacy, and empowerment training (Skill Pool, 2023). In connection with the project, Skill Pool will assist in mobilising the affected communities, support capacity building, and staging workshops. The main contact person is the Executive Director, Alie Swazie Bangura (see figure 39).



Figure 39: Alie Swazie Bangura

Rostock University is a strategic partner that was contacted in the early stages of the project. They are working on a pilot waste management site in Kumasi, Ghana, with strong resemblances with EWB-DK’s project. As of this coherence, they can provide valuable insights and advice to the involved stakeholders. Their site comprises many different recycling technologies combined into a complete waste management solution that can handle all common waste types. So far, they have scaled the solution from the ability to process approximately 50 kg. of waste per day, to handle more than six tons per day.



(a) Engineers Without Borders Denmark



(b) World Hope International



(c) Dansk Ingeniør Service



(d) Ocean Plastic Forum



(e) Skill Pool



(f) Rostock University

Figure 38: Current partners

4.9.2 Local Institutions

Local institutions such as governments and environmental organisations must be consulted when operating in foreign countries. Two stakeholders have been identified in this case: the Freetown City Council and the Environmental Protection Agency. These are seen in figure 40a-40b and described in the following:

Freetown City Council (FCC) is the municipal government of Freetown. Members of the FCC are known as councillors, except the deputy mayor Yvonne Aki-Sawyer in whom local executive power is vested. The council is responsible for the general management of the city and carrying out laws (Freetown City Council, 2023b). In the project, the FCC is a key political stakeholder in ensuring the



Figure 40: Local institutions

project’s legal leasing, construction, and operating rights. Before the project launched, they showed interest and endorsed it.

Environmental Protection Agency (EPA) is responsible for protecting the environment and its natural resources in Freetown. They work to sustainably manage the environment to ensure adequate quality for human health and well-being. Also, the EPA oversees enforcement, compliance, education, and awareness raising concerning environmental impacts. Together with the FCC, they legislate regulatory proposals and guidelines (EPA, 2023). In the project, they are a key public stakeholder to keep engaged while installing the floating barrier in the lagoon. This is due to the location, which is a natural ecosystem area under their jurisdiction. Communication and mutual partnership agreements with the EPA were established before the project launch.

4.9.3 Local Plastic Companies

While exploring the market for plastic product manufacturers in Freetown, several companies were found. They are so-called Original Equipment Manufacturers (OEMs) and a mix of small and large-scale production companies. Some do already work with recycled materials. Below, six companies are listed with a brief description (see figure 41a-41f).

Premier Enviro Solutions Ltd. is an enterprise based in Freetown with a vision of becoming a leader in integrated waste management. They aim to provide innovative, sustainable, and affordable solutions, focusing on the most hazardous types of waste that threaten public health. Concerning the project, they have developed a building brick consisting of plastic waste, sand, and gravel. According to the company, this solution is an energy-efficient, modular, and highly scalable



Figure 41: Local plastic companies

technology. This poses a way to recover resources from waste and construct sustainable buildings with positive social and ecological impact (Premier Enviro Solutions, 2023).

AH&M Ltd. is a plastic product-producing company based in Freetown. Since 2004, they have produced a selection of products of the highest quality with various options available to ensure customer satisfaction. They produce water tanks, pipes, and conduits sold to households and businesses (AH&M Ltd., 2023).

Crimson Grey Recycling is a newly started organisation aiming to become a global force that pioneers eradicating plastic waste across Africa. Also, they focus on educating communities about the environmental benefits of recycling and show them how to create a more sustainable future (Crimson Grey Recycling, 2023).

Milla Group is a large company producing plastic products in Freetown. According to themselves, they have the largest capacity in Sierra Leone. Their product catalogue covers a wide field, from water tanks to kitchenware and household items.

They use injection moulding, rotation moulding, blow moulding, film extrusion and PVC extrusion (Milla Group, 2023).

Shae Recycling is the first local waste management and recycling company operating in the country. They aim to build a low-cost waste collection infrastructure with local community involvement. At the same time, they strive to raise general awareness of the importance of recycling for both social welfare and environmental sustainability (Shae Recycling, 2023).

G. Shankerdas & Sons Ltd. was established in 1939 as a trading and merchandising house. Since then, they have transformed multiple times, adding more industries to their portfolio. As of today, it produces various plastic products and is the leading beverage supplier in Freetown (G. Shankerdas & Sons Ltd., 2023).

4.9.4 Local Waste Companies

In Freetown, two local waste companies are found, shown in figure 42a-42b and described below.



Figure 42: Local general waste companies

Masada Waste Management Company (Masada) is a privately owned waste collection company in Freetown. They offer waste management services and can handle diverse waste streams. From 2012 Masada was in the lead of the waste management of Freetown but stopped their operations in 2017 due to defaulted payments. They implemented a door-to-door collection system funded by a subscription fee. Today, they still operate but at a limited scale, serving households and businesses and dumping the waste on the legal dumpsites (Masada Waste Management Company, 2023).

Freetown Waste Transformers (FWT) is a provider of organic waste-to-energy solutions in Sierra Leone. They collect organic waste and turn it into electricity, heat and fertiliser. Their vision is to become the leader in waste valorisation by utilising innovative technologies to deliver eco-friendly and sustainable bio-energy. This is to be done to contribute to green transformation and job creation for waste collection partners. In Freetown, the company has set up waste-to-energy installations housed in shipping containers and hopes to expand further. According to their website, the site is fed and operated by Masada Waste Management Company (The Waste Transformers, 2023). As described previously, FWT launched Freetown’s first-ever waste management solution, DortiBox, in May 2023.

4.9.5 International Organisations

Four international organisations are identified that can contribute in various ways. These are seen in figure 43a-43d and described below.

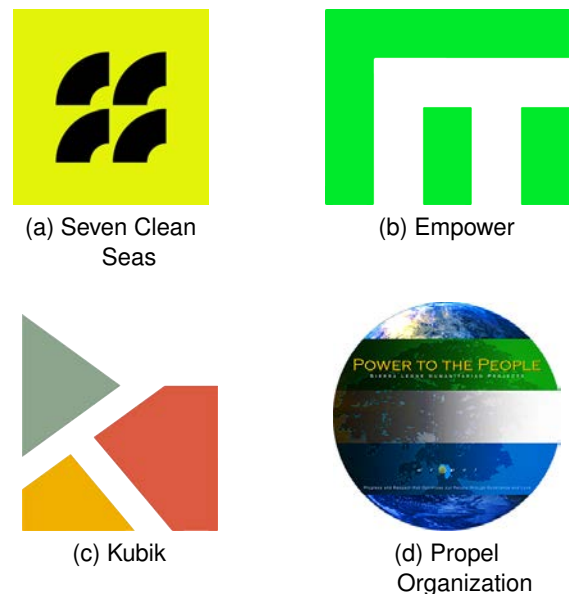


Figure 43: Potential international partners

Seven Clean Seas (SCS) is a company based in Indonesia that is on a mission to make the oceans free of plastic. They offer plastic credits that businesses can buy to support the environmental initiative. When a credit is purchased, SCS’s Cleanup Crew recovers/intercepts plastic from a Marine Protected Area and sends it for sorting, separating and classification in their Materials Sorting Facility. Eventually, SCS issues a *Plastic Credit Certificate* to the client (Seven Clean Seas,

2023). Previously, SCS has been in contact with EWB-DK on the prospects of selling plastic credits. The company has expressed interest in partnering to integrate plastic offsetting as a financial stream for plastic waste collection. This involves using their process of registration and verification etc.

Empower is a Norwegian company that has extended the idea behind national plastic exchange systems, such as the Danish 'pant system', to the global scale. Empower has implemented the blockchain to allow seamless tracking and monitoring of plastic. Also, this makes it possible to operate in third-world countries where most of the population has no bank account. When tracking a plastic's journey, transparency is achieved, which is highly attractive to brands, plastic processors and consumers. According to Empower, this increases the value of waste plastic and makes the collection a viable, revenue-generating business (Empower, 2023). In the spring of 2023, Empower was contacted concerning the prospects of applying their system to the project. Empower showed interest in collaboration and is excited about the undertaking.

Kubik is a Kenyan startup that turns plastic waste into low-cost, low-carbon building materials, addressing a global affordable housing need. They buy pre-processed plastic waste from suppliers and manufacture interlocking wall components for selling to real estate developers. Kubik is located in Ethiopia, but they are considering expanding their business to West Africa (Kubik, 2023). In the spring of 2023, the author spoke to the CEO about their product and business prospects in Sierra Leone. The potential of selling recycled plastics to Kubik can be explored concerning the project.

Propel Organization is a local NGO focusing on raising awareness and action in Freetown's waste management. They are located in the western part of the city and have, in periods of high demand, up to 100 employees hired locally. The primary funding comes from an American man and a South African woman. Also, an adjacent beach bar and different funds, some rooted in the FCC, subsidise Propel's operations. Propel Organization is doing beach cleanup on Lumley Beach and has mounted a net to collect waste going towards the sea (Appendix A.1.8). They can prove to be a strong collaborator for the project as they have first-hand experience and several waste management initiatives.

4.9.6 Summation of Stakeholders

A summation of the identified stakeholders is shown in table 1.

Table 1: Stakeholder identification

Identified stakeholders	
Locals	EWB-DK
Waste collectors	WHI
Rostock University	OPF
Premier Enviro Solutions	DIS
AH&M Ltd.	Skill Pool
Crimson Grey Recycling	FCC
Milla Group	EPA
Shae Recycling	SCS
G. Shankerdas & Sons	FWT
Masada	Empower
Pottor community	Propel Organization
Gemata community	Chief Sally Sesay
Pastor Abdul Karim Turay	Chairlady Rookie
Mariatu Kamara	Kubik

Objective Setting

Defining the objective of the solution development based on the challenges, outlined as research questions



5 Objective Setting

Following the situation analysis, numerous challenges were identified, and the objective was defined for solution development.

5.1 Challenges Identified

The high number of identified challenges are shown interlinked in figure 44. The magnitude of the problem might seem overwhelming, making the solution development very ambiguous. To navigate the complex pattern of challenges and facilitate the definition of concrete objectives, a *Root Cause Analysis* was applied.

5.2 Root Cause Analysis

To meet the project objectives, it was crucial to dig deeper into the underlying causes of the challenges. Understanding the root cause is essential for defining the most effective solution and preventing recurring issues. In this context, the *Five Whys* method is valuable for investigating cause-and-effect relationships within the problem space. The method was developed by Sakichi Toyoda in the 1930s and is a popular iterative interrogative technique to explore the underlying causes of a problem by repeatedly asking *why* and uncovering deeper layers of causation. The response to the fifth *why* typically reveals the root cause, showing what issues to address directly (Serrat, 2017).

Problem definition

Freetown struggles to manage plastic waste, which affects the environment, causes health hazards, creates flooding issues, delimits socio-economic sustainability, and reduces the overall quality of life.

The Five Whys

1. Plastic waste is dumped all over the city - why?
2. The city's waste management system is unsuccessful - why?
3. The FCC focuses on different and perhaps more pressing problems - why?
4. Waste management has not been deemed a source of income - why?
5. Freetown lacks waste management infrastructure - why?

The root cause

Derived from the *Five Whys*, the root cause is that Freetown lacks a sustainable waste management practice; hence the fundamental infrastructure is missing. The city lacks the facilities, resources, and systems to manage and handle waste effectively. The absence of a proper waste management infrastructure hinders the implementation of efficient waste disposal methods, leading to the dumping of plastic waste throughout the city. Additionally, the lack of infrastructure may indicate a broader issue of insufficient investment and prioritization of waste management, as it is not perceived as a viable source of income or as pressing as the city's other problems. Concerning figure 44, the root cause is highly linked to challenge number five.

5.3 Research Questions

Based on the *Root Cause Analysis*, the following research questions are formulated to lead the solution development. The main research question is:

“How can a business model be devised for recycling plastic waste focusing on developing a waste management infrastructure?”

It is further elucidated using two sub-questions, as follows:

I: “How can the model be implemented and performed with the management of stakeholders?”

II: “How can the associated risks be mitigated?”

These research questions are sought answered in the following sections.

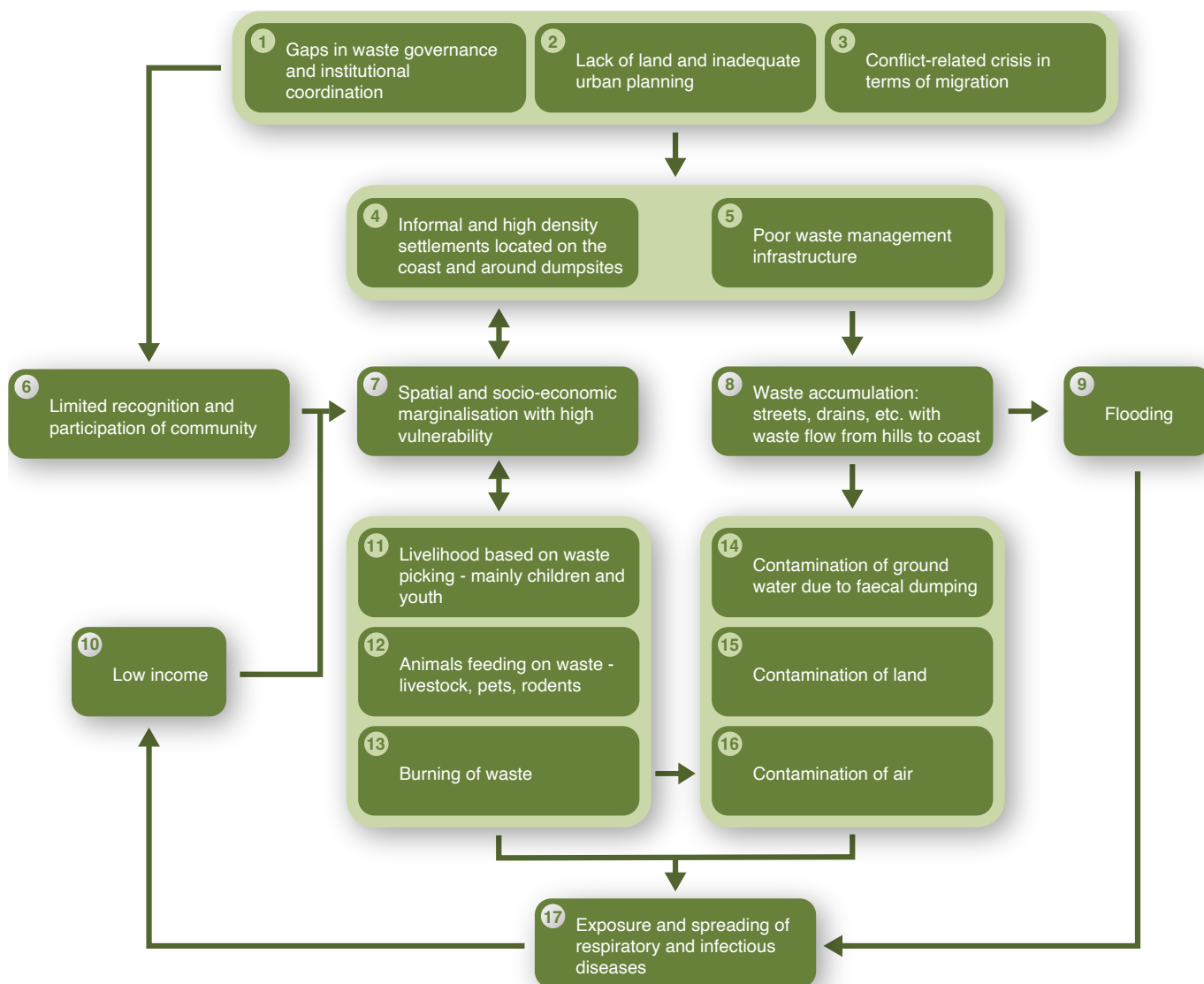


Figure 44: Accumulated challenges

Solution Development

Deriving a business model through a technology screening, applying theoretical frameworks and exploring the solution space



6 Solution Development

Multiple objectives are to be addressed to develop a solution. Owing to the sub-projects' trinity, the barrier's site and collection and sorting site establishment is included in the business model. This is done to provide the bigger picture and to keep all the essential aspects in mind.

6.1 Value Proposition Canvas Applied

Based on the root cause analysis and the derived research questions, the *Value Proposition Canvas* is applied.

Customer Profile

It was found that the *Customer Jobs* for the citizens of Freetown is first and foremost to have proper waste disposal where plastic waste is managed responsibly and efficiently. As a result, the plastic waste is removed from the surroundings to prevent flooding by ensuring the drainage systems are clear. Furthermore, the citizens desire a source of income to cope with poverty.

The *Pains* include Freetown's missing waste management system leading to plastic waste accumulation. The issue leads to increased flooding during the rainy season as plastic waste obstructs the drainage systems and exacerbates flooding. Moreover, health hazards follow as plastic waste contributes to health risks due to disease spreading. Also, Freetown lacks a reliable power supply with several side effects and stands in the way of fostering development. The pains affect not only the environmental issues but also the social and economic aspects of citizens' lives.

The *Gains* from implementing waste management solutions include a cleaner and healthier environment where the citizens will benefit from a more immaculate town with reduced pollution, leading to improved health and well-being. The citizens will have access to a sustainable and responsible waste management system from which they can potentially earn a profit. In addition, the flooding will be reduced as a solution that effectively manages plastic waste can help keep the drainage clear during the rainy season.

Value Map

The *Products and Services* that is to be provided to Freetown's citizens is a waste collection system that focuses on properly disposing and recycling plastic waste. It will entail community engagement to create income-based local activities. Furthermore, the service will enhance the infrastructure and entail measures to prevent plastic waste from obstructing drainage.

The *Gain Creators* induce environmental sustainability by promoting sustainable waste management practices and encouraging citizens to preserve the environment. Also, economic prosperity is generated by creating job opportunities through waste collection, recycling, and developing a waste management infrastructure. In addition, flood prevention is helped by ensuring proper waste management and preventing drainage obstruction.

The *Pain Relievers* include an efficient, reliable and regular waste collection and management service to prevent waste accumulation in the townscape. Additionally, establishing a recycling centre encourages citizens to recycle their plastic waste. Lastly, the intervention will introduce public health initiatives that address the health hazards associated with plastic waste and promote clean and healthy practices.

From the application of the *Value Proposition Canvas*, it stands clear that the solution must include several components such as waste collection and recycling, infrastructure improvements, education and awareness raising and, if possible, power production. This is the main interest of Freetown's citizens, while the recycling of plastics is secondary to the citizens of Freetown. Because of this, the solution space and business model must revolve around removing waste as its primary objective, with recycling being secondary.

6.2 Technology Screening

A technology screening examines the diverse potential technologies for processing plastic waste. The technologies are characterised as both *Recycling waste* and *Recover Energy* as defined by *The Waste Hierarchy* (see figure 10). The identified technologies are presented in figure 45 (Renewable Carbon, 2022 and Johansen et al., 2022), but firstly four underlying plastic processing approaches are presented in the following to supplement the screening.

Plastic processing approaches

Recycling technologies for polymers are categorised under four different terms, which are shown in figure 45 and described in the following:

Primary recycling refers to the re-introduction of clean scrap and single polymers in a manufacturing process to produce products of similar material. Manufacturers commonly do this in their processing line, though it is rarely applied among recyclers, as the materials available seldom possess the required properties and quality.

Secondary recycling is the most common kind of recycling, including some of the most low-tech methods. Generally, it is referred to as mechanical recycling and involves products that have reached their end-of-life or production waste, which is fed into the system again. Depending on the requirements, the materials, such as pellets, flakes, or powder, are often mechanically processed to the desired form. The term also includes simply reusing materials in their original form for a different purpose.

Tertiary recycling involves advanced chemical treatment processes where either fuels or petrochemical raw materials are produced.

Quaternary recycling refers to energy recovery, which involves controlled combustion of plastic waste to recover some of its original value. Low-grade energy recovery processes are standard practice in developing countries but in an uncontrolled format (Al-Salem, Lettieri, and Baeyens, 2009).

The different terms appear from figure 45 where they are placed with specific technologies for processing plastic waste.

6.2.1 Technology Assessment

The identified technologies for processing plastic waste are assessed in the following.

Mechanical recycling is a primary process that involves shredding plastic into smaller pieces, washing it to remove impurities, and separating different types of plastics based on their densities. The cleaned and separated plastic is melted, filtered, and pelletized into small pellets or granules. These recycled plastic pellets can be used as raw materials to manufacture new plastic products. Mechanical recycling is widely used, but its effectiveness depends on the type and quality of the plastic waste.

Dissolution is a solvent-based secondary process that utilises heat and solvents to dissolve plastic, resulting in a solution consisting of the original polymers and additives from which it was made. When dissolving mixed plastic waste, targeted polymers can be targeted with a suitable solvent. In this case, the polymer's chemical structure can remain intact. Components such as pigments, additives, fillers and non-targeted polymers remain un-dissolved and can be removed from the target polymer. Subsequently, the precipitation is initiated by adding an anti-solvent. In contrast to solvolysis, the polymer can be obtained directly where no polymerisation step is needed.

Enzymolysis is a tertiary technology based on biochemical processes that utilise biocatalysts to depolymerise a polymer into its core building units. It utilises enzymes to break down plastic polymers into more minor fragments by breaking the chemical bonds and causing the plastic to degrade. The resulting smaller molecules can be further processed or recycled. However, the application of enzymolysis to plastics is still a developing field, and further research is needed to optimize enzyme formulations, improve efficiency, and address scalability challenges for large-scale implementation.

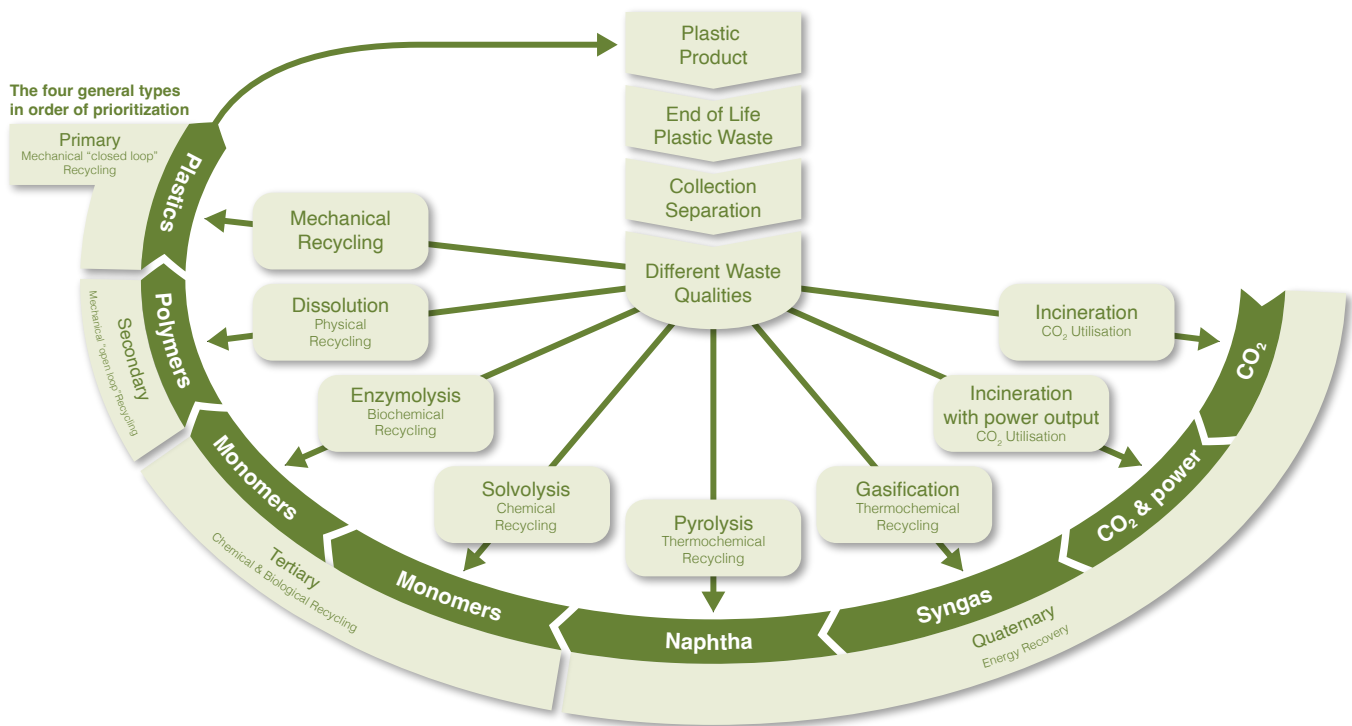


Figure 45: Plastic processing technologies

Solvolysis is a tertiary solvent-based chemical process that involves depolymerization and can be accomplished using various solvents. This process breaks down polymers into constituent building blocks, such as monomers, dimers, and oligomers. Once the breakdown occurs, the building units must be cleaned to remove additional plastic components, including additives, pigments, fillers, and non-targeted polymers. Following the cleaning stage, the building units are polymerised again to synthesise new polymers. Both enzymolysis and solvolysis are advanced processes that use potent chemicals that must be cautiously handled (Renewable Carbon, 2022).

Pyrolysis is an advanced quaternary thermal decomposition technology that converts organic materials, including plastic waste, into a liquid fraction, known as pyrolysis oil or bio-oil, which contains a complex mixture of hydrocarbons and can be refined to produce fuels, lubricants, or chemical feedstocks. During the pyrolysis process, plastic waste is heated to high temperatures in the absence of oxygen, causing it to break down into gas, liquid, and solid residues. The gas fraction produced consists of various hydrocarbons and can be used for energy generation or further refined into valuable chemicals and fuels. The solid residue, often called char or carbon black, mainly contains carbon and

inorganic materials and can be used as a solid fuel or an additive in various industries (Biogreen, 2023).

Gasification is an innovative quaternary technology that converts plastic materials into a synthesis gas, syngas, through controlled partial oxidation. Plastic waste is introduced in a gasifier and heated to high temperatures in a low-oxygen environment. During gasification, the plastic undergoes thermal decomposition, breaking down into a mixture of gases, primarily carbon monoxide and hydrogen, along with carbon dioxide and other trace gases. The syngas produced from plastic waste gasification can be utilized as a clean and versatile energy source for power generation or heating applications. Syngas can also be further processed through cleaning, upgrading, and catalytic reactions to remove impurities and adjust their composition for specific end uses. The process can handle various types of plastic waste, including mixed or contaminated plastics that are challenging to recycle mechanically (Saebea et al., 2020).

Incineration is a quaternary technology that involves the combustion of plastic materials at high temperatures in specially designed incinerators. During incineration, the plastic waste is subjected to intense heat, typically exceeding 800 degrees Celsius, causing it to combust and release energy in the form of heat. Incineration can significantly reduce the volume of plastic waste, as it converts it into ash, gases, and heat. The gases produced during incineration, known as flue gases, must be carefully treated to minimize air pollution and remove harmful substances, such as particulate matter, heavy metals, and dioxins. Ash generated from incineration must be collected and requires further treatment or disposal in specialized facilities. Incineration is considered a waste-to-energy approach, but its environmental acceptability and sustainability depend on factors such as energy recovery efficiency, emissions control, and the overall waste management hierarchy, focusing on reducing and recycling the plastic waste as the preferred options.

Incineration with power output is a way to utilise the heat generated during incineration. It can be used for various purposes, such as steam generation for electricity production or heating applications. Plastic waste incineration can contribute to energy recovery by utilizing the heat produced by generating electricity (Plastic Solutions Review, 2023).

6.2.2 Technology Evaluation

The technologies are evaluated in proportion to the criteria; *Cost*, *Complexity* and *Realisability* concerning their implementation in Sierra Leone. This is performed with the help of Michael Langlo from DIS, who has expert knowledge in plastic recycling technologies. The performed evaluation is summarized in table 2, where an overview is provided.

Mechanical recycling is deemed relatively cost-effective as it involves simple sorting, shredding, and melting plastic. However, the initial investment in machinery and infrastructure can be significant; hence, a moderate *cost* is to be expected. The technology is very straightforward and of low *complexity*. Regarding *realisability*, the technology is well-established and widely adopted globally, making it highly realistic and feasible for implementation in Sierra Leone.

For **dissolution**, it is deemed that the *cost* can vary depending on the solvent used and the scale of the process. It may require investment in specialised equipment and solvent waste management; hence, the *cost* is estimated high. The process can be complex due to the need to select suitable solvents, optimise process conditions, and handle chemical waste. Due to this, proficient expertise in solvent chemistry is essential for the running of such a system, leading to a high *complexity*. Based on the research, dissolution recycling is a relatively emerging technology, and its application on a larger scale may still face challenges in terms of cost-effectiveness and availability of appropriate solvents. The realisability depends on the availability of appropriate solvents and the expertise to handle them safely. Due to this, the implementation may require significant research and development efforts, which is why the *realisability* is considered low.

For **enzymolysis**, specialised enzymes must be applied to break down plastics, which is considered very cost-intensive when performing enzymolysis. The cost is influenced by the need for expertise in tailoring the enzymes and developing efficient enzymatic processes, which entails a high *cost* and *complexity*. The optimisation of enzyme reactions and the recovery of enzymes add to the complexity of targeting specific plastic types. Research shows that while the technology shows promise as a recycling method, it is still in the developmental stage and not yet widely commercialised. Its *realisability* in Sierra Leone is considered low as it depends on the availability of suitable enzymes, infrastructure for enzyme production, and research and development efforts.

Solvolysis involves using solvents to break down plastics. It can have high *costs* due to the need for specialized solvents and equipment. The cost-effectiveness would depend on the specific solvolysis process used, adding to a high *complexity* as careful control of temperature, pressure, and solvent selection is required. Research shows that the technology is still in the experimental and research phases, and its implementation on a large scale may face challenges. The *realisability* in Sierra Leone is deemed low as it depends on the local availability of suitable solvents, research support, and close partnerships.

Regarding **pyrolysis**, research shows that the cost of the technology can vary depending on the scale of the operation and the equipment used. It often requires significant investment but can be economically viable with proper infrastructure and market demand for pyrolysis products. Based on the industry statements, the technology has a growing global interest and is undergoing notable development, making it relatively mature and commercially available. Due to this, the *cost* is considered medium. The *complexity* is high as it is an intricate process that requires careful temperature control and management of byproducts requiring high levels of expertise. Its implementation in Sierra Leone would require investment in appropriate equipment, infrastructure, and market development for pyrolysis products, leading to a medium *realisability*.

For **gasification**, it is estimated that the *cost* of can be significant due to the high *complexity* of the system that requires high temperatures, controlled oxygen levels and additional systems for gas cleaning and conditioning. Furthermore, specialised technical expertise and maintenance must be prioritised. Regarding *realisability*, gasification is feasible but requires substantial investment and expertise in operating and maintaining the gasification plant. This entails a low *realisability*.

In general, **incineration** is deemed very cost-effective but requires significant capital investment to construct the plant. The technology is relatively straightforward and has a low level of *complexity* with unsophisticated handling of waste and control of combustion conditions. It is widely used for waste management globally, including in many African countries, so the *realisability* is considered high. Its implementation in Sierra Leone would depend on the availability of suitable incineration facilities, compliance with emission standards, and proper waste management practices.

Incineration with power output (Inci. w. power) combines incineration technology with electricity generation. The *cost* is typically higher than traditional incineration due to the additional equipment and systems required for power generation. The *complexity* of incineration with power output is also slightly higher, as it involves integrating power generation systems such as steam turbines or gas turbines. It can be a viable option for waste management in Sierra Leone if supported by proper infrastructure, emission control measures, and market

demand for the generated electricity. However, it requires careful planning and expertise to ensure efficient energy conversion and compliance with environmental regulations, causing a moderate *realisability*.

Table 2: Technology evaluation

Technology	Cost	Complexity	Realisability
Mechanical	Medium	Low	High
Dissolution	High	High	Low
Enzymolysis	High	High	Low
Solvolysis	High	High	Low
Pyrolysis	Medium	High	Medium
Gasification	High	High	Low
Incineration	Medium	Low	High
Inci. w. power	Medium	Medium	Medium

6.2.3 Conclusion

The assessment and evaluation of the recycling technologies lead to the following conclusion regarding the potential for implementing such in Freetown.

Based on the criteria, mechanical recycling, incineration, and pyrolysis are better suited for implementation in Sierra Leone (see figure 2). They have moderate *cost*, medium *complexity*, and medium to high *realisability*. However, it is essential to consider other factors, such as waste availability, infrastructure, market demand, and environmental considerations, to make a well-informed decision on the most suitable recycling technologies for plastic waste in Sierra Leone. From the situation analysis, it is clear that Freetown has many waste and power infrastructure limitations. Due to this, pyrolysis is precluded from the solution space as it requires high standards in that respect. Therefore, a combination of mechanical recycling and incineration is the preferred line of action.

Concerning *The Waste Hierarchy*, incineration is positioned in the lower end as *Dispose Waste* or *Recover Energy* based on the processes applied. If the incineration can be designed to include energy conversion to supply the grid, it would contribute to the country's independence energy-wise.

Because of the above, the business model can be bipartite, where the majority of the plastic waste of low quality is incinerated. In contrast, plastic of higher quality is allocated for either reuse or mechanical recycling.

6.3 Potential of Circular Economy

Despite the many challenges a country such as Sierra Leone faces, transitioning to a circular economy is not impossible. Whether and how the project can contribute to the transition, the concepts of *Circular Economy* introduced previously are applied to investigate.

The concept *Cradle-to-Cradle* can show very powerful in the context of Freetown. If the waste is referred to as assets instead of a harmful by-product that must be cleared away, it would presumably generate incentives to include it in businesses. The elimination of the waste concept facilitates the reframing and re-utilisation of the waste as raw material. As the technology screening showed, multiple technologies can process and repurpose waste and give it new life. In the case of incineration, the recommended technology to implement, heat output, does not provide much value directly. However, if the extension of power output is added, incineration contributes directly by recirculating the waste's value. This could be done by establishing a waste-to-power facility that generates in collaboration with the FCC. Alternatively, it could be investigated whether the *Kingtom Power Plant* could be powered by waste. To accommodate a comprehensive *Cradle-to-Cradle* system, the solution must include processes comprising different waste types, quality, and purities.

From the concept of *Cradle-to-Cradle*, the most significant learning to pass on is the importance of reframing waste to a valuable asset. In this way, an incentive is created to utilise the waste and transition the waste sector to a circular economy.

The concept of *Performance Economy* can be applied to plastic waste management to encourage more sustainable and efficient use of plastic materials. Here, the focus shifts from selling products to delivering the services and functionalities that products provide. In the case of Freetown, three different ways to approach the principle are:

1. Instead of consumers owning and purchasing plastic products outright, the *Performance Economy* encourages a shift towards leasing, sharing, or renting models. Plastic product manufacturers can offer services where they retain ownership of the products while providing access to customers. Manufacturers can provide reusable containers on a subscription or rental basis instead of selling single-use plastic contain-

ers. This approach incentivises manufacturers to design durable and high-quality plastic products that can be used repeatedly, reducing the demand for new plastic production.

2. Plastic product manufacturers can retain responsibility for the entire lifecycle of their products, including end-of-life management. This means they are incentivised to design products with materials that can be easily recycled or safely disposed of. As seen in different African countries, EPR programmes can be a part of this, outlining corporate responsibility from safety to social and environmental issues (see figure 18). For example, manufacturers can establish take-back programs to ensure the proper collection and recycling of their plastic products, avoiding them ending up in landfills or oceans. By taking responsibility for their products' entire lifecycle, manufacturers can better manage plastic waste and promote a more sustainable approach to resource management.
3. By settling collaboration and partnerships between manufacturers, consumers, waste management entities, and other stakeholders to address plastic waste challenges collectively. Manufacturers can partner with waste management companies to ensure proper collection, sorting, and recycling of plastic products. Collaboration can also drive innovation and the development of new technologies or business models that improve plastic waste management practices.

The presented approaches entitles comprehensive engagement with the plastic product manufacturers to facilitate the transition to a circular economy. Concerning *Performance Economy*, they hold great power in forming the sector. The most significant learning to pass on is the paramount collaboration between internal and external stakeholders to address the subject jointly.

The concept of *Regenerative Design* can be applied by adopting strategies that aim to minimise waste, maximise resource efficiency, and promote the regeneration of natural systems. This can be facilitated by designing products to enable circularity and prevent waste generation. Manufacturers can design plastic products to be easily disassembled, repaired, or upgraded, promoting their longevity and reducing the need for new plastic production. This includes considering modularity, standardised components, and accessible material separation to facilitate recycling and repurposing at the end of the

product's life. Just like the concepts of *Performance Economy*, the manufacturers possess great power, underlining the importance of collaboration.

6.4 Platform Thinking Applied

Before exploring solutions, *Platform Thinking* is considered. This is done to support the final solution's applicability and enable the realisation of the project through alignment with existing local and global tendencies.

During an interview, Manfred at *Propel Organization* described the well-defined processes they have implemented for their waste management operations (see Appendix A.1.8). For their weekly clean-ups, they use 50 kg. rice bags for collection as it is commonly found in shops but also among the waste. Regarding waste transportation, vehicle standards in Freetown are favoured as they ease the implementation and heighten the accessibility to spare parts. Manfred stated that their truck often needs maintenance due to a harsh work environment and spare parts of low quality. Because of this, a standard vehicle such as a tricycle or truck is preferred. The applicability and a potential partnership are fostered by imitating the practice of *Propel Organization*.

As observed and shown in figure 20, plastic bottles are found in large quantities everywhere in Freetown. In a global context, plastic bottles are well-known and often recycled, such as in Denmark, where the "pant system" circulates the bottles. Therefore, concerning offsetting the collected plastic, plastic bottles can serve as an excellent platform for reuse and recycling. Because of this, offsetting solutions targeting plastic bottles must be explored.

Because NGOs develop the undertaking and do not hold significant financial capabilities, existing platforms such as monitoring systems, plastic credit frameworks, and management tools must be incorporated. Also, future enlargement and implementation are supported by basing the operations on well-known global systems.

6.5 Solution Space

An exploration of the solution space is commenced. The solution space reflects the performed technology screening, which led to the conclusion that Sierra Leone does not have the capabilities to bear highly advanced recycling technologies. Even though this paper focuses on plastic waste, other types are included as it is undeniably a part of the aggregate waste collected and must be dealt with. Due to the limitations of the project, the method of sorting the waste at the collection and sorting site is "black boxed" and must be investigated as future work.

The solutions are put in order of the flow from sourcing to offsetting. Firstly, the sources of plastic waste are listed. Secondly, transportation. Thirdly, the location of the collection site and sorting site. Fourthly, processes that provide value and, lastly, the offsetting of plastic waste.

A map is shown in figure 46 to provide an overview of the solutions' locations and interlinkage. The map is a simplified version of the complete overview, "Location of interest", made by the author and shown in Appendix A.2.

6.5.1 Waste sourcing

For the sourcing of waste, various locations were identified in western Freetown. This includes several communities, a beach area and *Propel Organization*.

Gemata community

Firstly, the Gemata community was identified as a potential site for sourcing waste, and as described previously, this is also the location of the floating barrier mounting. The community is located at the lagoon outlet, and it is highly affected by large quantities of waste, which is not only generated in the community but also hail from elsewhere (see figure 47). The lagoon has several rivers linked to it, from which waste is transported towards the ocean. The alternating tide movement causes waste to enter and leave the lagoon multiple times daily. When observing the waters around the community, the waste accumulation seems to be never-ending.

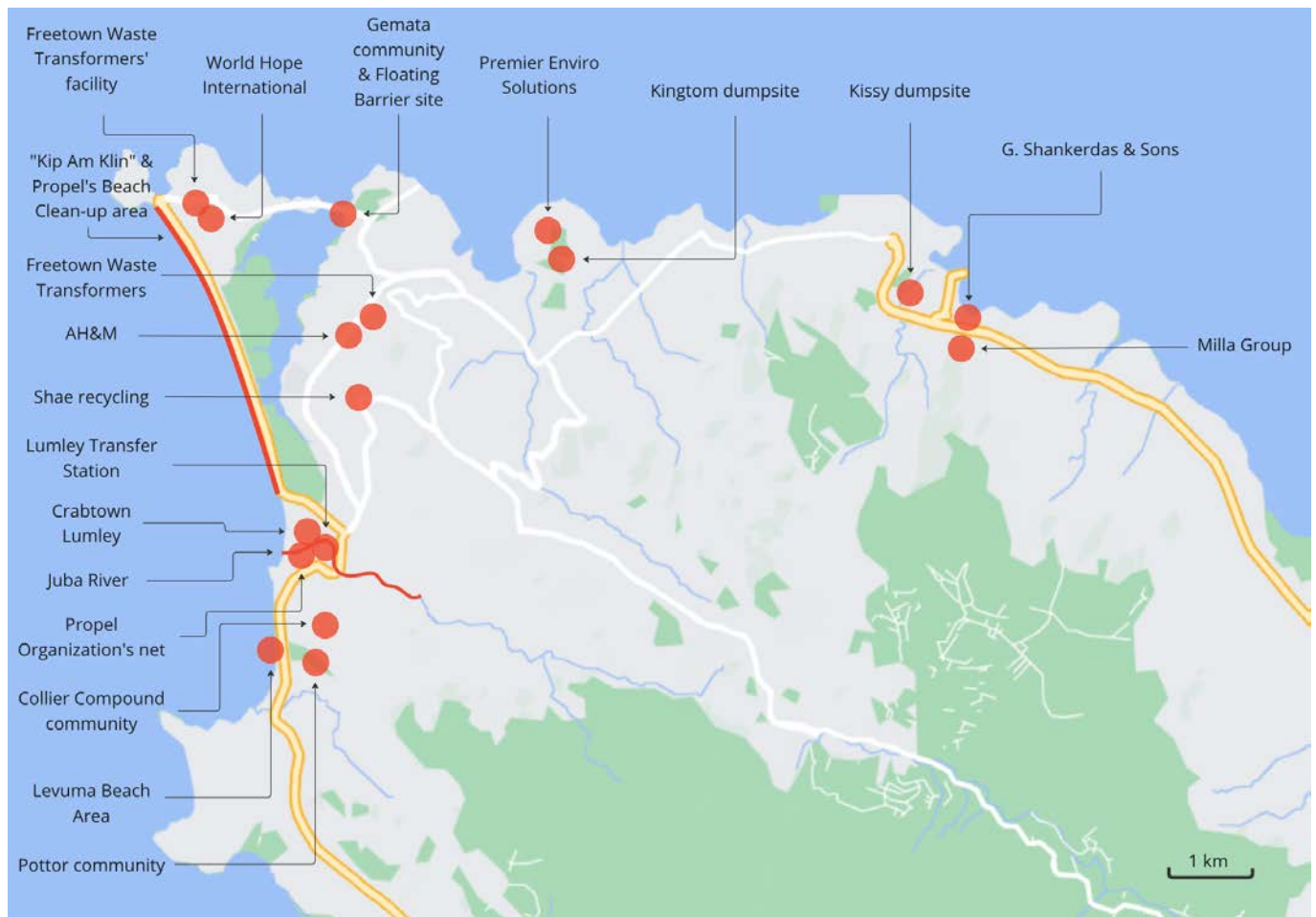


Figure 46: Freetown with points of interest

Pottor community

The Pottor community was identified as a waste source due to preceding collaboration on other EWB-DK projects. The community is very exposed to flooding during the rainy season as the abundance of dumped waste blocks the drainage. As seen in figure 48, large amounts of waste have been dumped near a river, leading to vegetation and crop contamination further down the stream.

Levuma Beach Area

This site is next to the main highway where waste accumulates in the adjacent river, which leads directly to a small community by the ocean (see figure 49). It poses a great risk in the rainy season as the river's waters can not pass, creating a complete blockage. As the site is not in anyone's possession, nothing has been done to prevent the unfortunate flooding in the area due to the aggregated plastic waste. From time to time, in the spring of 2023, the author visited the area and witnessed how floods alternating filled the area with waste and emptied it into the ocean.

Collier Compound community

In the proximity of the previous sites, the Collier Compound is located. It is a small community shaped like a doughnut where the citizens live on the outer ring while waste is thrown into the centre hole. As seen in figure 50, the waste aggregates and the community even cultivates the area right next to the dump site. Until recently, the dump site was confined but has been opened through conversation with the community leader. According to the locals, the waste incrementation does not have an end as long as no proper waste management is set in place together with training of the citizens in waste separation.

Crabtown Lumley community

Close to the ocean and adjacent to Juba River, the community of Crabtown Lumley is located. Situated centrally in the community is a site with abundant amounts of plastic waste, which lies water of unknown depth (see figure 51a). According to the locals, the waste originated from the community and other communities further upriver. The increments



(a) Under Aberdeen bridge



Figure 48: Pottor community



(b) The shores by Gemata community

Figure 47: Gemata community



Figure 49: Levuma Beach Area

do not seem to have an end, and the community is left impotent. Close by the plastic, a highly contaminated pond bears witness to the discharge of faeces in the community's waters (see figure 51b). This points to the fact that the community's waste is highly polluted and must be handled carefully. Generally, this prompts the reminder to handle waste carefully and only when appropriate safety equipment is used.

Propel Organization

As described previously, Propel Organization is doing beach clean-ups and has a net installed in a river to collect waste. Currently, the waste is dumped at the *Kingtom dumpsite*, but with the advantage, they could be implemented as a waste source in the project. They have a clearly defined structure and collect waste in large rice bags (see Appendix A.1.8).



Figure 50: Collier Compound community

6.5.2 Transportation

For transportation, the solution space explores different ways that waste sources are linked with the collection and sorting site and potentially also



(a) Accumulated plastic waste



(b) Contaminated pond

Figure 51: Crabtown Lumley community

to the offsetting waste stream.

Tricycle service as transport

A popular choice of transportation in Freetown is the tricycle. They are seen all over town and used for various purposes. As described, the tricycle groups have formed WCMA and provide services within waste management (see figure 31). Often the groups belong to specific communities and can be reached by phone or through the newly launched *DortiBox* application. This service can be utilised for the transport of waste with scheduled pick-ups. According to the *DortiBox* application, a pick-up of 1-50 kg. of waste costs 10 SLE, which is equivalent to 3.5 DKK as of May 2023.

Privately owned tricycle as transport

Instead of using the tricycle service, a tricycle can be purchased to be privately owned. According to Alie, a brand new tricycle, as the one seen in figure 31, would cost approximately 3,000 USD equalling 21,000 DKK as of May 2023 (see Appendix A.1.10). EWB-DK, WHI, and Skill Pool have several projects

so that the tricycle can be utilised broadly on all projects. Due to private ownership, expenses for service and maintenance must be considered but are hard to estimate currently.



Figure 52: Propel Organization's 814 truck

Rented truck as transport

A different approach to organising transport is to rent an 814 truck. The trucks are seen all over the city and would be appropriate for regular waste transportation. This is also the type of truck that Propel Organization is using for their waste management operations (see figure 52). According to Alie from Skill Pool, it would cost 3,000 Leones to rent an 814 truck per day (see Appendix A.1.10). As of May 2023, this is equivalent to 1,000 DKK.

Privately owned truck as transport

As an alternative to renting an 814 truck, a truck can be acquired instead. As mentioned, EWB-DK, WHI, and Skill Pool have several projects together; hence the truck can be utilised broadly on all projects. According to Alie from Skill Pool, a brand-new 814 truck cost 4 million SLE, equiv. to 150,000 DKK in May 2023 (see Appendix A.1.10). However, service and maintenance costs must also be considered if a truck is purchased. According to Manfred from Propel Organization, the truck they use for similar operations costs 500 USD (equiv. to 3,500 DKK in May 2023) a month to maintain and service. However, in this case, the truck is somewhat worn, as seen in picture 52, and according to Manfred, the spare parts available are of low quality; hence repairs must be done frequently (see Appendix A.1.8). Thus the costs would not be the same for a brand-new 814 truck, but future expenses must be considered.

6.5.3 Collection and Sorting site

For the establishment of a collection site, two different options were posed. These are the current dumpsite in the Pottor community and the Lumley Transfer Station.

Pottor community

Firstly, the area close to the dumpsite in the Pottor community was discovered as a potential site for establishing the collection and sorting site (see figure 48). Previously, approval to use the site has been obtained by WHI through the community's chief, Sally Sesay. Currently, the site functions as an illegal dumpsite and must be cleared of waste before a building to house the operations can be constructed. This also included facilities for power and water access. In April 2023, when the author visited the site, it was found exposed to flooding. The youth leader, Michael, described how the site and its proximity had been flooded after just one hour of rain (see Appendix A.1.5). It is deemed possible to handle if a water blockade is constructed.

Lumley Transfer Station

Secondly, the Lumley Transfer Station was identified as a potential site for establishing the collection and sorting site. It is one of the seven transfer stations the government built to manage the large amounts of waste in the proximity (see figure 23). This specific transfer station is accessible and located next to the Peninsular Highway, which connects it with the identified sites with large amounts of waste. The transfer station is fully walled, water and power are available, and an office and toilets are provided. As the site is part of a governmental project, the FCC must approve operating at the location. This was attained in May 2023 at a meeting between the author and the Chief Heat Officer at the FCC (see Appendix A.1.6). Approval was provided for using the transfer station as a collection and sorting site. However, supplementary information was presented. The elevated platform has to be reconstructed due to the low-quality materials used in the construction. This will take some time; hence, the start of the operation must be postponed accordingly.

6.5.4 Processes

To sustain the operations and generate income, processes such as *Monitoring Systems* and *Plastic Credits* are presented.

Mobile Payment System

In terms of the financial structure in Sierra Leone, Orange Money is the single biggest financial service provider with over one million three hundred thousand customers in the country. Even though Orange is a telecommunication company and operator, its Application Programming Interface (API) functions as a digital bank and strongly resembles how crypto-currency is traded. Their mobile money system API is, to a great extent, the financial hub of trading and facilitates a quick and easy payment service. The API systems lead the financial inclusion in Sierra Leone, and a large majority of the cashflows in Freetown take place through mobile payment systems (Bangura, 2021). This points to the potential of partnering with one of two major mobile operators, Orange and Africell. This kind of partnership is also sought after by Freetown Waste Transformers and seems like an obvious way to handle transactions (GSMA, 2022).

By incorporating the system, households and businesses could pay directly for waste management services. Likewise, if they deliver waste to the collection site, they are paid through the API. The mobile money payment system can automate and streamline the payment process and make the operation cashless. The operation could operate on a secure platform where funds can be collected and hosted. This would also improve the site's safety as no physical assets are stored there.

DortiBox application

As presented previously, the DortiBox application was launched by Freetown Waste Transformers in May 2023 (see figure 36b). It offers waste management pick-up service for all types of waste, which is easily organised through the mobile application. As the project does not encompass the processing of waste types such as organic, metal, etc., alternative measures must be taken to tackle these waste streams. Here, DortiBox comes in handy as the pick-up services can be arranged to manage the other waste types when separated from the plastics. In addition, the organic waste picked up through the application goes directly to FWT's Waste-To-Energy plants. Thus, the local enterprise and its energy production are supported.

Monitoring System

To monitor the waste collection closely, a monitoring system can be implemented. This is very valuable for keeping track of the operations, analysing methods, and optimising processes. Also, it enables the possibility of tapping into credit systems, as proper documentation is a requirement. Here, an option is to use KoboToolbox to monitor the collected plastic waste (see the logo in figure 53). KoboToolbox is a global data collection, management, and visualisation platform for humanitarian action, research, development, environmental protection, and peacebuilding operations. The system is open-source and works on any device, whether online or offline. If the device is offline during the data collection, data will be uploaded automatically once the device goes online (KoboToolbox, 2023). This is helpful in Sierra Leone as access to power and the internet varies greatly.



Figure 53: Logo of KoboToolbox

Previously, KoboToolbox has been used by EWB-DK, WHI, and SP for several projects in Sierra Leone and has fulfilled the purpose well. The prior experience has shown that the system is highly user-friendly and very accessible, making it easy to get started quickly. For the project, plastic waste would be monitored and evaluated regarding parameters such as the type of plastic collected, the amounts, the condition, etc. This will enable the operators to track the operations close and facilitate the implementation of Plastic Credits.

Plastic Credits

The international organisations Seven Clean Seas and Empower (see figure 43a-43b), which were identified, offer plastic credits. These credits are purchased by public or private organisations to either support plastic removal from the environment, to compensate for their carbon emission footprint, or out of pure goodwill. Thus, companies can outsource plastic footprint reduction and use plastic credits as part of their mitigation strategy to reduce plastic waste in the environment (South Pole, 2022). SCS and Empower function as middlemen that pay the collector on a 1:1 weight basis. 1 Plastic Credit equals 1,000 kg. of plastic removed from the environment (see Plastic Credits in figure 54). By collaborating with SCS and Empower, an offset-

ting mechanism can be established whereby the plastics collection is financed. Hereto, the companies have specific guidelines for how the plastics are processed upon collection, which must be followed. Transparency in the collection process with embedded traceability, among other things, is vital to have in place why a monitoring system must be implemented to obtain plastic credits. Prices are not publicly available for SCS's plastic credits. However, according to Empower's website, one ton of certified recycled plastic is worth approximately 88 USD (equivalent to 610 DKK as of May 2023) (Empower, 2023).



Figure 54: Plastic Credits

6.5.5 Offsetting

According to *The Waste Hierarchy* (figure 10), the most preferred way to tackle waste is to *reduce* waste, followed by *reuse* of waste. It might be difficult to change waste creation on a large scale, but solutions within *reuse* are developed. Due to the finding of many plastic bottles (see figure 20), solutions with these as the primary plastic resources are investigated. Also, concerning platform thinking, plastic bottles are a great widespread platform that can be reused for many purposes.

Housing made of Plastic Bottles

In Freetown, proper housing is costly, especially for people living in slums and low-income areas. Houses are often built of scrap metal and are usually filled with water in the rainy season, damaging property and making it difficult for people to live decently. Considering the housing challenges, a way to reuse plastic bottles is to use them in housing construction. This is done by *Upcycle Africa* in Uganda, which replaces traditional bricks and uses plastic bottles and mud to construct houses. *Upcycle Africa* collects plastic bottles, compacts them with soil, and stacks them together with mud



Figure 55: Upcycle Africa

as an adhesive (see figure 55 - credits: IKEA Social Entrepreneurship). Housing construction is cost-effective and affordable as the only materials needed are plastic bottles, soil, and water. Furthermore, according to *Upcycle Africa*, the buildings are durable, buffer heat, and earthquake resistant SINA, 2023. Secondary recycling could be done by selling a package of plastic bottles and the remaining materials and tools needed. This package could include the required materials for constructing a complete house, including work guidelines.

Flooding Protection made with Plastic Bottles

As described previously, Freetown is experiencing annual flooding, which is worsened by the blockage of drainage by plastic waste. What if the cause was flipped to a solution? The plastic waste could be used in foundations, walls, and barriers as protection against flooding. Likewise, in the housing solution, packages of a certain amount of plastic bottles can be sold along with the remaining materials and tools needed. This should be accompanied by guidelines showing how to construct flood protection in the best possible way. The solution would prove significant to the citizens as protection solutions are in short supply. Also, it is a cheap and durable solution if it is done correctly.

Offsetting to plastic product manufacturers

Six local plastic companies (see figure 41a-f) were identified as buyers for offsetting plastic waste. However, when contacted, only a few showed interest in purchasing recycled plastic waste. *Milla Group* did show interest in recycled plastic waste, though, despite several attempts to establish contact with leading employees, no settlements were made. The same applies to *Shae Recycling*, which initially showed interest but severed the dialogue

shortly after. Despite several attempts to reestablish the contact, the company remained silent. At *G. Shankerdas & Sons Ltd.* various employees emphasised that they were not interested in recycled plastic waste. The opposition was steadfast despite the author’s account of the benefits of recycling and corporate responsibility. The company *Crimson Grey Recycling* was not reachable at any time, and indications pointed to the fact that they were not operational yet. Left, two local plastic companies, AH&M and Premier Enviro Solutions, were willing to buy recycled plastic waste and are added to the overview below (see table 3). When collecting waste, it is presumed that the waste is mixed. Therefore, two other local waste companies (see figure 42a-b) are also present in the overview.

Table 3: Waste type demand

Plastic waste
AH&M
Premier Enviro Solutions
Organic waste
Freetown Waste Transformers
Mixed waste
Masada Waste Management Company

Based on talks with the local plastic companies, they have different demands in terms of plastic types (see Appendix A.1.2 and A.1.14). In table 4, the respective companies are listed with the plastic types demanded. This separation indicates how the plastics must be sorted for offsetting.

Table 4: Plastic type demand

Company	Plastic type (RIC)
AH&M	PE, HDPE, LDPE
Premier Enviro Solutions	All types

Also, it was made clear that the companies are demanding a specific state of plastics. This entails the processes the plastic must have been through before they are willing to buy it. The demand will dictate what kind of processes must be added to the collection site to accommodate the sale of plastics. In table 5, the demand for the plastic’s state is listed for the companies.

Table 5: Plastic state demand

Company	Plastic state
AH&M	Washed & dried
Premier Enviro Solutions	All

From the overview, it is clear that AH&M poses higher requirements for plastics than Premier Enviro Solutions, both in terms of purity and state. This is important to notice for waste sorting as plastics of better quality should be offset to AH&M. However, the processes of washing and drying, presumably, are necessary to sort the waste properly. Therefore, the processes must be applied to all waste collected either way.

Incineration of waste

To handle low-quality plastic waste that is either contaminated, mixed, or in other ways unusable, incineration can be applied. A deliberate plan is not derived for the incineration process. However, it is included in the solution space for future development. An existing plant in Freetown must be located, or a new one must be constructed.

Incineration of waste with power output

In continuation of the above, power generation can be added as an extension to waste incineration. Likewise, a deliberate plan is not derived, but the process is included in the solution space for future development.

6.6 Evaluation and Selection

As the aggregate partial solutions for the business model have been derived, they can be evaluated. For assessing, the criteria *Cost*, *Complexity*, and *Realisability* are introduced to formalise the procedure. They are chosen as they represent critical aspects of development projects and will support the decision-making of whether the partial solutions are selected for the business model. The evaluation ranges between *low*, *medium* and *high*, and the map (figure 46) is used to assess the location, transport accessibility and distance between key locations. To conclude the evaluation, the partial solutions are either chosen to be included in the business model or not indicated with **Yes / No**, as shown in table 6 that summarises the evaluation.

Waste sourcing

For the sourcing of waste, Gemata and Pottor pose some challenges as the communities have to be highly involved in the process. This requires training of personnel, monitoring and a lot of engagement. According to locals in the Pottor community, whom the author met on the field trips, they have already started collecting plastic waste in large bags, as shown on the cover for 'Solution Development'. They did not plan to offset the waste, but the incipient steps have been taken (see Appendix A.1.9). As further curation is needed for the collection of waste to run smoothly, the *complexity* is set to a medium. In terms of *cost*, Gemata has located relatively far away from the other waste sources and the possible collection and sorting sites (see figure 46); hence it requires more transport and is deemed slightly more expensive than Pottor. As a result, the *realisability* is set on a medium. Due to the above and based on the author's engagement where the communities express high willingness to collaborate, they are both chosen as waste-sourcing sites for the business model.

The identified site at Levuma Beach Area is not officially part of any community. Thus, it does not require any engagement to adopt this waste source. Also, it is located right next to the highway, making it very accessible (see figure 46). As a result, the Levuma Beach Area is an obvious choice for sourcing waste, with all evaluation measures set at the most favourable and included in the business model.

Since *Propel Organization* is privately owned, the *cost* is deemed higher than the other waste sources. The organisation must generate a venue to sustain its operation and thereby have some additional charges. However, the *complexity* is very low since the procedures are clearly defined, and the personnel has been trained to collect waste (as of Appendix A.1.8). Because of the organisation's well-defined structure and capabilities in supplying waste at a steady level, sourcing waste from *Propel* is deemed highly realisable and included in the business model.

The community of Crabtown Lumley is located very close to a main road, fairly accessible and near the Lumley Transfer Station and the other sourcing sites (see figure 46). However, a big concern is that the waters where the plastics are situated are highly contaminated due to faecal dumping. This is

seen from the pond in the community, which has a bright green colour, indicating severe contamination (see figure 51). Due to this, the *cost* is considered medium while the *complexity* is deemed to be at a high stage as the waste handling must be done with many precautions. In conclusion, the site is ranked medium in terms of *realisability* and is included in the business model.

Transportation

For transportation, different options were posed. Firstly, using tricycle service as transport entails further stakeholder management as the transport must be arranged with external entities every time. This causes a medium *complexity* whereas the *cost* is low as 1-50 kg. of waste only costs 10 SLE to have transported through the DortiBox application. The utilisation of the application makes the operation relatively simple, but additional stakeholder contact prompts a medium *realisability*.

Alternatively, a privately owned tricycle can be used for transport. This would boost independence and flexibility; hence it entails a low *complexity*. Due to the vehicle's purchase price and the required service and maintenance over time, the *cost* is of a medium degree. However, this implies uncertainty as the prices are not fully mapped based on single statements. Despite the limbo, utilising a privately owned tricycle is deemed very plausible thus, the *realisability* is high.

The next option is to rent a truck that is considered to require external involvement. Thus, a medium *complexity* is to be expected, just like for the tricycle service. Based on Alie's statements, the *cost* is presumed to be of a medium degree (see Appendix A.1.10). The *realisability* is defined as medium due to similar organising requirements for the utilisation of the tricycle service.

The last option is using a privately owned truck for transport. Compared to the acquaintance of a tricycle, the *cost* is ranked high. Similarly to the tricycle, the arrangement is less complex as the vehicle can be managed internally; hence, the *complexity* is low. As the project is at the initial stage, purchasing an expensive truck is deemed daring, and the truck's capacity might be too large as the initial waste sourced is small. Because of this, the *realisability* is low, though the truck acquaintance could be reconsidered when reaching a more mature stage for the project.

In conclusion, it is chosen to proceed with a privately owned tricycle as transport due to more promising scoring concerning the criteria.

Collection and sorting site (C&S site)

For the collection site, two options were posed. Upon visiting the site in the Pottor community, it was pretty clear that a lot had to be done to make space to construct a building housing the collection centre. Also, the location is relatively remote and inaccessible for larger trucks (see figure 46). Also, the need for flooding protection is a worrying factor, and it can eventually turn out to be very expensive and untrustworthy; hence both the *cost* and *complexity* are set at a high level. Thus *realisability* is deemed to be low, and therefore, the site should not be chosen as the main site for collection and sorting. However, it can be used as an intermediate collection site where the citizens of Pottor dump their waste before it is transported to the actual collection and sorting site.

The second option was the *Lumley Transfer Station* which is already standing tall. The facility offers power, water, an office and even toilets. At first sight, it seems like the perfect solution, which is even located right next to the main road (see figure 46). For this reason, it is very accessible, and the *complexity* is considered low. It was not possible to attain price estimates for the use of the site. However, compared to the Pottor site, the *cost* is ranked as a medium due to the low need for actions before the operation starts. Despite the approval from the Chief Heat Officer to operate at the site, further negotiation must be initiated to obtain a final verdict (see Appendix A.1.6). For the final acquisition, WHI has to sign a Memorandum of Understanding (MoU) with a formal document stating ownership. This is difficult during the general election as the responsibilities within the FCC are not rooted. Despite the actions needed to acquire the site, it is considered highly *realisable* and the best solution as it already encompasses a complete facility with the infrastructure in place. Also, as six additional non-operational transfer stations exist in Freetown, potential for future expansion exists, which fosters the practice of *Platform Thinking*.

Processes

In the solutions space, four processes were posed to facilitate the running of the business. A *Mobile Payment System* would prompt a digital payment system to automate and streamline the payment process and make the operation cashless. However, to create an API system, partnerships must be made with one of the prominent mobile service providers; hence the *cost* is deemed medium and the *complexity* high. The solution seems ambitious and less necessary at this point as the trade in Freetown is made in cash to a large extent. Herof, the *realisability* is set at a medium, and the solution is not chosen for the current business model. However, in the future, at a more mature stage, implementing a Mobile Payment System is highly recommended.

Using the *DortiBox application* is an intelligent way to handle surplus waste types. The *cost* is low compared to handling the waste oneself, and materials recycling is strengthened by collaborating with Freetown Waste Transformers. Due to the versatile user interface and simple implementation, the *complexity* is also low, leading to a general high *realisability*. For this reason, it is chosen to incorporate the DortiBox application in the solution.

A *Monitoring System* like KoboToolbox is a great way to monitor waste collection. The internal stakeholders' prior experience with the software will presumably entail easy implementation; however, further training must be added to ensure success, prompting a medium *complexity*. As the software is provided open-sourced, the *cost* is low, and the overall *realisability* is medium; hence the system is to be included in the business model. Furthermore, the use of a system can facilitate obtaining plastic credits. In continuation thereof, obtaining *Plastic Credits* is a valuable way to commercialise waste collection. By using the services provided by SCS or Empower, the business can diversify its revenue base and have an additional revenue stream besides selling recycled plastic. With the inclusion of the *Monitoring System*, the *cost* will be low. In contrast, the *complexity* is high due to the added level of documentation and needed application for credits. Because of this, the *realisability* is a medium plus *Plastic Credits* will be part of the business model.

Offsetting

According to Alpha Massaquoi, a Freetown citizen, the reuse of plastic bottles for the construction of housing and flood protection is a great solution and should be implemented. He has seen it done in the neighbouring country, Liberia, while it is not practised in Sierra Leone due to a lack of knowledge and guidance (see Appendix A.1.12). Due to this, the *complexity* for both is set at medium as the buyers of the packages need support. As the necessary construction materials are at a bare minimum and available all around, the *cost* is deemed low. This is also because the solutions are unaffiliated with power. In conclusion, both solutions are ranked high in terms of *realisability* and included in the business model.

In the solution space, the range of local plastic companies as potential offsetting companies was reduced to AH&M and Premier Enviro Solutions. They are willing to buy recycled plastic waste but have slightly different requirements. In the case of AH&M, the specific plastic types, PE, HDPE, and LDPE, must be sorted out; hence the *complexity* is a medium. This stands in contrast to Premier Enviro Solutions, which is willing to buy everything; hence low *complexity*. In terms of *cost*, the waste handling expenses are low for both cases. In conclusion, the *realisability* is high for selling to both companies, and they are included as offsetting channels in the business model.

Concerning *incineration of waste*, the *cost* is deemed medium as a facility must either be located or constructed. The *complexity* is considered moderate as additional preparations lie ahead before the incineration can take place. Despite the absence of a concrete plan and detailed information for establishing an incineration system, the method is currently the only way to process the absolutely lowest quality plastic waste. Therefore, it is included in the business model with a moderate *realisability*.

In terms of generating power from incineration, additional expenses must be expected; hence the *cost* is considered high. Also, it must be underlined that this type of energy recovery must be implemented with a regional or national scheme to ensure proper operation practices. This requires extensive engagement with governmental institutions, involving high *complexity* and low *realisability*. Therefore, it is deemed unattainable, so the focus must be to incinerate without power generation.

Table 6: Evaluation of partial solutions

	Partial solutions	Cost	Complexity	Realisability	Chosen
Waste sourcing	Gemata community as waste source	Medium	Medium	Medium	Yes
	Pottor community as waste source	Low	Medium	Medium	Yes
	Levuma Beach Area as waste source	Low	Low	High	Yes
	Propel Organization as waste source	Medium	Low	High	Yes
	Crabtown community as waste source	Medium	High	Medium	Yes
Transportation	Tricycle service as transport	Low	Medium	Medium	No
	Privately owned tricycle as transport	Medium	Low	High	Yes
	Rented truck as transport	Medium	Medium	Medium	No
	Privately owned truck as transport	High	Low	Low	No
C&S site	Pottor community as C&S site	High	High	Low	No
	Lumley Transfer Station as C&S site	Medium	Low	High	Yes
Processes	Mobile Payment System	Medium	High	Medium	No
	DortiBox application	Low	Low	High	Yes
	Monitoring System	Low	Medium	Medium	Yes
	Plastic Credits	Low	High	Medium	Yes
Offsetting	Packages of plastic for housing	Low	Medium	High	Yes
	Packages of plastic for flood protection	Low	Medium	High	Yes
	Selling to AH&M	Low	Medium	High	Yes
	Selling to Premier Enviro Solutions	Low	Low	High	Yes
	Incineration of waste	Medium	Medium	Medium	Yes
	Incineration of waste with power output	High	High	Low	No

6.7 Sustainable Business Model Canvas Applied

Upon selecting what partial solutions will be included, the SBMC (see figure 12 and 13) is applied to formalise the business model.

The *Key Partners* include the joint venture partners EWB-DK, WHI, and SP. WHI and SP are vital partners, as they are the main drivers of the project on the ground in Sierra Leone. EWB-DK serves as consultants providing valuable resources through voluntary engineers. Also, close collaboration with the local community leaders exists in the various communities where the operation is to occur.

The *Key Activities* of the business is to organise and manage the waste collection, transportation, sorting, and offsetting. The purpose is to engage the local communities; hence, stakeholder management and awareness-raising are also key activities.

In terms of *Key Resources*, waste is an essential asset as a physical resource together with equipment for processing the waste and locations for operating. Additionally, human resources are vital for the business consisting of valuable personnel with expertise in navigating the legislative and organisational frameworks in Sierra Leone. This concerns both top-tier

level understanding of the governmental structures and the circumstances within the local communities.

The *Value Proposition* is remarked through providing a system for managing waste to tackle the increasing challenges Freetown faces due to the lack of control. Furthermore, the aim is to heighten the accessibility and ease of use such that operations are sustained and work efficiently in the best sense.

The *Customer Segments* include different groups of people and organisations, some of which generate revenue. The business model targets a segmented market where AH&M and Premier Enviro Solutions will purchase recycled plastic waste. Locals will purchase housing and flooding protection packages, while SCS and Empower will pay for plastic waste collection by selling plastic credits.

Also, the communities where waste is collected are customers, as value is created for them. However, it does not generate revenue.

The *Channels* used to reach and communicate with the customers involve different methods. To inform and communicate with the locals, community awareness is raised through meetings where the project, products and services are described. Here, the appertaining councillors function as channels due to their prominent role in the administrative system. Due to personal relations and close locations, the local partners WHI and SP communicate directly with AH&M and Premier Enviro Solutions. SCS and Empower are reached through their online platforms, where all communication occurs. In addition, publicity is obtained through collaboration with the FCC; hence, future customers can be reached.

The *Customer Relationships* vary for the different customers. In terms of selling plastic packages for housing and flooding protection, a "personal assistance" relationship is established to help the customers during the sales process or after the purchase. This is done to guide the customers as the product presumably is very unfamiliar. With AH&M and Premier Enviro Solutions, a long-term relationship is established, as interaction is needed regularly to align expectations and deliverables. A self-service relationship is established for selling plastic credits through SCS and Empower's services, as no supplementary dialogue or assistance is needed.

The *Cost Structure* is rooted in the remuneration

of staff hired to collect, transport, clean, sort, and distribute the plastic. Hereto, costs incurred regarding the procurement of supplies and equipment, including vehicles, the operation of its physical waste management facilities, incineration, and the management of its partnerships. Furthermore, the DortiBox pickups add a regular cost when other waste types than plastic are handled.

The *Revenue Streams* are generated in multiple ways. Firstly, through selling recycled plastics to AH&M and Premier Enviro Solutions as common asset sales. Then, by selling packages for housing and flood protection to the locals, and lastly, payments are received from SCS and Empower based on the amount of waste collected.

The business model induces several *Eco-Social Benefits*. Regarding the ecological benefits, implementing an efficient waste management system in tackling the increasing challenges of waste control leads to a cleaner and healthier environment, reducing pollution and potential harm to ecosystems. By selling recycled plastics to AH&M and Premier Enviro Solutions, the business model promotes the circular economy and reduces the need to produce new plastics. Recycling helps conserve natural resources, reduce energy consumption, and minimize the environmental impact of plastic production. Through awareness-raising, the local communities are engaged and informed of waste management by which behavioral change is promoted. This encourages responsible local waste disposal practices and contributes to a more sustainable and environmentally conscious community. As a result, the business model aligns with SDG 6, 13, 14, 15, and 17 (see figure 9) and contributes to sustainable ecological development.

Concerning social benefits, the business model emphasizes close collaboration with the local community where waste is collected, promoting social inclusion, empowerment, and local ownership. It creates job opportunities for community members and improves their quality of life. Additionally, offering locals housing and flooding protection packages improves community members' living conditions and safety, particularly in areas prone to flooding. As a result of this, the project addresses social needs and enhances resilience against environmental hazards. In this way, the business model aligns with SDG 3, 11, 12, and 17 (see figure 9) and contributes to sustainable social development.

The business model induces some *Eco-Social*

Costs. While the business model aims to address waste management challenges in Freetown, waste collection, transport, sorting, and offsetting may still have ecological costs. The incineration of waste, for example, can contribute to air pollution and the emission of greenhouse gases unless appropriate pollution control measures are in place. It is important to ensure that waste management activities are carried out in an environmentally responsible manner to minimize any negative ecological impacts.

While plastic recycling is a positive aspect, it is essential to consider the overall impact of plastic waste generation and its disposal. Efforts should be made to reduce plastic consumption and promote sustainable alternatives whenever possible.

As for social costs, the emphasis on local community collaboration may induce social costs associated with ensuring genuine community engagement and inclusion. It is crucial to consider the perspectives and needs of community members, address any power imbalances, and avoid potential negative impacts on local livelihoods, cultural heritage, and social cohesion.

Additionally, while selling packages for housing and flooding protection to locals can offer social benefits, there may be social costs related to affordability and accessibility. It is crucial to ensure that the pricing of these packages is fair and affordable for the target customer segments, particularly those from lower-income backgrounds. Accessibility should also be considered, ensuring that the products and services reach a wide range of community members and not exacerbate existing social inequalities.

The collection, sorting, and processing of waste can involve health and safety risks for workers and nearby communities if proper precautions are not taken. Exposure to hazardous substances, inadequate waste handling practices, and poor working conditions can pose social costs regarding worker health, safety, and well-being. It is essential to prioritize worker safety, provide appropriate training and protective equipment, and comply with relevant health and safety regulations.

Implementing a formal waste management system may affect informal waste workers who rely on waste collection and sorting for their livelihoods. It is crucial to consider the potential social costs of displacing or marginalizing these workers and explore opportunities for their integration, training, or alternative income-generation options.

6.8 Proposed Business Model

A proposed business model has been derived upon exploring and evaluating all the various possibilities and applying the SBMC. It is elaborated in the following with the numbering appertaining figure 56, showing the proposed business model's waste flow. The transport between different steps is indicated with arrows.

The five identified locations (1)-(5) will be used as waste sources. The first four are considered equal in quality and contamination; hence they are mixed during collection. In the case of the last one, the Crabtown community (5), the collected waste is brought directly to controlled incineration without being mixed with the others due to the plastics' contamination. In the Gemata (1), Pottor (2), and Crabtown (5) communities, local community members have been gathering waste that is ready for pick-up. Also, at this point, the transport staff registers the collected waste in the Monitoring System. The collected waste from the first four locations (1)-(4) is transported to the Lumley Transfer Station (6) by Skill Pool, which will be responsible for all of the transport needed and be equipped with a tricycle. At the Transfer Station (6), the waste is washed and dried to be sorted (7) into different sections based on waste type and quality. Waste such as organic waste, metal, etc., is scheduled to be picked up by the WCMA through the DortiBox application (8). This will be utilised until alternative arrangements can be made with the WCMA and Freetown Waste Transformers. Plastic waste is sorted in terms of quality and type. Firstly, PET bottles (9) are identified and sorted out to be used for packages for housing and flood protection (13). Secondly, the plastic types PE, HDPE, and LDPE (10) are sorted out to be sold to AH&M (14). Then, the undefinable plastic is sorted out (11) to be sold to Premier Enviro Solutions (15). Left is the lowest quality plastic, which is either contaminated, mixed, or in some other way unusable (12). This is mixed with the waste from the Crabtown community (5) and sent to controlled incineration (16). While offsetting the plastic waste, the amounts and procedures are registered in the Monitoring System to apply for Plastic Credits.

To outline the existing revenue streams and costs, an overview is presented in figure 7. For this, the payroll cost per person is set at 800 SLE per month, according to the minimum wage for Sierra Leonean, as of 2023 (Sierraloaded, 2023).

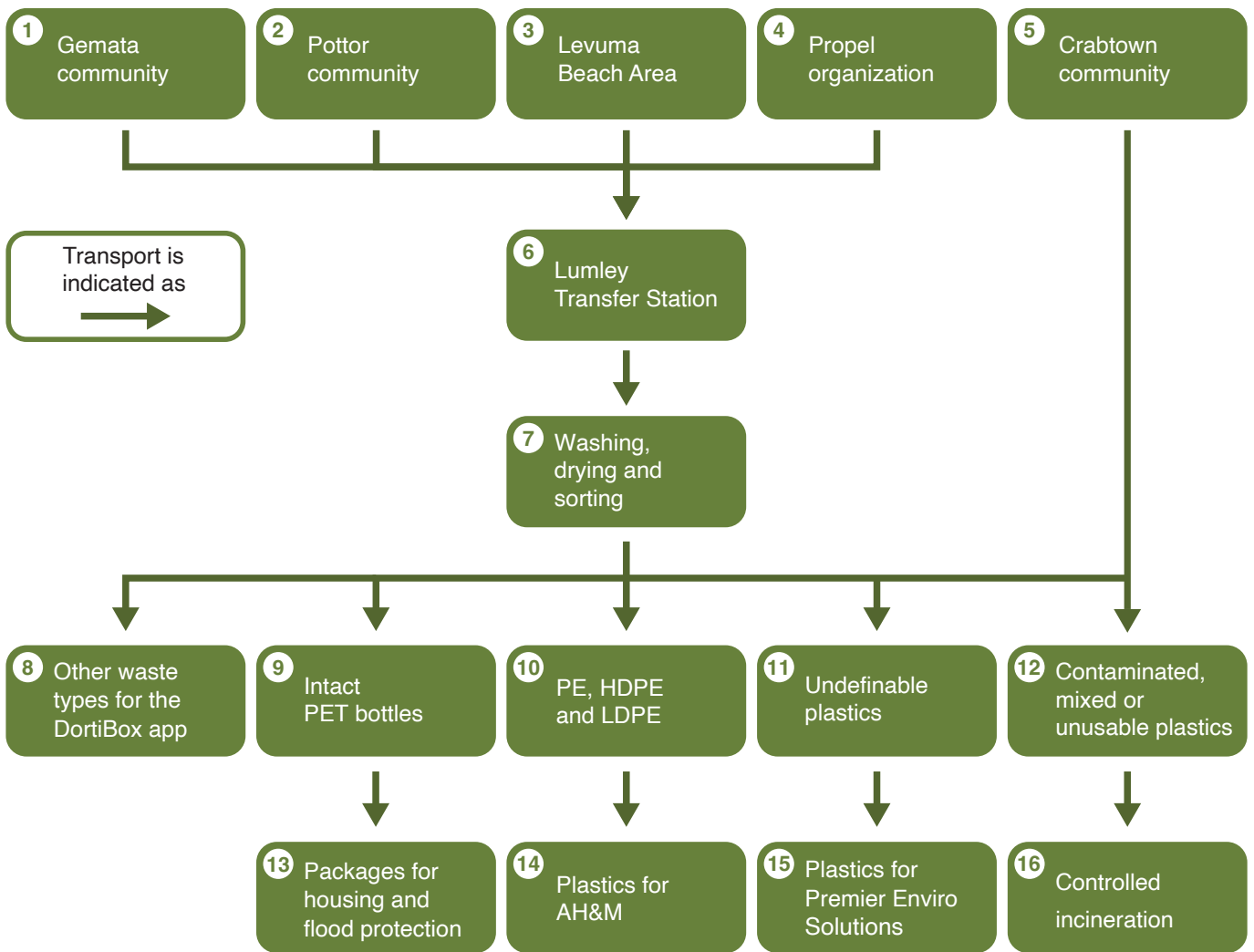


Figure 56: The proposed business model's waste flow

Table 7: The proposed business model's revenues and costs

Revenues	Amount
Payment from SCS and Empower	≈ 88 USD per tonne
Payment from AH&M	Unknown
Payment from Premier Enviro Solutions	Unknown
Payment for plastic packages	Unknown
Costs	Amount
Payroll cost per person	800 SLE per month
Tricycle purchase	≈ 3000 USD
DortiBox pickups	10 SLE for 1-50 kg. of waste
Tricycle maintenance and service	Unknown
Rent of Lumley Transfer Station	Unknown
Incineration facility	Unknown
Incineration operation	Unknown

6.9 SWOT Analysis Applied

A SWOT analysis is applied to evaluate the business model and its strengths, weaknesses, opportunities, and threats (shown in table 8).

The business model demonstrates several strengths that can effectively counteract its weaknesses, capitalise on opportunities, and address potential threats. Community inclusion, diverse sourcing and offsetting channels, government involvement, and value creation for stakeholders provide a solid foundation for success. However, addressing the weaknesses related to the high dependency on local communities, financial transparency, unknown waste information, and a lack of physical presence in Freetown is essential. Regarding community dependency, deliberate implementation plans can presumably pave the way for successful community involvement. Weaknesses such as unknown revenue streams and costs, lacking waste information, and missing incineration plan exist due to time limitations of the current project and are included in future work in section 10.

The environmental impact, financial stability, and political endorsement can be enhanced by leveraging opportunities such as further collaboration with the FCC, upscaling through transfer stations, and diversifying waste sources and offsetting channels. These opportunities show promise and underline that further development is possible. However, they can be counteracted by threats such as potential community disengagement, low plastic waste quality, and political uncertainties. These threats must be addressed by nurturing community relationships, investing in waste testing, and diversifying stakeholder support beyond political authorities. This is considered in the implementation plans derived in section 7.3.

In conclusion, the business model can achieve long-term success and significantly impact waste management in Freetown by prioritising: community engagement, diversifying waste sourcing and offsetting channels, collaborating with the government and proficient local partners, and addressing financial uncertainties and waste quality concerns. Continuously exploring opportunities for upscaling and growth while proactively mitigating threats will contribute to the project's sustainability and effectiveness in implementing the recycling of plastic waste.

6.10 Risk Analysis

To further investigate potential issues that could negatively impact or jeopardise the project, a risk analysis is applied to identify and analyse risks. It is done to become aware of the existing risks, evaluate them and find determine mitigation measures to mitigate and potentially avoid them.

The identified risks are divided into contextual, organizational and programmatic risks and evaluated concerning the parameters; *Likelihood* and *Consequence*, leading to an assessment of the *Overall risk*. The parameters' scales are shown below.

Likelihood:

Possible → Almost certain → Certain

Consequence:

Minor → Moderate → Critical

Overall risk:

Low → Medium → High

From the risk evaluation, the risks' respective *mitigation measures* are listed. See table 9 for the contextual risks, table 10 for the organisational risks and table 11 for the programmatic risks.

By considering the risks appertaining the business model, the mitigation measures can be incorporated in the implementation phase to counteract the risks.

Table 8: SWOT analysis applied

Strengths	Weaknesses
<p>Strong inclusion of local communities</p> <p>Diverse waste sourcing channels</p> <p>Diverse offsetting channels</p> <p>Government involvement through the C&S site</p> <p>Simple procedures for processing plastic waste</p> <p>Value creation for multiple stakeholders</p> <p>Proficient local partners</p> <p>Presumably, endless collectible plastic waste quantities</p> <p>International collaboration with knowledge within various areas</p>	<p>High dependency on the local communities</p> <p>Many unknown revenue streams and costs</p> <p>No exact information about the plastic waste's plastic types and conditions</p> <p>EWB-DK is not physically present in Freetown all the time</p> <p>Rely greatly on political endorsement</p> <p>No plan for incineration</p>
Opportunities	Threats
<p>Upscaling is possible by including more Transfer Stations, sourcing more waste, and adding more offsetting channels</p> <p>Diversifying the offsetting channels even more</p> <p>Further collaboration with the FCC</p> <p>Emerging demand and focus on plastic waste management and recycling</p> <p>Few to no competitors in Freetown are developing a system alike</p>	<p>If the local communities choose to cancel the collaboration, new sourcing sites must be identified</p> <p>If the plastic product manufacturers choose to cancel the collaboration, revenue is lost</p> <p>The plastic waste's condition is too bad to be recycled</p> <p>Due to lack of presence, EWB-DK is excluded</p> <p>The political authorities withdraw the endorsement, causing less support</p> <p>Competitors might emerge as the focus on the subject is growing</p>

Table 9: Contextual risk analysis

Risk	Likelihood	Consequence	Overall risk	Mitigation measures
Political instability	Almost certain	Minor	Low	Scale down or shift the community to monitoring, evaluation and documentation or do strategic work with select strategic actors in the period
Corruption	Certain	Critical	High	The partnerships made with local partners and authorities must be well-developed and have solid transparency in the management of funds
Lack of public infrastructure	Almost certain	Minor	Low	Independence is essential, and ensuring this is also a part of the implementation plan
Lack of public governance	Almost certain	Moderate	Low	Address lack of public service delivery from a user/private service strategy and assist with the absent knowledge
Negative environmental impact on the beneficiaries	Almost certain	Minor	Low	All work, cross-community visits and outreach must be planned to be carried out during the dry season
An outbreak of epidemics	Possible	Critical	Medium	Risk can not be mitigated in this case. Instead, project activity must be adjusted accordingly

Table 10: Organisational risk analysis

Risk	Likelihood	Consequence	Overall risk	Mitigation measures
Lack of human resources	Possible	Critical	Medium	Ensure that implementing partners have substantial experience and personnel to carry out project activities
Lack of relevant technical skills	Possible	Critical	Medium	The technical capacity is ensured by training the main stakeholders sufficiently
Lack of financing	Possible	Critical	Medium	A thorough budget must be made in collaboration with the local partners to avoid a lack of financial capacity
Lack of digital recording	Possible	Critical	Medium	All digital data must be stored on an open source system, and systematic back-up must be performed with partners.

Table 11: Programmatic risk analysis

Risk	Likelihood	Consequence	Overall risk	Mitigation measures
Poor partner collaboration and time management	Almost certain	Moderate	Medium	Discuss the project in depth before initiating partnership to align expectations, capacity and ways of communication
Low participation and engagement from local community	Possible	Critical	High	The project must be designed, communicated and delivered in a participatory manner to include the communities
Service delivery by private sector agents is poor	Possible	Moderate	Low	The project activities must involve training in technical skills to root skills locally
The project is not meeting the needs of beneficiaries	Possible	Critical	Low	The project must be based on a bottom-up assessment with involvement of local stakeholders to ensure relevance at all levels
Lack of strategic stakeholders capacity	Possible	Moderate	Medium	The project must be discussed at repetitive sessions with communities to mobilise and engage
Lack of local ownership	Possible	Moderate	Medium	The local communities must be involved all the time, and specific key individuals must be selected for the hand-over of the project
Lack of maintenance performed by the communities	Possible	Moderate	Medium	Key individuals must be selected and trained

Implementation

Development of implementation plans through stakeholder management and the application of theoretical frameworks, followed by a risk analysis to mitigate risks



7 Implementation

One thing is to develop a feasible solution, and another is to execute it properly. The developed solution might seem ambiguous to Freetown's ordinary citizens, so proper implementation is paramount. For this, the management of stakeholders is investigated, followed by deriving an implementation strategy by applying theoretical frameworks.

7.1 Stakeholder Management

As previously outlined in the stakeholder identification (see table 1), the project has numerous stakeholders taking part in different ways. To organise, monitor and sustain the relationship with them, a plan for stakeholder management is derived. The process involves systematically identifying the stakeholders' engagement throughout the various levels of the project while also analysing their power, interest, needs and expectations. In this way, the interactions between the stakeholder can be coordinated to ensure the success of the project and its implementation.

7.1.1 Stakeholder Distribution

Firstly, the stakeholders are divided into internal and external stakeholders. Internal stakeholders, such as employees and management, are positioned within the organisation, while external stakeholders, such as the government and trade associations, are outside the organisation. Since the initial stakeholder identification, some stakeholders have been sorted out, including Kubik, Masada, Rostock University and the plastic product manufacturers that did not want to purchase recycled plastics. However, based on findings in the solution development phase, the Crabtown community was added. As previously discovered, the communities each have an appointed leader. For example, in the case of Gemata, Rookie, the Chairlady is the leader. These will be included under their respective *community* for brevity in the following. However, the individual councillors will be named as their responsibility extends beyond the single communities. In the final solution, Levuma Beach Area was listed as a waste source, but due to the absence of ownership, it does not appear in the stakeholder management.

Table 12: Stakeholder position

Internal	External
EWB-DK	FCC
WHI	EPA
OPF	FWT
DIS	SCS
Skill Pool	Empower
	Locals
	Waste collectors
	Propel Organization
	AH&M
	Premier Enviro Solutions
	Rostock University
	Gemata community
	Pottor community
	Crabtown community
	Pastor Abdul Karim Turay
	Mariatu Kamara

From table 12, it is clear that the project holds its stakeholder majority externally. This signifies that stakeholder management is crucial as many actions lie outside the internal stakeholders' supervision. To a certain extent, the responsibility for communicating with the external stakeholders lies with WHI, the local partner. To attain an overview of the external stakeholders' engagement throughout the different stages of the project, the distribution of external stakeholders is outlined.

In table 13, it can be seen how the three stages share the first five stakeholders. Because of this coherence, these stakeholders must be involved in all stages of the implementation and operation phase. SCS and Empower must be informed of all operation steps, as monitoring the plastics' journey is a prerequisite for acquiring plastic credits, which is a vital component in the project's cash flow. Then, the difference between the stages comes down to the community and councillor involvement in the *Waste sourcing*, while the offsetting companies are present for the *Offsetting*. This distribution seems natural and underlines that the stakeholders do not require information beyond their area of interest. To further comprehend the stakeholders' roles, they are distributed concerning their type, outlined in nine levels in table 14. Here, the internal stakeholders are also included to provide the complete picture.

Table 13: External stakeholder distribution

Waste sourcing	C&S site	Offsetting
FCC	FCC	FCC
EPA	EPA	EPA
Locals	Locals	Locals
SCS	SCS	SCS
Empower	Empower	Empower
Waste collectors		AH&M
Gemata community		Premier Enviro Solutions
Pottor community		FWT
Crabtown community		
Propel Organization		
Pastor Abdul Karim Turay		
Mariatu Kamara		

Table 14: Stakeholder types

Costumers	Owners	Employees
Locals	EWB-DK	EWB-DK
FWT	WHI	WHI
AH&M	OPF	OPF
Premier Enviro Solutions	(Pottor community)	Skill Pool
SCS	(Gemata community)	
Empower	(Crabtown community)	
Investors	Suppliers	Trade Unions
EWB-DK	Gemata community	<i>Non-existing in Sierra Leone</i>
WHI	Pottor community	
OPF	Crabtown community	
DIS	Propel Organization	
	Waste collectors	
Communities	Creditors	Governments
Pottor community	<i>No creditors</i>	FCC
Gemata community		EPA
Crabtown community		
Pastor Abdul Karim Turay		
Mariatu Kamara		

As outlined in table 14, an overlap between the *investors* and the *owners* do exist due to the way the project is structured. In collaboration, EWB-DK and WHI applied for funding through CISO and are the main drivers of the project together with OPF, whereas DIS joined with additional funding. Below *owners*, the communities, Pottor, Gemata and Crabtown, are listed in parenthesis as they must

become future co-owners of the project. Regarding *employees*, EWB-DK contribute with project management and numerous volunteers, while WHI has paid staff hired for the project. Skill Pool is hired through WHI as an external partner to assist with the project. The *customers* consist of a mix of locals and companies, which was also outlined in the later part of the solution development. They must be

Table 15: Power-Interest grid

Keep satisfied (Low interest - High power)	Manage closely (High interest - High power)
FWT	Gemata community
AH&M	Pottor community
Premier Enviro Solutions	Crabtown community
SCS	Propel Organization
Empower	Pastor Abdul Karim Turay
Locals	Mariatu Kamara
	Waste collectors
Monitor (Low interest - Low power)	Keep informed (High interest - Low power)
(Locals)	FCC
	EPA

treated differently; how is elaborated later on. The *suppliers* and *communities* are largely equivalent, which suggests that their participation is of great importance. Without the *suppliers*, the operations do not run; hence it is crucial to involve the communities as best as possible. Their involvement must be prioritised as they will be the future owners of the operation, which is indicated as they are listed with parenthesis below *owners*. *Trade unions* usually outline the guidelines for working conditions. However, in Sierra Leone, they do not exist, which is why the *owners* must stay vigilant to comply with international best practices. No *creditors* are involved in the project as the project is financed through funding without the expectation of returns. This is important regarding the financial part of the business model, as nobody needs to be paid back from sales. As outlined, the FCC and EPA are determined as *governments* and do not hold other decisive shares in the project. The performed elucidation on the stakeholder position, distribution and types leads to scrutinising the stakeholder participation to shed light on how they must be involved.

7.1.2 Stakeholder Participation

In determining the participation of the stakeholders *The Power-Interest grid* is applied to categorise the stakeholders based on their power and interest (Ackermann and Eden, 2011). It allows the development of strategies to manage all stakeholders effectively. In the case of stakeholders with high power and high interest, they want to be engaged regularly. In contrast, low-power and interest stakeholders do not require thorough and regular communication. From table 14 and 15, it is clear that the waste

sources, including the communities, councillors and waste collectors, must be managed closely. They stand as pivotal cornerstones with high power and interest why persistent engagement is necessary. Any response to the undertaking, both positive or negative, must be observed and reacted upon. It is essential to underline that the project occurs near their home, which is why the citizens and communities must be respected and listened to.

The *customers* must be kept satisfied but treated in different ways due to their type of involvement. FWT, AH&M and Premier Enviro Solutions will purchase physical products that meet specific demands. Presumably, the project does not break even if they do not buy recycled plastics why their perseverance is vital. The *locals* will purchase packages for housing and flood protection containing intact PET bottles. Similarly, they must be satisfied with the products to ensure continuous support. Also, *locals* are placed under *monitor* as the undertaking affects their surroundings in terms of waste removal; hence the *locals'* response must be observed. SCS and Empower are "passive" customers who do not receive a specific product but sell plastic credits to other companies based on the collected plastic. They must be satisfied with the documentation quality and the undertaking's compliance with guidelines and frameworks. The FCC and EPA must be kept informed as they do not hold much power but a lot of interest in the project. It is vital to sustain their support and acknowledgement by informing and complying with reporting standards outlined by governmental institutions. In addition, a close relationship with the FCC can yield new business possibilities and further collaboration in the waste management sector.

7.2 Frameworks Applied

The presented theoretical frameworks for implementation are applied to foster a sufficient execution of the project.

The Golden Circle

The model underlined the importance of communicating the initiative's purpose before diving into the substance of the undertaking (see figure 15). Previous EWB-DK projects have shown that the *Why* is often neglected due to additional challenges that overshadow the initial target problem. In this case, the project's objective must be clearly stated and repeated on various occasions. This also relates to the three incentives that must be in place to sustain the project's course.

Concerning the project, the *Why* must be dissipated to all relevant stakeholders in the beginning; hence startup meetings must be held with all the relevant stakeholders. Iterated follow-up meetings can, with a great advantage, be held during the project period to keep all stakeholders aligned. In this regard, the messages to the respective stakeholders must follow the findings from the *Power-Interest grid*; thus, the communication is fulfilling (see figure 15). Every meeting's agenda must follow the hierarchy of *The Golden Circle* to elucidate the message best. When proceeding to the next step in the implementation plan, the purpose and method must be clarified before commencing the activity. Participants might want to jump directly to the *What*-part, but it is crucial to facilitate the discussion such that *What* is not elaborated as the first thing. Likewise, the *How* must be elaborated even though it might involve technical aspects that the stakeholders are unfamiliar with. In this case, one must best explain the technical aspect in a down-to-earth sense. It is essential to underline that the project is performed with the locals and not for them. In this way, the learnings are transmitted decently, and ownership is attained among the locals.

Push and Pull strategies

The model argued for the importance of the counteracting forces that affect a project. It advocates for reducing or retraining them to create a *pull* effect. Through the application of the *The Golden Circle* where the purpose of the intervention is communicated, the basis for *pull* forces is created. Here, support is established through the generation of local pioneers. In that respect, councillors and com-

munity leaders are essential to the project's driving and must be on the same team. They are highly respected in both the communities and the governmental system; thus, they hold the power to shape the intervention's course. Thus, the locals listen to them with respect and follow their directions. By collaborating with councillors and community leaders, a *pull* is created where the communities support and assist in realising the project. A counteracting force will persist if this support is not obtained through mutual respect and dialogue.

Due to the structure of the society and the need for community involvement, a *push* strategy is found inevitable. Still, it must be handled carefully not to damage the initiative severely. Initially, the strategy must hold some *push* effect as the citizens will be conflicted due to the *Power of Default Bias*. Over time, when a *pull* is created, the strategy must adapt and make room for external forces.

Breaking the Default Bias

The model introduced the phenomenon where people behave as they always have without considering other options. Breaking through the current status quo can be done by making the desired behaviour as easy as possible. It will potentially make the locals willing to adopt the new ways of waste management. Therefore, the implementation must be planned to be straightforward and encompass small changes at a time. Every kind of barrier or challenge the locals face makes the desired behaviour harder, and the chances of them changing their status quo bias decrease.

Freetown's citizens may naturally resist change, particularly when altering their waste disposal habits or adopting new waste management practices. This bias must be challenged by raising awareness about the new system's benefits, providing clear information on how to participate, and engaging the community in the decision-making process. Similarly, many citizens may be unaware of the environmental and health impacts of improper waste disposal or the benefits of a proper waste management system. Challenging this bias involves implementing activities to educate and create awareness to inform citizens about the importance of responsible waste management and its positive effects on their lives and the environment. These activities must be a part of the implementation plan to support proper embedment in the citizens' mindset.

The citizens may prefer convenience over responsible waste management practices. They may choose the easiest and quickest disposal method rather than following proper waste separation and recycling procedures. This bias can be addressed by ensuring that waste collection points are easily accessible, providing clear instructions on waste sorting, and emphasizing the long-term benefits of responsible waste management. Here, the neat location of the C&S site is an excellent advantage as it facilitates easy access. Through community meetings, instructions on waste sorting and processing must be delivered.

Some citizens may feel entitled, expecting the government or waste management authorities to handle all waste-related issues without their active participation. Challenging this bias involves fostering a sense of shared responsibility, emphasizing that waste management is a collective effort, and encouraging citizen engagement through activities such as community involvement and recycling training.

Also, some citizens may exhibit a bias toward individualism, prioritizing their own convenience and interests over collective efforts for waste management. Challenging this bias involves activities emphasizing the shared responsibility of waste management, highlighting the community-wide benefits and promoting a sense of collective identity and pride in maintaining a clean and sustainable city.

Due to prior experience, citizens may have a bias of mistrust toward government authorities or waste management agencies, perceiving them as inefficient or corrupt. This bias can be challenged by fostering transparent and accountable governance, involving citizens in decision-making processes, and establishing citizen oversight and feedback mechanisms. In this case, meetings where the FCC and the citizens meet and discuss the project must be held.

By challenging the outlined biases and actively engaging with citizens, it becomes possible to encourage behaviour change, promote responsible waste management practices, and create a sense of ownership and participation in the new waste management system. To actively foster this behaviour change, the deduced activities will be included in the implementation plans.

7.3 Implementation Plans

With the application of the methodology, plans for the project's implementation are derived to define a structure for the course of action. As WHI and Skill Pool are the local partners in the project, they have the main responsibility for the activities on the ground. However, EWB-DK will also be involved in most activities.

During the initial parts of the project launch, the following points need to be addressed to ensure a smooth commencement.

1. Making the communities sign an MoU to enforce the desired waste management actions to persist. Also, in this way, the communities become aware of the laws dictating this behaviour and will ensure they comply.
2. Invite representatives from the FCC, local communities and other operators to the site of Propel Organization and show how waste collection and management can be performed. The purpose is to provide inspiration and knowledge sharing to ensure the best possible understanding of the undertaking.

For the implementation, two plans have been made in collaboration with EWB-DK and WHI. The first two phases of the project, waste sourcing and the C&S site's establishment, are combined and shown in table 16. Secondly, a plan for the offsetting phase has been made and is shown in table 17.

Table 16: Implementation plan for waste sourcing and C&S site

#	Activity	Responsible	Involved
1.	Open and participatory startup meetings are held in the local communities to create awareness and attain local partner capacity-building engagements. Also, this involves Councillors, Chiefs and Chairladies.	WHI	EWB-DK, Skill Pool, Gemata, Pottor, Crabtown
2.	Identification and recruitment of local waste management task force in the communities.	WHI	EWB-DK, Skill Pool, Chairlady, Cheif
3.	The task force receives advocacy, mentoring, waste handling and awareness-raising training.	WHI, Skill Pool	EWB-DK
4.	Development of community waste management guidelines, including the monitoring system.	WHI, Skill Pool	EWB-DK
5.	Supervise the task force in training the communities in the "5s" - reduce, reuse, recycle, recover and residual management for handling solid waste.	WHI, Skill Pool	EWB-DK
6.	Follow-up meetings are held in the communities where all stakeholders give a progress update, evaluation, and provide feedback.	WHI, Skill Pool	EWB-DK, Chairlady, Chief
7.	10 youths are selected from each community to be trained in maintenance and repair of the site to secure local ability for future maintenance. Also, this involves training within construction and plumping to maintain the water stand posts at the C&S site.	WHI, Skill Pool	EWB-DK
8.	The youths participate in the establishment of the C&S site.	WHI, Skill Pool	EWB-DK
9.	Participatory development of sustainability structure and maintenance guidelines for the C&S site.	WHI, Skill Pool	EWB-DK
10.	Community engagement and awareness-raising events are held at the site to show how the facilities are used.	WHI, Skill Pool	EWB-DK, Chairlady, Chief
11.	Advocacy engagement with the local authorities and stakeholders are involved and invited to visit the C&S site.	WHI, Skill Pool	EWB-DK, FCC, EPA
12.	Follow-up meetings are held in the communities where all stakeholders give an update, evaluate and provide feedback.	WHI, Skill Pool	EWB-DK, Chief, Chairlady
13.	Best practices, lessons learned, and key reports are compiled and presented to the FCC and the public.	WHI, EWB-DK	Skill Pool, FCC

Table 17: Implementation plan for offsetting

#	Activity	Responsible	Involved
1.	Identification of staff to be appointed responsible for offsetting plastic waste.	WHI, Skill Pool	EWB-DK
2.	Commence dialogue with the offsetting companies about the initial testing of recycled plastic waste.	WHI, EWB-DK, Skill Pool	AH&M, Premier Enviro Solutions
3.	Alignment of the monitoring system to commence application for plastic credits.	WHI, EWB-DK, Skill Pool	SCS, Empower
3.	Outline guidelines for using the DortiBox application for handling waste types other than plastic.	WHI, Skill Pool	EWB-DK, FWT
4.	Open and participatory meeting with the FCC on establishing a waste incineration plant.	WHI, EWB-DK	FCC
5.	Recycled plastic samples are prepared and presented to the plastic product manufacturers.	WHI	AH&M, Premier Enviro Solutions
6.	Follow up on the implementation of the DortiBox application.	WHI, Skill Pool	EWB-DK, FWT
7.	Have follow-up meetings held with the offsetting companies where they provide feedback.	WHI, EWB-DK	AH&M, Premier Enviro Solutions, FWT
8.	Development of recycling guidelines in collaboration with the plastic product manufacturers.	WHI, EWB-DK	AH&M, Premier Enviro Solutions
9.	Best practices, lessons learned, and key reports are compiled and presented to the FCC and the public.	WHI, EWB-DK	Skill Pool, FCC

Discussion

A discussion of the research's findings and their implications concerning limitations and alternative approaches to pursue



8 Discussion

The research findings and implications are delved deeper into and discussed in the following.

Plastic contamination

During the exploration of the solution space, it was concluded that waste found in the Crabtown Lumley community was highly contaminated, wherefore it was sent directly to incineration in the final solution. The other waste sources are presumed to contain a different degree of contamination, but to be sure, the hypothesis must be tested. If the waste does resemble the same contamination degree, the business model must be reconsidered, as highly contaminated plastics should not be reused under any circumstance. This uncertainty prompts the need for an assessment of the collected waste.

Unknown revenue streams and costs

As seen in figure 7, the proposed business model holds many unknown revenue streams and costs. For the revenue streams, only the payments for plastic credits have a set value. The costs also entail many unknown values. This jeopardises the solution's economic sustainability and underlines that further assessment must be performed thoroughly to substantiate the business model.

The offsetting companies AH&M and Premier Enviro Solutions are included in the revenue streams as they are willing to purchase recycled plastic waste. However, a concern is that the companies will ask for payment to bring recycled plastic into their production lines. The industry interviews found that sometimes recycling companies get paid for receiving recycled plastics from sorting plants. If this prevails in Sierra Leone, the anticipated revenue streams from AH&M and Premier Enviro Solutions are questioned.

Applied methodology

For the study, the *System-Oriented Problem Solving* approach was applied and formalised throughout the thesis period. It proved a great method for managing a complex and advanced engineering project, inducing valuable steps such as situation analysis, objective setting, stakeholder management, and implementation. The approach involved these various aspects surrounding the solution, in contrast to the alternative method, the *Double Diamond*, that presumably would have proven more goal-oriented (Design Council, 2005).

As the project took place in a very unfamiliar context, it is presumed that valuable information would have been missed if the *Double Diamond* method had been applied.

The applied methodology provided significant value to the project's execution. As the author spent three months in Freetown, field research was the most profound method applied and yielded information galore. The interviews and talk with stakeholders not being deliberately planned, though the output proved very valuable. However, they might have unveiled hidden information if they had been more planned. In addition, field visits did contribute greatly to the understanding of the circumstances. Without the extensive fieldwork, the solution and thesis, as a whole, would not have been as accurate and contain numerous shortcomings. In this regard, the project holds one shortcoming: the "black boxing" of the waste sorting method at the collection and sorting site. This was due to the project's timeframe and must be explored in future work.

For the solution development, the *The Waste Hierarchy* outlined the basic principles for waste treatment alongside environment protection considerations. It proved valuable in defining the research base and evaluating the deriving subsolutions. The *Value Proposition Canvas* greatly concretises the value the solution must fulfil based on the identified challenges. It listed the pains, gains etc., which were essential to acknowledge for deriving actual value with the business model. Without the framework's application, the core item in the *Sustainable Business Model Canvas* would be missing, and the solution might not meet the citizens' needs. The environmental and social effects were encompassed by supplementing the *Sustainable Business Model Canvas* with the sustainability extension. Without sustainability considerations, the business model would lack information concerning socio-economic benefits and costs. Despite the sustainability extension's inclusion, further analysis can be performed to encompass all aspects of the business model's socio-economic implication. For this, additional frameworks assessing sustainability can be applied to fully grasp the degree of sustainability that the business model holds.

As the derived business model holds the potential to dissipate multiple sectors, additional models could prove valuable to apply. This could, for instance, be *Life Cycle Assessment (LCA)* that would shed light on aspects of plastic recycling, such as energy consumption, resource demand etc. In this way, the solution is evaluated extensively, and it might show that the most favourable according to the *The Waste Hierarchy* scores low according to the LCA. The combination of the frameworks would prove valuable as various perspectives are included. However, performing an LCA might not make sense at the project's current stage due to a lack of knowledge, but must be kept for later.

Regarding the implementation, the various theoretical frameworks provided significant value to the business model. *The Golden Circle* outlined how to facilitate stakeholder engagement by following a set chronological order. Without this knowledge, the dissemination would not been as successful and might have confused the recipient. The concept of *Push and Pull strategies* induced the importance of centralising the councillors as the main drivers of a pull effect. Without this insight, the collaboration with the locals would presumably have met challenges, given the lack of internal support. Lastly, *The Power of Default Bias* illustrated the many default biases that must be dealt with and how they affect behaviour change. Had the concept not been introduced, unforeseen tendencies would have appeared in the implementation phase.

In supplementing the frameworks, others could be applied to investigate change management further. This includes frameworks such as the *Transition Stages*, by Adams et al., which provides an understanding of the process a person experiences when going through transition (Adams, Hayes, and Hopson, 1976). Otherwise, the concept *Tipping Point and Critical Mass* by Smith et al. could be introduced relating effort and adoption to determine the tipping point of when the business model is successfully implemented (Smith et al., 2014).

Recycling technologies

The technology screening showed that mechanical recycling, pyrolysis and incineration were the best-suited technologies to apply in Sierra Leone. Suppose mechanical recycling was performed on a large scale. In that case, the plastic must retain a high degree of cleanness as the bacteria are not eradicated upon processing, sorted well and still possess good mechanical properties. Tests show that every time plastic is mechanically reused or recycled, the mechanical properties worsen. This is also valid for plastics exposed to wear from the elements for a long time (Young, 2021). Perhaps, the plastics found in Freetown are too decomposed and unusable in mechanical recycling. The business model would be jeopardised as offsetting is questioned. As this uncertainty is pivotal for running the operations, a technical test should be conducted on a sample to investigate whether this is the case for plastic waste found in Freetown.

In continuation of the above, the cleanness of plastic waste is hard to evaluate, and knowledge in chemistry is limited in Sierra Leone. The risk of introducing recycled plastic waste in the food industry can be significant if the offsetting companies are to produce such products. If the plastics are to be used in any product in close contact with humans or food, they must not be contaminated by biomaterials or chemistry at all (Miljøstyrelsen, 2023). The uncertainty means that corporate responsibility is compromised, and further engagement with offsetting companies is essential to avoid undesirable outcomes like this.

Due to the mentioned uncertainties concerning mechanical recycling, it could be replaced completely by energy recovery technologies capable of handling close to 100% of all plastics and do not hold potential health hazards. Initially, pyrolysis was precluded due to the assumption that Freetown's fundamental challenges would render it impossible to implement. However, through interviews, it was considered possible, given modern solutions, to overcome such challenges. Also, the interviews unveiled that MAN Energy Solutions has been performing tests, showing that modern pyrolysis oil could be directly inserted into internal combustion engines. If true, pyrolysis oil could be used in Freetown's many locally-owned power generators, supporting the city's power independence. Alternatively, the pyrolysis oil could supply the Karadeniz

Powership Dogan Bey and boost the overall life cycle sustainability of the project's operations. Due to this potential, pyrolysis must be explored and reconsidered.

Also, based on the global trend in creating symbiosis plastic processing networks, a long-term plan for Sierra Leone could be establishing a symbiosis network with biogas and pyrolysis where converting organic waste to power propels plastic recycling in the pyrolysis plant. With this combination of processes, the CE concept of *Cradle-to-Cradle* is introduced as the plastic waste is re-utilised as raw material for fueling other production processes. As FWT already operates biogas plants in Freetown, collaboration can be explored.

Learnings

A recap of the most prominent insights obtained in Sierra Leone that yield both personal and universal learnings for future projects



9 Learnings

Through the execution of the project, valuable insights are obtained that offer significant lessons for future endeavours. Below, personal and universal learnings are presented that arose from the author's experiences in Freetown, Sierra Leone. They are listed in order, starting with case-specific and moving towards more generalised learnings.

Working in a developing country

Working in Sierra Leone can come with a unique set of challenges. One of the biggest challenges in Sierra Leone is the lack of power infrastructure, which makes it difficult to access reliable electricity and the Internet. Additionally, safe food and water availability took a lot of work to retrieve, creating uncertainties in everyday life. Throughout the local partners, economic instability dominates, where a lack of resources and funding limits the ability to operate and implement new projects. Also, safety concerns imbue society as political activities are ramping up for the general elections. Working in Sierra Leone generally requires constant flexibility, patience, and a willingness to adapt to new environments and challenges.

To manage the challenges, it is vital to do research and prepare ahead of time. This could include learning about the local language and customs and understanding the region's political and social climate. Additionally, investing in reliable backup power sources and disinfectants can help mitigate the impact of unreliable infrastructure. Establishing transparent and open communication channels with colleagues and partners in the region is essential, as well as building relationships based on mutual understanding and respect. Finally, prioritising safety and security, such as keeping a low profile and staying informed about potential risks, can help ensure a successful and productive work experience.

General elections

As the project was undertaken in the spring of 2023, it collided with the general elections in Sierra Leone on June 24, 2023. Due to this coincidence, the author encountered several challenges and setbacks, especially close to the election date. During this period, essential figures in the political system, including the Major herself, were out of office, and it needed to be clarified where the

responsibility lay. The political system stopped and was almost completely paralysed for an extended period. The circumstances hampered the project's decision-making process as certain decisions needed approval from the FCC. Despite the hassle, the involved councillors were very active in this period as they needed the publicity to be re-appointed. Their drive proved a great advantage and was, to a great extent, decisive in the project's success.

In the future, the project's execution must be chosen wisely, as the timing is paramount for progress. If projects coincide with general elections, misunderstandings are to be expected, and handovers might not always be conducted comprehensively.

Local partnership

The partnership with World Hope International was fundamental for the project execution but did also pose particular challenges. The different working ethics could have helped keep pace from an early point. In this case, expectations should have been discussed and matched before the project launch. This is also valid because the project's objective and plan were unclear. Also, transparency and regular briefings needed to be improved, proving to be a disadvantage as one part operated solely online and needed to be in touch with what was happening.

From the collaborative work, it was clear that work ethic concerning timing and punctuality is very different in Sierra Leone compared to Denmark. Danes show up at precisely the agreed time, while Sierra Leoneans see it as a time slot of three hours. This difference created unfortunate situations that could have been avoided if communication had been sustained.

In this continuation, strategic planning is an unfamiliar term as decisions are made daily, and future consequences are not considered beforehand. For example, when the team was to select a site for the collection site, a place with high flooding exposure was initially chosen. This was despite the team's acquaintance with the annual rainy season and its severe impact on the area.

The circumstances led to another challenge in the potential mismatch between work title and technical capacity. From the collaboration with the local partners, some employees had working titles that did not correlate with their technical prowess and work ethics. In some cases, this posed unfortunate situations as the working title

entitles a certain degree of respect; hence, the statements must be of equivalent quality, or else recipients are misled.

Discussing the project in depth with the potential partner before joining forces is recommended in the future. Clear and persistent communication is paramount and must be addressed at any point. Project plans must be made well before the launch and followed strictly. Along the timeline of activities, the local partners must be briefed and frequently reminded to ensure understanding and coherence between the organisations. In terms of the capabilities of the local partners regarding time, technical prowess and enthusiasm for the project, serious and transparent dialogue is needed. From my experience, the foreign organisation must stay vigilant while working in parallel with local partners to coordinate the collaboration sufficiently.

Need of funding

As stated previously, the project received funding in late May 2023. The funding was crucial for the involvement of the local partners as they only commenced work upon receiving funding. The author was dispatched to Freetown from March to May, meaning research had to be done independently without the local partners. The circumstances entailed numerous challenges for the author, as the lack of support led to an incoherent working practice. The utilisation of the dispatched personnel could have been better, resulting in several setbacks. Also, the circumstances put the author in a vulnerable position that could pose a danger.

For future projects, funding must be secured before dispatching personnel. This way, the output is of much greater value, and the personnel can operate in a more reassuring environment with a supportive framework. If funding is unobtainable in time, decisive conversations with local partners must be carried out to find an alternative workaround.

Sustainability focus

Among Western nations, the main focus of the term *sustainability* is set on the ecological aspects. States and organisations are doing everything possible to minimise their carbon footprint and contribute to a sustainable future. However, sometimes the focus is somewhat narrow as it disregards the entailed implications outside of the field of vision. For example, when Western nations reduce their use of

petroleum, it limits the economy in African countries, whose economy is based on extracting and selling petroleum. As a result, social and economic sustainability is diminished in entirely different parts of the world than where the initial change happened.

During the current project, the EWB-DK project group had a heightened focus on the ecological improvements that the project entailed. For them, this was the main objective. However, the local partners had a much larger focus on the social and economic aspects. As a matter of fact, an anomaly existed between some of the stakeholders, which might have deteriorated the collaboration. Given the country's situation, it also makes sense that social and economic sustainability is way more important to focus on, wherefore EWB-DK's focus might be aligned.

As a recommendation for future projects, regardless of the setting, sustainability must be evaluated broadly to encompass all social, economic and environmental aspects. For this, local partners must be involved in the assessment and provide their views on the project's sustainability improvements. Furthermore, this will ensure that the solution holds long-term sustainability.

Realistic expectations

In continuation of the above, the EWB-DK project group had very high expectations at the beginning of the project and created highly advanced solutions that were unrealistic to implement in Sierra Leone. Locally, the partners focused on developing small, unsophisticated solutions, taking small steps at a time. This was a necessity that the Danish team neglected. The misalignment caused a waste of valuable time for the EWB-DK volunteers, which could have been avoided with proper communication with the local partners. Therefore, as a recommendation for future projects, regardless of the setting, involve the locals as much as possible. Despite a lack of education, they hold valuable knowledge that must not be disregarded.

Legislative framework

As it was found, many African countries have implemented regulatory and legislative frameworks for managing waste, including Sierra Leone. However, studies found that, in most cases, the enforcement was not fulfilled. Often, a deliberate plan for the implementation does not exist, hence why the effect ebbs out. Deriving reforms was not a core objective of the current project. However, as it pro-

gresses, legislative reforms become more relevant to consider. The legislative frameworks push the boundaries upon introducing a change, drive the sustainable transitioning and sustain the changes.

In the case of Rwanda, consistent and ruthless regulations have shown to be highly effective. It is not argued that countries like Sierra Leone must copy Rwanda to the fullest, but rather pick out specific articles.

Based on the above, it is recommended to advocate for more legislative frameworks through future projects and, with this, provide a plan for implementation and enforcement simultaneously. A start is to ban plastic bags just like many other African nations. This was also recommended by a local, Alpha Massaquoi, during a talk with the author (see Appendix A.1.12). This shows that the citizens of Freetown are aware of the severe consequences that plastic bag entails, and they are prepared to change. The framework should be targeted upstream in the value chain through legislation affecting the early driving forces. This could entail requirements of EPR systems to emphasize the corporate responsibility and sustainable design of plastic products and packaging or prompt reduction of plastic usage in products and packaging. In connection with the global trend in instituting eco-labelling and certification schemes, international organisations can consult the local authorities in introducing such to facilitate corporate sustainability commitment.

The recommendations are not restricted to Sierra Leone but concern countries that generally lack regulatory reforms. As shown in figure 18, many African nations are well underway, though as studies found, a deliberate implementation plan is decisive.

Question of responsibility

The author encountered a widespread tendency in Sierra Leone to accuse the Western world of global warming and its consequences. It mainly dominated the lower end of society, but the government and the FCC applied the accusation in their political defences. As an example, the government blames the Western world for the financial crisis that the country is currently facing. The war in Ukraine is causing much controversy even though it is very far away. Parts of the indictment are justified as global turmoil currently impairs food imports. However, the financial crisis did also take place before the war in Ukraine, which is why the Western world's demeanour can not solely substantiate it.

For others working within the field of sustainable development in developing countries, a recommendation is to be aware of the existing indictment to navigate prudent dialogue with the locals. The parties can meet on par and sustain the collaboration only by understanding the respective perception of responsibility. The author was not aware of the circumstances, and on one occasion, a local asked the author: "Why don't you just stop polluting the world so that we can live in peace?". To this, the author did not know how to reply.

Conclusion

Concluding remarks on the project, its progress and results in deriving a sustainable business model



10 Conclusion

The objective of the master's thesis has been to develop a sustainable business model addressing one of the most critical environmental challenges in the world today. The work focuses on the potential of recycling the enormous amounts of plastic waste in the capital of Freetown in Sierra Leone, West Africa.

The comprehensive research, in which both primary and secondary data collection methods were used, identified several causes of the plastic waste management challenges. This complexity led the main research questions to focus on developing a business model around the development of a waste management infrastructure. Also, it identified how critical it would be to implement the model with a high degree of stakeholder management to anchor the operations locally and mitigate risks.

The research results answered the research questions and enabled the proposal of a sustainable business model with implementation plans and risk mitigation measures.

Based on a technology screening, a combination of mechanical recycling, reuse and incineration is proposed for the business model. Incineration is applied to low-quality plastic waste, while high-quality plastic is allocated for reuse or mechanical recycling. Also, it was found that incineration holds the potential to support the power infrastructure. The theoretical frameworks identified plastic bottles as a splendid platform for reuse due to their global prevalence and versatility. Also, they highlighted the value of adapting the practice to existing infrastructures to facilitate broader applicability and upscaling.

The business model is based on unsophisticated processing of plastic waste, which is sourced in five different locations and transported to a collection and sorting site, where the waste is cleaned and sorted. Based on type and condition, the plastic waste is hereafter distributed to different offsetting channels. These include the DortiBox application, housing and flooding protection packages, local plastic product manufacturers AH&M and Premier Enviro Solutions, and incineration. Revenue is generated through the sale of recycled plastic waste and subsidised by payments for plastic credits traded with SCS and Empower.

The business model's strengths are its simplicity, governmental support, and the strong involvement of the local communities in the operations. With the large amounts of plastic waste and few competitors in Freetown, there is a unique opportunity to upscale the operations. However, it is a weakness that the model currently involves many unknown revenue streams and costs. Due to this, the business model can not yet be considered profitable, and further work is needed to prove that it is economically sustainable. Also, the constant support needed from politicians and the presence of foreign aid organisations, like EWB-DK, is a shortcoming. Corruption and lack of engagement from the local community are identified as the most critical risks against success. Therefore, a constant focus is required on stakeholder management, empowerment, and transparency in the management of funds.

The implementation's strengths lie in its strong engagement of essential stakeholders. A pull effect is created through the involvement of the community councillors, and mutual responsibility is underlined by challenging biases that hinder responsible waste management practices. At the same time, individualism and authority mistrust are suppressed. However, the weakness lies in the many uncertainties and risks associated with the business model. In targeting this, mitigation measures like discussing the project in depth with all stakeholders and training key local individuals to root skills are key.

The research discussion brought up several concerns and limitations that may affect the project's success. One identified issue was the level of contamination of plastic waste and how it affects recycling. The benefits and drawbacks of the applied methodology were reviewed with regard to the obtained results, and it was suggested that frameworks like LCA could be applied. The recycling technologies chosen in the technology screening were also discussed, and it was recommended to explore the pyrolysis technology further.

The research has provided valuable insights into the complexity of establishing sustainable business models in developing countries, combatting plastic pollution, and the need for international collaboration. Learnings from the project apply universally to developing new sustainable businesses, including recommendations for local partnerships, sustainability focus, and legislative frameworks. The results are valuable to organisations, academics, and policymakers to guide the development of equitable and inclusive waste-based value chains.

For future work, focus areas are identified in section 11, including waste sampling analysis, sorting guidelines and studying the unknown revenue streams and costs to develop an economically sustainable business model.

Future Work

Exposition of points for future investigation, execution and assessment concerning the project in both Sierra Leone and Denmark



11 Future Work

For future work on the project, the following points should be considered. The points include tasks in both Sierra Leone and Denmark.

1. Have a waste sample inspected by Teknologisk Institut in Denmark to thoroughly understand what type of plastic is found and its condition in terms of wear, water content and level of contamination. Other research institutions can be chosen, but it has come to the project group's understanding that Teknologisk Institut can test the plastic profoundly. The examination will show how the plastics' condition can be treated and the potential for entering a circular economy.
2. Derive guidelines for collection, sorting, and off-setting and formulate validation and verification procedures to list the requirements for the collected plastic.
3. Study the unknown revenue streams and costs (see figure 7) to develop an economically sustainable business model.
4. To facilitate the attainment of plastic credits, a framework for certification of the waste management service provided must be set in place. In continuation hereof, the existing framework by Empower must be investigated.
5. Contact the authorities in Kenema and investigate their waste management service and dumpsite. According to a local waste worker, they have a controlled dumpsite regular waste pick-up service.
6. Map the power infrastructure in Freetown more thoroughly to explore potential areas of intervention concerning waste-to-energy conversion. In continuation, investigate whether the *Kingtom Power Station* can be converted to incinerate waste.
7. Map the recycling water sachet supply chain.
8. Embark on knowledge and experience-sharing travel to visit Rostock University's waste facility in Kumasi, Ghana, for knowledge sharing on management, suitability and technical requirements.
9. Investigate whether a DRS can be established in collaboration with the FCC and local plastic product manufacturers.
10. Continue the close dialogue with Freetown's authorities and the government and request subsidies towards the waste management facility running. A proposal draft should be made together with the communities on supporting and providing financial contributions for the continued running of the waste management facility.
11. Commence knowledge sharing with other interested neighbouring communities on waste management shows how the facility operates with local involvement and shares best practice guidance.
12. In collaboration with DIS, develop a plastic shredder based on the previous design made by Peter Lindhøj Tuxen (former intern at EWB-DK in spring 2023) that can be manufactured locally. Once completed, it should be tested to determine whether a local manufacturing company can produce the shredder. FINIC Industries can be chosen as the guinea pig since they have proven skills in previous projects.
13. Engage further with Propel Organization on their waste management learnings and prospects of potential collaboration.
14. Investigate the potential of collaborating with Kubik to bring their product to Sierra Leone.
15. Explore the potential of implementing pyrolysis technology in Freetown. Also, explore the possibilities for collaborating with FWT on a symbiosis network.

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Comprehensive list of sources, including academic papers, books, articles, and other relevant materials, cited in the thesis to support the information, arguments, and claims presented



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Appendix

List of supplementary information for the thesis, consisting of transcriptions and a map of locations of interest



A Appendix

A.1 Transcriptions

A.1.1 Interview with a waste collector

The interview was performed at Kingtom dumpsite on March 14, 2023, with a local informal waste collector.

Nicolai FÜRSTNOW: What do you collect on the dumpsite?

Waste collector: I mostly collect plastic waste.

Nicolai FÜRSTNOW: How do you collect it?

Waste collector: I just walk around and pick it up. Then I sort them into large bags.

Nicolai FÜRSTNOW: Who do you sell the plastic waste to?

Waste collector: Regularly, a merchant comes by and buys the plastics in large quantities from all the waste collectors on the site.

Nicolai FÜRSTNOW: Do you know the name of the merchant and is he independent or part of a larger corporation?

Waste collector: No.

Nicolai FÜRSTNOW: Do you know what the merchant does with the plastics?

Waste collector: Yes, he brings it to Guinea where some company buys it.

Nicolai FÜRSTNOW: Do you know what they do to the plastics in Guinea?

Waste collector: No.

A.1.2 Interview with AH&M Ltd. Sierra Leone

The interview was performed at the company's headquarters on March 16, 2023, with the proprietor Hassan Hijazie.

Nicolai FÜRSTNOW: How do you source your plastic materials at the moment?

Hassan Hijazie: Currently, we import our plastic materials from the US due to the low price. The market is highly driven by the market price, though we would be interested in buying local products if it made profitable. We have already been considering buying recycled plastics as another provider at Wilkinson Road, Freetown has offered products. Though they have not delivered anything yet.

Nicolai FÜRSTNOW: What plastic types do you use in your production and what types would you be interested in purchasing?

Hassan Hijazie: We use the plastic types PE, HDPE and LDPE for our products. These would be the types that we would be willing to buy. It can be in a sorted format or as a mix, as long as it is PE. With this, we do not intend to manufacture products for consumables but rather pipes and isolating commodities.

Nicolai FÜRSTNOW: If you were to buy recycled plastic material, what is your monthly capacity?

Hassan Hijazie: We would be able to do 20-30 tons a month depending on the type and quality of the plastics. This would of course also affect the pricing. As a start, we ask for a sample of 25 kg. to test the materials. In this regard, we can provide expertise in how to optimize the products.

A.1.3 Interview with Clasdiving Co. Ltd.

The interview was performed at the company's headquarters on April 17, 2023, with the proprietor Anders Peter Hansen.

Nicolai FÜRSTNOW: What do you and the company do in Freetown?

Anders Peter Hansen: I founded a diving company in 2000 and have been operating in Sierra Leone, Guinea, Ghana, Togo, Benin, Nigeria and the Ivory Coast. Our expertise is the surveying of ships, geological surveys of the sea and support of harbours in maintenance and construction projects. We are located next to the lagoon in Freetown and have a lot of work around the area.

Nicolai Fürstnow: Have you been able to spot any climate changes while living here?

Anders Peter Hansen: Yes, definitely. The sea temperature has risen two degrees Celsius in the past 20 years. I have clear evidence as we follow the sea a lot due to the work below the surface. Previously, I would use a diving suit with a thickness of 4-5mm. Nowadays, I simply find it too warm so I have changed to a 1mm diving suit. Also, in recent years three new types of corrosion have emerged that make the degradation of metals more rapid.

Nicolai Fürstnow: How has the lagoon changed over the years?

Anders Peter Hansen: A lot of illegal embankment has taken place all around the lagoon where the mangroves have been eradicated. More and more waste is littered in the lagoon by the locals that do not go to the dumpsite and can afford waste services. The tides affect the lagoon greatly and the height can vary up to four meters a day. Also, when the waters are high the locals often throw dynamite in the water to kill and catch fish.

Nicolai Fürstnow: Where do the locals dump waste?

Anders Peter Hansen: They dump it wherever they can. Mostly in the sea if not at the Kingtom Dumpsite, called 'Bomme'.

Nicolai Fürstnow: What are your experiences with implementing projects in Sierra Leone? What kind of difficulties do you see?

Anders Peter Hansen: I see a lot of difficulties in anchoring changes as the locals often forget everything they have learned or do not care. Be sure to repeat the procedures and have a reliable local project owner. Also, things get stolen, a lot. I have had a lot of equipment stolen when I did not keep an eye on it for a short period. It is a must that the floating barrier is secured properly. The thieves might not have a purpose with the stolen goods but will steal them anyway.

A.1.4 Interview with a formal waste collector in Douda Town, Kenema

The interview was performed in Douda Town, Kenema on April 23, 2023, with a formal waste

collector from Kenema City Council.

Nicolai Fürstnow: How often do you collect waste in this village and what does it cost?

Formal waste collector: We collect waste from private housing three times a month for a fee of 80 NLE that is paid monthly. The fee also includes a garbage can.

Nicolai Fürstnow: Where do you dump the waste?

Formal waste collector: We bring the waste to a controlled dump site 7 miles outside of Kenema. The waste is lightly sorted and then the organic waste is covered with dirt to begin the process of making fertiliser.

Nicolai Fürstnow: What is the fertiliser used for and who is it sold to?

Formal waste collector: I do not know.

Nicolai Fürstnow: Is the waste sorted?

Formal waste collector: At the dump site, informal waste collectors sort the waste and sell it for a living. It is not commercialised to a large scale.

Nicolai Fürstnow: How did the service start?

Formal waste collector: We were a group of people that started as a small-scale company with tricycles. Eventually, the tricycles broke and the city council lent us a garbage truck for collection in exchange for a deposit.

A.1.5 Talk with the Youth Leader Michael in Pottor community

The talk was undertaken in the Pottor community on April 28, 2023, with the community's leader of the youths.

— It is observed that the community has been exposed to light flooding recently. Waste is scattered all around the community, close to houses, in the fields and at the dumpsite —

Nicolai Fürstnow: I can see that there is waste scattered all around the area in the proximity of the dumpsite and the houses nearby. Why is that?

Youth leader - Michael: Yes, last week we had some rain as the rainy season is slowly starting. The rain flows through the community and scatters the waste all around.

Nicolai Frstnow: How much rain did you have? How many hours?

Youth leader - Michael: Approximately one hour of rain.

Nicolai Frstnow: Okay, and how far up did the water rise?

Youth leader - Michael: Up to the knees.

Nicolai Frstnow: Is it normal?

Youth leader - Michael: Yes, and this is only the start of the rainy season. It gets worse later.

A.1.6 Talk with Mrs. Eugenia Kargbo, Chief Heat Officer at Freetown City Council

The talk was undertaken at Freetown City Council on May 5, 2023, with Mrs. Eugenia Kargbo, Chief Heat Officer.

— Presentation of the project —

Nicolai Frstnow: We are looking for a site to establish our collection and sorting site. In that connection, we have discovered the Lumley Transfer Station which does not seem to be in operation. Would it be possible to use this as the site for our operations?

Mrs. Eugenia Kargbo: Yes, the Lumley Transfer Station is currently not in operation since the construction has a lot of flaws. The materials that were used for the transport deck were of low quality hence it must be demolished and rebuilt. We will have a meeting on the plans next week and start the rebuilding soon.

Nicolai Frstnow: Okay, great! How about the prospects for us to be part of the site's operations?

Mrs. Eugenia Kargbo: Is recycling also included in your project? This is very important as it was the purpose of the transfer stations.

Nicolai Frstnow: Yes, this is the plan. Firstly, the recycling of plastic is in focus. Then subsequently we will find ways to recycle organic waste etc.

Mrs. Eugenia Kargbo: Alright, it sounds interesting. We would be very interested in seeing what you can support us with. After our meeting on the plans for rebuilding, we can have a follow-up meeting.

Nicolai Frstnow: Exciting, thank you!

A.1.7 Talk with Mr. Sheku Kemokai, the Chief Environmental and Social Officer at Freetown City Council

The talk was undertaken at Freetown City Council on May 5, 2023, with the Chief Environmental and Social Officer.

— Presentation of the project —

Nicolai Frstnow: We would like to undertake a test of our floating barrier prototype below Aberdeen Bridge next to the Gemata community. Previously, we have received acknowledgement from the FCC and EPA of the project. As of now, we have received the acknowledgement and formed a collaboration with the community and the associated councillor.

Mr. Sheku Kemokai: Sounds interesting. How about marine life? Are you sure it will not affect this?

Nicolai Frstnow: In the design of the barrier we have taken this into consideration and adjusted accordingly. Though, we do not know to the fullest before we test the barrier in the waters below the bridge.

Mr. Sheku Kemokai: Okay, this lies a bit outside of our domain. To attain permission to test it, you must derive a "Letter of Notification" and send it to the Ministry of Environment, Tourism, Local Government and Marine Resources as well as the Department of National Disaster Management. Then when they accept your undertaking you can commence.

Nicolai Frstnow: Alright, we will do that. Thank you!

A.1.8 Talk with Manfred Pearce from Propel Organization

The talk was undertaken at the headquarters of Propel Organization in Juba, Freetown on May 10, 2023, with Manfred Pearce.

Nicolai Fürstnow: Are beach clean-ups your primary activity?

Manfred Pearce: No, we also sponsor education for children and young people and educate communities in Climate resilience.

Nicolai Fürstnow: What kind of waste do you primarily find during your clean-ups?

Manfred Pearce: Plastic, paper, clothing, vehicles tyres, medical, shoes, wood, metals, dead animals (mostly dogs), household electrical appliances, etc.

Nicolai Fürstnow: Do you know the distribution of the waste? What percentages?

Manfred Pearce: I would say that plastic makes up 50% of the waste. It is primarily plastic bottles and water sachets. The rest is a complete mix so quite hard to give estimates on.

Nicolai Fürstnow: How do you fund your organisation and operations?

Manfred Pearce: The primary funding comes from an American man and a South African woman. Also, on one of the beaches that we clean, we have set up a beach bar from which the profit funds us. Then we also apply for funding at different places such as the *Marine Foundation*. To supplement the business I personally work on the side as a consultant and teacher from which part of the salary goes to propel.

Nicolai Fürstnow: How many people do you have in your organisation?

Manfred Pearce: As of now we are nine administrating personnel while we have previously been 18 but had to lay off due to lack of funding. Then we have 70-80 paid field workers responsible for cleaning the beaches around Lumley and Aberdeen. They are paid a total of 6000 USD a month. Additionally, we have 10-15 volunteers that participate out of pure goodwill.

Nicolai Fürstnow: How do you transport the collected waste and what do you do with it?

Manfred Pearce: We collect all the waste, using pure manpower, in large rice paper bags of 50 kg. and use our own truck to transport it to the Kingtom dumpsite designated by the FCC. As we are an organization we are actually asked to pay for dumping at Kingtom. It is not an official prerequisite but middlemen ask to bribe 200 USD to issue the permission. We see this as facilitation which is needed sometimes to get things done.

Nicolai Fürstnow: What does it cost you to operate your own truck?

Manfred Pearce: It cost us approximately 500 USD a month, including fuel, maintenance and service. The spare parts available in Freetown are of very low quality so we need to do repairs very often.

Nicolai Fürstnow: Have you thought of ways to recycle the waste?

Manfred Pearce: Yes, there are lots of ideas we are currently exploring: bricks used in house construction, tiles used for road pavement, generating electricity, etc. Should the funding become available... we'll definitely implement some of these ideas.

Nicolai Fürstnow: In continuation of recycling, do you plan to have a collection and sorting site?

Manfred Pearce: Yes, we do consider doing collection and sorting hence two sites have been appointed to us outside of Freetown. Though, it is in the initial phase and not operational nor do we have a plan for them yet as funding is needed.

Nicolai Fürstnow: Do you know *Shae Recycling*? Your recycling ideas remind me of them.

Manfred Pearce: Yes, I was the founder's mentor so I know them fairly well.

Nicolai Fürstnow: Have you seen a change in the waste management in Freetown?

Manfred Pearce: Yes, 15 years ago, the city had containers placed at junctions where citizens would discharge their waste. Then collection services appointed by the government would bring the

waste to the dumpsites. The containers have been removed because the authorities feared the spreading of diseases. So we did actually have a system but it was torn apart, so that now people just dump wherever.

Nicolai Fürstnow: As I understand, today, Masada is appointed by the government. How are their operations compared to previously?

Manfred Pearce: Masada also serve a small part of town. Having Masada do collection can be as expensive as five million leones a week for organisations. It is less for private households but way out of the budget for common people. Therefore, it is barely used by locals as no one can afford it. Actually, we are looking into doing a collection of waste similar to Masada from households and businesses. When we transport our waste we could just as well bring others' waste to the dumpsite.

Nicolai Fürstnow: How do you tackle the dangers your staff expose themselves to when working in contaminated areas such as the waters?

Manfred Pearce: We are very aware of the dangers hence we provide safety equipment for doing the dirty work. Also, if the staff become sick and needs treatment from a hospital, we pay the bill.

Talk with Almami from Propel Organization

The talk was undertaken at the operation site of Propel Organization in Juba, Freetown on May 10, 2023, with Almami.

Nicolai Fürstnow: How have you made the net?

Almami: It is a very simple construction with sticks put down into the riverbed and a net spread across. At the moment, it is a pilot that we are doing so everything you see is temporary. As of now, the coming flooding will definitely destroy the net, but then we just build it again. We have built it to test the effect of the net and investigate the prospects if we were to expand.

Nicolai Fürstnow: How about the wildlife in the waters? How is it affected by the net?

Almami: The net's mesh is large enough to allow the fish to pass through. Though, we do not know

for sure.

Nicolai Fürstnow: How often do you empty the net?

Almami: At the moment, we empty it twice a week but in the rainy season it will presumably be more often.

Nicolai Fürstnow: Now, I mostly see plastic bottles dumped everywhere. How about the water sachets? Why are they not prevalent as they are the most common source of water for the locals?

Almami: Yes, great observation. This is due to the fact that a system for recycling the water sachets exists already. I do not know exactly who but somebody buys used water sachets in Freetown and bring them to Conakry in Guinea where a company recycles them. This is well known to the public hence the locals collect the water sachets and sell them.

A.1.9 Talk with locals in Pottor community

The talk was undertaken in the Pottor community on May 12, 2023, with a few locals.

Nicolai Fürstnow: I can see that you have collected water sachets over here. Why do you do this?

Locals: We collect them to keep the square tidy and to avoid the sachets flying around and ending up everywhere.

Nicolai Fürstnow: What do you do with them afterwards? Do you sell them?

Locals: We just collect them. We do not have any deals with anyone to buy it. Though, once there was a man who bought the sachets.

Nicolai Fürstnow: Do you know what he bought them for?

Locals: No, we do not.

Nicolai Fürstnow: Do you have his contact details?

Locals:No, we do not, but we can call you when he is here.

— Subsequently, contact details were exchanged to accommodate future conversations —

A.1.10 Talk with the executive director of Skill Pool - Alie Swazie Bangura

The talk was undertaken at a field trip on May 13, 2023, with Alie Swazie Bangura.

Nicolai Fürstnow: How much will it cost us to rent a 8'14 truck?

Alie Swazie Bangura: I would estimate that a 8'14 truck is 3,000 Leones for rental a day.

Nicolai Fürstnow: Okay, then how about, if we were to acquire a truck?

Alie Swazie Bangura: A new 8'14 truck costs 4 million Leones.

Nicolai Fürstnow: How about a tricycle? What is the cost of a new one of those?

Alie Swazie Bangura: A new tricycle costs approximately 3000 USD.

Nicolai Fürstnow: Okay, so what do you think we should do?

Alie Swazie Bangura: It's better that we buy one for the project instead of renting it. When we multiply the rental cost it is preferable we get our own. And then maintenance and service per month depend on the workload or activities it is used for.

Nicolai Fürstnow: How about the operation of the truck? Who will be responsible?

Alie Swazie Bangura: We as Skill Pool will take responsibility. We do also have people with qualified capabilities to operate the truck.

A.1.11 Interview with the operator of the "Kip Am Klin" truck

The interview was performed at Lumley Beach on May 13, 2023, with the operator of the "Kip Am Klin" truck belonging to Africell.

Nicolai Fürstnow: Who does the truck belong to?

Truck operator: It belongs to Africell.

Nicolai Fürstnow: How often do you clean the beach?

Truck operator: We clean the beach multiple times a week.

Nicolai Fürstnow: How does it work?

Truck operator: The truck has a rack that sorts the waste out when it is dragged through the sand.

Nicolai Fürstnow: Where do you dump the waste?

Truck operator: We dump it at Kingtom dumpsite.

A.1.12 Talk with Alpha Massaquoi, a citizen of Freetown

The talk was undertaken with Alpha Massaquoi at Aberdeen, Freetown on May 22, 2023.

Nicolai Fürstnow: What do you do with your waste?

Alpha Massaquoi: A local kid comes by my house with a trolley picking up the waste thrice a week. This is quite common for the neighbourhood as no official service is provided.

Nicolai Fürstnow: Where does he bring the waste and what does it cost?

Alpha Massaquoi: I pay him 5 Leones each time. I do not know where he brings the waste, though, I would expect that he dumps it in a slum nearby or in the sea. The Kingtom dumpsite is simply too far away so it is normal procedure to dump it close by.

Nicolai Fürstnow: I have heard that the government plan to establish a new dumpsite in Freetown - what do you think about this?

Alpha Massaquoi: The government has been talking about the establishment of a new dumpsite for years. However, it does not make any sense as it would be placed very far away so that no one would use it. Already now the official dumpsites are located too far away.

Nicolai Fürstnow: I have seen people collecting water sachets and they tell me that they sell them. Do you know the industry for this?

Alpha Massaquoi: There used to be a business for recycling used water sachets. It was a Chinese company in Cline Town, Freetown that was making flip-flops. It was great for the city and many people

got involved in collecting water sachets. As of today, the company has stopped its operations due to unknown reasons. However, the people are not aware of this hence they are still collecting the plastic waste.

Nicolai Fürstnow: Do you know of any other kind of recycling going on?

Alpha Massaquoi: Yes, the recycling of metal is very well-functioning. You hardly see any metal dumped as it is being collected and sold.

Nicolai Fürstnow: What do you think about the idea to construct walls and flood protection with plastic bottles? Would that be a great solution to Freetown?

Alpha Massaquoi: Definitely, it is a great solution! I have seen it done in Liberia where it works very well. However, due to a lack of guidance dissemination, it is not done in Sierra Leone. This also underlines the need for education of higher quality and actions needed from the government. The people that run this country do have an education but it is of such low quality that they are not capable to run it properly.

Nicolai Fürstnow: What waste management initiatives do you think should be made in Freetown and Sierra Leone in general?

Alpha Massaquoi: I think that a place to start is to ban plastic bags just like countries such as Kenya. It would help so much to avoid them as they are always dumped and cause drain blockage.

A.1.13 Talk with Suleiman - a plastic trader

The talk was undertaken at a field trip on May 26, 2023, to the Gemata community where the author met Suleiman by chance.

Nicolai Fürstnow: Why do you collect waste?

Suleiman: I am buying waste from the community.

Nicolai Fürstnow: What type of plastic do you collect?

Suleiman: I only collect water sachets and thin plastic bags.

Nicolai Fürstnow: What do you do with it?

Suleiman: I bring it to Guinea and sell it.

Nicolai Fürstnow: What do they do with the plastic? Do they recycle it?

Suleiman: Yes, they make household things and flip-flops.

Nicolai Fürstnow: What is the name of the company in Guinea that buys plastic waste?

Suleiman: I do not know. They speak French so we barely speak. I just hand it over in Conakry and get paid.

Nicolai Fürstnow: I can see that you are weighing the plastic waste. What price do you buy the plastic for per kilogram and what do you sell it for?

Suleiman: To the community I pay 5 Leones per kilogram and then I get paid 10 Leones per kilogram in Conakry, Guinea.

A.1.14 Talk with Walid Bahnsoon, the founder of Enviro Premier Solutions

The talk was undertaken by members of the EWB-DK project group on November 15, 2022, with Walid Bahnsoon.

— Presentation of the project —

Project members: Can you tell a bit about your company and its operations?

Walid Bahnsoon: Yes, we are a local company in Freetown that is producing construction bricks made from plastic waste. We mix the plastics with common materials such as gravel at a ratio of 20% to 80%. Ordinary bricks cost 18 NLE while we can do it 15-20% cheaper. At the moment we are working on the establishment of our operations, ordering of equipment and creating contacts.

Project members: Would you be willing to buy plastic waste?

Walid Bahnsoon: For now, we are not ready to take in large amounts of plastic waste. Currently, our setup consists of a shredder and an extruder that

is capable of processing 200 kg. a day. However, when we start our operations in July, we will be willing to buy up to 10 tonnes of plastics per day. In order to sustain the business we need to process 20-40 tons a day hence the operations will be scaled over time.

Project members: What types of plastics are you willing to buy?

Walid Bahnsoon: All types.

Project members: Do the plastics need to be sorted, washed or dried before you receive it?

Walid Bahnsoon: Actually, no processes are needed. I would prefer the plastic waste to be processed as little as possible. But let's see what you can deliver and go from there.

Project members: What price would ask for the plastic?

Walid Bahnsoon: We would be willing to buy plastic waste for 400 Leones per. kg.

