Redefining Waste: Developing a Plastic Recycling Economy in Ghana

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Exemplary Quotes & Images

"Community is in need of [a] compound with [a] health center, for a place to create a school… something could be done towards these" - Barima Oppong Kyekyeku, Chief of Batabi, 1/23/2023

"Today, we are destroying nature. We are not protecting nature" - Interviewee 1, 2/8/2023

"Before this, people are giving a lot for volunteering work, today they are only for the money… [they] are not paying much attention to the development of Dwenase" - Interviewee 1, 2/8/2023

"People will donate bags of cement, money to start… they call on people who have traveled from here… Rome was not built in a day" - Barima Ahenkorah, Chief of Abompe, 2/4/2023

"The rubbish is actually destroying not our land, but our health" - Interviewee 12, 2/21/2023

Image: Shredded plastic waste at Nelplast which will be recycled into repurposed building material

Image: Accumulation of waste, including plastics, by the ocean at Cape Coast

Image: Building which will become the collection center in Akyem Dwenase

Image: Project team testing potential cheap bailing techniques

Image: Burned waste in front of a recycling bin.

Promoting Sustainability: Using Plastic Recycling to Create a New Development Paradigm

"Before the chief was enthroned…God revealed to him in prayer that when he comes, Dwenase…will see development.…He has shown actual love… for people in the town, and...is very concerned…in every little thing.…He is interested in every detail aspect of every human life." - Interviewee 7, 2/20/2023

Image: Burning waste, including plastic, outside of the Akyem Dwenase Guest House.

Plastic consumption worldwide becomes increasingly detrimental to communities that do not have the facilities to handle this waste. The West African Country of Ghana, with a GDP of 77.59 billion USD,[i] annually produces 1 million tons of plastic waste.[ii] In municipalities in the Eastern Region - including Abompe, Batabi, Dwenase, and Tumfa - plastic waste is often littered or burned in small fires causing unique problems. Solid rubber waste often clogs drains and hurts the natural landscape, while burning plastic releases toxic chemicals that are harmful to community members and the agriculture they depend on.

Recycling in Ghana is limited, with only 10% of plastic waste being recycled.[iii] There was a lack of plastic recycling in Ghana before 2012, which contributes to a break There is environmental damage caused by non-biodegradable plastic litter which causes associated health concerns. This includes higher instance rates of malaria due to the litter clogging drains contributing to standing water and mosquito breeding.

Littering has negative impacts; however other instances of waste removal can be worse. For example, if plastics are burnt, compounds such as CO_2 and CO are released into the air. During our time in Ghana, we learned that many times plastic waste burns in high-traffic areas where it accumulates. From this, an increased amount of people are breathing in these

compounds, and microplastics further put the community's health at risk. Often too, these communal grounds are places where children congregate. In Dwenase, the soccer field is a popular location located on a main road next to the Dwenase Junior High School The large open field makes the space very attractive for festivals, and for playing football after school; however, they are breathing in the pollutants as they congregate.

In villages like Aykem Dwenase, there is no established recycling system. Plastic waste is discarded throughout the community- in farms, fields, playgrounds, and schools- either left littered or burned. In general, these massive environmental and health concerns have led many African countries to create counteractive systems to combat this waste. Many are disproving the longstanding idea that a country needs to be fully developed before its citizens have enough disposable income to make environmentally and health-conscious decisions. This is established by creating circular economies where plastic is eliminated, and value is returned to the community.

When considering this problem, the important questions that one has to ask, are: why villages burn their waste? Are there any alternatives that could be implemented? Could educating the community on this harm be a solution? Or is there a lack of means to recycle or even dispose of waste? If there are no alternatives, is there a possibility to create one? To respond to these questions, one must look at the culture and the system of governance within these communities.

In our research and attempt to answer these questions, we have focused our solutions on two areas: the logistical information required to implement a recycling system and the underlying cultural information of how to get people involved in the system. For the logistical aspect of our project, we determined how plastic, money, and building materials can flow through the different communities. For the plastic, we determined transport logistics, and how to replicate the bailing and sorting processes. For the money and building materials, we created different collections, transportation, and return options. All these can be found in the Implementation Manual, attached in Appendix C. For the cultural aspect, we conducted interviews, both with the chiefs of participating villages and the citizens of Dwenase. These provided an understanding of the values and motives within these towns so we can grasp how to incentivize people to join the system.

Although many people in Dwenase are aware that they are destroying the environment (see our interviews in Appendix B,) many are not conscious of the impacts of burning plastic on their health. In many of the interviews conducted, we found people believed that burning plastic was not detrimental, or even that it was good. This is why this project is so important: education is a tool that can transform communities. People need to be educated on the importance of recycling before they can be incentivized to join the system. We need to account for this and understand both the current knowledge and motivations which drive people. From this, our research will attempt to answer how we can use the pre-existing cultural attitudes of individuals to create incentives that will motivate said individuals to participate in a recycling system.

Importance of Co-Design

"Being chief they see you as somebody. There could be development, including the elders, they embrace it. They look forward for you to bring development into your community" - Barima Oppong Kyekyeku, 1/23/2023

Image: Plastic sachet waste littering the local football field in Dwenase

Projects that fail to consider co-design can impact people in unforeseen and unintentionally negative ways. One example is the PlayPump – a merry-go-round used by children to power a communal water pump – which provided a solely temporary solution. Shortly after, many of the machines broke and children lost interest which worsened access to clean drinking water.[iv] To implement an effective project, one must understand the culture and social organizations of concerned populations. If not, there is a large risk of negatively impacting the community. Non-governmental ventures must aim to create sustainable solutions rather than mere development. Indeed, sustainable answers are those that provide generative justice by adding social and economic value. In other words, generative solutions require individualistic approaches that transcend local values and attitudes.[v] This requires looking at the problem contextually over time to implement positive change.[vi]

Our design process has been shaped by local history and culture to align with societal values and needs. As we don't have extensive experience with the community, we must remain conscious of local practices through social design. Developing a sustainable recycling economy relies on local participation. By considering current social practices, we are better equipped to avoid negatively impacting Dwenase; we intend to implement a sustainable solution that adds value back into the town. We are creating a living manual with the chiefs to outline and implement a flexible system that provides recommendations based on local feedback. The

manual provides a starting point enabling each village to change or expand the system in the future.

The social relationships among the population are another key consideration for our project. To create a useful system, we must consider the roles of different individuals. Network analysis looks at the relationships and interactions between groups based on similarities, social relationships, interactions, and flows.[vii] In Akyem Dwenase, the Chief takes on a key leadership role as an integral part of the community structure. His decisions and viewpoints have an immense impact on the village. This status is critical to our project design as our team should respect and uphold these social relationships. Additionally, we should consider the entire network analysis underlying societal relationships to avoid negative social impacts.

In Akan culture, there is an extensive and influential hierarchical structure of chiefs and traditional councils in each town and city. Chiefs are chosen by a Queen mother when the position is vacant, and approved by the Okyenhene, the Okyeman King. Chiefs, along with their councils, are largely responsible for culturally and economically leading communities.[viii] Chief Osabarima Owusu Aboagye III of Dwenase and the chiefs of the other villages have each expressed interest in a plastic recycling economy centered in Dwenase. The economy needs to be sustainable and incentivizing to successfully collect and reduce littered plastic waste to improve the quality of life for community members.

We are not members of the community in Dwenase. Our experience coming from an engineering school in the United States impacts our perceptions, thoughts, and approach to problems. In the past, there have been multiple examples of misguided voyagers coming to Africa and Ghana to impose their own views and practices. Ludwig Alberti, a Dutch lieutenant, questioned the appeal of "civilizing" Xhosas in the Cape Colony. A main consideration being the possibility to negatively impact the Dutch in the early nineteenth century.[ix] This is one demonstration of the disdain and lack of respect Europeans held during colonization.

Throughout the mid-to-late twentieth century, China pushed for political and economic influence to further its status as a global power in Africa. Shortly after Ghana established independence, China began to establish an alliance with Ghana, helping support development through infrastructure and loans. This shifted to focus on training Ghanaian youth for revolution in support of China's communist goals.[x] China used Ghana as a tool for their own expansion and success instead of treating Ghana as an equal partner. We must recognize historical relationships and their impact in terms of our project plan. The cross-cultural design will rely heavily on collaboration between ourselves, local leaders, and the community as co-designers.

Annually, Ghana produces roughly one million tons of plastic waste;[xi] yet, only ten percent is recycled.[xii] To establish a new system, we must create a model that will align with current recycling practices in Ghana. It must also work with the local village needs and their ability to go about the recycling process conscious of time, money, and sustainability. Getting feedback from the community and leaders is imperative to determine the goals of the system,

forms of collection, baling, and sorting, and how they would like to see returns. In the end, as a project team, we are here for roughly two months; yet the system is designed to last far beyond our stay through its sustainability and use over time.

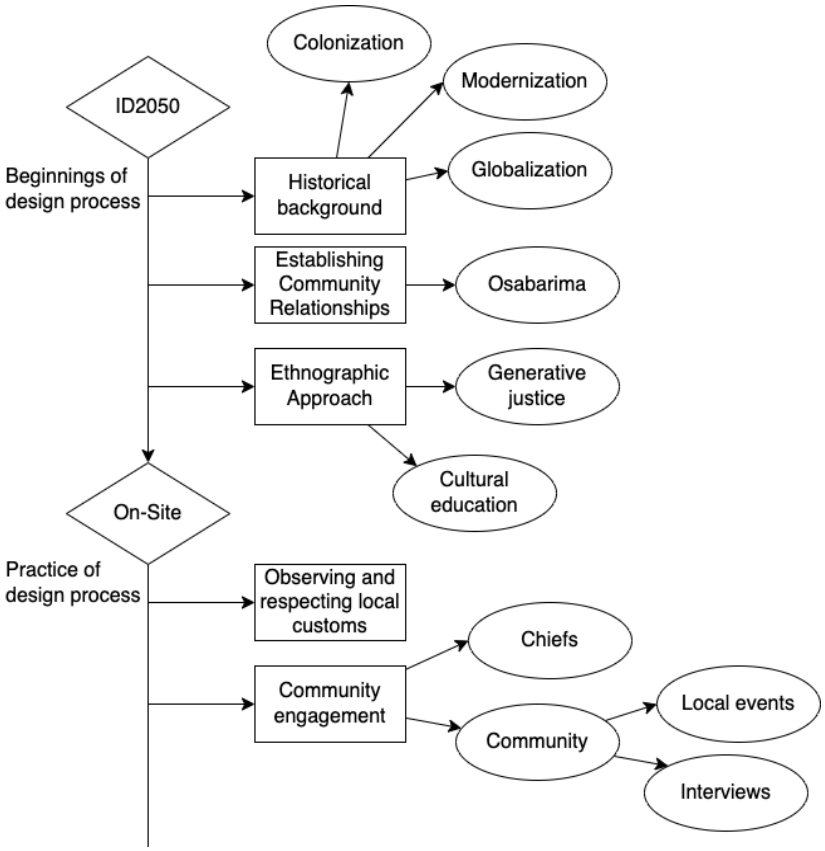

Figure 1. Chart of co-design process.

Adapting a Project to a Changing Environment

"Be prepared, these projects will most likely change as soon as you arrive in Ghana" - Professor Robert Krueger, 10/24/2022

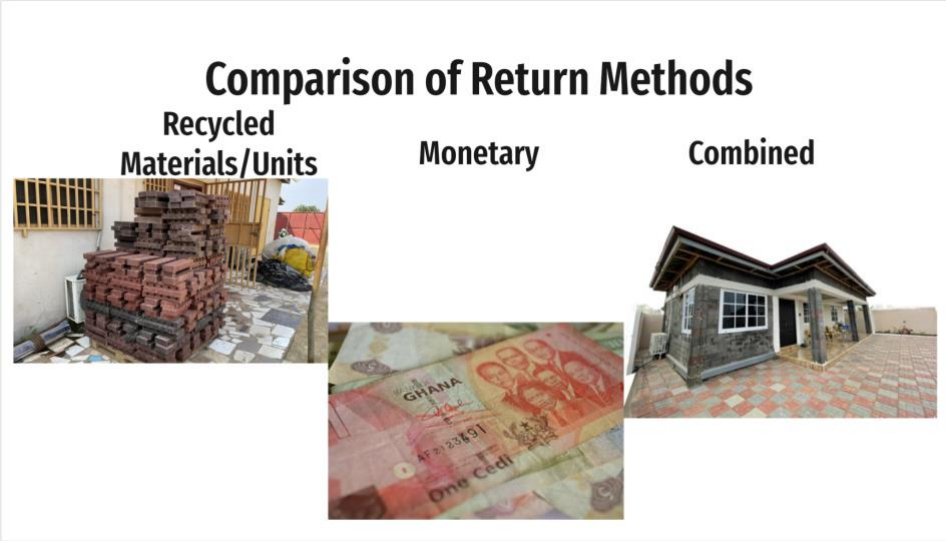

Image: Presentation slide of proposed options for partners.

In our first ID2050 meeting, Professor Kreuger prepared us that it was likely our projects would change once we arrived in Ghana. With that being said, adjusting our task in response to a better understanding of our environment was tumultuous. We started our work on location with a broad idea of how we wanted to structure our project and loose goals to adapt to new information. We originally aimed to craft a manual of how to use the qualities which support Susu to incentivize people to join a recycling system. We would supplement this manual with various models establishing the system's logistics. We wanted to then use system dynamics modeling to combine the incentive and logistical aspects into a complete system. Our major goal was to talk with the chiefs and notable members of the community. These conversations would set up the design of a sustainable and generative recycling economy based on how people living within the system want it.

To complete this over-encompassing goal, we had subgoals. We knew that we could not create a manual for creating a sustainable recycling community without consulting the people who know the town and its values. To hold true to the co-design process, it was important for us to have the chiefs and communities decide their goals for the project, to give them the largest role in creating what will be the system they are entrenched in. We aimed to find out from each chief how intensely they want to be included in the recycling economy, how much they want us to design, and how exactly they want their town to be incentivized to recycle. Another goal was to determine if Susu groups reflect a local circular economy that transcends the communities'

underlying values and beliefs. This research was going to help identify which incentives can be used to create a successful and sustainable recyclable economy.

The research that we completed on Susu before we came to Ghana led us to put forth three potential designs: to give money back to individuals, return the waste for recycled materials, and a combination of the two.

When we began looking at and interacting with these towns, these plans changed because of the influence of the community and our partners. Firstly, in Dwenase, we began to look at combining earnings with communal giving. In our first week, we saw multiple differences in examples of communal giving including the 60th anniversary and the parties leading up to it. We also saw the dedication to education during the anniversary and listened to graduates explain how education benefited their lives. We can expand on this in our system to make some of the returns donations to school funds or for teacher housing. If at communal events, like funerals or celebrations, the village can collect the plastic, they can exchange it for money for the current crowdfund.

When we talked to the chiefs of the included towns, our confidence in this change was solidified. Both chiefs expressed the importance of individual incentives to help the community members. They also relayed their excitement about a system that could work towards their broader goals. Some of these goals could be greatly supported by a communal fund or eco-building materials.

Instead of a collective gift, or individual incentives, from our observations and our conversations, we determined that there needs to be a combination of the two. This will ensure these incentives are equally as incentivizing and beneficial to the community.

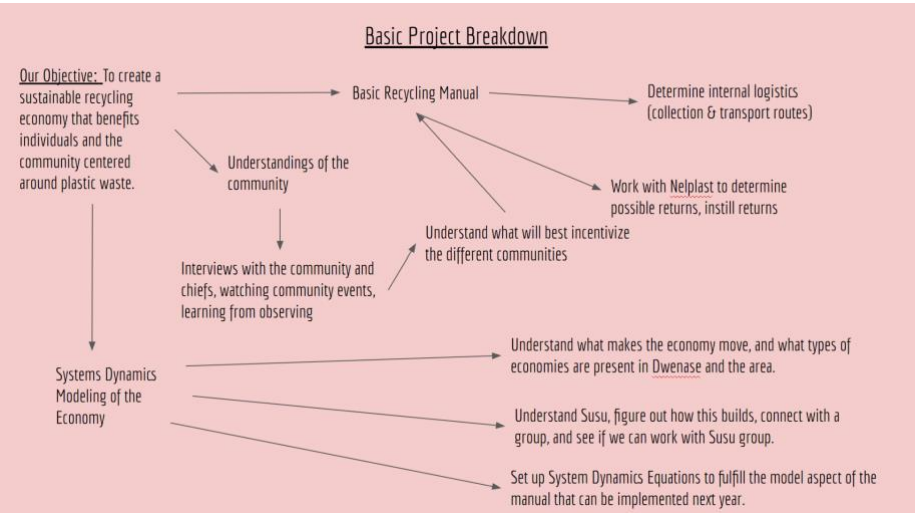

Figure 2. Initial Project Map of our Project Process

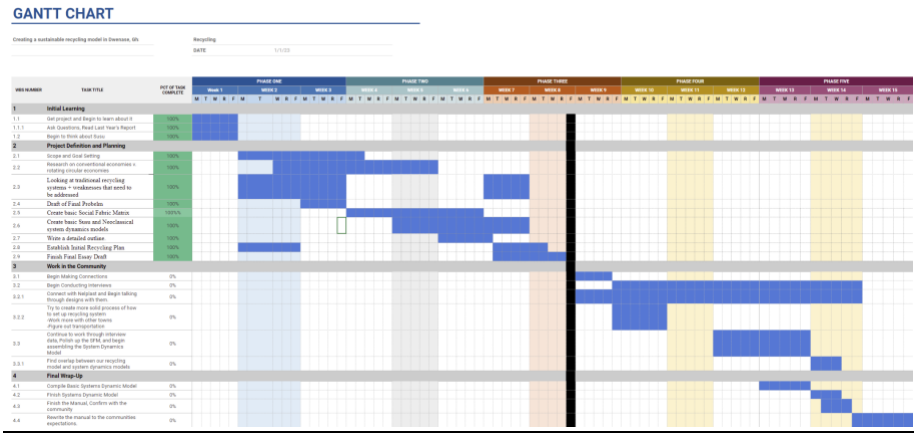

Figure 3. Initial Gantt Chart detailing our original plan for the project

The Realities of Recycling in Dwenase

"*Osabarima is so happy with the way you interact with the community. Especially the children, the children are so happy"* - Richmond Boadu, 2/24/2023

Image: Member of the team using a potential baling machine.

Community engagement, brought about by living and co-designing within Dwenase, constantly gave insight into the perspectives and realities the residents hold. It also demonstrated how we, with our own perspectives, relate and react to this as friends, learners, and researchers. At the base level, this can highlight the similarities and differences in our perspectives. It can also give a lot of insight about our individual personalities, experiences, and communication styles.

For the sake of time and clarity, we sometimes did this by asking questions outright. Interviews helped us practice an ethnographic approach toward topics such as community opinions on recycling, traditions, values, and existing economic structures. In general, this process generated a lot of data points. When considered collectively, the points began describing the intricacies of the Dwenase and the history that brought the village and region to its present-day reality. Though all this data will be put forth into consideration of the values and traditions of the population, not all will be able to be outlined in detail in research write-ups. Future work will likely also use these data points in the creation of a social-fabrication model or network analysis model.

Outside of formal interviews, we have also conducted many informational conversations with leaders of partnering communities: the King Okyenhene, the chiefs of Dwenase, Abompe,

Batabi, and Tumfa - Osabarima Owusu Aboagye III, Barima Ahenkorah, Barima Oppong Kyekyeku, and Barima Osreh Adom II respectively - as well as certain members of Osabarima's council. These conversations supported the background of our project, and in the spirit of codesign, they gave the project direction in a way that was appropriate for their villages.

In addition, it should be mentioned that we also found community engagement in conversation and informal shared activities, such as football and dance. These interactions are further documented in Appendix D.

The importance of community engagement is extensive. We were told in ID2050 that Dwenase holds values such as education, family, and progress. Often, the leaders of the village spoke of similar values. However, as beneficial as this knowledge is to the project, it provides a very general view of these concepts. Through deeper investigation, we look for the meaning behind the generalization and consider the context surrounding the named values. Our understanding of the importance of education took form in many ways. For example, during an interview, a woman indicated that adults show care for the children in Dwenase by working hard to fund their education. She says that the dream of many is for their children to get higher education and a job "in the city" so that they might return to Dwenase and support the village.

The first interview that the research team conducted helped guide our understanding of the interview process. Boadu, the translator for this interview, gave insight into the interviewee's answers as well as customs and practices in the community throughout the duration of the interview. This context is integral to our background understanding of this society and helped us recognize how to approach interviews in Dwenase.

In one of these instances, Boadu articulated something we had observed. The interviewee spoke in English to us but preferred to conduct the interview in Twi. Despite our lack of ability to understand, in the words of Boadu, she spoke, "as if [the interviewers] knew the language… She speaks from passion." This observation gives insight into how she felt about not only the concepts she was discussing but also the act of sharing these concepts with the interviewers. She spoke with passion about how the Chief and his motivation for positive change has benefitted her, changes in tradition over her lifetime, and what she believes to be important to the community: work and education.

The heartfelt answers from the woman from the first interview give not only information on why she cares about education but show the depth with which she cares. She visibly manifests the context around education and how it has touched her life. She also nonverbally indicates the relationship she wants with us as researchers, which is important to note, as not every person interviewed showed enthusiasm for our conversation. For further analysis of interviews, see the Interview Analysis under Appendix B.

We have learned a lot of information specific to life in Dwenase and the surrounding villages, which has supported the manual deliverable. Through community engagement, we have

also learned about the research process, valuing ethnography as a research skill, and delving deeper into the individual experience rather than relying on second-hand information. With this, the communication of information is so much richer and more honest. This level of connection is crucial in going forward with any research to ensure that we conduct ourselves appropriately in response to the people of Dwenase. It also decreases the likelihood of unforeseen negative broader impacts, of which in research there are rarely none, and informs our decisions to pivot away from them. It has allowed us to think about the future of this project and its effects on the village more accurately. For further analysis of community engagement conducted throughout this project and how it relates to these themes, see the Legacy Document under Appendix D.

New Perspectives

"I hope you remember my face" - Barima Oppong Kyekyeku, 1/23/2023

Image: Project team on a visit to Batabi to visit Barima Oppong Kyekyeku

After arriving, our cultural expectations and project scope drastically changed many times. One of the first things we found was that there was some miscommunication of design expectations among all parties; each of our partners had a different idea of what the outcome should be. Osabarima and involved community members believed that we would implement a recycling system, while our advisors envisioned the project as a multi-year endeavor. We needed to establish that our project focused on the design of all aspects of the recycling system which will be implemented by another group of students next year.

One of the most important cultural practices we engaged in was formally meeting with the chiefs, council members, and influential elders of all the villages acting as co-designers. Each meeting offered a fresh perspective on both the town as a whole and the importance of different factors within society, such as community values, education, and farming.

The first project-specific introduction was in the town of Abompe. Each member arrived fully prepared to fulfill unique roles for the meeting. We were surprised when we learned that, in our group of three female and one male presenting students, the female presenting members were not culturally permitted to introduce the project or ask and answer essential questions. Despite learning some of Abompe's desires for the recycling system, we left the meeting with many unanswered questions and unsure of our path moving forward.

After this meeting, we discussed these practices with Attah, the education director in Dwenase. We learned that, traditionally, men are expected to provide the introduction and purpose of the visit, and all accompanying members can speak after the first introduction. This knowledge helped prepare us for the next meeting with the chief and elders in Batabi; we were able to effectively learn what our co-creators wanted out of the project while outlining our designs and the options available for future implementation. In addition, we took a tour of Batabi after this meeting, allowing us to look at important locations in the town and visualize how recycling will function there.

To determine the options for incentive design of the recycling system, we initially intended on basing the design on Susu groups and working on a system dynamics model of both recycling and Susu. We planned to talk to local Susu group leaders and members and sit in on group meetings to observe the dynamics at play. However, we learned that a negligible portion of the population are associated with this system, colloquially referred to as a Susu group; it instead functions as a type of microfinance group and lacks the previously researched characteristics of a Susu group. Despite learning information about community members' trust in monetary institutions and attitudes toward savings, we needed to adjust our approach to better understand underlying incentives.

We decided that the best way to learn about the underlying values in Dwenase and develop incentive packages based on them was to talk and learn from the people residing in the village. Moving away from Susu, we submitted an IRB, and once approved, began talking to people with the help of Boadu, Osabarima's linguist, or Isaac Asante, a graduate student working in the town, acting as a translator. As a respected member of the community, Boadu was able to help the people we were communicating with be open and relaxed. This enabled us to hear and observe the information we needed to continue the project. However, we also recognized a possibility of biased information, especially about the Chief, due to his affiliation with the village council.

Boadu's language and temperament also helped us learn about the village. In the chief meetings, people often were jovial and laughed after Boadu conveyed something we said. After this happened a few times, he informed us that he often makes jokes in Twi - the local language - ensuring that people are engaged in the present conversation.

Boadu has also acted as a local well of knowledge. He has informed our process for every aspect of the project. He helped locate high-traffic areas, figure out transportation costs, and coordinate meetings and transportation. Boadu's invaluable assistance was unexpected prior to our arrival; this led to smoother than anticipated co-creation and community engagement.

Future Implementation of the Recycling Economy

"It would be irresponsible to implement the project without properly designing it to work for the community" - Discussion from project team, 1/24/2023

Image: Nelplast's First House Constructed Wholly of Recycled Plastic

The research conducted this term is sequential in nature, extending off preliminary library research conducted by the 2022 project team. This formed part of the background context on which the 2023 team and community partners have developed the model economy. The long-term goal is for partnering villages and future IQP teams to implement the model. Most of the completed logistical research is for the purpose of properly scaling the model and understanding the social and economic contexts surrounding it. While this information will help future teams, a lot of logistical information, including but not limited to the mechanics of shredding, washing, and weighing the sachets and bottles, and certain transportation details, will need to be researched by these future teams before implementation. For further information on the logistics of implementation, see the Manual under Appendix C.

It is also advised that future teams continue the analysis of public opinion and experience as found through the interviews (see Appendix B). Further implementation of the information collected into the execution of a recycling economy is integral to the sustainability of this system.

Other future work that is relevant to plastic recycling is the reclamation of metals and composting. Often, plastic is burnt alongside metals and organic material. Other methods of waste management could be beneficial in discouraging these kinds of dangerous disposal methods. We would also encourage future teams to look at the larger problem of imported plastic waste, as 2.58 million tons are imported to Ghana annually.[xiii] This could be a potential source of income within the system and help reduce plastic waste within the country. While this may not be feasible soon, it could be an area of expansion that could provide additional revenue and reduce plastic waste.

The development of other recycled materials as future work would also be of great local benefit, based on feedback we have received from leaders, adults, and children we have engaged with. Many have shared their wish for newly paved roads, indicating the importance of accessibility of traveling in and through the village. Roofing was also brought up as necessary material, as this is something many buildings lack. In conversation with Nelplast, they have indicated their goal of manufacturing new forms of the plastic blocks, but they are not yet available. Certain partnering villages' goals of constructing teacher housing, healthcare buildings, or other community meeting places has come to light based on the availability of the Eco-brick materials. However, the development of a wider array of building elements by recycling companies such as Nelplast offers more customizability for village incentives. In going forward with future work, teams should be informed by the information we have collected both logistically, which can be found in the manual deliverable, and ethnographically. The ethnographic information we have collected can be found in a variety of places: the legacy document, the manual, and sections of this paper.

Ultimately, we recommend the continuation of relationships with Dwenase. The local population largely agrees upon the positive impacts that Chief Osabarima has had on the village. One interviewee, who has seen three different Chiefs in office, noted that "he is working more than every other chief [she has] witnessed." There are a lot of directions that he wishes to extend with both this project and many others. Before going forward with future work, co-designing with Osabarima and the community must be used by incoming project teams to properly move forward.

Credits and Acknowledgements

We acknowledge all the individuals who have helped with the project over the past several months. We thank Professor Mahamadou Lamine Sagna for his continuous support and direction as an advisor during our time in Ghana. We also recognize Professor Robert Krueger for his guidance on the project earlier in the year and for the work he has done to establish the project site and Professor Achirri Ismael for his assistance on the development of our project. We acknowledge the Chiefs of Abompe, Batabi, and Tumfa. Their continuous efforts and feedback on the project as co-designers to build a comprehensive system. We would like to extend further acknowledgements to our primary partner, Chief Osabarima of Dwenase, for his feedback and commitment to development in Akyem Dwenase. We express appreciation to Richmond Boadu Tinyase for acting as a translator in numerous meetings and interviews; as well as, serving as a consistent source of local knowledge and practices. We appreciate Samuel Yusuf and Enis Boateng for their work as project managers. We acknowledge Nelplast Eco Ghana Ltd., Nelson Boateng, and Selina Ama Segbefia for their recycling expertise and future partnership with the local system. We recognize Francesca, the Headmistress of L/A Junior High School, and Kwasi, Deputy Chief of Agriculture, for serving as local contact points on recycling in Dwenase and giving their feedback on establishing a full system. We acknowledge everyone we interviewed for taking the time to share their experiences with us. Lastly, we thank Dwenase for taking us into their community.

Image: Aerial view of Akyem Dwenase from the water tower

Appendices

Appendix A: Interview Questions

1. Personal Introduction
    a. What is your age?
    b. Can you tell us about your job?
        i. How long have you been doing this?
    c. Have you always lived in Dwenase? How long have you lived in Dwenase? How long has your family lived in Dwenase?
2. Social roles/dynamics
    a. Are you involved in the community of Dwenase? How?
        i. A: volunteering, community labor (what kind?)
        ii. B: community focused job (what kind?)
    b. What do you think other people appreciate about the activities that you do?
    c. How do you see the role of children, adults, and the elderly in community activities?
    d. Are people treated differently based on income level?
3. Leadership
    a. In your opinion, what has the Chief done to benefit your life?
    b. How does the Chief preserve tradition?
    c. Who do you consider other leaders in the community?
4. Tradition
    a. Have you noticed any shifts in culture or tradition over your lifetime?
        i. What is important to the community? Why?
        ii. What are some traditions that are important to you?
5. Recycling
    a. In your opinion, are we preserving or destroying nature?
    b. What do you know about the effect of burning plastic?
    c. What do you know about recycling and other types of waste removal?
        i. Do you recycle?
6. Social-Economic Organizations
    a. Are you involved in Susu? If so, how is your Susu group organized? How many people are involved?
7. Community Events
    a. How do you support the community?
        i. Do you donate money or resources to the community?
    b. How often do you partake in community events like festivals or church? Why do you attend these events?
    c. Do you help with any of these events?

Appendix B: Interview Analysis

General Interview Information

- The purpose of these interviews was to determine pre-existing cultural attitudes that can be used to incentivize individuals to participate in a recycling economy centered in Akyem Dwenase.
- These interviews were conducted under accord of an IRB from Worcester Polytechnic Institute and were carried out from February 8th, 2023, to February 23rd, 2023.
- The interviews were conducted on different days at a variety of times to capture a more varied pool of participants.
- A translator was used for all interviews to be conducted in Twi.

Personal Introduction

- Personal information was collected for analysis. No personally revealing or harmful information was recorded.
- Interviews were conducted with 10 females and 10 males. This resulted in a total of 20 interviews from the Dwenase community.
    - We note that this is a small sample size; however, it allowed the group to get feedback on local practices at the time of the project.
- The ages of the interviewees ranged from 18 to 85.
    - No children were interviewed in this survey.
    - The mean age was 49.44 years, the median was 50 years, and the mode was 65 years.
- There were a variety of jobs from the participants. Some of the reoccurring jobs included 3 farmers, 3 masons, and 2 seamstresses.
- 47% of interviewees lived in Dwenase for their entire lives. Others had moved to Dwenase from other areas in Ghana like Kumasi or Accra.

Social Roles and Dynamics

- The interviewees indicated differing levels of community involvement.
    - 9 individuals said they were involved, 4 said they were not, and 1 indicated occasional participation.
    - One of the most common responses was helping through communal labor.
        - Individuals older than 65 years do not need to participate due to their age and ability to carry out such work; however, 5 elders mentioned they did communal labor when they were younger.
        - Additionally, older participants (50 or older) were more likely to participate in community labor or did participate before they aged out. During one interview, an elder expressed that younger populations care more about money than community labor. This potential shift in mindset is

considered in the recycling system through a hybrid model, providing both individual and communal incentives.
    - Other responses included supporting funerals through attendance, the funeral committee and development of the grounds, or church.

Leadership

- When asked how Osabarima, the Chief of Dwenase, personally benefited their lives, not all could pinpoint a specific example.
    - 5 individuals indicated they haven't seen any personal impacts.
    - However, 73% of those who responded mentioned his commitment to supporting the community.
        - From this, 71% of these mentioned his focus on development in Dwenase.
        - Examples of these are as follows: school (11 responses), roads (4 responses), guest house (4 responses), palace (2 responses), and funeral grounds (2 responses).
- Out of those who responded, 86% indicated the chief was preserving tradition well. Some examples shared included building a palace (4 responses) and discipline (3 responses).

Tradition

- Looking at some of the communities' favorite traditions, the most common responses included communal workdays on Thursday when no one goes to the farm (4 responses) and Holy days (2 responses).
    - Communal workdays help support local upkeep and development. If used to aid in the recycling project, it should be done in a way that aligns with local practices and regulations. Additionally, this could help get the community more involved with the system and increase overall participation.
- Interviewees mentioned that school (7 responses), roads (3 responses), and the clinic (2 responses) were the elements most important to the community.
    - The devotion to education was supported from our observations within the community. Children are expected to attend school in the hopes they will support the community later in life.
    - These elements also align with an earlier question regarding how Osabarima is supporting the community. Based on the connection between these questions, these factors should be considered the most in a recycling system.

Recycling

- Almost all participants indicated that the environment is being destroyed.
    - Some mentioned that one large factor in this was the lack of reclamation for illegal mining.

    - 3 individuals also mentioned that it is being preserved in some ways, 1 couldn't say and 1 said that it is necessary for business.
- There was a wider range in responses on the effects of burning plastic.
    - Of those that answered, 3 said it was good, 9 said it was not good, and 5 didn't know.
    - Some answered that it pollutes the environment and negatively impacts personal health.
- Of those who responded, only 70% of individuals were aware of recycling.
    - Many of those who were aware had limited knowledge on the actual process.
    - All of those interviewed under 40 years old were aware of recycling; whereas there was more variety among older populations. The system could consider differing types of education based on age and the associated widespread knowledge and attitudes.
    - Since there is a general lack of knowledge about recycling, some form of communal education on its importance and practices may help participation in the recycling economy.
- No one in the interviewee pool recycled.
    - Some mentioned that they did know of people in the community who recycled.
    - From this, we can hypothesize that there is a low percentage of community members who recycle. This affirms the importance of incentives in the system to gather a high participation rate since recycling will be a new practice for many.

Community Events

- 88% of responses indicated they supported the community through time, money, or resources. Some examples of this include community labor, fundraising, or providing advice.
    - There is an evident want to help the community. The recycling system we designed aimed to uphold this through a communal fund which supports these efforts.
- 11 out of 15 respondents shared that they attended church. Many also indicated they attended funerals (7 responses) and festivals (5 responses).

General Overarching Thoughts

- The results from these interviews remained relatively consistent comparing different demographics based on age, gender, and location. This shows that many community members hold similar practices, views, and beliefs. For this project, looking at the feedback from these interviews seems to be applicable to most of the community. This eliminates the need to alter approach based on these groupings; rather, the general system should be applicable to all.

Appendix C: Recycling Manual

Proposed System Breakdown

Introduction

This manual is sponsored by Chief Osabarima Owusu Aboagye III of Akyem Dwenase and produced by a team of students from Worcester Polytechnic Institute. Our purpose is to propose a plastic recyclable economy to be implemented in the towns of Akyem Dwenase, Abompe, Batabi, and Tumfa. This manual is designed in partnership with the chiefs of these villages and is therefore specific to the needs and values of these communities. However, this system could be expanded and modified in the future to be applicable to other communities. This manual describes the larger objectives of the system as well as implementation strategies associated with the collection, processing, and incentivizing return of plastics. Each participating town is encouraged to modify the strategies described in this manual to fit their own agenda in this program as they see fit.

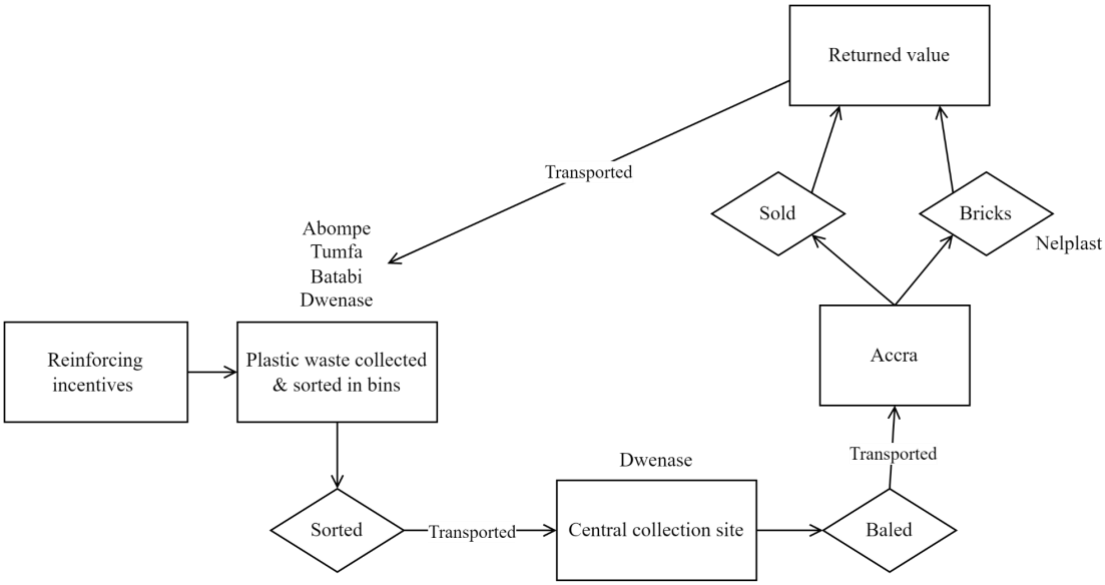

Figure 4. A graphic overview of the proposed system.

System Overview

System Goals

There are multiple goals of the recycling system.

1. Reduce the amount of dangerously disposed plastic waste[1]
2. Ensure continued community engagement in the system to increase recycling levels
3. Create returns in the form of money and/or building materials for both individuals and participating villages

[1] Recycling in Ghana is limited, with only 10% of plastic waste being recycled. Irresponsible waste removal, specifically the common practice of burning plastic, releases microplastics and compounds such as CO_2 and CO into the air, which have impacts on the community's health.

a. Provide returns for plastic brought in by individuals
b. Use communal bins and taxation system to support village needs

4. Increase local employment through recycling system

Village Network

The current scope of the recycling system includes four villages located in the Eastern Region of Ghana: Akyem Dwenase, Abompe, Batabi, and Tumfa.

Figure 5. A map displaying the villages involved in the system.

Within this system, the centralized collection site will be Dwenase. From here, it will be transported to Accra to be exchanged.

Figure 6. Two maps displaying the villages involved in the system in relation to Accra and a possible route from Dwenase to Accra.

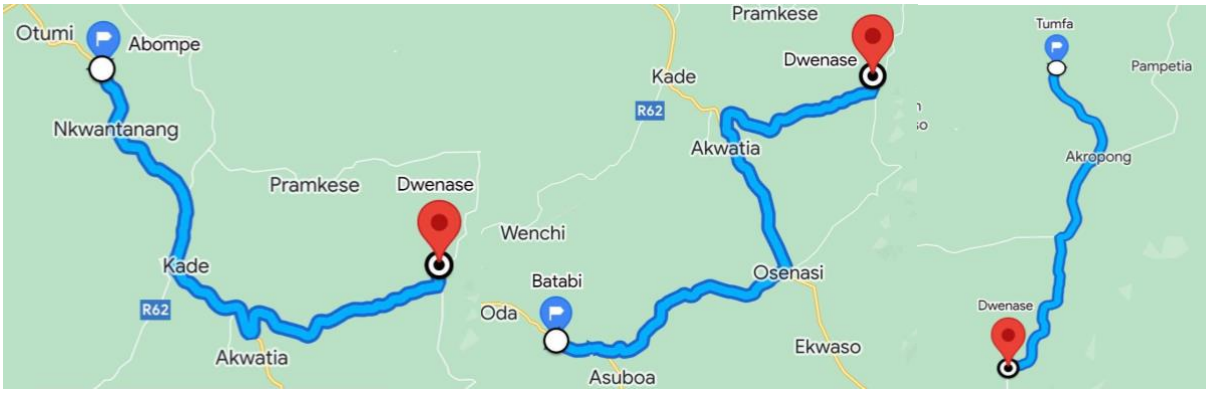

Figure 7. Maps displaying the driving routes from the villages to Dwenase. From left to right the maps show Abompe, Batabi, and Tumfa.

Collection

Collection Strategies

Based on feedback from the chiefs involved with the system, they suggested using education and announcements to help reinforce the collection of plastic waste.

Education

Through our conversations and experience in these communities, education plays a critical role in the development of the community and the social mobility of individuals within the community.

From this information, education can be used as a tool to get the community to engage in a plastic recycling economy. This could be done in numerous ways to explain the importance of recycling and increase participation for the system.

1. Explain the impacts of burning plastic on personal health and the environment
2. Introduce it into the local education system to reinforce the importance overtime
3. Explain to the community how the system works, including the returns to support local development, to eliminate confusion

Announcements

The chiefs and sub-chiefs of these villages take on an important authoritative role within the community. This is an important consideration for the system that can be implemented. Within this recycling system, the communication between the chiefs, sub-chiefs and each village will reinforce the system and help increase participation.

1. Speak on behalf of the importance of recycling
2. Support community education on how the system functions
3. Continue to remind the community about the recycling system for prolonged use
4. Communicate updates on returns and progress towards community goals

Process

The recycling system begins at plastic waste production. The most notable forms of plastic waste in this system are sachets and water bottles.

There are two options for collection: individual or community based. Individual or household collection would involve individuals compiling and storing their own waste. This could then be brought to a centralized location to be exchanged.

The individual would then be able to return the plastic to a larger collection site for monetary exchange. There is also an option to take a small percentage of individual returns and place that money into a community fund. This would ensure that individuals are getting money back for their own plastic and could serve as a source of income for some locals. Alternatively, a communal fund would help support public projects.

Community-based collection would consist of bins placed around each town. Individuals would be able to place their plastic waste in these bins, rather than being left scattered in the environment. These would be placed in more highly visited areas to increase their use. Examples of these areas could include:

- Schools
- Churches
- Funeral grounds
- Community events (festivals, funerals, weddings, etc.)
- Football field
- Households
- Workplaces (farms)
- Other prominent community areas

Another option for collection, recommended by the Chief of Batabi, is to organize the collection by clans rather than individuals. If heads of each family in a clan were responsible for organizing the recycling of their family, this would target two of our problems. Firstly, this would act as an incentive to recycle, as the returns are more directly returned to the individual compared to an entire community-wide return. Secondly, it would provide a better way to track individual returns.

Although this manual outlines many of these and helps account for the setup, much is still dependent on individual towns and issues may arise during the installation which the towns will have to combat. While many of the towns want individuals to recycle and get back equal returns, household bins will most likely be logistically unrealistic to implement the first year. Additionally, setting up a collection facility in each of the satellite towns and finding employment may also be unrealistic to set up until the system is fully established. A more individualized but still collective system, like the clan-based system, would be a good compromise; at least until the system is successfully operating years down the line.

In addition to either of these collection methods, the community would have the option to establish a pop-up plastic exchange market. During large events, like funerals, weddings, or political parties, where non-residents are coming to the town, there would be a small stand where people can get a small amount of money for their plastic. This plastic would later be combined with the greater centralized collection location. From here, it would be brought to a village collection site to be further processed and sent to the central collection site in Akyem Dwenase.

Options for Collection Workers

Should the village instill a collection worker to oversee the collection and/or transportation process, there are options for their compensation. As advised by our partners in the participating villages to maintain simplicity, compensation in the form of commission may be organized. It has been indicated that rather than wages, a certain percentage from the received financial payment may be taken as payment for the workers. This would eliminate the need for outside funding to create a more self-reliant system.

Another option for workers within the system would be to use communal labor. Community workdays or labor hours could be put towards keeping the system running. This could help reduce additional costs and put more of the financial return on the needs of the community. However, if it is a community effort then there would be more training required overall.

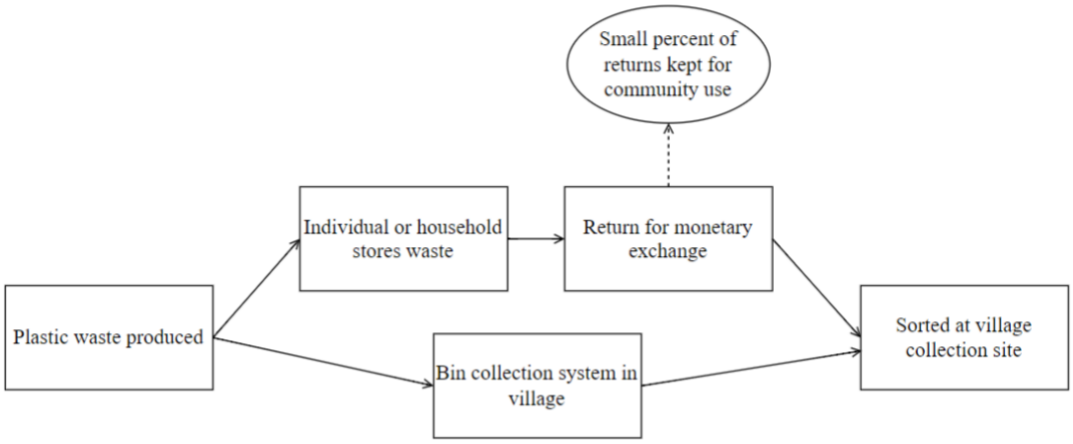

Figure 8. A diagram displaying collection options.

Sorting

For Nelplast to buy plastic, it must be sorted at the collection site by the producers. The plastic is sorted by type (sachet, water bottle, etc.). There are multiple options for sorting these plastics collected through the system.

One option would be to sort the plastic through multiple community bins. This would be accomplished by putting out additional bins that are labeled by the type of plastic. Posters could

be put up demonstrating how to sort the plastic and that the plastic should be crushed before they're disposed of. This could be a simple way to complete the sorting process gradually and without the need to spend money or decrease the returns by hiring additional labor.

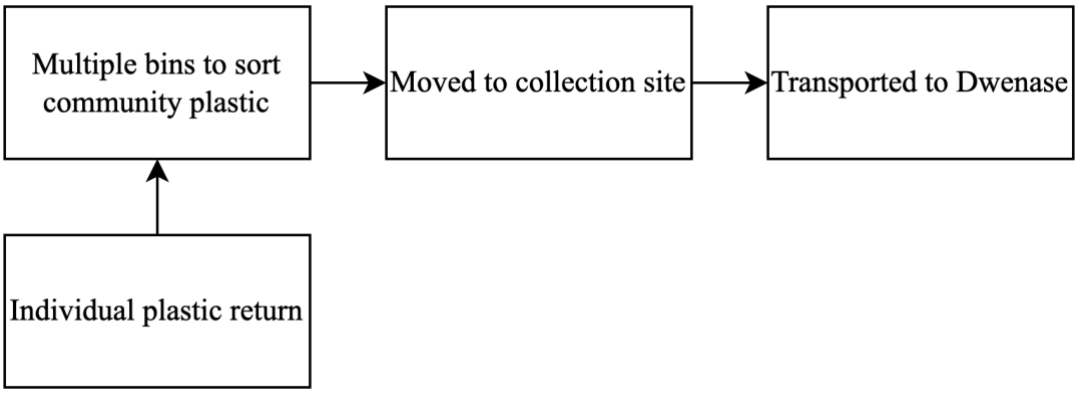

Figure 9. Option 1 for sorting which relies on community-based sorting.

The second option would provide employment but would increase the cost of the entire system. A job could be created at the collection site with the purpose of sorting the plastic by type. This person could then be paid by the local governments, or from the price of returns. This option would be further complicated once the other towns are included in the system. Each town would have to decide what makes the most sense for their community. Employing someone to sort and crush the plastic at the site would have slightly less returns. But it decreases the work for the community and provides employment. Another option is to collect the full value of the returns. This would require educating the community or providing visuals on the process to aid proper sorting.

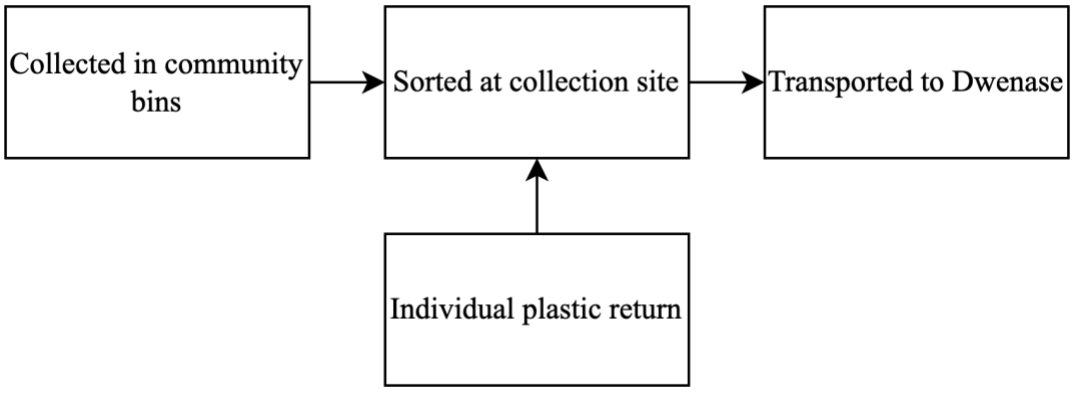

Figure 10. Option 2 for sorting which would hire employees to sort.

Baling

Options for crushing, or baling, the plastic:

1. Manually crushing the plastic.
    a. This would entail people compacting their plastic before they turn it in. Then, an employee at the collection center would further crush it into plastic bags before it is transported. This would be inefficient, and there is no assurance that it would be compacted enough to match Nelplast's standards to fit onto one truck. Nelplast requires loading 2 tons of plastic onto the trucks for transportation. According to a contact at Nelplast, the plastic could be manually pressed. This would also make less money; however, this is currently the easiest and most inexpensive method.

2. Using something that already exists in the community.
    a. We have been shown multiple tools within Dwenase that we can repurpose to either bale or shred plastic waste. Repurposing existing machinery would reduce costs and decrease training needed, as people in Dwenase are already familiar with their use and maintenance. Some of the machines we are considering include palm fruit presses, motorbikes, fufu machines, and clothing presses. One issue is the dual use. If we use something that has multiple purposes, not only are we decreasing its usage life, but we are also removing it from fulfilling its original purpose.

3. Creating something new but inexpensive for the community.
    a. Our next plan is slightly more expensive but would be more efficient and wouldn't take other equipment away from workers. If we can either buy or build an inexpensive machine (≈100USD), like a book press or levy system, we can eliminate the dual usage problem while building something functional and efficient. Enis Boateng, a project manager at WPI, recommended creating a manual screw press. The biggest issue is that we are unsure if we will be able to create enough force to overcome the compression force of the plastic and get it to hold its shape.

Figure 11. Image of a potential design: A manual screw press.[xiv]

4. Buying an inexpensive hydraulic press.
    a. The final solution is both the most expensive and the most efficient. If baling companies have a minimal and inexpensive baler, we could very efficiently and quickly compress plastic. This would eliminate a need for containers, as the baler can press with a force that exceeds the compression strength of plastic. The compressed plastic would then hold shape. Also, the baler is the safest as it comes with multiple safety breaks and could be used in the collection site for the sole purpose of compressing plastic.

Figure 12. Image of a potential design: A vertical hydraulic baling press.[xv]

Safety within the Baling Process

One of the major considerations is safety precautions. With any machinery there is a probability accidents will occur, but it is our responsibility to not only make the chance as small as possible, but also to educate the people working within the system on the possibilities and what the safest options are.

In terms of baling, a vertical hydraulic press will be the safest option. Manufactured hydraulic presses come with multiple different safety options, including safety latches that prohibit accidental crushing. The most dangerous would likely be manually crushing the plastic, as there is always a chance something could end up within the bins, like glass or sharp shards. If people are manually pressing the waste with their hands and no protective equipment, there is a risk of injury. Another alternative with some level of danger is building something new for the community. Especially if it's something like a manual press or a levy system, there is a large amount of force being pressed down, with no or minimal protections being put in place. This could be an area of future work, as a team that investigates alternatives to the baling process could also determine safety measures for each process.

Transportation

There are multiple options for transporting the plastic from Abompe, Batabi, or Tumfa to Dwenase. The driving distance between Dwenase and the towns is 36 km for Abompe, 49 km for Batabi, and 20 km for Tumfa. If a community collection route is used to include all the towns in one day, the best sequence of villages would be Batabi, Abompe, Tumfa, and then Dwenase, for a total distance of 119 km. Fuel costs are extremely subject to change, but currently are about 50 Cedi[2] per gallon. These price estimates include driver costs but not maintenance costs. They are also higher than average in the current economic climate. The best option will be decided and paid by each town. The options are as follows:

1. A **tricycle** is likely to be the best option, especially if it could be bought for an upfront cost of approximately 12,000-15,000 Cedi. A driver can be hired for about 50 Cedi per day. Alternatively, a tricycle can be hired for a daily wage of 100 Cedi. This could be a daily collection cost split between Abompe, Batabi, and Tumfa. A tricycle travels approximately 80-90 km per gallon. It must be noted that a driver's wage and gas prices will fluctuate. The approximations given are based on the current economic climate.
    - The fuel cost for one way transportation from **Abompe** is about 20-22.5 Cedi. If Abompe is the only town on the collection route for the day, the total cost would be about 90-95 Cedi in total with a community tricycle and 140-145 Cedi without for a round trip.
    - The fuel cost for one way transportation from **Batabi** is about 27-31 Cedi. If Abompe is the only town on the collection route for the day, the total cost would be about 104-112 Cedi in total with a community tricycle and 154-162 Cedi without for a round trip.
    - The fuel cost for one way transportation from **Tumfa** is about 11-12.5 Cedi. If Abompe is the only town on the collection route for the day, the total cost would be about 72-75 Cedi in total with a community tricycle and 122-125 Cedi without for a round trip.
    - The fuel cost for a collection route including **all towns** is about 66-75 Cedi, plus 20-22.5 Cedi to send the tricycle back to Abompe. The total cost would amount to about 136-147.5 Cedi in total with a community tricycle and 186-197.5 Cedi without, split between all three towns. This would be about 45-50 Cedi or 62-66 Cedi per town respectively.
2. A **small truck** is likely to be the best option if a large amount of plastic is being transported, especially if it could be bought for an upfront cost of approximately 70,000 Cedi. Alternatively a truck can be hired for an hourly wage of about 600 Cedi. A truck travels approximately 30-40 km per gallon. It must be noted that a driver's wage and gas prices will fluctuate. The approximations given are based on the current economic climate.

[2] All cost estimates in the transportation section were acquired by communicating with locals. All costs fluctuate with the market conditions.

- The fuel cost for one way transportation from **Abompe** is about 45-60 Cedi. If Abompe is the only town on the collection route for the day, the total cost would be about 140-170 Cedi in total with a community truck and 690-720 Cedi without for a round trip.
- The fuel cost for one way transportation from **Batabi** is about 61-82 Cedi. If Batabi is the only town on the collection route for the day, the total cost would be about 173-214 Cedi in total with a community truck and 723-764 Cedi without for a round trip.
- The fuel cost for one way transportation from **Tumfa** is about 25-34 Cedi. If Tumfa is the only town on the collection route for the day, the total cost would be about 100-117 Cedi in total with a community truck and 650-667 Cedi without for a round trip.
- The fuel cost for a collection route including **all towns** is about 149-199 Cedi, plus 45-60 Cedi to send the tricycle back to Abompe. The total cost would amount to about 347-447 Cedi in total with a community truck and 897-996 Cedi without, split between all three towns. This would be about 115-149 Cedi or 299-333 Cedi per town respectively.

3. **Trotros** could be used to transport the plastic waste. Reusable sacks are commonly used for transporting goods.
    - A trotro would cost about 5-15 Cedi per sack for **Abompe**
    - A trotro would cost about 10-20 Cedi per sack for **Batabi**
    - A trotro would cost about 2-10 Cedi per sack for **Tumfa**

Return Options

The most important aspect of this process for the individuals involved are the options for return. Each community has different needs, and therefore will want different returns. We have worked through the basic set up process for two options: Either the community's plastic is returned for an equivalent monetary amount, or the plastic is made into recycled building materials and returned to the communities for their community work projects like health or education centers. These incentives can also be combined in any ratio.

Nelplast Eco Ghana Ltd.

There is also potential for the system to work in partnership with Nelplast Eco Ghana Limited. The company is based in Tema, in the Greater Accra region, and was founded by Nelson Boateng. Nelplast produced eco-friendly building materials from a mixture of sand and plastic. These include Eco-bricks, pavement blocks, and the potential for other building items in the future. Their production process is displayed in the figure below.

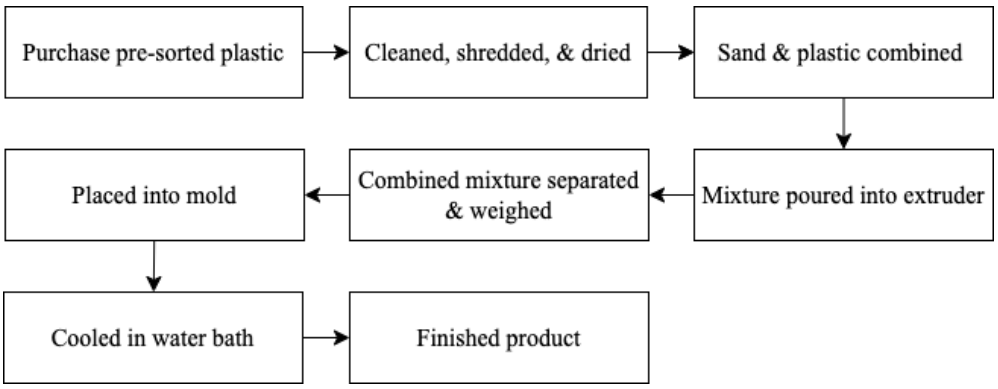

Figure 13. Nelplast production process.

Nelplast has agreed to purchase the plastic from Dwenase and pay for the transportation. However, they require that the plastic is baled or compacted enough that a truck could compact about 2 tons of plastic.

There is also a possibility to explore a direct exchange system with Nelplast. This would entail getting eco-bricks back from the plastic waste. While the company is open to this idea, there is limited information on the logistics of this interaction such as how much plastic would yield a block or how these bricks would be transported back.

Incentives

Each participating village has outlined unique priorities for returns from the plastic collected. In partnership with Nelplast, there are several applicable strategies that villages can choose from to best support the community and ensure sustainability of the economy. These strategies are outlined as follows:

Individual Return

The Individual Return strategy allows individuals to collect the entire value of the plastic they give.

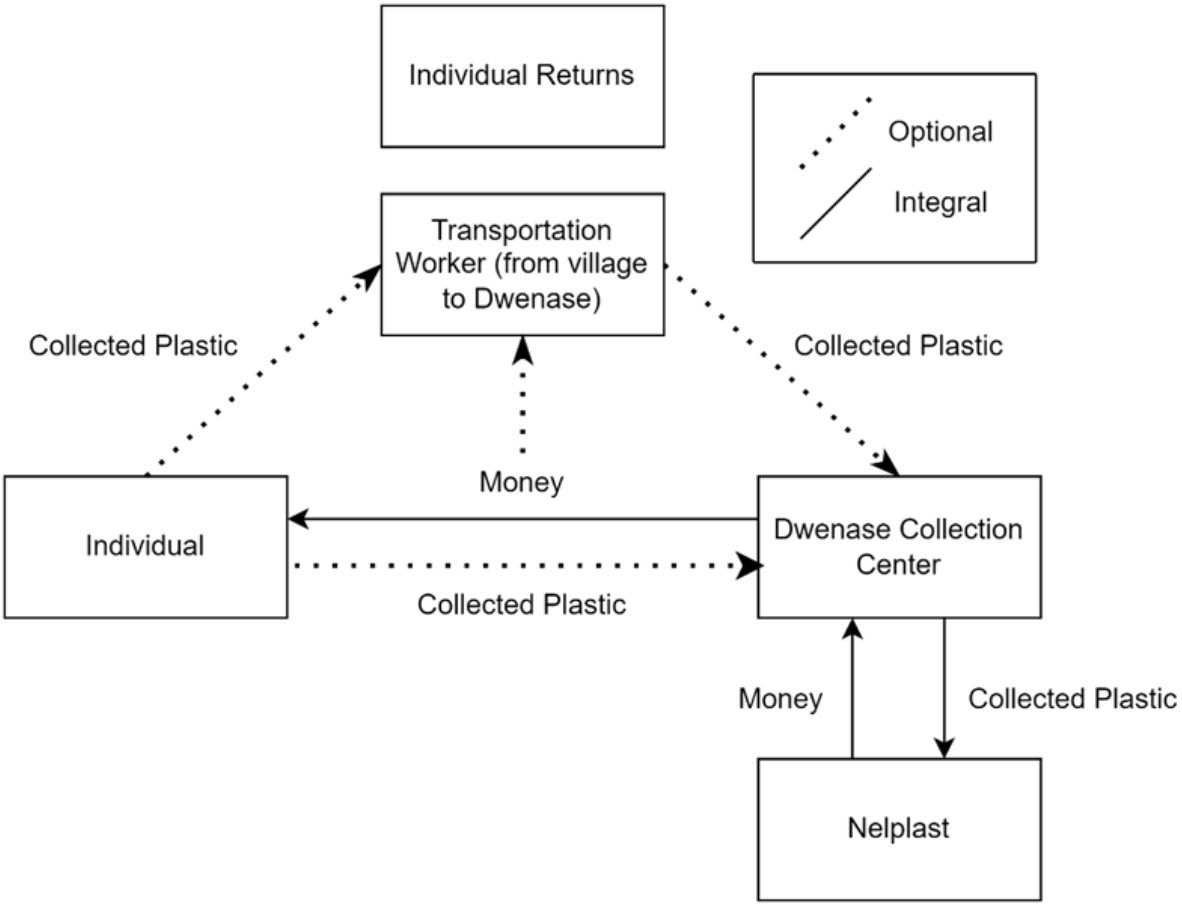

Figure 14. Individual incentives model.

Individual Monetary Incentives

Plastics can be exchanged by individuals for financial incentives. Once weighed, the individual would receive a monetary payment proportional to the amount and type of plastic, for example, sachet or plastic bottle. With current approximated return rates, Nelplast would exchange one cedi and fifty pesewas for one kilo of sachet and bag film and one cedi for one kilo of plastic bottle. These prices are subject to the current market price for plastic waste by Nelplast.

Pop-Up Exchange Market

An optional addition to the recycling system is creating a pop-up plastic exchange market at community events such as festivals and funerals. Non-resident community members would be able to bring their plastic to the market in exchange for monetary returns, similar to the individual model.

Community Based

The Community Based strategy allows the community to collect the entire value of the plastic in the form of money or building materials rather than returning the value to individual collectors.

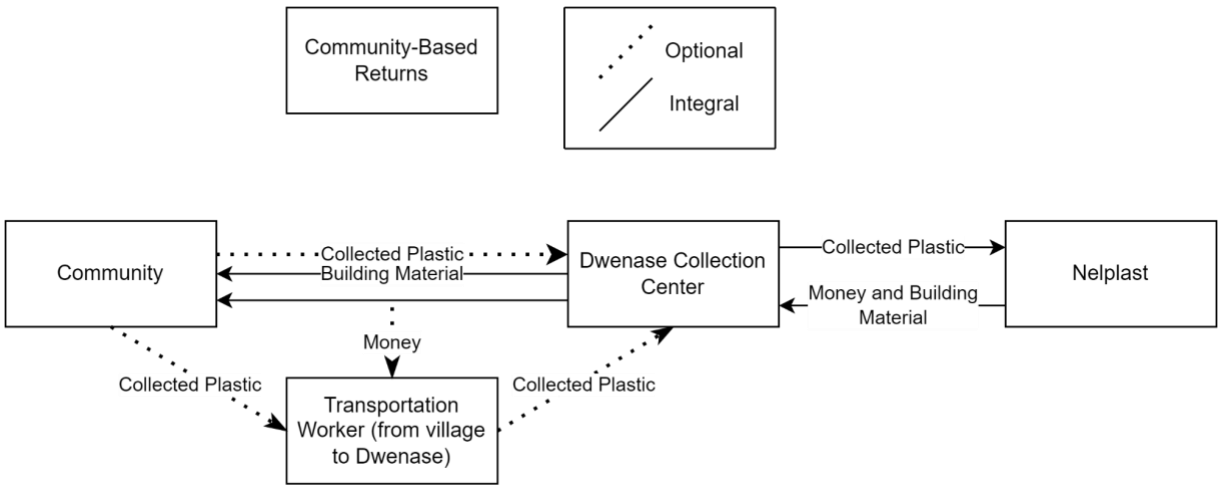

Figure 15. Community based incentives model.

Monetary Incentives

Like the individual monetary return model, the community monetary return would sell the plastic waste to Nelplast at the market price. However, instead of the money going to the individuals who collected plastic, the entirety of the returns would be put into the community fund for projects the town wants, such as building a health center or housing units.

Building Materials

Should a village wish for returns in the form of building material rather than only financial incentives, Nelplast has agreed to exchange a village's plastic waste for Eco-bricks for the community to use. The need for teacher residences, permanent healthcare buildings, and other constructions have been brought up in discussion with participating villages. An exchange rate has yet to be established; however, each Eco-brick is 8 cedis. For the system, we estimate the return rate will be of similar value.

Clan-Based

Another community-based option would be to give the returns to clans rather than individuals. Instead of the small amount of money each individual would receive, the returns would be given to the individuals' clans, allowing it to accumulate into a more substantial fund. This would be used to help the family as a whole. This could be implemented with either or both monetary incentives and building materials.

Hybrid Model

Using a hybrid model, a village would combine any amount of the individual and community return strategies as the chief and community sees fit. This could manifest, for example, as a community tax on individual returns or a system that returns money to individuals as well as Eco-bricks to the community.

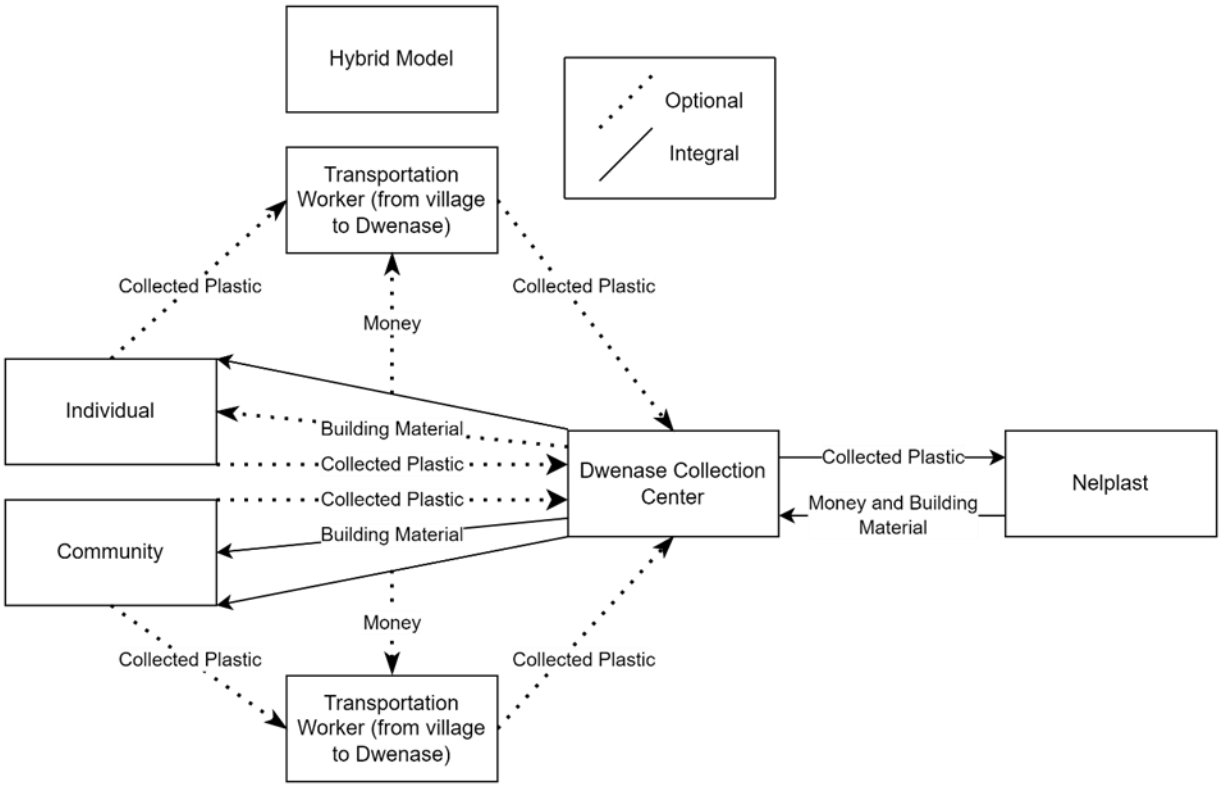

Figure 16. Hybrid incentives model.

Community Tax on Individual Returns

Within the individual return model, there could be an option to take a percentage of the returns to go towards a community fund. For example, when an individual brings 2 kg of sachet plastic waste, the total return value might be 3 cedi. If the community tax is 20%, the individual would receive 2 cedi 40 pesewas and 60 pesewas would be collected to the fund. This fund would be used for community projects decided upon on a town-by-town basis. These projects could include the construction of a health center, building teacher housing, and more.

Financial Individual Returns, Material Community Returns

The final option explored in this manual will be one in which the return value of the plastic will be split by some set proportion between monetary incentives for individuals and material returns for the community. These material returns would then be used in construction of a community project, whether that be for teacher housing, permanent healthcare structures, or other.

Other Considerations

Some of the aspects of our project will need to be considered by the individual towns without our intervention. In following the co-design process, each individual town must create their own system. This manual is only supposed to outline the overall process, allowing for the towns to create their systems. An example of this is bookkeeping. A major aspect of the system is keeping track of who contributed how much plastic, and how they will get back an equivalent return amount. If a town chooses to have a more decentralized system, the need for bookkeeping will be decreased as the community will be receiving all the returns, and Nelplast/Dwenase will do the majority of keeping track. It will also be simpler because the plastic will be brought in larger amounts by fewer people. If a town believes that individuals need to get returns to be motivated to participate in the system, then a greater amount of recordkeeping will be needed. The more people there are to keep track of, the more intense the system needs to be. This will have to be a consideration for next year's team, and for the individual towns.

Another consideration is the transportation of building materials back to the towns. If a town chose either to get returns as money and building materials, or just building materials, it will need to be accounted for how those materials get transported back to the towns. Although Nelplast will pay for the transport from Dwenase to Accra, they will not pay for the transport of the blocks back to Dwenase or the satellite towns. Whether the towns want to pay to transport them back or negotiate with the transport companies to pick up the bricks on the way back to pick up plastic, this will have to be considered, especially as it could be another cost to the system.

Appendix D: Legacy Document

This document is a guideline of our engagement with the community, partnerships, and logistical information to help provide a cohesive shift to next year's team.

Network and Contacts

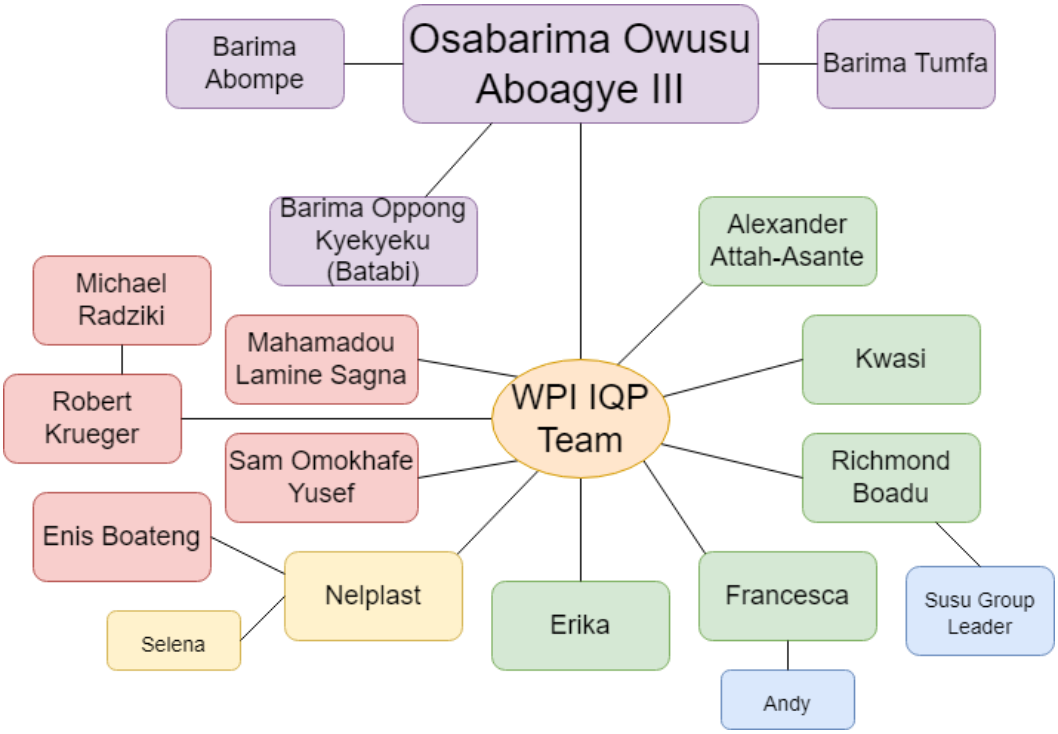

Figure 17. Community Engagement Diagram.

Figure 17 shows the network of people within the Dwenase and Worcester Polytechnic Institute (WPI) communities who have contributed to the execution of this project.

Within the Dwenase community, primary contacts include Boadu and Francesca. Boadu, the village linguist, has assisted in connecting with other community members, such as a local Susu leader, where we learned of its limited application to the recycling system. Francesca, the head teacher at the Secondary School, provides a connection between the research team and the school, which has led to information gathering of the logistics of the plastic storage within Dwenase. Osabarima tasked Francesca and Kwasi, the head farmer in the village, with setting up the recycling initiative. Alexander Attah-Asante and Erika have each influenced the project as community contacts.

Nelplast, a plastic recycling company in Accra, and one of their employees Selina Ama Segbefia have been an integral part of the project network. This company played a large part in determining the logistics of preparing and transporting the plastics to Accra.

Through WPI, we have been working with our advisors Professor Mahamadou Lamine Sagna, Sam Omokhafe Yusef, and Professor Robert Krueger. Other important WPI community members include Professor Radziki and Enis. Though not an explicit example of our team's local engagement with Dwenase, it is an example of further collaboration with the WPI campus. The level of connection we require to develop this economy runs deeper than the individual and relies on these contacts, networks, and engagements in America.

Steps Taken by 2023 Project Team

Community Engagement

Ethnographic Study

With all the changes that developed throughout the duration of this term, we pivoted our focus to put more emphasis on the ethnographic aspect of the project. This included talking to our advisors, the community, and noting relevant observations to create a project fitting both the needs of the community and our goals. Rather than focusing as intensely on the logistics of the project such as the mapping, collection routes, and Nelplast-centered aspects, we engaged with key individuals who would make more significant changes to our plans through critical conversations, which will be explored in the following sections.

Formal Leadership

The King

On Monday, January 16th, we traveled as a project group to meet the Okyenhene - the King of Akyem Abuakwa - Osagyefuo Amoatia Ofori Panin. His lecture to us expanded on his view on women, education, and the environment, stressing the importance of supporting marginalized groups and the region.

Meeting the Okyeman King broadened our view of the history, current culture, and future of Ghana and Dwenase. The King's discussion of his goals for the future helped define the context of the project. Understanding that which is important for leaders within the Ghanaian community draws attention towards values and institutions they consider relevant to their future.
Osabarima

We had many conversations with our advisors, Professor Krueger, Professor Sagna, and with our sponsor Chief Osabarima Owusu Aboagye III. This allowed us to gauge what they wanted from our report, and what would be possible in our timespan. Based on these conversations, we decided to shift from a manual focused on creating a Susu-based recycling economy. Instead, we used interviews to write a research paper connecting community values to incentivizing recycling, as well as a broader manual with further details on setting up a recycling system.

During ID2050, we worked on establishing an understanding of the basic topics around which this project was centered (such as Susu and systems dynamics). On the ground, we were tasked with communicating with Osabirma and the Dwenase community about the information we collected and plans we had developed to ensure they were in line with him and his community's needs.

There were certain logistical inconsistencies demonstrated, such as our understanding of Susu, the logistics of working with Nelplast, and community values. We determined a need for more cohesive communication with the Dwenase community before moving forward with the project.

In the light of the discussion, we had with Osabarima on January 19, in which he surprised us by asking us to shift our focus in ways we were not expecting, our group discussed how to proceed with this project. This not only changed the scope of our project, but also our research process moving forward. For example, we have learned the importance of contacting the Chiefs of each community early and clearly communicating our project to them. We recognized the importance of building deeper relationships with our Dwenase partners as we work together more closely. These two things allowed for less miscommunication. We also began to expect that, while an ethnographic approach indicates the importance of implementing all community needs into the model, it may be impossible to do so.

Our group has reached out to Professor Sagna and Professor Krueger to discuss this term's project direction, due to these changes. Continuous conversations about what our advisors and sponsors want out of this project became top priority for the team to continue working to keep this research responsible and community centered.

During the meetings with Professor Krueger, and with new information about Nelplast and the limited Susu groups in the community, we changed the scope of the project to focus less on Susu and recycling logistics to a heavier focus on an ethnographic approach. To reach this goal, we were advised by Professor Sagna to conduct interviews with as many people as possible. We expect to begin this process once the IRB, ensuring ethical research methodology, has been accepted. On the IRB application, our goal for the interview process was described as the following:

"Through interviews, we aim to take an ethnographic approach to collect and analyze information on the perspective of the larger community of Akyem Dwenase, Ghana in relation to recycling and economic structures already in use. The goal of this questionnaire is to get a more in-depth look into the traditions and values of the community. These questions will act as a guide for conversation with members of this community."

Designing the IRB application and interview questions was a major focus. We wrote documents describing the interview questions, methodology of research, and a summary of

important information. We relied on our Dwenase contacts in the creation of these documents, as Boadu helped us create a translation for our verbal consent script and advised on certain methodology logistics.

In preparation for the interview process and through the IRB, we had to shift our approach to communication with the community. We had several meetings with our advisor, Professor Sagna, to design the questions. We also discussed their wordings with Issac Asante, to ensure comprehensible wording. In and out of these meetings, we looked at each question carefully to make sure it would elicit effective and relevant information. We then discussed this interview with Alexander Attah-Asante, one of the advisors to Osabarima. This conversation was enlightening, gave us more relevant background information, and helped us shift the content of our interview questions. For example, we noticed the length of the interview and decided to cut down on unnecessary questions (keeping in mind that some interviewees may be less talkative). Much of the information covered was not specifically asked for, which affirms that our list of questions is not only designed to target specific information, but also provides some leeway for the interviewees to share what is important to them. We also noticed that, despite our efforts, some questions remained unclear to Attah. Although during interviews, we did have a translator with us, we had prepared to rephrase our questions on the spot if the interviewee is having difficulty understanding. Preparing ourselves for the impact of a language barrier helped create a smoother interview process overall. However, we also believe that it could be informative if people were to interpret a question in an unintended way. Their unpredicted answers could give us insight into what is important to them.

Chiefs of Abompe, Batabi, and Tumfa

We began engaging with the Chiefs in the other towns participating in the model. We have written out and are prepared to send an introductory message explaining who we are and what our project entails. For simplicity's sake, we are waiting until next week after getting more clarification on the project before proposing any plans and getting feedback. Additionally, on our way back from visiting the King, we stopped in Tumfa and formally introduced ourselves.

In terms of speaking to the other communities, we were able to connect with the two of the other Chiefs and had discussions with both. We were able to determine what they wanted to get out of a recycling system and how logistically we will include that into the manuals. From this, we were able to finalize the direction of working towards community projects rather than individually incentivizing.

We also met with several Chiefs. Our introduction to the Chief of Batabi (via phone call) did not have major impacts on our goals and future work. However, it did affirm that Batabi, as one of our community partners, is motivated and confident in the project direction. This is important, as it indicates success in our attempt at co-design.

In response to the current project direction, the Chief of Batabi was encouraging and seemed interested. He noted that he would be happy to take the necessary steps to implement the system and that he believed there to be two important forces that will effectively motivate the community to recycle: education and announcement. Education, which is very important to him, will help people understand why recycling is important. Announcement of policy will encourage people to act. He indicated that it might also be helpful to select people to monitor the bins, saying that this would be "not something difficult at all."

When we asked about financial support and community giving in Batabi, we were told that they have tried community fundraising for "repairs in the community." He himself also personally contributes to the community by cooking and buying items to give out on Christmas last year. Lastly, his focus now rests on the health center, which he says needs to be developed.

In response to the questions, we asked him, the Chief of Batabi gave insight into personal, community-based, and logistical relevancies that will be noted and considered moving forward. As the project has shifted into an ethnographic approach, this conversation will be a useful piece of the puzzle and can be analyzed as such to understand the bigger picture of the values of this region of Ghana.

When asked about what being a Chief meant to him, he said that as Chief, the community sees him as someone who can bring development. This indicates that he sees this economy as something he could implement to give back to his community, which affirms our codesigned project statement. With this, we can expect to highlight the role of the Chief in the model of the economy. There are varying levels of participation that we have been expecting from each member of this economy, and through community engagement, we are discerning where these levels of participation realistically lie.

Another important outcome of this phone call is the establishing of a connection. Before ending the call, we set up a day and time to meet in person next week. We were told that if we have more questions, we should reach out to him again.

We also conducted a phone conversation with Barima, the Chief of Abompe. Though he had less time to spend with us over the phone, and therefore we were not able to ask him as many questions as we had with the Chief of Batabi, it was still necessary that we established a connection and scheduled a second meeting to be in person.

Our meeting in person was formal. Everyone introduced themselves and we told the Chief why we were there. Regarding future work for this term, we expect to reach out again over Whatsapp to ask more questions or schedule an informal meeting if time allows.

During the meeting, we noticed that the questions we were asked by the Chief were very logistical and showed a misunderstanding of the project scope. Much like one of the

conversations we had with Osabarima of Dwenase last week, the Chief of Abompe was under the impression that we were helping to implement the system rather than design it. This again reaffirms the importance of clear communication and codesign - everyone on the project team including the Chiefs should understand the work we are doing so that they can contribute to it in an informed way and the project can fit their agendas.

One example of a question he asked was about the collection process. He was worried that people would not transport their plastics back from the farms they went to during the day. This gave us pivotal information about the community of Abompe. Even though both Dwenase and Abompe are mostly farming communities, each has a different concern in motivating their residents to recycle depending on other factors, in the case of Abompe, distance between work and home. Finding out what these factors are, in addition to the values of the public, is important.

Answering our questions for him, the Chief noted that he prioritizes healthcare, as they have service providers but no place for them to work. This could allow us to focus more on Eco-bricks rather than financial community giving in the manual for the recycling economy. However, he also noted that the community will not recycle if the individual does not get immediately reimbursed. Because this is different from Dwenase, where we were told the public would recycle without individual financial gain, we may need to design different optional procedures for reimbursing the contributors so that each town can implement the one that works for them.

More information was given and received during this meeting. Though not all of it is included in this document, it has been considered in the creation of the deliverables.

Though many of the interactions we've had have been helpful for our project, because of the demographic breakdown of our group, we have run into issues in adequately communicating our project design. In our meeting with Abompe, each of us went in prepared to fulfill certain roles. When we arrived though, that preconception was quickly broken. After we each introduced ourselves, we were told that we were going to follow the customary Ghanaian customs. One of these customs is that when a man travels with women, the women do not communicate their purpose for traveling. All three female-presenting members in the group had to sit in silence as the male member spoke about the project. Since those who prepared the introduction and questions were couldn't speak initially, it was increasingly difficult to communicate. The chief maintained his misunderstanding of our project and his answers came from this misconception. Although we did get some relevant information from the meeting, it was not nearly as helpful as it could have been. In future meetings, we needed to take a different approach because of this interaction.

Combining Conversations

Understanding what is important for leaders within the Ghanaian community drew our attention towards values and institutions considered relevant to their future. We intended to monitor any broader impacts to these from conducting research. Contacting other local leaders resulted in similar impacts. Some of the leaders in Dwenase, such as Chief Osabarima, Francesca, the headmistress of the Secondary school, and Kwasi, the head farmer, were an integral part of teaching us what the future of the town might look like.

For example, the King, Osabarima, and Francesca drew our attention to education. Community members, such as Paul (a national police officer stationed in Dwenase), spoke of Osabarima and past chiefs' active role in developing programs. Within the village, this included a focus on job production and education. Osabarima has specifically discussed putting money and resources into schooling. Combined with local commitment to scholarship and hard work, this has paid off. Francesca shared in her speech at the 60th Anniversary of her school that over the past few years, the school has seen significant amounts of academic progress. She noted exam scores increasing over time from 60% to 100%. We plan on learning more about education in Dwenase.

Osabarima has been striving towards other developmental goals. One of these includes building a hotel for the community, using his contacts abroad to bring international students from WPI into his community and work with them. He also plans to promote tourism with Dwenase's natural resources, such as historical caves near the gold mines and waterfalls.

Understanding the leader's goals for the future helped build a co-designed project. We could better observe and monitor the impacts this project will have on the community. Working on this project, we do not personally have a cohesive understanding of the community's needs. Thus, the co-design process is crucial to weigh the pros and cons of potential impacts and pivot the design accordingly.

An example of this is how we considered the idea to add a Nelplast satellite factory to Dwenase. Before talking with Nelplast personally, we were advised there would be a Nelplast factory put in Dwenase. Though it is an unlikely option, we did discuss how a satellite factory might impact the plastic recycling economy, as well as local social and cultural aspects of life. We examined the impact outsourcing versus local labor might have on the people and resources of the village and how to mitigate these hypothetical changes.

This mindset was useful for other topics discussed throughout this project. Considerations such as where plastic collection bins are placed, who is collecting the plastic, and who is given the money to distribute, among other very important parts of this economy, are expected to produce many broader impacts for the community at large. Bringing these impacts to light will increase the chances that the recycling economy is sustainable and avoid unforeseen damage.

Additionally, we worked more with Francesca and Kwasi on recycling logistics. We discovered that they were assigned to work on recycling in Dwnease a few years ago. With this, Francesca specifically helped determine the best way to bale the plastic. Based on our experience, as engineering students in America, we would have a very specific decision-making process. We would be mainly considering efficiency and cost as factors. In this process, we do not have control over all the variables. It is not up to us to decide how much money Dwenase should be spending on the system. Instead, the manual we created encompasses a variety of available and reasonable options. We detailed out what is important to the community and provide recommendations based on conversations with locals. This covers the safety, cost, ease of use, and efficiency of each of the options. In some cases, we took on a more intermediary role, acting as the middleman between Nelplast and Dwenase. By gathering information on behalf of the project, we aimed to help create a system that will work the best for both parties. Overall, the communities' expertise allowed us to gain valuable contact points within the community.

Experts Beyond Formal Leadership

The first interaction on the ground was with Richmond Boadu, the linguist of Chief Osaburma Owusu Aboagye III. This discussion focused on getting more information about the culturally specific social and economic systems at work in Dwenase, as well as to determine preliminary logistic information about recycling in the community. Relevant information we learned included that it is possible to stratify local economic levels, that half of the population of Dwenase live outside of the village, and there are no homeless community members. We learned that sachets are the most used source of drinking water and that the most efficient sites to put plastic recycling bins, based on population density and popularity of location. These include the schools, churches, the local field, households, and commercial centers.

We also discussed Susu, learning that there is only one Susu group in town, and that being part of one is "not very common." We later learned that this group functions as a microfinance group; rather, it is colloquially referred to as a Susu. Boadu also discussed funeral costs, another economic system in the community.

In the discussion of current recycling practices, he said that there are a few individuals who pick up and recycle plastic for money; however, many people have professions in gold mining and farming because of the higher salaries. The salary for common occupations is more informal and fluctuates based on many aspects. Giving an average figure is very difficult, but Boadu provided an estimate for what people spend in a day: about 20 cedis.

Though many of our interactions had positive impacts on our project, some interactions were at odds with the community's understanding of our work. When we went to weigh the plastic sachets, we instead found out that our partner Francesca had a completely different idea of our goal. She believed that we were implementing the recycling system and got the

schoolchildren to bring us more plastic waste. Though we have since cleared the air about our project, we needed to be clear to successfully work with and for Dwenase.

One of the more drastic changes in the project resulted from the meeting we had with the organizer of the only Susu group in town. He explained to us the premise of his business, the details of which we will omit for anonymity.

Based on the individual nature of the Susu system, we concluded that it is largely irrelevant to a community-based collaborative system such as the recycling economy we are proposing. We considered this evidence towards shifting the project scope towards an ethnographic approach. Rather than looking at the hyper specific community of Susu in the Dwenase area, a broader view of the community would provide a better understanding of financial and social economies in the area. From this, we sought to do interviews to gather a better sense of this information.

Community Members

Since we lived in, constantly interacted, and extensively worked with the village of Dwenase, we had the most community-charged development on our project. Most of our interactions have been with the children, Chief Osabarima, Boadu (Osabarima's linguist), and Francesca (the Headmistress of the secondary school).

There was a multitude of interaction between the children and the WPI students. Every night, the kids came and visited us. They mostly talked, played, or hung out with us while teaching Twi or getting help with their homework. The children appear to enjoy school and take their schoolwork seriously. They talk about education as something to be proud of and value it above a majority of institutions in their lives. The children showed us the importance of both community and education.

Francesca and Osabarima both corroborated and emphasized education's key role in the village. In an informal setting, three of the project members talked with Osabarima about the importance of education. He explained how far education takes the children and how important it is to further the community. Francesca took pride in where she had taken the school in her time as headmistress, and again what she was able to help support in the town.

We also interacted with the community outside of the workday in other ways; these included both formal events, such as the Festival on January 10th or the 60th Anniversary Celebration of the Secondary School on January 14th, and informal gatherings, like playing soccer with children in the village.

During the Festival, we witnessed and participated in donations. This alerted us of an important economic system functioning in the town: community donations. While children

danced and other festival activities occurred, attendees contributed money to a communal bowl. This informed our understanding of the financial support structures acting in Dwenase.

We also discussed donation systems with Boadu; he informed us about other economic systems at play, such as the process for funeral donations. After a child completes secondary school, the head of their family writes their name in a book as a contributor; when a contributing member of the community passes away, each living contributor is required to give a set number of cedis - around 1 cedi - to the bereaved family. This contribution helps cover the expensive cost of a funeral.

Another formal event we attended was the town soccer tournament. During and after this event, we saw a large amount of plastic litter on the field, mainly in the form of sachet water bags. Yet, within 24 hours, people cleaned up all the litter. While we are unsure how it was disposed of, it demonstrates a community initiative to keep local areas plastic free.

Other informal discussions with children shaped our understanding of the community's desires from our partnership. Multiple groups of children told this IQP cohort that the biggest need in Dwenase is paved roads. Within our own travels in Ghana, some of the roads require extensive maintenance. Though we haven't yet seen any pavement, we heard that the government is currently in the process of paving the main road. Similar infrastructure goals might inform where the returned funds could be most effectively spent to improve quality of life and incentivize residents to participate in the economy.

Community events are critical to our understanding of Dwenase, and we tried to attend as many as we could; however, we were unable to attend all types of events. One primary type of event we missed was funerals. During the drive back from Abompe, Boadu informed us of a funeral happening over the weekend while we were traveling on an excursion. Since we couldn't attend the event, he discussed the funeral process. This process displayed important themes in Dwenase's community such as communal grieving and celebrating.

After the missed funeral, we were able to witness local village elections. We heard about them through word of mouth; Chef Erika ran in a race. This indicated the importance of word-of-mouth communication. While at the election, we met with Boadu, who explained that candidates were running to oversee the polling stations. We were able to visit two of the three stations: one at the funeral grounds, which seemed very quiet and organized, and one at the field near the Secondary School, which seemed the opposite. Voters began verbal altercations which escalated until they involved many people. Though we did not understand what was said because the conversations occurred in Twi, the voters laughing and calmly conversing around the arguing group indicated a light-hearted nature to the election. Two things were clear from this juxtaposition; people cared about the topics at hand, but general community support remains stronger than political boundaries in Dwenase.

Watching parts of these elections showed a section of Dwenase that we had never seen before. We had interacted with traditional leadership such as the Chief but not with popularly elected figures. This informed our view of leadership in the village, which is important when examining the public's motivation to contribute to the community and environment through recycling. Inspired by the polls, possible future work for this term might include reaching out to elected officials for their opinion on interacting with Dwenase's public.

Another informal community interaction we had was helping cook groundnut soup with Erika. The women cooking were all chatting in Twi while cooking, briefly pausing to explain their cooking process in English. This gesture indicated a willingness to share knowledge with people outside of the traditional roles. They each knew exactly what to do while cooking and split the work equitably, operating as a close-knit group that shared many resources. This was most evident while making the rice balls, where they made an assembly line for each person to perform a different role, and when they shared water sachets and the food amongst themselves. After finishing the soup, they were already preparing another meal for the funeral later that same day, showing Dwenase's reliance on their work. Interacting with female dominated spaces in Dwenase is essential to ensure that women can benefit from the recycling system as well.

Understanding these different types of economic systems and community interactions gives a better insight into the driving motivations of Dwenase. This inspired us to consider a wider array of possibilities when designing the method to incentivize recycling. Some initial brainstormed options are as follows:

1. Collect plastics just in households
2. Collect plastics individually or in self-defined groups (households, Susu, religious, social, etc.)
3. Collect plastics in households (or groups) as well as communally
4. Collect plastics in Susu groups only
5. Collect plastics communally only

The above options would result in collectors directly receiving plastic goods manufactured by Nelplast, monetary compensation, or both in some sort of set proportion. However, after engaging with the town throughout the term, we updated and refined the incentive structure informed by the co-creation process. The specifics are outlined in the 'Incentives' section of our manual.

Some of our considerations in differentiating and selecting options included: the simplicity of introducing and carrying out the system, the level of individual against communal economic incentive needed for sustainability, the potential to support marginalized groups and people with special circumstances within the system such as women or non-residents traveling back to their community, flexibility and utility of the products of the system, and the availability of plastics to recycle - sachet bags commonly available, but this may not continue. Although they

are cheaper, they are becoming less popular as they are less consistent; sachet water has been found to have more bacteria than other purified water sources. In the future, we need to evaluate all forms of plastic waste, especially those packaging water or serving other essential functions.

Nelplast

To gain insight on potential incentives, we spoke to Enis Boateng, Nelplast CEO's brother and one of our project advisors. He helped set us up with a tour of Nelplast and answered questions regarding how Nelplast products could fit as community or individual incentives in our system. Through him, we were able to discuss ways we could increase the buying price for plastic to put more money back into the community. We also discussed methods of changing the incentives; rather than buying the plastic, Nelplast could exchange it for Eco-bricks or decreased pricing on Nelplast housing units. These options should be considered so we can best utilize or distribute incentives when enabling the economy.

The tour of Nelplast was one of the key experiences we had that pivoted our project. Before our tour, we thought the plastic would be brought to a processing plant in Dwenase. There, it would be manufactured into recycled roofing material. Roofing was thought to be a highly incentivizing material not only because it is in high demand, but also because it would provide immediate benefits to the community. Whereas a building made of Eco-bricks might take an extended amount of time to construct. However, after we met with Nelplast and talked about the feasibility of these plans, we worked with our advisors to find a path that would both allow us to complete our project and successfully fulfill the community's requests.

Logistical Steps

Much of the logistical information gathered throughout the term can be found in the Manual document included in the Appendix of the Final Report. However, more research into certain topics is necessary before project implementation. The scope of this research is subject to the project direction chosen by future teams.

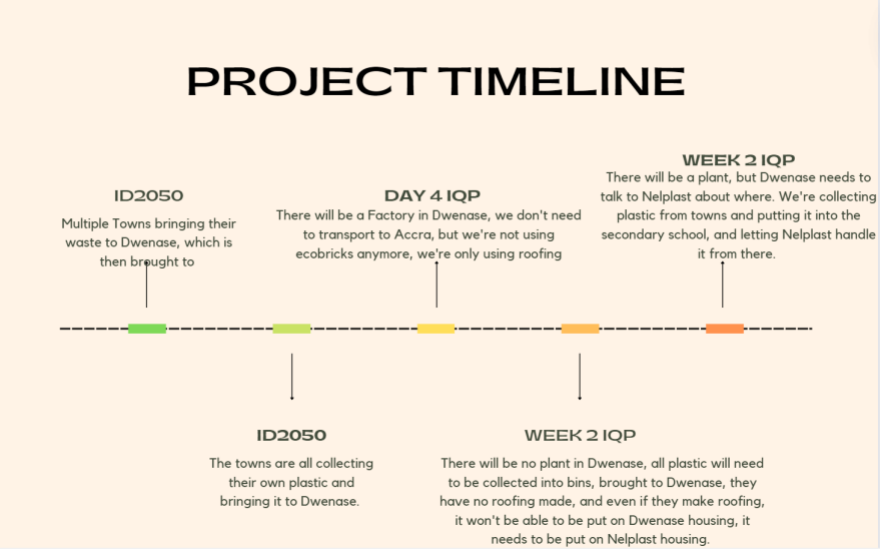

Figure 18. Timeline Describing the Team's Changing Understanding of Project Logistics

In terms of logistical steps, the most important consideration for the setup will be working with the towns to create the system that they want. The 2023 team has determined the incentives, and the basic outline for the system and the incentives that will ensure it will run. Ironing out the details so the system can be implemented will be the next step.

At the most basic level, the system works in the following way. Four towns will each collect plastic. Said plastic will be collected in bins placed in high traffic areas, by clans, and at highly attended events. By the bins and the collection sites will be posters and other educational methods telling people how to sort the plastic, why plastic/plastic burning is harmful, and what can go into the bins. Each town will centralize their plastic in one location. Three of these towns, Abompe, Batabi, and Tumfa, will then transport their plastic to Dwenase. Sometime down the line, Dwenase, and potentially the other towns can attempt to replicate Nelplast's process (cleaning, drying, shredding, or any combination of these) to increase the return price. For that, a larger collection center with a more intricate process will be needed. These options are outlined in the manual. The plastic will then be transported by truck, which Nelplast will most likely help to pay and negotiate, to Accra. The returns -whether monetary or material- will then be returned to the towns and those who contributed.

The biggest logistic questions that need to be determined are:

1. Who will collect the plastic?
    a. Who is collecting the plastic and how/if they are paid will be up to each town? We've outlined different ways this can be done, either with wages paid by the towns, or with returns from the community. Children can also do it at larger events, which they already do. We have been asked about this, as this is already a

source of income for disadvantaged people in the community that we and the chiefs are reluctant to remove.

2. How are people being disincentivized from disposing other materials into the bins?
    a. The best method we have determined is to rely on education and the incentives. If people know of the harm that burning plastic can have on them and their environment, and they know what they can by selling the plastic, they will be much less likely to mistreat the system.

3. What Education should there be?
    a. A combination of posters, school lessons, and announcements from the chiefs detailing how to sort, what the returns will do, and the harms of plastic will be the most beneficial.

4. Who will pay for the system?
    a. While the system will eventually pay for itself, and some plastic bins have already been bought for Dwenase, we would suggest attempting to find a grant, or some sort of USAID like program that can help with the established fees. Especially for the initial transport and wages for the other towns, these seem like the largest barriers of entry for the surrounding towns.

5. How will the money/materials be returned?
    a. This will be one of the most complicated issues, and the setup will be the most intensive. We have outlined a couple different options. It seems like a combination of individual and community incentive is most effective. One possible setup for this would be splitting the returns in three ways. Have individual people contribute plastic and get an equivalent money back. Have families contribute as a group, and then also get that money back, and then have the community collect in high-traffic areas or at festivals/large events like funerals, and have those returns go to the community fund/project.

6. Will people receive payment when they turn in the plastic, or will they have to wait?
    a. It would be best if people immediately received payment, but that might be too difficult. It would most likely be reliant on how much Nelplast/Dwenase would be willing to invest in the project, or if the system can receive foreign investment.

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