BLUE GAS

EXPLORING A KISUMU-SPECIFIC TRANSITION TO BIOGAS

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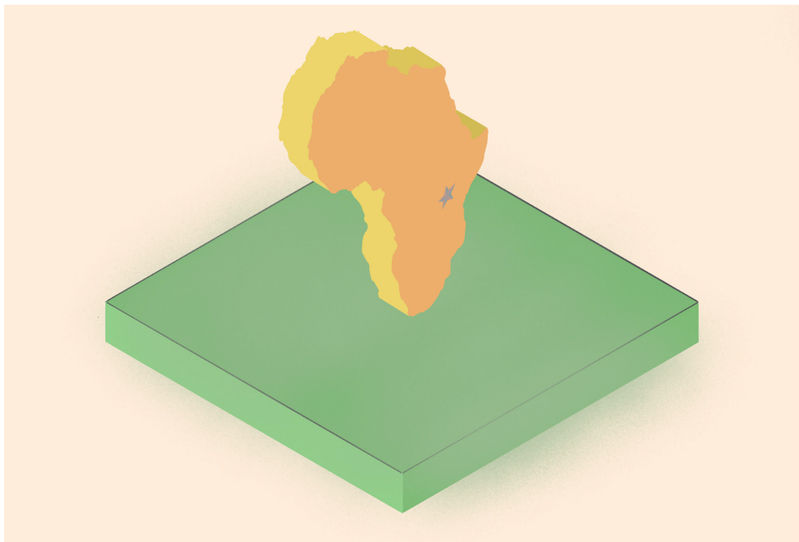
ABSTRACT

For a city and culture that excels at adding value to waste, Kisumu struggles with a systematic approach for solid-waste management. Food and animal wastes run rampant in the streets while families still cook for hours every day using harmful fuels like kerosene, charcoal and firewood. This project takes to heart the insight that if a solution isn't affordable to those who need it the most — it's not a solution. Using only locally-sourced materials and a grassroots innovation approach, the solution proposes a way to imagine the Kisumu-specific transition to BioGas - ushering in a safer, more sustainable development path from the bottom up.

Using Design Research methods, this project looks into the business possibilities and affordability models of a domestic biogas digester, a harvesting storage bag, and a modified biogas stove. The goal is to provide the most affordable model for a piecemeal transition to alternative and renewable energy fuels in the household. The concept was eagerly supported and encouraged along the way and received great feedback at an Exhibition with hundreds of local community members. The project is being carried on and continued as a joint project from multiple parties within Kisumu today.



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INTRODUCTION

> *"A PLANNER THINKS HE ALREADY KNOWS THE ANSWERS; HE THINKS OF POVERTY AS A TECHNICAL ENGINEERING PROBLEM THAT HIS ANSWERS WILL SOLVE. A SEARCHER ADMITS HE DOESN'T KNOW THE ANSWERS IN ADVANCE; HE BELIEVES THAT POVERTY IS A COMPLICATED TANGLE OF POLITICAL, SOCIAL, HISTORICAL, INSTITUTIONAL, AND TECHNOLOGICAL FACTORS. A SEARCHER HOPES TO FIND ANSWERS TO INDIVIDUAL PROBLEMS ONLY BY TRIAL AND ERROR EXPERIMENTATION. A PLANNER BELIEVES OUTSIDERS KNOW ENOUGH TO IMPOSE SOLUTIONS. A SEARCHER BELIEVES ONLY INSIDERS HAVE ENOUGH KNOWLEDGE TO FIND SOLUTIONS, AND THAT MOST SOLUTIONS MUST BE HOMEGROWN"*
>
> *- WILLIAM EASTERLY, THE WHITE MAN'S BURDEN*

William Easterly's poignant understanding of the development industry and its impacts are just as important today as they were when he published his book -The White Man's Burden- in 2006. Top-down planning design vs. bottom up grassroots design is a central theme to my project's exploration and execution. In the context of Easterly's work, the planner is the traditional top-down approach in which governmental institutions can "spend over $2.3 Trillion on foreign aid over five decades and still not manage to get twelve-cent medicines to children to prevent [...] malaria deaths" (The White Man's Burden (Easterly, W. (2006), p. 4), while the searchers could find ways to make that task make sense at the local level by working through local groups and distribution channels. It was my duty to not fall into the trap of executing a top-down inspired impact project, knowing well that that solution likely wouldn't hold up or last the test of time.

But truly, the impetus for this thesis work is rooted in my desire to understand how design works outside of the corporate product development world. With the skillsets that I've worked to acquire, the first-world product development world is what makes most sense for me to delve into - but as my last academic student project - I had an intense desire to understand not only how the rest of the world functions with innovation and product creation - but how design research leading up this differs in dramatically different contexts. After my time in Kisumu, I think it's a valuable experience for all first-world designers - whether professional or student - to understand that the world in which they be "creative" and "innovate" is a relative echo chamber. The increasingly globalized world predicts a future of unprecedented connectedness, but it also creates rippling effects on emerging economies that we are only just now starting to

A cow grazing in the rice fields outside of Kisumu's City Center

understand. It's every designers duty to not only focus on the beauty of color combinations, manufacturing bottom lines and finishing textures, but also on how all of these small decisions may impact the bigger picture of development.

Additionally, constant and legitimate creation with constant feedback by an actual user was a huge part of this motivation. A majority of products in the first-world are created in order to make profits and create beautiful user experiences. They are created with an audience in mind and if the product company even bothers to define a user, they are more often than not first-world facing. Even when design educations introduce a prompt for a design project that could be development-oriented or socially minded, it's a rarity to be able to actually visit the users in the genuine context that you would be designing for.

This is the crux of what I wanted to experience. Plenty of literature suggests that top-down planning for development projects is a futile effort while just as much literature suggests that grassroots organization and bottom-up innovation techniques are the most successful for social impact innovation. But I couldn't help but notice how many different social-impact

focused product companies based in Europe or America were claiming to be able to 'save the world' or 'end poverty' with their product interventions. I was excited to visit Kisumu and see some of these products in action.

But unsurprisingly - these interventions were nowhere to be found. In fact - many locals hadn't even heard of the products that I had been reading about for the weeks leading up to my field-work experience. The literature is true: not all top-down, first world created product solutions for Africa work or are implemented at all. There must be many difficult product journey points along the way to implementing these solutions. It's incredibly complex and it isn't my thesis approach to understand the complexities of failed product innovation rollouts in smaller Kenyan cities (although it would be interesting and worth the investigation). But I did what I could do and just asked people what they thought about it all from their perspective.

Their comments were enlightening. They would not mince words when they explained to me that solutions that are dropped into their environment meet tons of local resistance. Sometimes it has to do with cost. Sometimes it has to do with local bureaucracy. But most of the time, it simply has to do with the fact that local actors SHOULD to be involved with the innovation process. Otherwise - it isn't grassroots driven. They have to feel like they are driving forward parts of their own development.

This being said - there is a division amongst the local communities (and this may split somewhere along the socio-economic status spectrum) about the reliance on outside innovation and the creation of a beggar economy. If all innovations are dropped into Kenyan communities from some other location, most of the business profits get funneled back out of the community. What grassroots innovation is able to offer for a community is tenfold. It can bring pride, It can bring economic business opportunities to them directly and it can bring self-reliance. These are things that ALL Africans/Kenyans/Kisumu-ites can agree on.

This is why we see so many more successful innovations grabbing hold in Kisumu being driven by grassroots campaigns than we see top-down drop in solutions. To put it in the words of Nabeel Hamdi, former UN Habitat employee and community action planning expert, "intelligent practice builds on the collective wisdom of people and organizations on the ground - those who think locally and act locally - [...] make a difference globally" (Hamdi, N, 2004, p.xviii). In practical terms, good development begets emergence. It's infinitely more appropriate and effective to build a system based on a set of dense elements in an interconnected system that can allow for more sophisticated actions to trickle up over time. You must work with what you have at a grassroots level and scale from there. In the words of managing director of Zingira Community Crafts and one of my mentors and work partners in Kisumu, Evance Odhiambo - "we don't need big ideas filling our minds with false hopes. We can't skip ahead to self-driving cars or advanced biofuels. We need small incremental change. We need things that we can move forward ourselves with the resources we have".

DESIGN THINKING METHODOLOGY APPLIED

In the weeks before heading to Kenya, I took a very critical approach to what my design methodology would be when I arrived. I've learned so many slightly different variations of the design process that I spent much time comparing case-studies and understanding the research behind other product interventions in order to see what processes other designers went through to prepare themselves for a social-impact focused design project.
On the first day that I walked into my first Stanford University Product Design class nearly five years ago, I was shown this graphic:

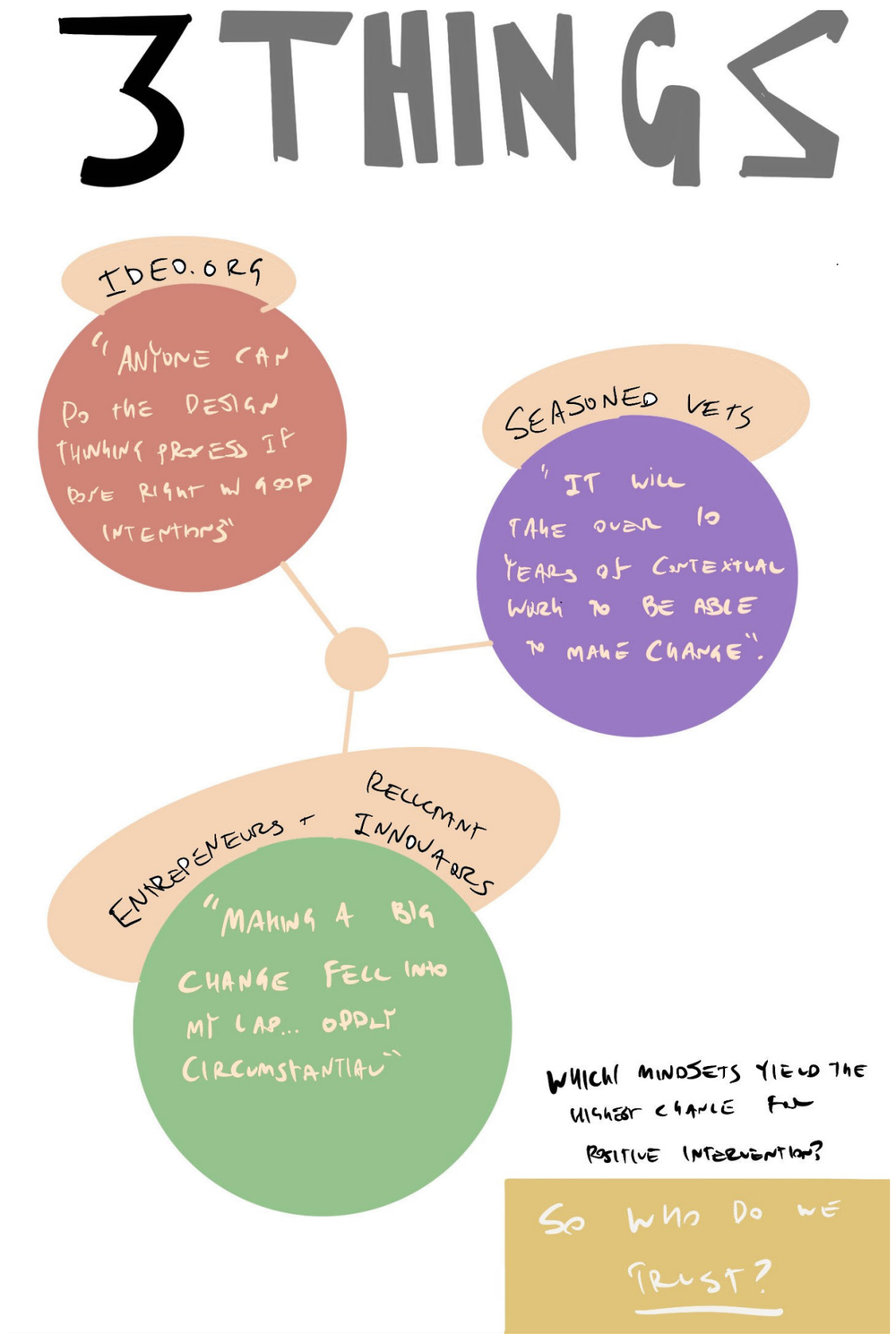
This is the bible depicted in five hexagons for all Design Thinkers in the San Francisco Bay Area and beyond. It's a User-Centered model for product design creation and relies on the heavily iterative model that requires the designer to cycle back through this linear process as many times as necessary in order to reach the most user-centric solutions.
The first step is Empathize and is critical in understanding the contexts, needs and lifestyles of those that you are designing for. The second step asks the designer to take all of the learnings from their empathy work and define the space - define the user - define the journey. Make statements from your insights and findings from your user research and develop a design directive that is rooted in research to move forward with. The Ideate and Prototype stages focus on iterating through product solution ideas quickly and efficiently in order to get feedback as early and as often as possible.

These steps prioritize quantity over quality and emphasizes user feedback when deciding on what ideas have the quality. When you have narrowed in on your solutions, the Test stage relies on heavy testing with the user to have them help define the use-cases of the product. This user-centered process - when followed correctly - is an incredible toolset to finding real solutions to difficult problems. But "when followed correctly" is the key phrase there. It's difficult. Every step of the process is difficult. Involving users is hard because as a designer and as a creator, feedback isn't always taken well. It's hard to have your hardwork in the office get picked apart by the real world when you take your fragile "idea baby" outside the confines of the workshop and into the grindhouse of reality. I'd go as far as to say that a lot of first-world facing products have a bit of wiggle room with this feedback-centered approach because the design teams creating these products are mostly first-world designers that happen to be in the financial group that would allow them to buy their own product on the market. So in a sense, they are designing for themselves. While this may be a general statement - it's not meant to be an attack on first-world product design. It's simply a point on the social innovation design process. While it's possible that the same echo-chamber issue could exist if the grassroots team designing in a Kisumu context is solely comprised of Kisumu locals, for the purposes of my project work - I was coming from such a vastly different perspective and life-style from the local Kisumu residents that I couldn't make any assumptions and default to design for myself. This is the difference.

When your default is designing products for your own user group, the empathy-based research part can get lazy - and in some cases - it never happens at all apart from some assumptive hand-waving. And it is this default that could inform why so many first-world designers fail in their attempts to create solutions that actually are implemented and scaled in the field. There is a lack of empathy and a lack of understanding for the user-group in which they design for.

In short - I got tired of these assumptive hand waving habits I had been consigned to doing for previous projects where I couldn't get consistent access to a user-group or when I was designing for … myself. I got tired of it being okay if I cut a corner or two with the research. I got tired of admitting that mediocrity was okay. So I sought out the opportunity that would squeeze that out of me and force me to do the best design work I could do. And if I "followed the steps correctly", it would have the potential to be the most meaningful design work I would do so far.

The Stanford d.school's design thinking methodology graphic



A HANDDRAWN GRAPHIC I MADE TO THINK THROUGH THESE ARCHETYPES

THE THREE MODELS OF SOCIAL INNOVATION DESIGN

My preparation work for this trip was focused on the strategy that I would employ when I arrived. I read as much as I could about the methods employed in the field with development innovation and fieldwork research. I read multiple case-studies online from IDEO.org and Research Foundations. I read books that were recommended to me from the course instructors regarding development, architecture and design, and even some books that I found interesting on my own.

And from my reading I grossly simplified the strategies that I encountered into three basic thought groups:

Human Centered Design Thinking Groups

Seasoned Development Vets.

The Non-Designer, Reluctant Innovator.

DESIGN THINKING GROUP

This group's mantra: Anyone Can Design! If you follow the fieldwork and the methods of Design Thinking—while keeping the user at the center of the process—you will be able to implement meaningful change. It's Optimism on Steroids. I read through the Ideo.Org Field Guide in excruciating detail and their seven principles are as follows: Empathy, Optimism, Iteration, Creative Confidence, Making, Embracing Ambiguity, and Learning from Failure. From reading the first intro pages of the field guide—I really felt like I could do anything. I've spent years now living out these principles not only in my academic work, but also just generally—and I always had this hesitation about my access and/or ability to apply it to this social innovation sphere.

Their overall strategy seems to be: Don't think too much about it. Follow the methods. Keep the user as your guiding light and forge on into uncertainty.

Learn from Failure

Don't think of it as failure, think of it as designing experiments through which you're going to learn.

—Tim Brown, CEO, IDEO

Creative Confidence

Creative confidence is the notion that you have big ideas, and that you have the ability to act on them.

—David Kelley, Founder, IDEO

Optimism

Optimism is the thing that drives you forward.

—John Bielenberg, Founder, Future Partners

Snipits from IDEO.ORG's Social Innovation Fieldguide

THE SEASONED DEVELOPMENT VETERANS

While it is true that Design Development Veterans and or/Co-Creation Experts in this field have an infinite number of perspectives, with this group I specifically mean those who do not practice explicit design thinking in their work. In fact—they may not even have a motivation of pushing innovation. This refers to the International Relations experts and Historians who have devoted their lives to not only studying the complexities of aid, social development and poverty, but have spent tons of of time in the field as well to see it and reflect on it firsthand.

This group's oversimplified message is this: It takes years if not decades to get to a point of cultural and contextual understanding in order to be able to make systemic and long-lasting change. Grassroots is the key and donating billions of dollars to government sponsored aid programs and mosquito nets are not going to end poverty. This group is full of ethnographic researchers, community organizers, and social workers. They are incredibly empathetic to the everyday lives of those living in undeveloped countries. They have sacrificed large swathes of their adult lives to move to places where they can become accepted in the developing communities over time. This archetype elucidates an incredibly important perspective that we should never toss aside.

THE RELUCTANT INNOVATOR

I think this group deserves it's own thing entirely because it's such a fascinating mixture. And I took this idea directly from a book that I read under the same name. It consists of people who weren't trained as designers or developers. They were just getting their feet wet in a developing context. This group's message is as follows: When you come across a problem you have to solve—whether you have extensive knowledge about a culture or technology or not—you simply have to solve it. In most cases, this directly relates to their ability to bring money or experience or perspective into the scenario. It could be motivated by profit, entrepreneurial spirit or just simply the goodwill of their soul. Sometimes it is just the "right place, right time" kind of scenarios. The challenge almost presents itself to you and you have no choice but to solve it - or at least start some momentum in a direction to solve it.

Someone visiting for a short time or a year long fellowship comes across a solution to a problem that maybe they aren't the most cut-out for, but they just simply realize that they can help. For example, MedicMobile was started by Josh Nesbit, a Stanford Student on a summer internship to a hospital in Malawi. He realized that simply communicating via text from community health managers to hospitals could save locals hundreds of miles of travel and time by knowing when patients were starting their often lengthy journeys to the hospitals for simple checkups. It was simple, and to be honest, a lot of people could have suggested this low-tech solution, but he was there for an amount of time that let him try and implement it and coming from a prestigious institution and background gave him a sense of credence that few people questioned. With some immediate feedback he simply had to do this. There were too many lives at stake that he could see first hand. He had no experience. He had no special IT or tech skills. He just had an idea and enough empathy and grit to see it through and make sure it didn't die after he left.

I share these here, because I think they are nice models for how to think about this process. I think they are well-developed and accurate in their simplification. I also share these here, because I'd love to have a control case to compare with what ended up being my process. To account for the crazy complexities of field work in an an entirely different cultural context, whilst working alone on a Master's thesis, I've devised my own retrospective design process. I'll leave this idea for now - but will return to it at the end.

STARTING BOTTOM LINE DESIGN PRINCIPLES

I devised a set of bottom-line design principles before arriving in Kisumu to act as a compass for my process.

- [ ] **DESIGN FOR THE MOST VULNERABLE**
- [ ] **STAY TRUE TO GRASSROOTS INNOVATION TACTICS AND CO-CREATE A SOLUTION WITH THE USER.**
- [ ] **DON’T TAKE SHORTCUTS ON THE RESEARCH.**
- [ ] **CREATE A POTENTIAL BUSINESS OPPORTUNITY FOR SOMEONE.**
- [ ] **CRAFT A SUSTAINABLE EXIT STRATEGY.**

THE FIELD STUDY

EARLY MORNING FISHERS IN KISUMU

THE KIBERA SLUM IN NAIROBI, KENYA. OVER 600,000 INHABITANTS LIVE HERE

REALITY STUDIO

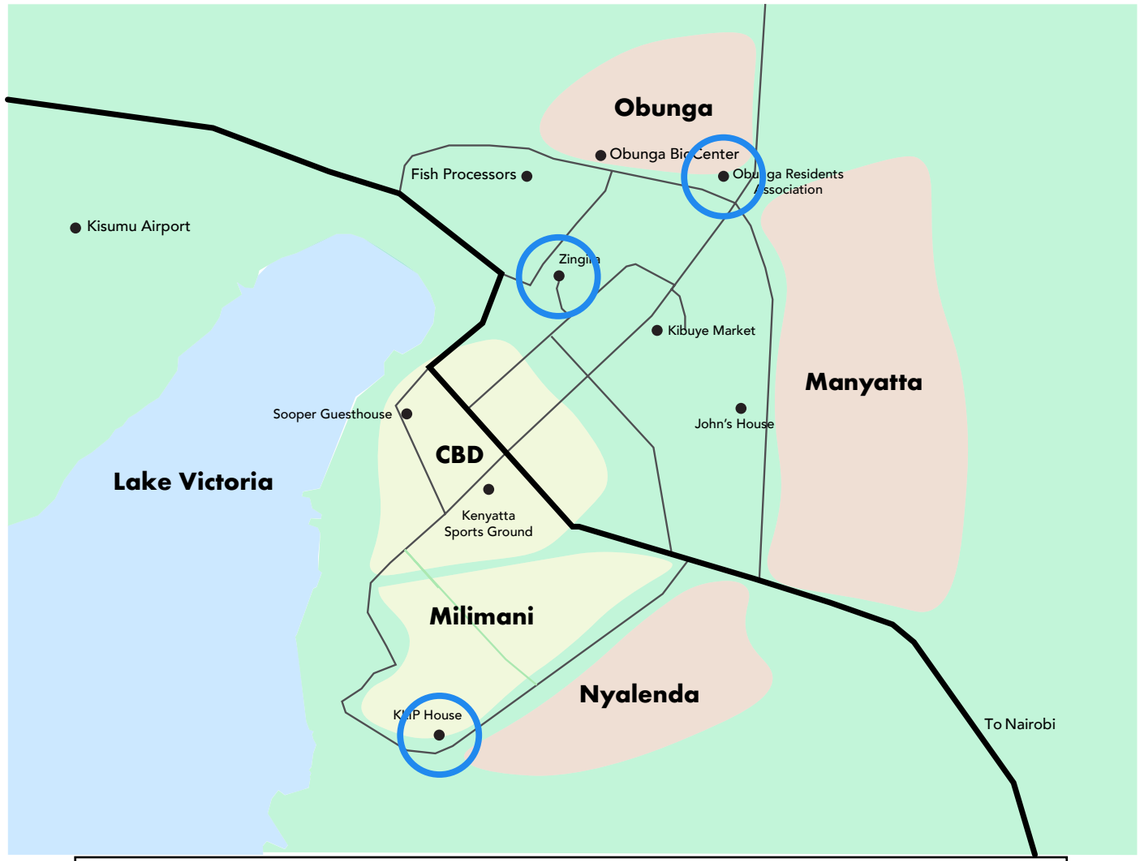
Chalmers University offers a six-eight week field study program every year for students interested in the intersection of Social Impact and Architecture/Design. Barring unforeseen political or environmental interruptions, the program takes students to Kisumu, Kenya and has been doing so since the early 2000s. The community connections run deep and the trip offers an immersive experience in Kenya's third-largest urban city. The trip format puts most of the emphasis on the time given to students to execute the field research and project work that they wish to explore, but the first week is full of site visits and partner introductions. Students fly into Nairobi, allowing for an opportunity to visit Kibera (Africa's largest slum and fourth-largest in the world) and the United Nations Habitat campus. Both of these visits are paramount to the experience, as it gives a large top-down contrast between those supposedly solving these problems and those affected heavily by the successes or defeats of those solving these problems. The entirety of the field work is framed within the context of local grassroots innovation and co-creative participatory design processes. The arrival in Kisumu makes this apparent with our immediate introduction to the local actors that we have direct access to there.

KISUMU CONTEXT

"Make sure you eat the fish!", is what every Kenyan mentions on your way to Kisumu - And it's justified. Kisumu is a fishing town on Lake Victoria. It sports a beautiful sunset lake views every day and fish is a staple food of most residents' diets - no matter their income. Kisumu is a relatively new city overall, as it was established in 1898 as a railway terminus. The city has grown rapidly over the past decades. While the census is never 100% accurate, it is believed that the "city has an estimated population of 500,000, while the metropolitan region comprising the city and its suburbs and satellite towns was estimated at over 1.5 million as of 2017". The City Center is full of different formal businesses, but 60% of the city's population resides in the outskirts in one of the many informal settlement slums that surround the city. The large slum areas raise the poverty level in Kisumu to 48% - 12% higher than the national average (Afd.fr, 2019).

The rapid movement from rural areas to the urban centers is predicated on a promise of good work and job opportunities, but the reality is that the small port city is incapable of providing enough good work. Because of this, most of the economy is informal and self-regulating. Stall markets line most busy streets, where merchants sell everything from donated clothing to locally crafted artisan goods. Agriculture still boasts the largest part of the economy in Kisumu, as it sits in an agricultural belt.

The Climate is quite brutal - with a scorching hot dry season with temperatures reaching up to 45 degrees celsius and a torrential rainy



A simple map of Kisumu Kenya. Red zones are informal settlements

Evance Odhiambo of Zingira Community Craft

season that can completely flood the southern parts of the city multiple times per year. The responses to these conditions is piecemeal. Most buildings in the informal settlements are unprepared for the elements and built not with sustainability in mind, but rather just simple livability in mind - Patchwork Economy at its finest.

I lived in the Central Business District in the Sooper Guesthouse (the yellow section on the map) and would commute by Boda Boda or Piki Piki around the city everyday to reach my desired destinations. Our local action partners were scattered around the city as such.

KLIP HOUSE

The KLIP (Kisumu Local Interaction Platform) House acts as a central communication hub for the local grassroots researchers and sustainable development actors from different parts of the Kisumu community. For example, actors from the local waste management organization will meet with those working with plastic reduction tactics in order to come together to achieve a common goal. In addition, it acts as a research platform for students and post-doctoral researchers that may be looking to conduct their research in Kisumu.

ZINGIRA COMMUNITY CRAFT

Zingira Community Craft incorporates dozens of skilled craftspeople in order to create sustainable business models for locals. They will lead workshops, educate people on how to craft, and introduce ways for people without work, but with crafting skills, to make a living. For example, they have used the water hyacinth - an invasive weed plant species - to create sanitary pads, chair decorations and even paper greeting cards in order to bring value to waste in the local community. Evance Odhiambo is the managing director of Zingira Nyanza Community Craft and has been a working partner with Reality Studio for a decade or more. Evance and Zingira evolved to be a close project partner during my project.

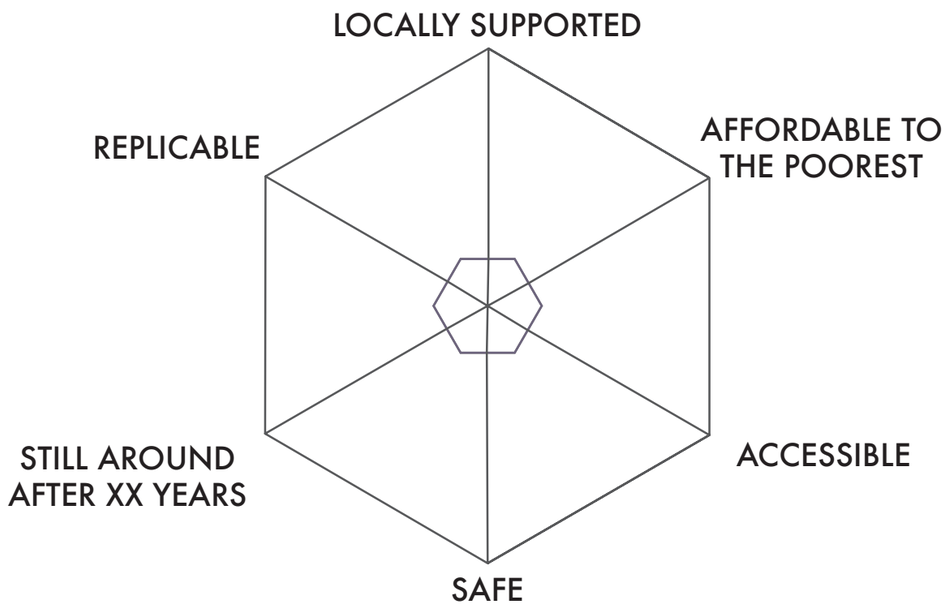
OBUNGA RESIDENTS ASSOCIATION

The Obunga Residents Association represents Obunga - one of the five informal settlement areas that surround Kisumu. Obunga is a struggling community with an intense desire to improve their well-being. They have organized a wide array of locally-supported organizations, like a widow-farm to support sustainable farming practices, multiple cyber cafes to facilitate the community's transition to technology use and a biocenter focusing on biogas formation and distribution.

A FRAMEWORK FOR USEFUL INTERVENTIONS

Through my experience of living in Kisumu and observing everything from a product design perspective - I analyzed a handful of social innovation products and put together what I gathered to be a Framework for Useful Interventions. It isn't based on hard data sets or anything technical, but it's based entirely on my observation and my conversations with locals. And although it is a framework created after the field work ended, I find it useful to place it at this point in the narrative. I will use five case studies of products/social innovations that I either had conversations with before my time in Kisumu or witnessed in the field to differing extents. I use my best judgement to assess the product's impact scale using the following factors:

Safety: referring to the inherent nature of the safety of the product in use and after use. How much it will impact a user's life negatively, how dangerous is it to operate, etc.
Accessibility: refers to how easy it is for local groups to access and use the intervention.
Locally Sourced/Locally Created: refers to how much of the product was created with the intended local user in mind and/or with thim throughout the process. It also refers to where the materials are from.
Replicable: refers to how easy it is for people to create their own version of this intervention.
Longevity: refers to the presence after a certain amount of time
Affordable to the lowest Socioeconomic brackets: this refers to how easily the poorest and those most in need of this technology can

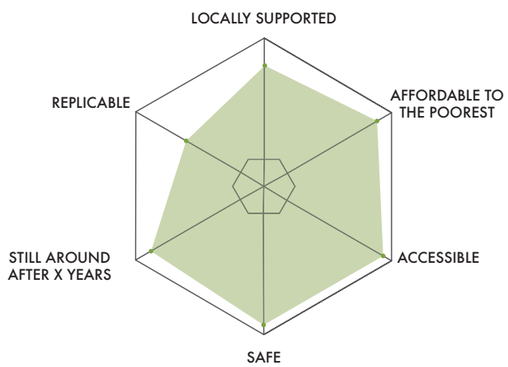


D.LIGHT

D.Light Solar is an inspiring company founded by two American Social Workers at the Stanford Graduate School of Business. They use user-centered design tactics to supply affordable solar-powered portable lamps to over 90 million people in over 60 countries in the world. They rely on user feedback at every step of the process of development. This HCD approach is made apparent by the founder's blog quote: "We gain so much insight from our customers and are committed to working with them to make the highest quality solar products in the world".

I didn't notice too many d.lights in people's homes, but I did notice a few d.light representatives out trying to sell their products at markets and would intermittently see their products displayed on the side of the street being sold or resold by local salespeople.

SAFE	**Yes**
ACCESSIBLE	**Yes**
LOCALLY DEVELOPED	**No**
REPLICABLE	**No**
STILL AROUND AFTER X YEARS	**Yes**
AFFORDABLE TO THE POOREST	**Yes, but the Tech is Changing**



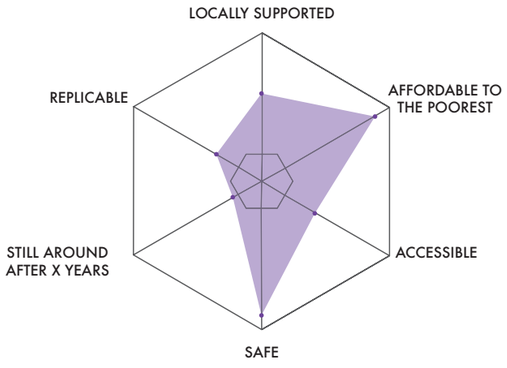
FreshBox

FRESHBOX

Freshbox is a company that I was lucky enough to be able to chat with on the phone before my field study. In fact - my original project plan was addressing a similar problem that they were trying to solve: reducing post harvest loss by providing solar-powered refrigeration units in Kenyan Markets and thus improving the livelihoods of those seller and allowing more goods to reach those who are food insecure. Freshbox was founded by a few Americans and a local Kenyan IT Graduate. They have this local connection and understand the grassroots solution process. Their website purports that "FreshBox's purpose is to tackle food spoilage across the supply chain in a localized context".

I had spoken with one of their founders - Forrest Redlin - and understood that they were having a hard time creating a working model. Their first prototype was in the field, but after six months had been repurposed for other types of storage and while they had a working model, it seemed to be expensive to manufacture and implement. But the Idea was rooted in solid research and local knowledge sources.

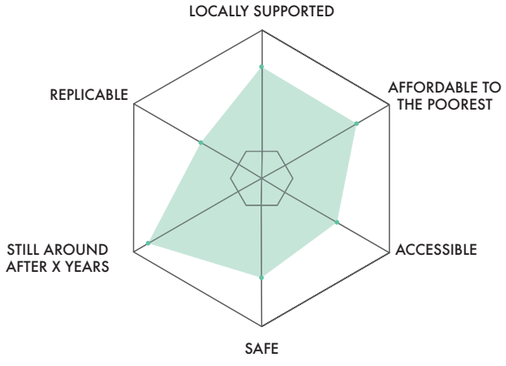
SAFE	**Yes**
ACCESSIBLE	**Only 1 market**
LOCALLY DEVELOPED	**Yes**
REPLICABLE	**No**
STILL AROUND AFTER X YEARS	**NO**
AFFORDABLE TO THE POOREST	**Yes, if it's around**



JIKOKOA

JikoKoa is another Kenya/American Collaboration company making high quality, longer-lasting jikos. These models make the charcoal last longer, saving users about $180 USD in cooking fuel every year. It claims to cook faster than normal stoves, gives off less smoke than other stoves and has a nicer, "designer feel" to it, while still being manufactured entirely in Kenya. It's seen around in Kenya in almost every shop and in most informal markets. Not everyone owns one, as it still is expensive, but some residents in informal settlements will even share one or borrow from a resident that has been able to acquire one.

SAFE	**Yes. Safer than other jikos**
ACCESSIBLE	**Yes**
LOCALLY DEVELOPED	**Yes**
REPLICABLE	**Yes - but not legally**
STILL AROUND AFTER X YEARS	**Yes**
AFFORDABLE TO THE POOREST	**Not really**

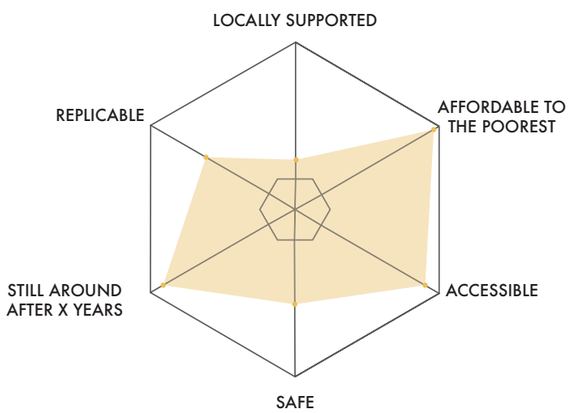


SWE PRIMUS®

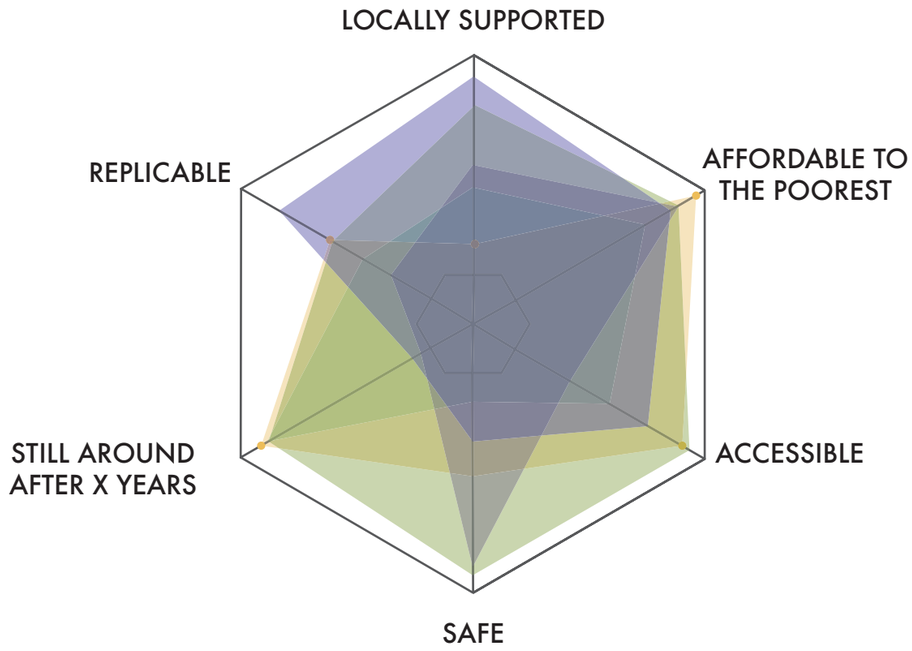
PRIMUS BURNER

The Primus burner is a swedish based outdoor company. They manufacture all kinds of stove equipments, but their product is found all over the place in Kisumu. It's costs about $5USD and is cheaply manufactured in China and floods the market. Everyone that owns a gas cylinder has one or two of these burners and the scrap yards are littered with hundreds of these parts. I know this because I spent an afternoon gathering parts for this. I reached out to Primus about this product and they didn't even seem really aware of how ubiquitous their product has become in Kisumu.

SAFE	**Yes**
ACCESSIBLE	**Yes**
LOCALLY DEVELOPED	**No**
REPLICABLE	**No**
STILL AROUND AFTER X YEARS	**Yes**
AFFORDABLE TO THE POOREST	**Yes**



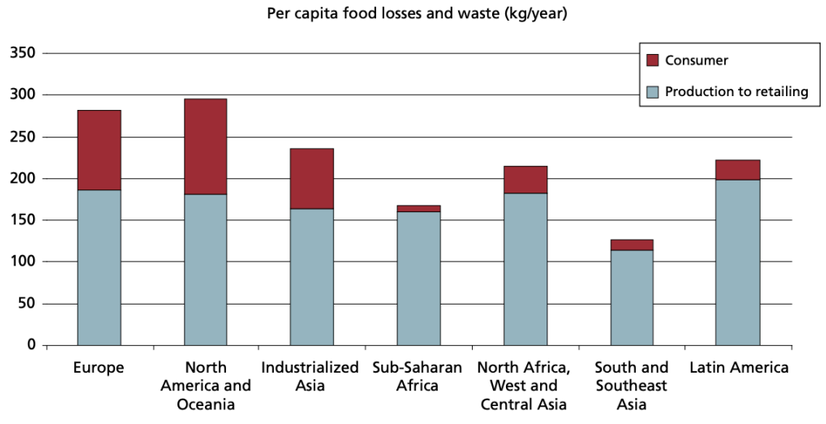
THE MATRIX



This Maxtrix may not be a perfect representation of design development interventions, and some of my "scores" that I've assigned may be a bit inaccurate if I saw more of these products contenxtualized in more spaces over more time. It simply holds as a way to think about solutions spaces whilst working through a product in real-time. There are many pitfalls along the way and the awareness of what makes a product fail in this space is worth exploring.

Different Grains stored in pest-resistant bags

Figure 2. Per capita food losses and waste, at consumption and pre-consumptions stages, in different regions



Food losses at different points in the Journey

Food loss assessments: causes and solutions. (2019). Case studies in small-scale agriculture and sheries subsectors. [online] Rome: Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/3/a-at145e.pdf [Accessed 31 Apr. 2019].

INITIAL RESEARCH & FIRST ROUND RESEARCH IN KIBUYE MARKET

The Reality Studio offered the students two project tracks for those that wanted to follow a project theme. The first was Children, City and Culture. This theme encouraged students to explore the role the city has in empowering children and bringing joy into their lives. The second theme was about Food Cycles and Systems. Both sounded interesting, but my interest in doing something with food systems predated the Reality Studio Project briefs, so the choice was easy.

My weeks of literary research led me to look at solid waste in markets and I was particularly interested in preventing food loss at the market level - something that is not being ignored currently. In fact, "In September 2015, the United Nations adopted the UN Sustainable Development Goals (SDGs), among them the UN Sustainable Development Goal 12.3: By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (United Nations Sustainable Development, 2019). It is a high-profile problem with legitimate and far-reaching effects. This seemed like a space, that although quite-saturated, would lead to plenty of user-centered intervention opportunities. But the saturation is justified, given the complexity in what seems like such a simple issue. The complexity can not be better stated than it is in a report published by the Food and Agriculture Association of the UN:

> *"WE HAVE QUANTITATIVE ESTIMATIONS OF FOOD LOSSES, WE KNOW THE CAUSES OF FOOD LOSSES, AND WE KNOW THAT FOOD LOSS REDUCTION WILL BE OF GREAT BENEFIT TO ALL ACTORS IN THE FOOD PRODUCTION AND SUPPLY CHAINS, TO FOOD SECURITY FOR POOR PEOPLE, AND TO THE ENVIRONMENT. HOWEVER, WE DON'T KNOW YET WHICH CAUSES OF FOOD LOSSES ARE THE MOST IMPORTANT, WHAT IS THE IMPACT OF SOLUTIONS AND WHICH SOLUTIONS ARE VIABLE AND COST-EFFECTIVE, IN ECONOMIC, ENVIRONMENTAL AND FOOD SECURITY TERMS. MEANING: THE SOLUTION TO FOOD LOSS SHOULD NOT BE MORE EXPENSIVE THAN THE FOOD LOSS ITSELF, SHOULD NOT PLACE A HIGHER BURDEN ON THE ENVIRONMENT AND GREENHOUSE GAS EMISSION, SHOULD MAKE MORE FOOD AVAILABLE TO THE PEOPLE THAT NEED IT MOST, AND SHOULD BE SOCIALLY AND CULTURALLY ACCEPTABLE."*

Waste Bins in Kisumu's Kibuye Market

Crops wrapped up for delivery in Kibuye Market

Rows of Toxic Barrels before repurposing in Kibuye Market

The UN is admitting that it's complex and they don't know all of the answers yet. But whilst walking through the markets in Kisumu, you wouldn't think that there was a food shortage issue. There are thousands of units of every possible food type available at every hour of the day, "but in developing countries more than 40% of the food losses occur at post-harvest and processing levels" (FOOD LOSS ASSESSMENTS: CAUSES AND SOLUTIONS, 2019). While this was something that seemed daunting to tackle, I wasn't going to let it stop me from learning more about it.

But in general, this means that what is seen on the market shelves in Kisumu isn't even all of what could have been. Just from this, there seem to be hundreds of intervention entry points, including farm-based practices, handling of produce during transit from farm to market and the handling and storage of food once it's transferred to the informal consumer markets. This isn't an exhaustive list of possibilities, but it shows just how dysfunctional the system is. The Rockefeller Foundation touts that "while the specific interventions to reduce PHL may not be very complex, coordinating the multiple levers of change that enable and incentivize PHL mitigation at scale has proven daunting for the global community". While this may be true, it hasn't stopped certain innovations from proving to add value into the market. There are grassroots organized innovations that have broken through the dysfunction to add value and lower the losses in the market. Some of these include pilot programs to create very cheap storage buildings, to create better storage bags for grains to prevent pest infestations and zero-energy cooling chambers for cold food storage.

In order to understand the complexities of trying to solve this problem, I reached out to FreshBox Co-Founder, Forest Redlin. I conducted an interview with him to understand the company, their motivations, their methods and any learnings they may have had. Their company missions seemed clear enough - Reduce Post Harvest loss in order to feed more people that needed food. They had a nice online presence and a well-designed website and most importantly - they were very willing to talk to me. We had a great conversation about design, process and the successes and failures of their project, but perhaps the most interesting takeaway was that they really struggled making this thing work. In Forest's own words - "we attempted refrigeration for 6-8 weeks and couldn't meet the numbers. After a few months we had sold only 1 unit and after a few more months the fridge was being used for entirely different reasons" (Redlin, 2019). He mentioned that changing the behaviors and mindsets of the old women that ran the food stalls was really quite a difficult task and dipped into some cultural issues. But we agreed that I would do my best to assess the context in Kisumu and attempt to shed some light on why some of the business factors didn't quite work out.

Even with this conversation with Forest, I still felt like that the space was ripe for some design thinking methodology. I figured that there must be something that can be learned from working with the women and men selling fruits and vegetables every day in the market. Perhaps there was a blue-ocean opportunity somewhere in the market for cold storage, food loss prevention, transportation, or even something tangentially related that would be gained from design research insights.

Thus, entering the Field Study, my Design Proposal Statement was as follows:

HMW DECREASE POST HARVEST LOSSES THE MARKET LEVEL OF THE FOOD JOURNEY IN ORDER TO REDUCE WASTE, MAKE MORE HEALTHY FOOD MORE ACCESSIBLE TO VULNERABLE POPULATIONS AND BOOST PROFITS FOR VENDORS.

The statement is simple but defined. I zoomed into the market level because of the logistics of what I would have access to as a student working alone. Dealing with the transportation and delivery vehicles to and from the farms proved to be difficult given the fact that most of the fruits and vegetables were being imported from neighboring countries - namely Uganda. This sounded like a exciting journey - but perhaps for a larger team with VISAS and longer period of study time.

Kibuye Market is the largest informal market in the entirety of East Africa. It houses approximately 7000 traders every day and this number can double or even triple on sundays for Market Day. This event every sunday is what defines Kibuye as the most important public space in the entire city. Traders, craftsmen and artisans from all over Kenya, Uganda, Rwanda and Tanzania will make the trek to occupy the market to sell and trade their goods. The Market has a large contingent of food and fruit salesman, a large market space for re-sold goods like clothes, chairs, furniture, and other household goods, and an impressive contingent of metalworkers, woodworkers and artisans that occupy a third of the space. These Jua Kali artisans are well-known for their resourceful mentality and able to create dozens of valued products from other recycled raw materials like metal barrels.

I spent the first few days of the field study focused on Kibuye Market's culture and functionality. I focused on food vendors in general, but it became very clear that more zooming in was going to be necessary. The complexities within the informality of this place were intoxicatingly interesting. To outline some of these first insights and findings from just observing and casually talking to different vendors:

THE BURNING OF TOXIC BARRELS WITH TIRES IN KIBUYE MARKET

A Each vendor had their specific food-focus. Some women just were selling leafy-green vegetables while some women only sold mangoes and citrus. Very few women sold a wide array of food items. Why was this? What governed who sold what?

B The informal selling stands were permanent locations for most food salesmen and had little to no space for any more equipment or gear. In short, the density is quite staggering.

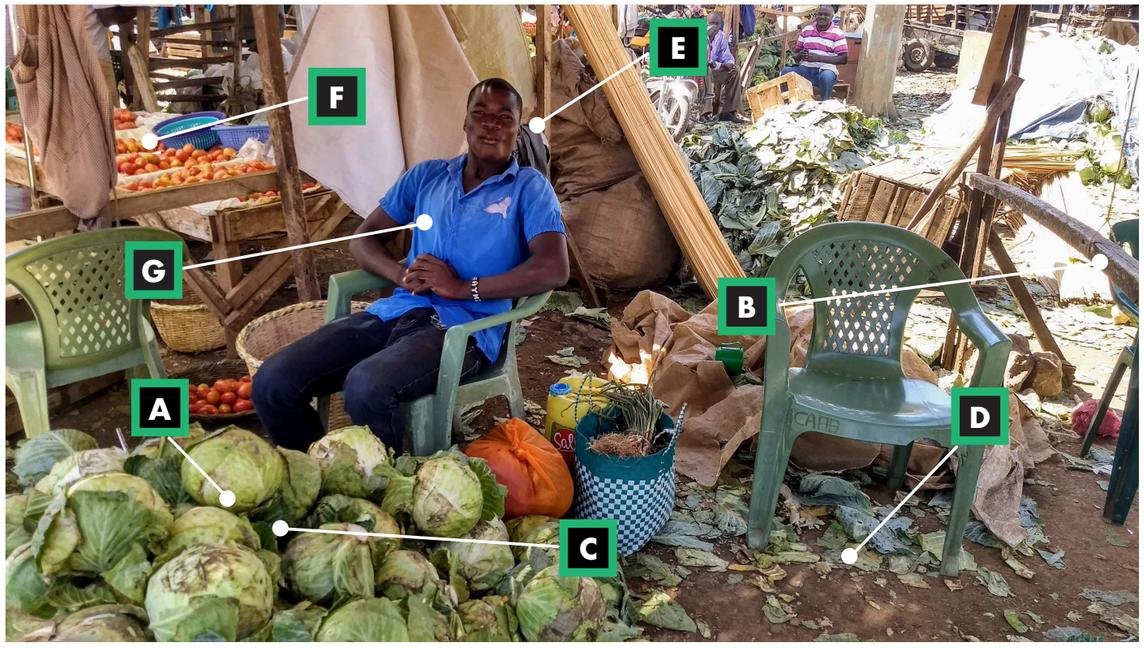
C The competition is fierce and is mostly reliant on returning customers or consistent clientele. There is nothing that makes any food item different from anyone else's. In short- there are no business tactics being employed.

D The sanitation is incredibly poor. There are mounds of food scrap and food waste in multiple places and goats and other animals consistently graze the place to eat meals. There is also a huge dumping site in the middle of the market. There are always two large trash dumpsters that get filled slowly throughout the day. The local waste actors will take four of these large dumpsters to the local Kachok dumpsite every single day - no matter the contents.

E The sun shade is spotty. Some salesmen have plenty of shade and some don't.

F There is no cold storage or communal storage spots. One woman I talked to complained about having to stash her unsold goods in the corner of the room or having to throw out so much every day.

G You can only work in the Kibuye Market if a vendor brings you in with them or you have a family member that can get you a spot to sell. Nepotism is real.



This is not an exhaustive list, but just the initial trends and things that I noticed from sitting and walking in the sun-battered market for a few days.

Relating to Post-Harvest Losses, these informal complexities added so many variables that were going to make any product intervention incredibly difficult. Every single salesman or woman sold, stored and transported their goods in a different way. There is simply nothing that is standardized AT ALL. The delivery of the goods in the morning is an "everyone for themselves" craziness that yields women snagging bags of produce and goods without being able to confirm whether the contents are even high-quality or not. There are no zoning laws dictating who can sell specific items in certain areas. And when it comes to safety and health, there's sadly nothing in place to regulate any standard of cleanliness. At the end of the day, transporting goods from the market back home was equally as hectic. Local Tuk-Tuks act as the normal transportation option for most sellers, but some use Boda-Bodas and some just carry it home - all in different carrying containers.

On one side of the coin, it seemed like it was a treasure trove of opportunity, but on the other side, something was telling me that if it was that easy, there would have already been some regulations or noticable interventions in place. And there really wasn't much. It was my duty to execute some empathic design research work.

MARKET INTERVIEWS

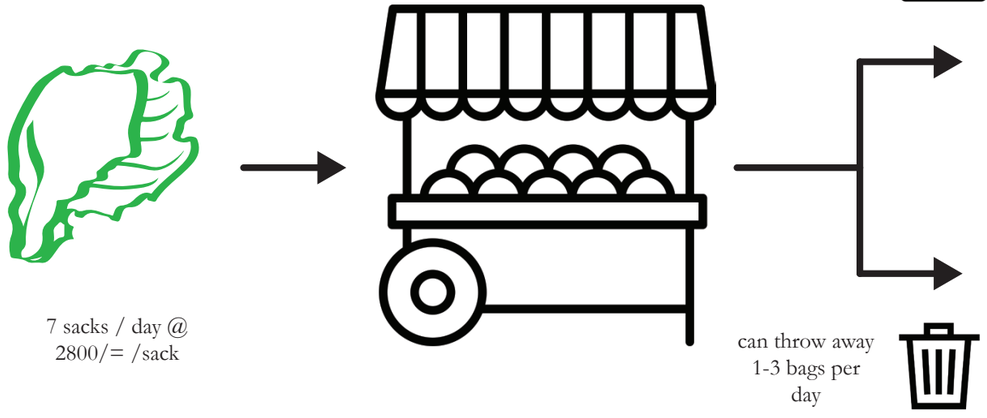
I set out to find some underlying patterns that could explain some of the informality. I interviewed representative sales vendors from all of the major food stuffs that were being sold to understand the profitability, waste habits, and storage techniques of all different kinds of fruits and vegetables. I focused on Green Leafy Vegetables, Cabbage, Citrus like Fruits/ Mangoes, And tomatoes. These were the most abundant foods in the market at the season I was there and gave a diverse set of foods with different natural spoilage times. I was helped by Harrison Otieno of the Local CBO Solid Waste Management team to execute the interviews. I was limited by the time that I could ask of them to take a break from their job that supplies them with a living wage, and the language barrier was something to work through as well - but Harrison's presence always provided clarity if I struggled to understand something.

My methodology was a simple two on one interview. I was insistent on understanding:

- The quantities that they purchase in the morning and the quantities of waste they have at the end of the day?
- Subsequently what they do with waste?
- How seasonal is all of this?
- How much they make / day selling the items they sell?
- Stories around spoilage. Why does it go bad? How do you dispose of it?
- How would food waste donation be handled? Is it possible?

FINDINGS

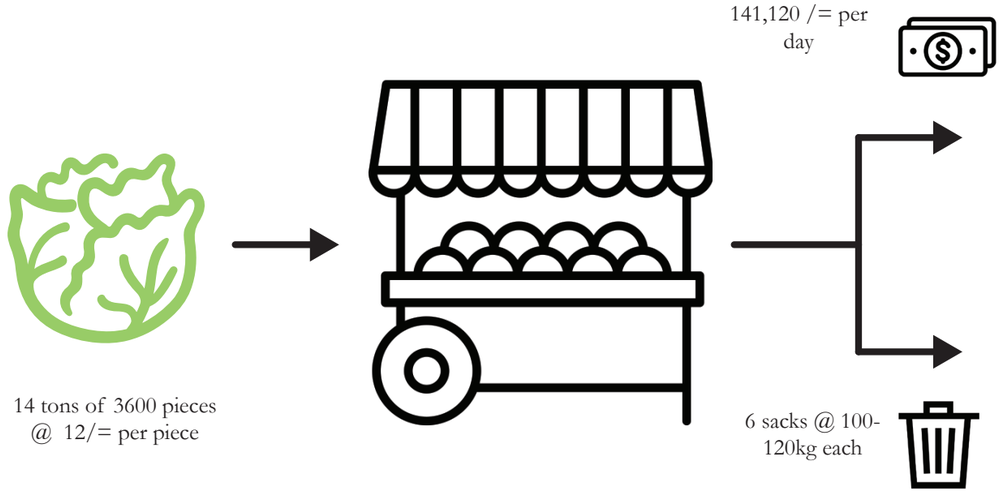
- There are so many transport breakdowns. Some mornings the vegetables don't even make it to the vendors. On these days, the vendor will just go home.
- Waste is super seasonal. When crop yields are high, plenty of waste. At this time of year, waste is super high.
- If fridge storage was around, they'd use it.



CABBAGE

FINDINGS

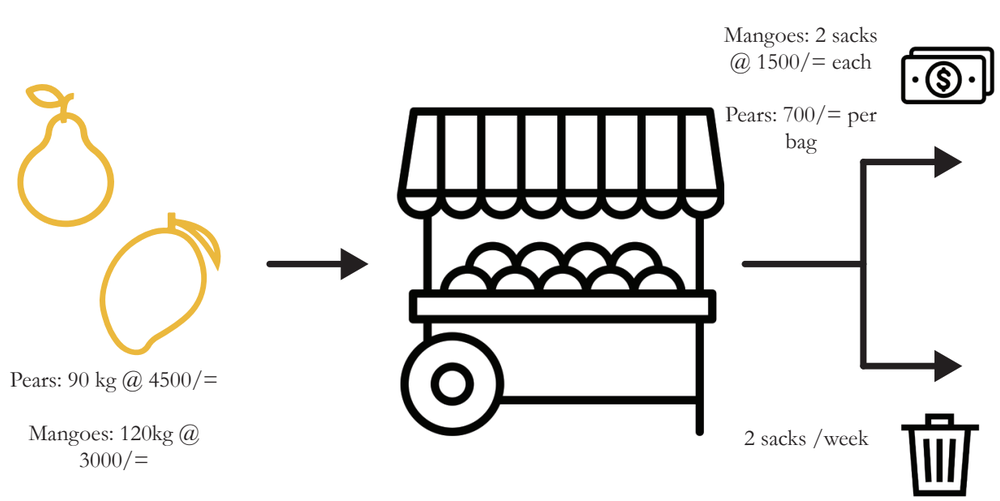
- They buy 14 tons and manually sort big to small for three different price sizes.
- There is hardly any cabbage waste that goes unsold for pig feeds. Which volunteers will come to take.
- It's a low-waste market food.
- Schools must have an environmental reasoning to partner and take extra food. They can't just come pick up food for free at the end of the day. There are steps you have to go through to apply for food waste pickup.



FRUITS

FINDINGS

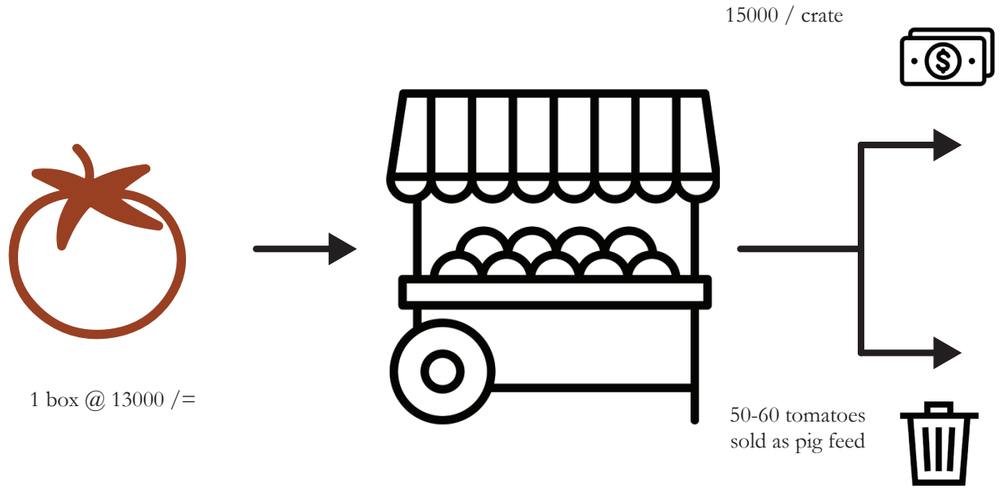
- Mangoes yield better margins than Pears and Citrus.
- You never know which mangoes are treated to last which ones aren't. The farms mix the treated mangoes with untreated and no way to tell when the trucks come in the morning. It's a crapshoot when you open your bag.
- No one would dare get food from the dumpster. Especially not for children to eat.
- No one would buy or donate damaged goods.
- Some people with time on their hands may deliver to street kids. This is rare



TOMATOES

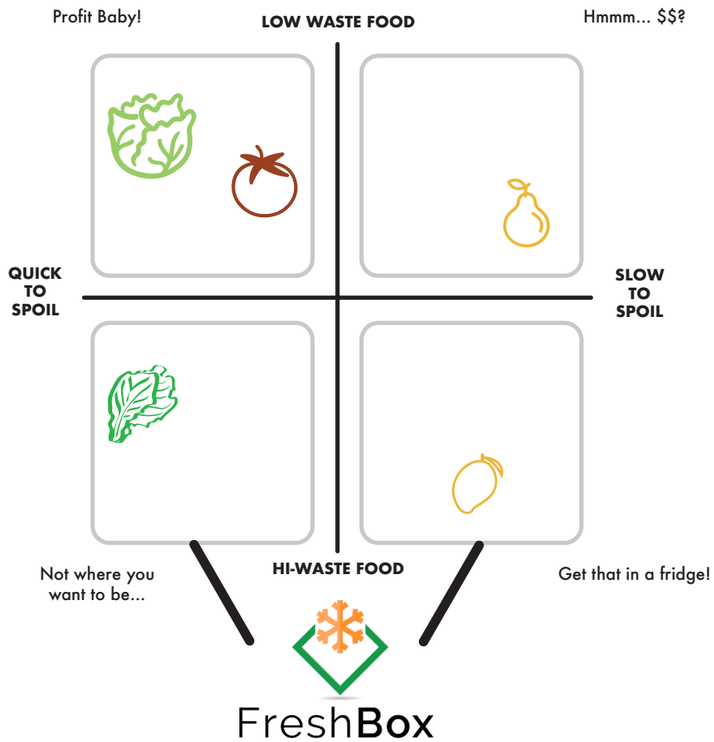
FINDINGS

- Cannot estimate waste with tomatoes - it depends on quality of the tomato.
- Sellers at the mercy of the middlemen.
- Tomatoes are low-waste as well - with people coming to pick it up for feeds, for hotels and for local restaurants.
- Tomatoes are expensive to buy and sell. High risk- high reward. But also seasonal.



OVERALL INSIGHTS

One immediate insight was that there seemed to be a hierarchy of profitability in the marketplace. To digest this better, I created a 2x2 matrix with the level of waste for each food item on the Y-Axis and the time to spoil on the X-Axis. There were some items you could buy and sell that had longer shelf-times and there were some items you could buy and sell that had value even after it goes bad. It seemed that you could make more profit as a vendor if you sold foods with value after it went bad - like tomatoes and cabbage for example. These items are sold even after it goes bad to local farmers and homesteads as cow and pig feed. In some cases, the tomatoes on the verge of going bad are even sold to local hotels to salvage and cook with. Meanwhile, fruits like pineapple, mango and pears had zero to little value after it went bad and yielded poorer profits. This led to my concluding that Freshbox, while creating a legitimate solution to a real problem, was facing two huge issues: Seasonality of produce and affordability. The seasons made the fridge very necessary in one part of the year and less necessary in others. This makes clientele unreliable - a huge factor of informal markets. It also made clear that it was tough for those who really needed the storage space to actually afford given the profitability of those items.



I moved forward with the idea that Food Waste was not Created Equal. There must be a way to create value from all of this waste, regardless of how much value it currently had.

CREATION OF METAL GOODS FROM WASTE BARRELS

CREATION OF SANITARY PADS FROM WASTE WATER HYACINTH

THE PIVOT

The most useful insight from my time interviewing in Kibuye was that fixing any sort of storage or post-harvest loss problem would do nothing to increase the access of food for those who were most in need of high-quality food. Along these same lines - it was clear from my interview that nobody was interested in donating or helping people out with their leftover foods. Kenya is a profit-driven development country and there are no handouts at a large scale. By increasing the shelf-life of certain foods in the market, all that would be accomplished would be a slight addition to the pockets of the salespeople that already have plentiful access to food and a relatively stable income. But any spoilage prevention would do nothing to improve the livelihoods of the people who needed varied diets in the informal settlements. There is no systemic solution in place to deal with the food waste other than moving it in large truckloads from the market to the large Kachok dumpsite in town. Once the waste is mixed and has sat in the sun, there is no chance to distribute that waste food to people who may need it. The vendors wouldn't allow it and the health issues involved would be a larger issue

The fulcrum of the pivot was centered at the distinction of waste reduction vs. waste use. Could there be way to explore the same basic design proposal from a waste value-finding perspective? If it was true that the only way to enact legitimate change in the Post-Harvest loss area was to enact systemic change like the UN was purporting, then perhaps there was room to work with the issue as it currently stood. To explore this possibility, I took a day to reflect on some of the waste-value additions I had witnessed in Kisumu since I had arrived. It seemed to be what made Kisumu so special in the first place.

For one, just 50 meters from the food stalls was the metal working section of the Kibuye market. Every morning they received hundreds of used metal storage barrels from neighboring countries. The barrels are covered in toxic materials when they arrive, so they burn them with a large tire fire to purify them of the chemicals. After this process, they have a charred barrel, but the raw material is then smashed and repurposed into dozens of metal products like cooking woks, jiko stoves, housing sheets, bird feeders and even metal luggage containers.

As a second example, any first time visitor will notice a green plant taking over large swathes of the lake coast - Water Hyacinth. This invasive species was introduced accidentally a few decades ago and has spread to such an extent that it has killed many local fish species and even has clogged the city water supply pipes and choked the city of water for days at a time. This menacing growth has been used to create crafts, chairs, ropes and even hygienic sanitary pads for women.

Thirdly, the fish industry in Kisumu has always been large and thus has created plenty of fish by-product. The fish processing center spits out thousands of kilograms of fish waste every week - which would have ended up in a dump if it weren't for Caren Onyango, who started taking their waste in order to create an informal

Creation of fish leather products from fish waste

and analog factory to extract the scales, bones and skins to create animal feeds, jewelries, and fish leather.

This ingenious repurposing of waste tipped the scales for me and urged me to explore the possibilities of value-additions that could be made to the food waste within the market.

In addition to this value-addition culture, I had visited a mini-biogas plant earlier in the week, had a few conversations about biogas possibilities with members of the Kibuye Waste Management team and the team at Zingira Community Crafts. With their input on potential case users, I decided to venture into a needfinding phase focusing on cooking fuels and the women who cook for multiple hours every day in the informal settlements in order to see how biogas formation at the home level would work.

- ☐ **DESIGN FOR THE MOST VULNERABLE**
- ☐ **STAY TRUE TO GRASSROOTS INNOVATION TACTICS AND CO-CREATE A SOLUTION WITH THE USER.**
- ☐ **DON'T TAKE SHORTCUTS ON THE RESEARCH.**
- ☐ **CREATE A POTENTIAL BUSINESS OPPORTUNITY FOR SOMEONE.**
- ☐ **CRAFT A SUSTAINABLE EXIT STRATEGY.**

With the pivot to focus on biogas and the family home, I was not sacrificing any of my bottom lines. I was still designing for the most vulnerable - and would most likely be targeting an even poorer segment of the population. The only vulnerable bottom line was the integrity of research. Given this pivot at this point in the fieldwork, I had to move fast. I not only changed my design space,, but I changed my supposed user. This was a high-risk move, but

NEW DESIGN PROPOSAL:

HMW CREATE A SAFER, CLEANER COOKING FUEL BY UNDERSTANDING THE DIFFERENT VALUES OF PARTICULAR WASTE ITEMS?

Focus group meeting with residents of Obunga Informal Settlement

USER-CENTERED STUDIES AROUND CLEAN COOKING ALTERNATIVES

The decision to pivot to finding value in the waste instead of preventing it necessitated a shift to a more user-centric study - something I wanted to incorporate from the get-go.
In Kenya, and in Kisumu in particular, the excess animal and food wastes are staggering. And in no place is this more noticeably a way of life than in the informal settlements that surround the city. For this reason, Biogas production is most feasible in the rural areas and the homestead regions of the city that make up most of the informal settlement areas. It is common to see plenty of cows and goats roaming in the streets of the informal settlement, creating plenty of waste on a daily basis. The waste is so plentiful, that excess dung is simply piled on the side of the street.
This environment informed the decision to focus on the women living in the informal settlements of Kisumu as a main user-group.
In order to understand if/how Biogas would be a viable solution for the home setting, I conducted research about the home cooking setup for these women that spend hours every day cooking. With the help of Wuod "Dan" Kisumo, community leader of the Obunga Residents Association, I was able to secure a focus group meeting time with a group of six local Kisumu Women that live in the informal settlements near Obunga in order to discuss their cooking practices and budgets.

I entered the focus group meeting with things I wanted to understand:

- The breakdown of their budget
- The perceptions of the different cooking options out there currently. Which is most dangerous?
- Their preferred cooking method and why?
- How many hours/day do you spend cooking?

I sat down with Rosaline, Lucy, Sylvia, Evarline and Mary and firstly asked for a breakdown of their budgets in USD.

	ROSALINE	LUCY	SYLVIA	EVARLINE	MARY
HEALTH	50.00	20.00	N/A	10.00	20.00
FOOD	100.00	180.00	90.00	150.00	150.00
SCHOOL	100.00	200.00	N/A	200.00	N/A
RENT	40.00	30.00	30.00	50.00	40.00
WATER	5.00	N/A	N/A	N/A	N/A

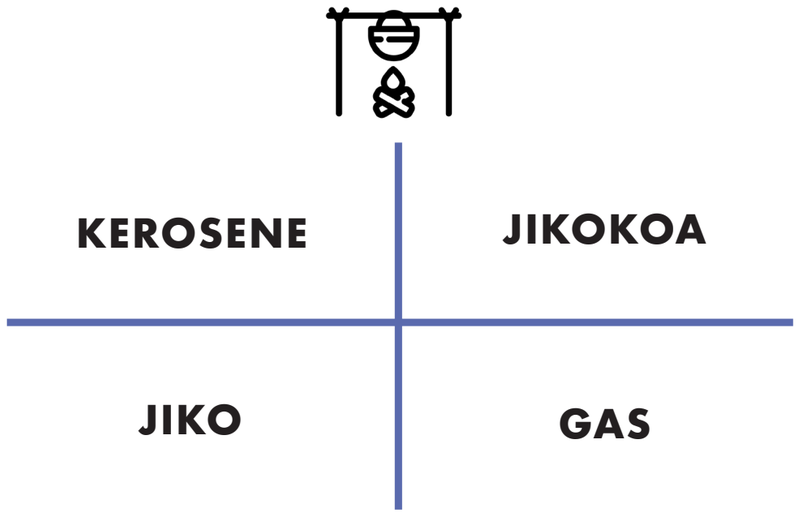
I collected some raw data about these women's monthly budgets by handing them all their own notebook to document. I encouraged them to standardize their budget lists by creating a list of the budget items that almost all women in Obunga would subscribe to spending money on. They boiled it down to health, food, school, rent and in some cases water. What's not immediately obvious here is that women with more children have more school AND food costs for more mouths to feed.

Food is consistently one of the top two costly budget items for women.

FUEL	ROSALINE	LUCY	SYLVIA	EVARLINE	MARY
CHARCOAL	16.00	16.00	30.00	10.00	90.00
GAS	11.00	N/A	N/A	N/A	N/A
KEROSENE	N/A	6.00	6.00	10.00	

Within the Food section, I asked them to itemize out what they spent on fuels and cooking tools. They overwhelmingly agreed that Charcoal and Kerosene were fuels that everybody in Kisumu spent their money on. Only Rosaline has access to a Liquid Petroleum Gas cannister - and she said that was an uncommon fuel source to own.

FOUR MAIN COOKING FUELS AND TOOLS



TOOL	STARTUP COSTS	MONTHLY COST	TOTAL/YEAR
JIKO	2.50	25.00	~250.00
GAS	60.00	11.00	~200.00
KEROSENE	6.50	8.00	~100.00
BIOGAS	80.00	1.00	~95.00

Lastly, I sketched out what the yearly costs of each fuel source/cooking kit would cost the women over time. the startup costs for charcoal and kerosene stoves are quite low, making them easy first purchases, but the continous purchasing of more charcoal fuel makes the Jiko the most expensive cooking tool over the course of a year. The women admit this and know this, but they have no financial choice. The Gas stove is too much of a startup cost and Kerosene is viewed as unhealthy and stinky to cook with.

I modelled how Biogas would fit into this once it was up and running.

KEROSENE

The Kersone Stove can be accessed in any supermarket or informal market. It is quite affordable (around $5USD) and cheaply manufactured in China. IT runs on Kerosene, which is a toxic and smelly fume that the women that cook do not necessarily like. It's primarily used for soft foods or tea.

INSIGHTS

- "It affects us". The smell and the smoke are toxic and the women know it.
- "I use this for light foods, or for tea"
- "If you have this, you also need a jiko"
- Some people with time on their hands may deliver to street kids. This is rare

JIKO

The Jiko is the classic charcoal stove found in Kenya. It is manufactured by the Jua Kali Engineers in the markets and costs somewhere between $2.50 and $6 USD depending on size. Charcoal is quite a dangerous fuel to be exposed to in the long term and can even kill you if you cook with it in an unventilated room. The problem with this is that there is too much wind outside to cook outside with good ventilation. The wind will make the charcoal burn quicker, thus costing them more money over time.

INSIGHTS

- "When you cook with a Jiko, it has a sweet smell. With Kerosene, bad smell"
- "If you're in a hurry - no Jiko. For slow foods"
- "Good and affordable for many people"
- "I like the Jiko but it depends on what you're cooking"
- "Good for large quantities of food"
- "It can suffocate you. If you leave the Jiko on and close windows, you won't wake up"
- "While lighting it, it pollutes the area"

GAS CYLINDER

The gas cylinder is perhaps the best financial option for the women - but the startup cost of 6000 /= is quite difficult for most. Only one woman owned a gas cylinder at the table of 6 women, which is telling. The gas cylinder is seen as just as dangerous as other cooking sources. But it is a faster cook, which makes it a popular cooking option for cooking rice, beans, or heavier foods over a long cook time.

INSIGHTS

- "The budget and money is not there for it"
- "Gas is 6000 and 1100 every month - this is better savings than charcoal. But with many kids, they will refill twice a month. So not every family has this budget"
- "The gas is cheaper than kerosene+Charcoal"
- "Buying gas is not a problem - it's just dangerous. When the kids or baby plays with it"
- "Maybe you put 1 cup of water and go to store - no good"
- "When she forgets to close it entirely, the gas spreads"
- "It is good but it is bad - gas cooks fast, but can't leave"

JIKOKOA

This is the 3000/= manufactured jiko that cooks faster, saves charcoal and exudes less C02. It is nearly 10x the cost of a normal jiko, making it difficult to justify for most women. Only one woman owned a jikokoa at the table, same as the gas cylinder.

INSIGHTS

- "I buy this in the jikokoa"
- "Some have it - it is 3000"
- "If you use this one, you save charcoal"
- "Cooks very fast. Faster than normal jiko"
- "Many people have this. Some. Few have it. Only I have it. Majority don't have it"

A COMMON INDOOR COOKING SETUP WITH MULTIPLE COOKING TOOLS LINED UP.

A MOTHER LIGHTING A JIKO WITH CHARCOAL. THE DEMONSTRATION WAS OUTDOORS FOR LIGHTING, BUT ALMOST ALL JIKO LIGHTING OCCURS INDOORS.

OVERALL FINDINGS & INSIGHTS

- All cooking practices viewed as dangerous
  - Gas for Children
  - Jiko for C02 emission
  - Kerosene as breathing exposure
- Everyone uses different cooking tools for different kinds of foods.
- JIKO good for hard foods that take a while to cook through.
- Biogas was naturally brought up without my prompt and interest was there.
- Maintenance is involved with EVERY cooking option
- Cooking faster is not worth the investment. Rather would invest to cook safer.

HOME VISITS

This first round focus group meeting was incredibly useful for understanding the basic contexts and attitudes surrounding cooking using different cooking instruments in the home. The next step was to see the spaces for myself. And not just to see them, but see how the women interacted with and prepared food.

I arranged for an afternoon of site visits in Obunga to three different women's homes to see all of the cooking stove tools in use. I paid special attention to the size, ergonomy and layout of their kitchen spaces and the safety factors at play when they prepared food.

INSIGHTS

- Home kitchens simply don't have much extra room inside.
- My Kitchen is big enough for me. I don't mind it.
- Adding another cooking solution for them would be a seamless transition to their already rotating cooking schedule.

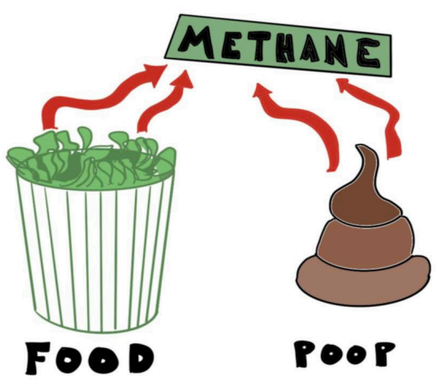
CO-CREATION

BIOGAS BACKGROUND & PRODUCTION

After the user-group needfinding phase - It became very clear that there was both an excitement about Biogas as a concept, but also that there was a need for feeling safer, while cooking. The average resident of Obunga isn't incredibly educated, making the understanding and absorption of a complex anaerobic process like biogas production not super intuitive to all unless it is simply and explicitly explained. But as I can attest to firsthand - the creation and maintenance of biogas, even at the small scale level is not as easy as lighting a gas cylinder burner. "Controlling the biogas process in an efficient manner requires knowledge of the microbiology behind the biogas process and of how microorganisms function" (Schnürer and Jarvis, 2019), and throwing this technology onto a resident of Kisumu without any knowledge would be both unethical and potentially dangerous. Despite this lack of information about it, the idea of "biogas" seems to be buzzing around and residents understand what it is and that it could help them.

BUT WHAT IS BIOGAS?

Biogas is the simple, renewable, anaerobic process by which organic matter is broken down by an active bacteria in order to release a mixture of methane (50-70%) and carbon dioxide (30-50%) (En.wikipedia.org, 2019). This gas that is released when the food or waste is broken down is a flammable gas source and can be used and harnessed for electricity as well. There are tons of benefits of using manure-based biogas, one of which is using the dangerous methane greenhouse gas released from sitting piles of waste for a better use. Methane as a greenhouse gas is "28 times more dangerous than Carbon Dioxide" (IPCC, 2015). Not only would harnessing the methane be better for the environment, but it is much more potent for creating biogas faster and cleaner.



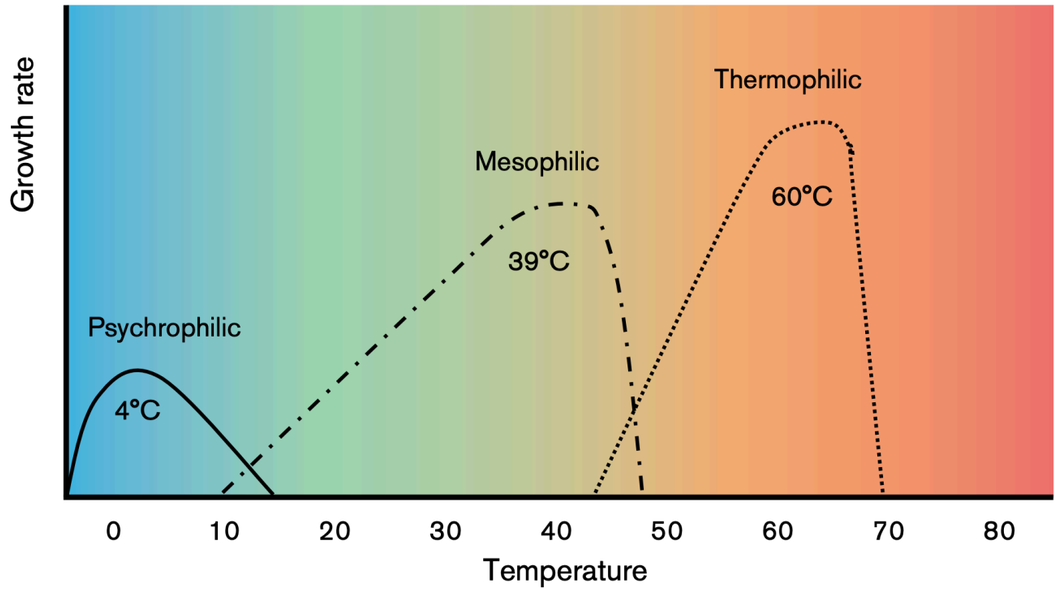
SIMPLE DRAWING FOR AN EXHIBITION SHOWCASE SIMPLY DESCRIBING THE ORIGINS OF BIOGAS FUEL.

WHAT MAKES GOOD BIOGAS?

There are many factors that can lead to good biogas, and seemingly infinite when it comes to creating industrial grade biogas plants. But at the domestic level, it comes down to a few different variables.

Airtightness - Biogas Digesters must be airtight, and without fail. A lack of airtightness will allow oxygen into the digester and degrade the quality of the biogas and could render it completely inoperable.

Temperature- The Microorganisms that live inside the active biogas sludge are plentiful, and they often are reactive at the temperature in which they are originally created in (Schnürer and Jarvis, 2019). Most bacterias that will be borne out of Fresh Manure will be Mesophilic - making Kisumu the ideal climate to create large quantities of biogas without any expensive aids.



SCHNÜRER, A. AND JARVIS, Å. (2019). MICROBIOLOGY OF THE BIOGAS PROCESS. UPSALLA: DEPT. OF MOLECULAR SCIENCES -SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES.

pH - The Bacterias involved will be happiest at neutral pH levels of around 7.0-7.5 (Schnürer and Jarvis, 2019). This means that certain acidic substrates that are added to a digester, like fruits, can change the ph level of the bacteria.

Salts - Salts occur naturally in the microorganisms and do not need to be added separately, but the breakdown of some materials can be very salt heavy - again inhibiting the growth of organisms, as salt is often an inhibitor to bacterial growth (Schnürer and Jarvis, 2019).

Starting Bacteria - Starting the Biogas Digester is a similar process to creating a sourdough starter. There needs to be a starting bacteria and an effort to give the bacteria the

chance to stabilize to the new environment and grow . This is dependent on all of the aforementioned factors, but using a dung or excrement is believed to be the most effective way to get live cultures the fastest because of the myriad of different bacteria that exist already. In Kisumu, Cow Dung is readily available and this fresh manure was used to start the bacteria growth.

Substrates - There is plenty of research looking into what substrates (or additives to the biogas digester) are the most effective as yielding the highest amount of biogas. In fact, most organic materials can be converted into biogas, given the right conditions (Schnürer and Jarvis, 2019), but not all organic matter is well-suited for purely-efficient biogas production. "The main substrates for biogas production today are sludge from municipal wastewater treatment plants, manure, crops and crop residues (tops etc.), waste from the food and feed industries, source-sorted food waste and slaughterhouse waste" (Schnürer and Jarvis, 2019). This is important to keep in mind and important for families in Kisumu to know, because the addition of substrate to the digester will be an almost daily occurrence.

CURRENT USES

As a scientific process, methane production is an old practice with quite a history. In fact in many developed countries, like Sweden, large biogas reservoirs are producing so much biogas, they are able to refine it, compress it and use it for public transportation systems. But in the developing world, only homesteads and rural farmers have begun to reap the benefits of this process for energy sources. India and China have been successful in implementing some of these technologies, but Africa's research and development is far behind. Walking through Kisumu, it's hard to find anybody with access to Biogas at all. For how easy and implementable it should be in Kenya, given the climate and the plethora of accessible parts, the lack of this biofuel is head scratching.

A BIOFUEL BUS. AGRICULTURAL JUGGERNAUTS LIKE GERMANY AND SWEDEN EXCEL AT PUSHING BIOFUEL TO IT'S TOP POTENTIAL.

MISCONCEPTIONS AND DANGERS

Biogas is considered a safe cooking gas in that if left on in a closed room for a long period of time, the room would not combust. The Biogas dissipates rather quickly in the air when it leaves it's compressed storage. But this biogas expulsion is a dangerous thing regardless for the health of humans and also for the environment. Methane is a greenhouse gas is nearly 28 times more harmful to our environment than carbon dioxide (C02). Ultimately, like any flammable gas, it has dangers if handled incorrectly. This should not be forgotten, despite its relative safety factors. With the digester, there are edge case instances to be aware of. For example, The creation of a natural "crust" at the top of the liquid slurry inside the digester could potentially clog the gas outlet, causing an over-expansion of the digester and potential explosion. This would be quite rare - and nearly impossible with the use of cow-manure as a main substrate, but not unheard of with acidic substrates that are hard to break down. The Dangers are incredibly few if the knowledge is there.

DUNGA BEACH KENYA FLEXI-BIOGAS

About 15 minutes away from the city center of Kisumu lies Dunga Beach, a fishing beach that is relatively unmarred from the Water Hyacinth infestation. On the beach front, there are dozens of women frying the freshly caught fish in vats of oil on large wood and charcoal stove tops. But about 20 meters away from the beachfront you'll see a large pair of greenhouse tarp-covered structures. From afar, it doesn't look all that exciting, but when you pull back the tarp you see large biodigesters that run completely off of cow dung and the same water hyacinth that is wreaking havoc in Lake Victoria. These digesters they have set up are over 1000L capacity and can cook for up to 8-9 hours/day. It's inspiring to see the system set up and working so well.

These digesters are built and maintained by Kenya FlexiBioGas - a Kenya-based company founded in 2011. Their website explains their motivation to provide affordable and accessible biogas solutions to people using local materials (Flexi Biogas, 2019). Their 15 years experience of research and development on the topic is nothing to scoff at. My meetings and consultations with them were super helpful but something didn't quite compute when they shared that all fifty modules that were installed in the Kisumu area were donated by Cambridge-based research foundation. Their cheapest model is nearly $750 USD - a total that simply isn't affordable to those that really need this technology. For financial context - the bulk of the population in Kisumu slum areas and informal settlements make between "3,000 and 4,000 Kenyan Shillings (KShs) every month" (Situation Analysis of Informal Settlements in Kisumu, Kenya, 2015). This equates to about $30-40 USD. A one time purchase of this kind of digester would be approximately 15-20 times their monthly income. A ridiculous sum to ask - even if on credit.

Outside of the Dunga Beach area and only

Some of the hardware and testing setup behind the Dunga Beach Biogas system.

A model of the domestic biogas system at Dunga Beach. This model costs $750 USD.

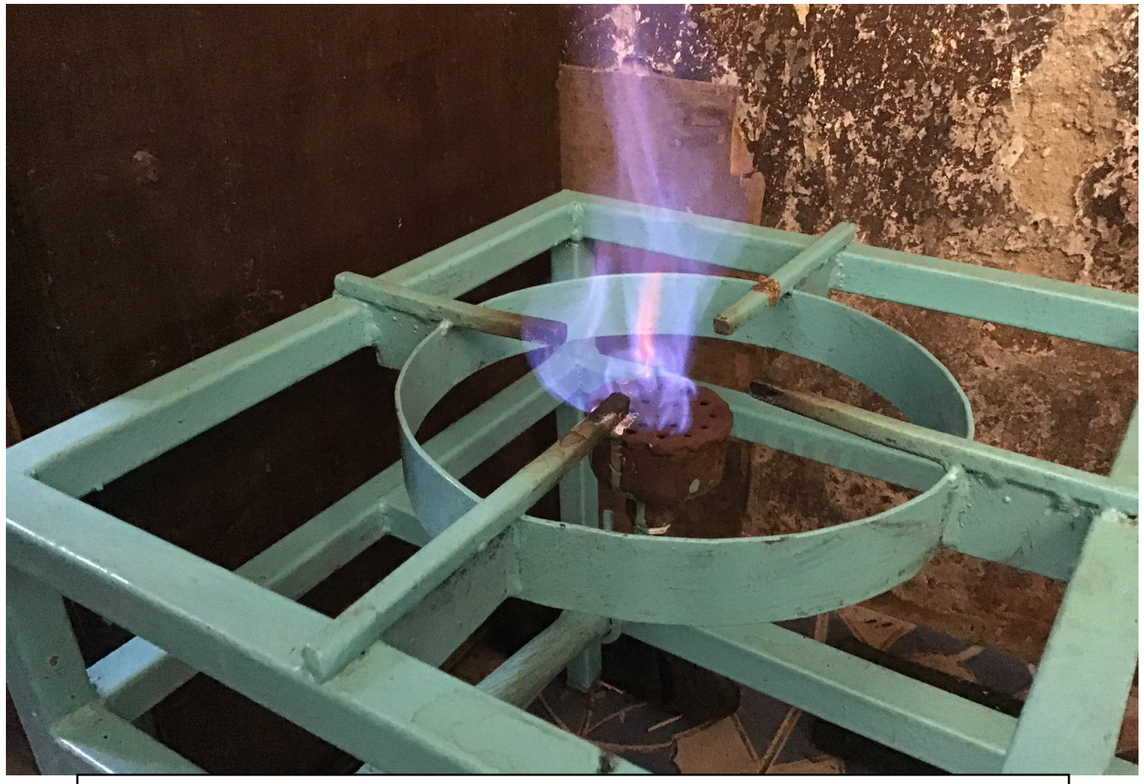
20 minutes away in Kisumu, this impressive biogas research is nowhere to be found. Part of this may be explained by the fact that FlexiBioGas is actually based in Nairobi, over 8 hours away by car. The insights driving the product may not be completely tapped into the city of Kisumu, but may be tapped into a different Kenyan context - one a bit more rural or homestead-based. Their most successful company interventions happen a slightly larger scale and for upper-class Kenyan families.

Ultimately, there are most likely many different reasons that this product is not making it to people in Kisumu. It could be distribution, manufacturing, marketing, or cost. But as a designer and stay true to user group I had committed to designing for. And therefore I had to approach it as a design insight problem.

I spoke with Dominic Wanjihia to understand his team's approach. It became very clear that his approach was centered around saving time and not money. When I proposed that I was considering making a biogas digester capable of cooking for about one hour / day, he responded: "by providing ½ capacity biogas, you may replace kerosene, but not firewood. You might think that that's a big saving, but the cost in cooking is not the fuel, it's the time" (Wanjihia, 2019). Dominic had a point. Gathering firewood is incredibly time-consuming. But the thing about Kisumu is that fetching firewood is quite rare. In very rural areas, this may be the use-case they are going for. But in Kisumu, it would be unheard of to hear of the average household searching three hours or more for fresh firewood.

In addition, KenyaBioGas's solutions are complete replacement products. They aim to replace the need for all other cooking stoves being used by Kenyan women. They want to replace Kerosene, Gas Cylinders, Charcoal and Firewood fires. Their domestic models cook for a minimum of five to six hours when maintained correctly. This amount of cooking time per day would absolutely replace most if not all of the other stove needs. And eventually, this must be the goal of domestic biogas solutions in the developing world. But unfortunately, almost every local Kisumu-ite claimed that the price of the KenyaBioGas digester was way too expensive for them to purchase. And a good number of those that I asked were not living in Informal settlements - they were instead middle class Kenyans. In addition, plenty of women that I spoke with would claim that one-hour of cooking gas every day would be an amazing addition to their current cooking setup. I don't think any woman that is supporting their family on a tight budget would say no to an hour of potential free cooking gas every day when they currently budget a huge proportion of their funds for combustible fuels. It's a wonderful thing when a solution is technically sound, but if it isn't affordable to the people that need it the most, it isn't a solution.

Thus became one tenet of the design brief for the project. Affordability first.



The blue biogas flame from underneath the Obunga BioCenter. this flame can run for

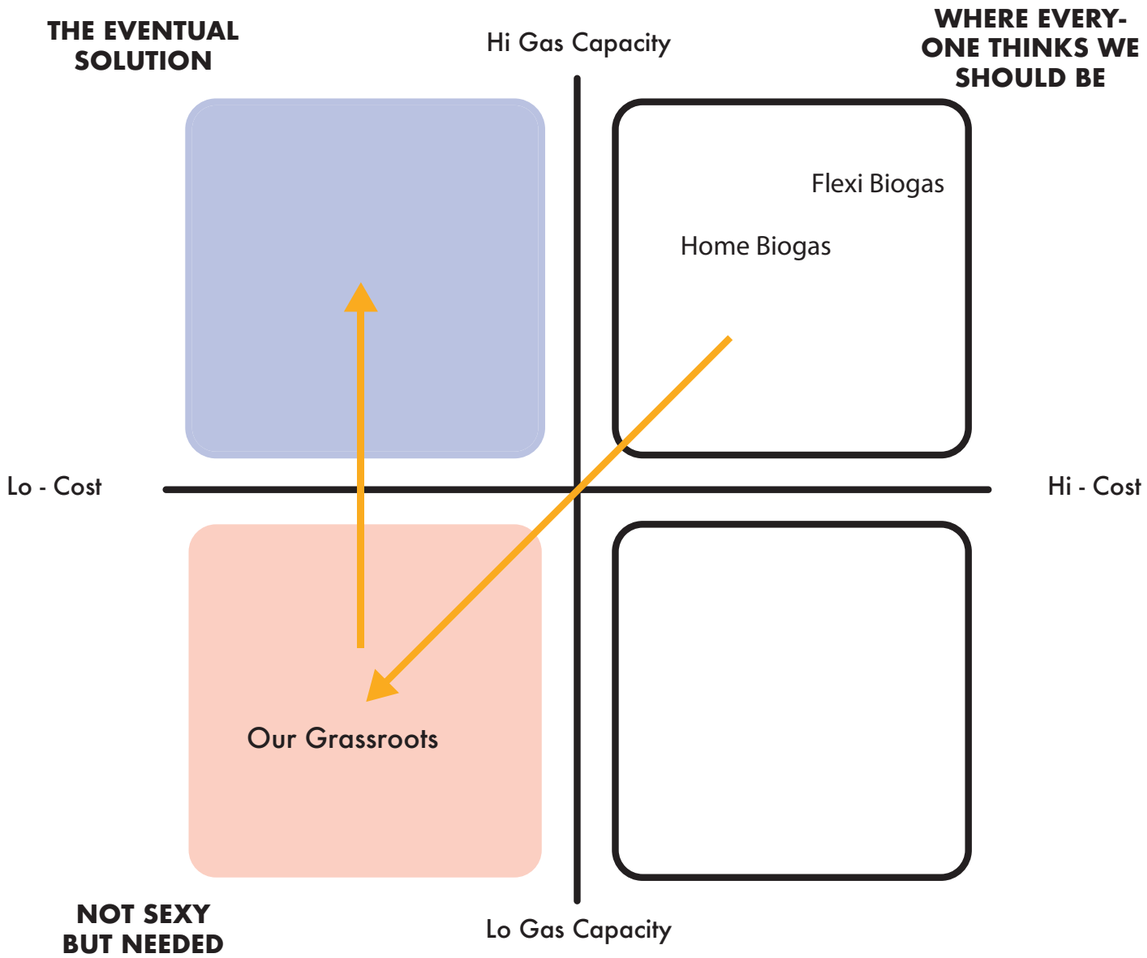
The Obunga BioCenter

OBUNGA BIOCENTER

I had heard from some women in Obunga that there was a local BioCenter in Obunga that was producing Biogas and enough for people from around the community to come cook with if they paid a small fee. I was shocked to hear that a communal system for renewable cooking fuel was in operation in the informal settlement. I contacted Evarline Ongayo through the Obunga Residence Association to set up a visit.

The plant itself was built in 2009 and was funded through through the Giselle Foundation, a US-based organization aiming to empower the local Kisumu population through drug prevention and self-help programs. The Giselle Foundation now employs locals to run the biogas plant, which requires the manager to charge for the toilet use and the cooking use. The Biogas storage is underground and was inaccessible, but is fed through the public toilets on the ground level. The human waste then provides enough organic waste to fuel the reservoir for enough cooking time for a full day's worth of cooking on the installed biogas stove. It sounded too good to be true until the team informed me that only approximately five people use the biogas stove per day. Tribal and community differences create a taboo belief that cooking food on another human's excrement is unhealthy and dangerous, which leads to lack of use and the eventual burning off of gas with no one reaping the benefit. When I pressed Evarline about why this was the case, she seemed even a bit embarrassed that the community operated this way. It is clear that there is no education or information being disseminated about the safety of biogas. Those that are using it have learned to look past the fact that it is human excrement-fueled or are aware that there are no health effects. This here was an opportunity to re-education or a product intervention.

It seemed like biogas was around and being experimented with in small pocket areas of Kisumu, but in this particular case, it was education and exposure that was the problem. Residents of Obunga either hadn't heard of the Obunga BioGas Center or they had heard that it was running off of human excrement and incorrectly believed that it would be unhealthy for them. Exposure and Education became the other tenets of the design brief.



FINAL DESIGN PROPOSAL

Focusing on the Household Women of the Informal settlements and understanding the local scenario around Biogas and the perceptions around it gave a nice platform for a project proposal platform:

- Any Product must start from a User-Centered Need
- If a solution to a problem isn't affordable - it's not a solution
- The entire Kenyan development story is that of patchwork solutions. Even for large problems like safe, clean, and affordable cooking fuels, we should consider piecemeal solutions.
- Any product must be replicable by the average Kenyan. This means all materials sourced locally and easily accessible.
- A successful network of smaller-scale biodigesters would not only supply residents with free cooking fuel, but would raise the knowledge and gradually trickle upwards to incorporate the food-waste that runs rampant in the city. Expanding to the Kibuye Waste Management context would connect this thread.

HMW CREATE AN AFFORDABLE & REPLICABLE SET OF DOMESTIC BIOGAS SOLUTIONS FOR CLEANER & SAFER COOKING PRACTICES

Digester Prototypes:

Top Left *: our first metal prototype with all of our materials laid out.*
Top Right*: The digester constructed and being airtight-tested*
Bottom Left*: The internals exposed on the water jug digester for Proof of Concept*
Bottom Right: *Allan holding out spray painted and poop-filled model.*

CO-CREATION AND PRODUCTIZATION

The Product Development Timeline was messy and overlapping, but in the end, I created a working Biogas Digester for the home, a working prototype for gas harvesting and a modified version of a gas cylinder stove for cooking with methane gas. Every product was iterated with and for locals and created with their budgets in mind. Every day consisted of product feedback and product testing.

THE DIGESTER - FIRST PROTOTYPES

Product development is a game of iteration. And our first biodigester was full of learnings and failures.

We procured a 250 liter cylindrical steel tank from the local Kibuye Market's metal working section. We hired a set of Jua Kali workers to cut open the internals and patch up our design. But for the first model we only needed an input pipe for feeding, an outlet overflow pipe for self-regulation of liquid, and a gas outlet for collection the gas that would build inside the digester. Additionally, it had to be airtight - which we tested with an air compressor and soap water. When sufficiently airtight, we filled it with a mixture of chicken poop, cow poop and food waste and placed it inside the kitchen in the back corner.

The results were less than desirable. We failed to account how much cooler it was inside the building than it was outside during the heat of the way. We also purchased the cheapest 250 liter container we could find - and this one happened to be metal, which isn't ideal for long term exposure to methane and carbon dioxide. This metal container would eventually corrode. After about seven days, we measured no methane being released from the digester.

The second iteration ran parallel to the metal digester. I purchased a 20 liter refillable water bottle and reused it to make a mini-digester as a small model. We used the same design internally and spray painted it black in order to keep the sun away from the microbes inside. After about a week there was very little methane formation, even though we left this small one outside in the yard exposed to temperatures well above 30 degrees celsius. My hypothesis is that this small digester failed to produce gas quickly because of our decision to also feed it with some food scraps within the first few days of activation.

PROTOTYPE 1

FULLY METAL 250L TANK

SOURCED FROM KIBUYE MARKET

LOCAL FUNDI-ENGINEERS INVOLVED

PROTOTYPE 2

PLASTIC 18.9 L WATER JUG

SOURCED FROM COCA-COLA FACTORY

SELF-BUILT

PROTOTYPE 3

PLASTIC 250L PLASTIC DRUM

SOURCED FROM KIBUYE MARKET

SELF-BUILT

LEARNINGS FROM ITERATIVE PROTOTYPES:

- The Activation Period is very important
- The general rule of thumb of biogas is that you can create the same amount of biogas in Liters as you have liquid in your digester under ideal conditions.
- Compression of gasses makes 250L hardly enough for more than one hour/day.
- The ratios of slurry and water are very important for activation.
- Must be plastic. And tough plastic.

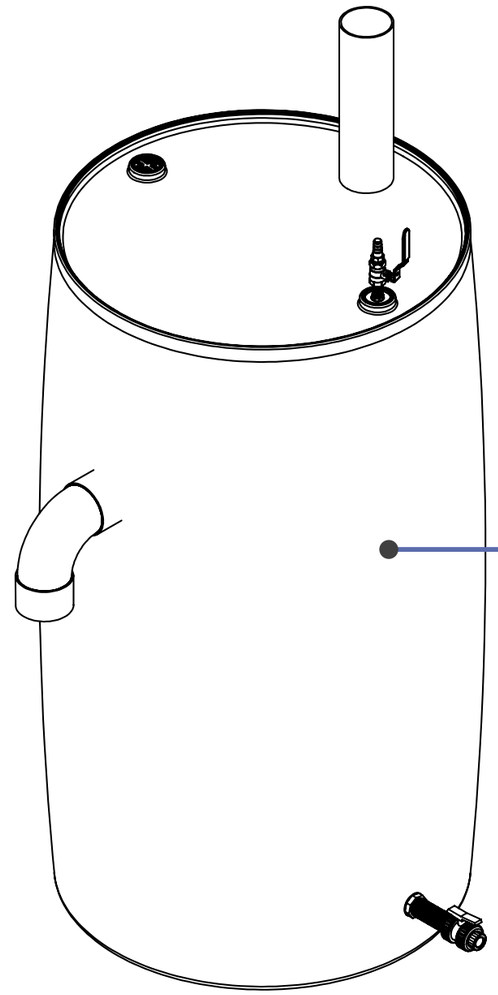
THE FINAL PROTOTYPE

A few final design adjustments were made to this final digester. For one, we used a plastic container in order allow for the expansion of gas and to prevent corroding. Secondly, we moved the overflow outlet about a foot up to allow for more space for liquid and biowaste in the digester . This will allow for more gas to form every day. Finally, we completely redid our activation method and followed a strict guide of ratios that was picked up from multiple online sources, including HomeBioGas's Technical Specification Sheet (See Appendix). We filled the tank completely with water until the water started pouring out of the regulator outlet pipe. We then retrieved fresh cow-dung that equaled 1/5 of the size of the digester liquid space. We approximated that there was about 200L of water space in the digester so we picked up 40L of cow dung from a local homestead. This 40L cow dung was then mixed with 40L of water to create a 1:1 watery slurry. Once we achieved the slurry consistency we then poured all of the mixture into the inlet pipe on the digester to displace some of the freshwater and replace it with the slurry mix.

We then let the digester sit outside in the sun for 10 days to let the bacteria start to grow before filling it with 4L of fresh slurry mix again, which we did every other day from then on out. By the end of the first week, we started to get a small amount of gas formation (10-20L / day), but when we started adding the new slurry after day 10, we started getting a lot more gas consistently (60 - 100L / day).

THE FINAL SETUP

AIRTIGHTNESS	TEMPERATURE
PH	SALTS
STARTING BACTERIA	SUBSTRATES



AT IDEAL CONDITIONS CAN CREATE ABOUT 1 HOUR OF COOKING GAS PER DAY

COSTS $60-70 USD TO BUILD

200L LIQUID CAPACITY

The Kibuye Waste Management Team planning out their construction tactics

Leading a workshop for visiting students about biofuels.

SCALING IT TO KIBUYE MARKET

Perhaps the most exciting part of this process was receiving a phone call from Harrison Otieno of Waste Management at Kibuye. The word had spread to some people on the Solid Waste Management team at Kibuye and he was requesting that I help them build a few models so they could start to create their own experiments and biogas. I gladly obliged and we spent two days devising and constructing biogas digesters nearly identical to prototype #3 with small adjustments. The goal of this exercise to impart the knowledge that I had picked up from my two weeks of iterative creation to them seamlessly. We documented the parts lists and plenty of process pics in attempt to create a step-by-step creation guide for future creators.

Harrison and his team were keen to display these biodigesters to a team of Brazilian Waste Actors that were to visit in late April 2019. The intent for the Brazilian visit was to add to the knowledge base of local, grassroots created micro-digesters. But the ultimate goal of the Kibuye Waste Team's biogas digester is to create a working model, prove the concept quickly and apply for funding for a larger-scale model that could eventually be used as a tool to help create reliable gas from the tons and tons of solid waste in the market. Scaling is always an issue at the grassroots level, but building an array of mid-size digesters could be a nice piecemeal approach to solving the complex bio-waste issue in Kisumu at a home level first.

The two final models ready to start the incubation process.

Different iterative models of the biogas harvest bag.
Top: *roofing sheets repurposed.*
Middle: *small models testing different plastics available in the Kibuye Market*
Bottom: *three 60L storage bags from Exxon LDPPE bags found in Kibuye Market*

THE STORAGE BAGS

Once all of these digesters were built and filled (five in total, including the models for The Kibuye Team), my attention turned to storage. The frugal decision to create the digester out of water storage tank plastic was informed by accessibility and cost, but created a cascading need for some gas storage. Storage is a common problem for non-flexible biogas digesters and for digesters that have large reservoirs - like that of the Obunga BioCenter. And the fact of the matter is - if a digester has no way to store and use the gas, the digester would be useless.

In the same manner as the digester, I set out to create a set of storage prototypes that were affordable, accessible and replicable. With these constraints in place, the design process was flipped on its head and I started with what materials I had access to. I rummaged through the closet of Zingira Community Craft to find a discarded roofing textile. I took it, duct taped the sides and inserted a tank fitting, a ball valve and a gas outlet to create a airtight-sealed block for air flow in and out of the bag. Some basic air-testing proved that it wasn't airtight, but there were so many imperfections with the duct taping and the original material had some micro scrapes in it that I hadn't seen upon first glance.

To explore more materials I headed to Kibuye Market to see if I could get some lucky with some cheap material samples. There was no guarantee that there was material either good enough, cheap enough or safe enough to be used for gas storage in Kibuye, but I scoured the back aisles of the market near the charcoal and metalworkers to find a fabric section that also sold some types of plastics that were used to weatherproof vendor stalls for the rainy season. There were some super-light clear plastics, and some slightly denser plastics that were a bit hard to distinguish. I purchased samples of all of these for a small price and purchased another that I found to be the most promising. The Material was a discarded ExxonMobile Low-Density Polypropylene (LDPPE) bag. These bags are normally collected, split apart and re-stitched together to create a long 2mx1.6m roofing material. From my initial research about airtight bags and gas storage, some digester systems use LDPPE as their storage material already.

Four different bags spliced together. With the connection techniques at our disposal, guaranteeing air-tightness proved extremely difficult.

PROTOTYPING A LARGE BAG BY MELTING THE PLASTIC AIRTIGHT WITH AN IRON

THE ORIGINAL BAG - UNFETTERED BY ANY PROCESS

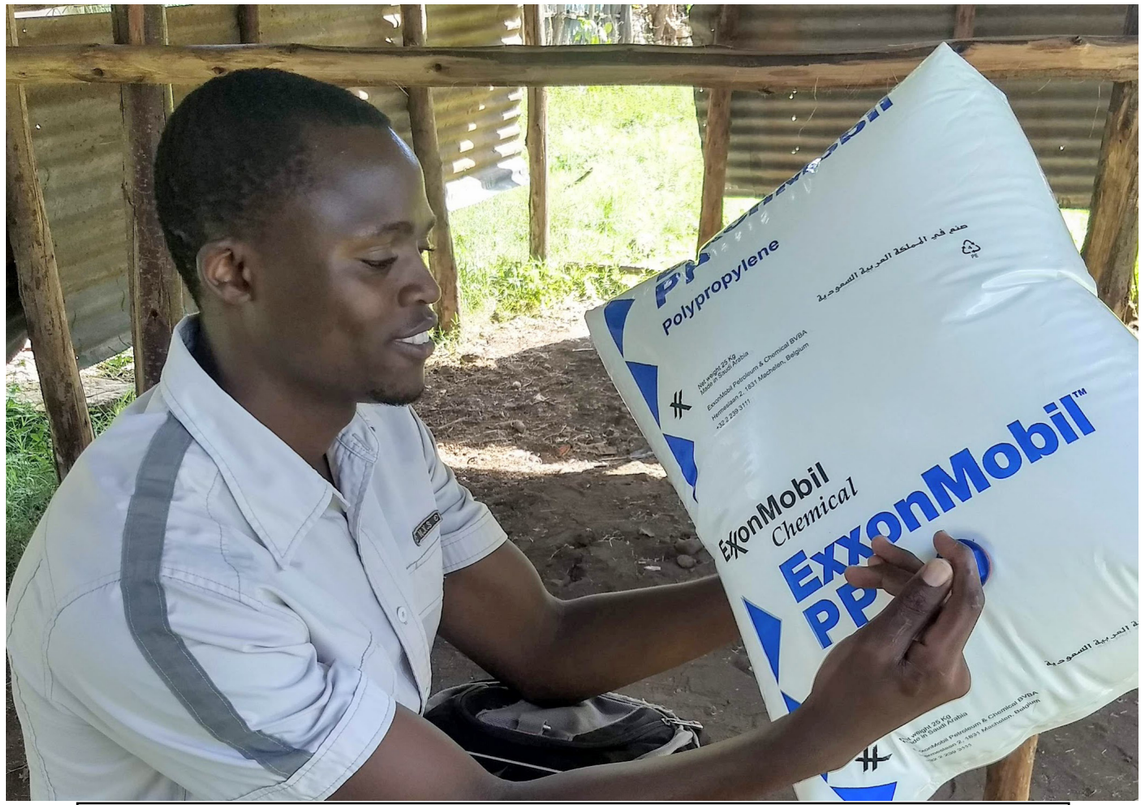
I went on a prototyping frenzy to try and test these materials and their airtight capacities. I used an iron that I purchased at a used-hardware stall for $5 USD to melt the plastic together to create the airtight seals the best I could. But of tantamount importance to the material was the dimensional design of the bag. The raw material from Kibuye Market came in predetermined sizes, making the creation of larger bags a difficulty because of the added number of melting seams I had to create. Without an industrial melder and sealer, my best efforts often-times created less than perfect seamlines, creating weak points along parts of the seam that would pop when really pressured.

The breakthrough came after about a dozen prototypes and airtight tests, when I realized that the bags could be purchased before they were split apart and stitched together at the market if I just followed the supply chain one more step backwards. These bags were already industrially sealed on 3 sides and only required one side to be manually melded with an iron. With a few iterations, I created some very reliable storage bags out of these LDPPE bags - complete with plastic hardware.

While prototyping is always a relatively expensive process, the final bag workable bag prototype consisted of the LDPPE bag and the three pieces of plastic hardware to equal about $9USD.

The final cost is irrelevant if the prototype doesn't work well. And the final question still remained as to whether this kind of LDPPE bag would be suitable to hook up to a biogas burner directly. In order to test this, I took some prototypes to the Obunga BioGas Center to plug these bags in directly to their biogas source in order to turn it around and immediately hook it back up to their biogas burner. The initial Proof of Concept test went successfully and we were able to get flame for about 12 minutes from one single LDPPE storage bag.

Filling up the storage bag with biogas from the Obunga BioCenter for testing.



John Xavier tesing out the airtightness of the seams.

The LDPPE bag had obvious weaknesses and while we had ideas on how to improve it, I set up a concept reveal feedback session with some local residents of Obunga. With the help of the Giselle Foundation Workers, we were able to gather a crowd of about 15-20 people and publicly exhibit the gas storage system. The Giselle Foundation and the members of the community were very excited about the idea and had plenty of ideas about how to make it safer or better. Some of the ideas were as followed:

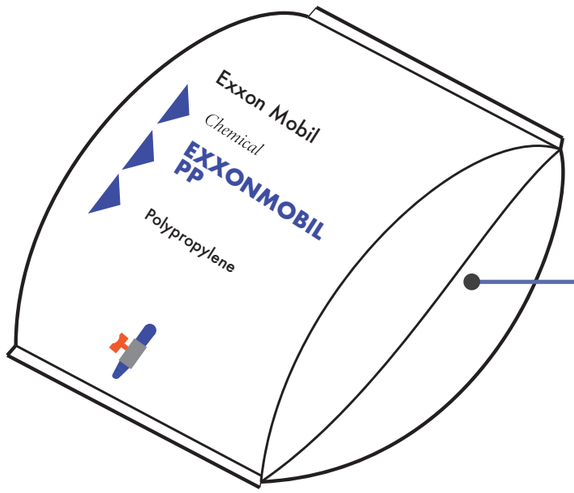
- Looking for better materials
- The counterweight system in place to keep pressure on the bag
- A removable hardware setup that could be attached to any storage bag to bring down costs for families owning multiple bags.
- Compressing the gas in a better
- Placing the bag in an "armour" kind of setup to protect it from the elements.
- Adding some safety factor to the wear and tear of the hardware on the bag.

Overall feedback was constructive and it seemed like the working model created a lot of excitement and comments about getting the bags of gas to the people that needed. The Giselle Foundation and the volunteers working there were energized by the possibility of supplying consistent gas to obunga residents. While there was some excitement about potential business opportunities, the first order of business was creating a bunch of prototypes and getting them in the hands of some residents for free.

A public testing of our storage bags boiling water for some local women.

THE FINAL SETUP

MATERIAL	WEIGHT
LDPPE	< 1kg
INTERNAL PRES-SURE	**DURABILITY**
Low	Medium
SAFETY	**AIRTIGHTNESS**
Safe if handled safely	Bag dependent



THIS BAG CAN COOK FOR ABOUT 15 MINUTES. ENOUGH FOR 2-4 CUPS OF TEA

COSTS APPROX. $9.50 USD TO BUILD

60L GAS CAPACITY

THE BURNER

For optimal cooking efficiency, biogas requires a different kind of burner stove. It's quite a technical field to reach optimal standards. But behind all of the science and physics that dictate compressed airflow and heat efficiencies, there are some simple concepts that can be digested by the average layperson. According to Energypedia, "For achieving a high efficiency of biogas stoves, the important factors to be considered [...] are:

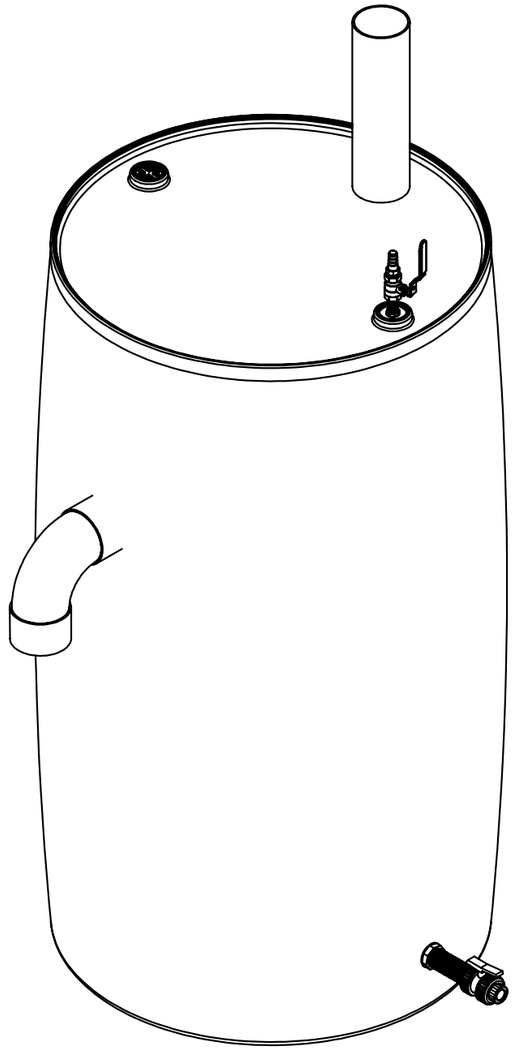
- Burner types (orientations of holes, shape and size of holes, burner size)
- Space between the burner and the tripod or other vessel supporting mechanism
- Air control mechanism and optimization on burning"

One option was to embark on a custom design journey and create a Jua Kali style burner with a metal-worker from Kibuye Market. The Obunga BioGas Center pursued this option back in 2009 when they constructed their own stove. The model was built by a local craftsmen with dimensions that were optimal for maximum heat flow with biogas. Replicating that model with a local craftsmen was quoted to me to be around $30-50 USD per piece. This checked off my desire to have it locally sourced, but almost eradicated my desire to keep it affordable and replicable by the average Kenyan.

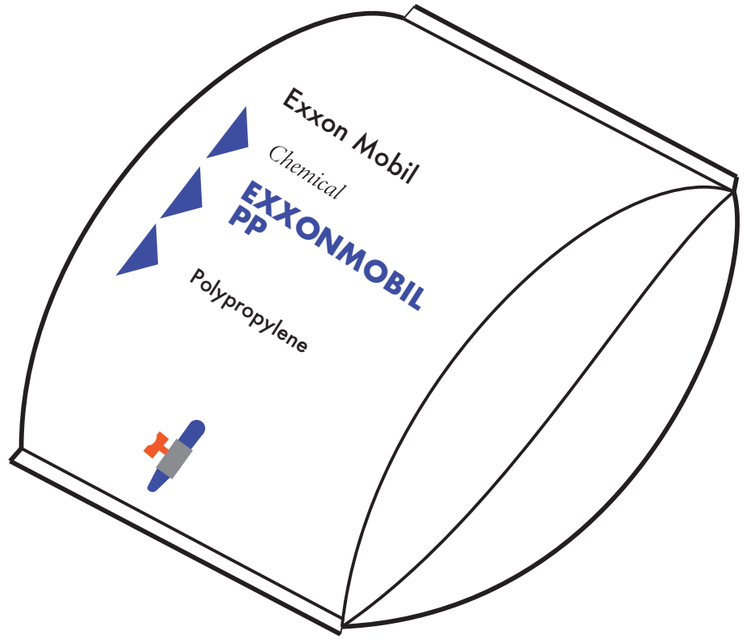
Eventually, a transition to a custom design would be desired, but to keep the project red-line in tact, I purchased a $5USD burner on the street - an LPG gas cylinder burner coincidentally designed in Sweden and manufactured in China. Every single resident in the city either owns or can afford this product, so I attempted to modify myself. The Nozzle on this model limited the gasflow and is around 0.5mm diameter in most models. This is simply too small for methane molecules. The minimum gas nozzle size must be at least 2.5mm diameter. In addition to the nozzle size, the gas hole sizes for biogas must be a bit larger for optimal heat dispersion through the burner, but what is more important is the the mixing of oxygen flow. As a starting test, I drilled a 3.0mm diameter hole in the nozzle to widen the flow and tested it on the methane source. It burned beautifully - a nice, even, blue flame. While the efficiency was difficult to test with the crude tools we had available, the slightly modified LPG stove was fixed to a paint can to improvise a pot stand and it boiled three cups of water in seven minutes. Evance and I enjoyed this tea on a beautiful afternoon two days before the public exhibition. I revered this as a huge success. I forewent the decision to modify the burner holes and the air flow holes for lack of time and resources.

But in the weeks since I've left, Evance Odhiambo has improved the burner design and created a working stand for it - which he claims can be made for $14 USD.

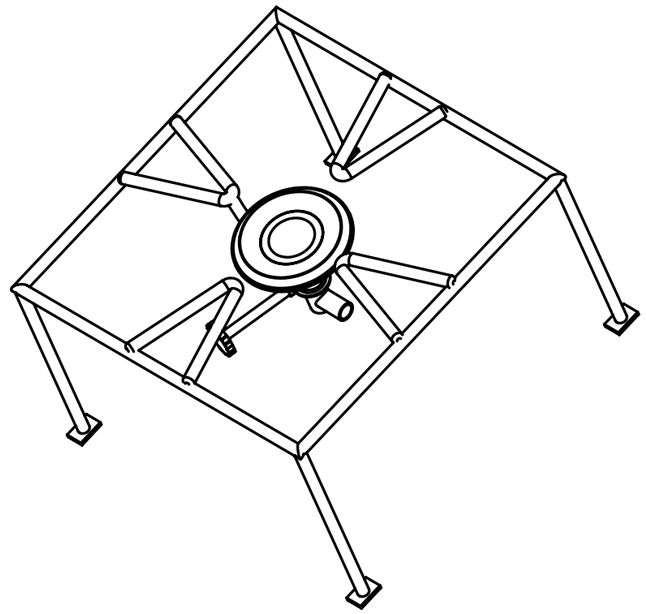
THE FINAL SETUP



250L BIOGAS DIGESTER



60L BIOGAS STORAGE BAG



MODIFIED CUSTOM BURNER

Locals attending the exhibition at Kenyatta Sports Ground.

Me doing my best to explain and demonstrate the project.

THE EXHIBITION

On April 13th at 11:00am, our group of students from Chalmers and Lund University exhibited our field work results at the Kenyatta Sports Ground in the center of Kisumu. The 5 weeks of fieldwork had flown by, and it was time to display what we had learned and what we had to share back to the community. Our Biogas table at the Exhibition demonstrated the entire narrative around how a Kisumu citizen could make a piecemeal approach to transitioning to Biogas. It presented a very simplified "science fair" like experiment about what Biogas is (See Appendix for Exhibition Printouts), a small scale portable digester with visible internals, the storage bags that were full of methane retrieved from the Obunga BioGas Center's Reservoir, and the makeshift, modified biogas burner. Every step of the process was depicted graphically and physically and the interactive nature of the live - working burning prototype was fascinating for most visitors. Hundreds of visitors passed by the exhibition and we collected over 50 emails/contacts to keep in contact with for future information dissemination. Dozens of visitors requested to have a copy of my exhibition materials and expressed their interest in creating their own biogas digester. While not a fact-based statement, perhaps the most telling anecdote from the exhibition was the continuous bewilderment and excitement when visitors witnessed blue flame coming out of the burner from the storage bag.

FUTURE STEPS

Member of the Kibuye Waste Management team very proud of the digester.

Evance of Zingira Community Crafts testing the bag to make tea.

EXIT STRATEGY

Design Engineering Interventions in the Developing world are tricky. As per my introductory comments on solutions that are developed externally and dropped into communities in hopes that they work, it's equally as difficult to create something with a grassroots innovation mindset and have it stick. Some immediate advantages are that the local inhabitants feel a sense of empowerment and engagement with the project, which I can say first-hand is absolutely the case from this project. A lot of my effort the final week I was in Kisumu was dedicated to making it clear to the actors I was working with what the expectation was for my exiting and what their role would be going forward.

KIBUYE WASTE MANAGEMENT

Their goal was and always will be creating a scaled-up version of the small scale digester that I designed. But individuals within the team are more interested in making small scale adjustments to the size in order to slowly prove the concept at different scales. One member of the team, John Xavier, played an integral consulting role in the project, intends to apply for funding to build a slightly larger system in series in order to hook up the local restaurant that he has been going to since his childhood. He believes that "if the community members see a working model at the center point of the community (the restaurant), members will invest in their own small-scale digesters without an issue"

ZINGIRA COMMUNITY CRAFT

Evance Odhiambo and the Zingira Team have historically been heavy hitting project partners with the Reality Studio students. Multiple projects that found a real need in Kisumu were carried on through Zingira when the students left. Evance made no contractual promises to me, but made it clear that he was interested in moving this project forward with the power and capabilities they have. In the weeks since I have left, Evance not only has continued to build a stand for the modified Primus burner, but he has presented the entire project to a visiting group of Swedish researchers that visited Kisumu at the end of April. He has been continually spreading the word and developing the idea slowly, and has told me how "people are so excited for this" and that "two women already want their own digester".
Evance and I stay in contact and continue to work on storage bag material, and burner modifications. I left Evance multiple copies of the storage bag design and a working biogas digester and he continues to fill his bag with Biogas everyday to make tea.

Evance and I enjoying Masala Tea.

Eric, Joseph and I discussing the future of the Bag Initiative at the Obunga BioCenter

OBUNGA BIOCENTER

The BioCenter expressed interest in carrying out this project going forward from the first day that I walked into their building. The staff at Giselle Foundation has been running low on resources and ideas in recent months and when they were exposed to a cheap and affordable way to consider harvesting gas in bags, they expressed their interest in creating a team to develop a prototype testing team. Eric, the Giselle Foundation Representative was a huge help and accompanied me to purchase over 20 ExxonMobile bags for future prototypes. The Giselle Foundation has plenty of material and all of the materials and information to develop their own bag prototypes. I spent two whole days at their office creating and troubleshooting the bag-making process with them. I keep in touch with three members of the Giselle Foundation team to see how the Development process is continuing.

MISCELLANEOUS CONTACTS

The 50+ contacts we collected before, during and after the exhibition are all connected on a public facebook page and email list. I distribute information to them through these channels and plan to give them a comprehensive local Kisumu Construction guide for how to build their own Digester, Bag and Biogas Burner.

EXIT STRATEGY CONCLUSION

Whatever the strategy was, I was intense about making sure that the local communities and stakeholders felt a sense of ownership over the prototyping and development process going forward. I made sure that whatever was created was affordable, replicable and accessible by the average Kenyan.

The most validating feedback I received has directly from Evance who told me to my face that "the way that [I] stayed true to the user, kept the disadvantaged at the front of [my] mind in every decision [I] made was inspiring and absolutely the way projects should be carried out".

If the solution isn't affordable, it isn't a solution.

WHAT'S NEXT?

FUTURE PROJECT THEMES

This Project exposed a treasure trove of future projects that could be explored by future researchers, locals, or students of reality studio. See the Appendix for detailed PADS.

- Creating a cost-efficient modified burner system for Biogas. The current Biogas Stove market is unsustainably sourced, creates waste and is unnecessarily expensive for households that would most-likely have access to biogas in the first place. This project modified a very cheap burner that was used as a patchwork solution to a larger problem. This can be improved - and drastically. There is plenty of science and engineering behind this problem for the mechanical and technical designer.
- Improved Bag materials for Biogas storage. This project also made a working prototype model that is safe enough if handled nicely, but it absolutely can and should be safer and more durable. Only the top of the surface was scratched when it comes to cheap local materials available. It also needs to be made larger.
- Along this same line is a cheap and affordable protective case for the storage bag. Presumably this storage will be stored outside. The housing must protect the bag from aberrative tears and harsh weather environments.
- The safe cooking space is saturated, but mostly with the same products. All different kinds of stoves, but there are plenty of other more creative paths that could be taken. For example - given the multiple kinds of cooking tools used, there is tons of misused space in the kitchen. The kitchens are cramped and small as it is, and having three or four stoves on the ground horizontally is poor. One could consider creating a Vertical cooking station for women in their kitchens. Maybe the stoves with the most harmful toxins can be kept higher on the vertical ladder to lower the amount that may rise directly to the human level. Another idea would be an add-on part for a Jiko that filters or redirects the smoke. They are all similar product ideas that address the same problem.

ROOM FOR IMPROVEMENT: THE DIGESTER

- The Hardware could be sources more efficiently and more cheaply.
- The user friendliness. It could be more clear when and how you need to operate the ball valves to not let the methane get released and compromise the air-tightness.
- Kid safety factors.
- How the bag attaches to the side of the digester reliably without weakening the connection the digester or the connection to the bag.

ROOM FOR IMPROVEMENT: THE BAG

- The shape could be iterated on depending on the size of the storage and placement in the kitchen. Also need to consider how it connects to the digester
- The Material MUST be improved.
- The safety factors must be better researched and improved.
- User testability and interface design needs to be implemented.
- The counterweight and transport of the bag

ROOM FOR IMPROVEMENT: THE BURNER

- The efficiency of the burner
- Complete custom proprietary housing design specifically for the primus burner

FURTHER ETHICAL CONSIDERATIONS

In what ways could this affect other parts of the market?

Implementing this solution at a grassroots level would encourage local ingenuity, local business, and waste-value addition. It would also encourage a slow transition to biofuels and wean the use of unhealthy cooking fuels like charcoal, firewood and kerosene. But of course, the implementation of any idea has far-reaching effects across any market. Lowering the demand of other cooking fuels and practices would affect the livelihoods of women and salespeople that sell charcoal and other cooking materials like Jiko. The transition would be slow enough that the impacts wouldn't be intense, and the arc of development is moving away from this anyways, but it's important to state the ways that a transition could be felt.

How could this be harmful or misused?

The largest bunch of ethical questions arise around the use and misuse of the technology. Investing in this kind of system would be a smart financial decision in the long-run, but misuse and sometimes unpredictable factors could lead to a lack of gas production or maybe even a breakdown of the system entirely. Resetting the system would be time-consuming and would require semi-professional help. Having an investment like this breakdown would be difficult for the consumer. The misuse of the system could also lead to some dangerous interactions with the products. The Digester in particular scenarios could break down, expel methane or even explode if things go really wrong. The Bag could in theory come too close to the flame source itself and end with a small explosion. And while all of these things are unpredictable in a way, the fingerprints of our work covers the design, and any acknowledgment of edge-case danger and potential ethical concerns are worth stating.

CONSTRUCTION MANUAL

One of the red-line desires was to bring better livelihood to people. Perhaps the most effective way to do this is put more money in their pockets. But Siphoning it through their own hard work and business savvy is perhaps the most effective. There is a high potential for a small grassroots business and education initiative to be created out of this. A small team of engineers created multiple biogas digesters in my final weeks in Kisumu and the knowledge on how to create digesters and a system for how to make them work is there. The model for how to teach and distribute is less evolved and a future offshoot of this project, either for myself or for a future student. I created a lengthy and detailed construction and sourcing manual for how to create all of the products described in this thesis work. I have included where to purchase each part, how to construct and assemble every part with CAD model drawings and engineering drawings. This document has been edited and checked off with multiple stakeholders. This manual can be accessed upon request.

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APPENDIX

LIST OF TERMS

Jua Kali - A Swahili term meaning “under the hot sun”. A Jua Kali refers to an engineer without formal training that is a de facto expert in a certain creation technique.

BioGas - a renewable biofuel comprised of methane and carbon dioxide molecules created from organic materials and waste.

LLDPE - linear low density poly-ethylene. It differs from LDPE from it’s manufacturability processes and its higher tensile strength and higher impact resistance.

Boda-Boda - A network of informal motorbike transportation.

Tuk-Tuk - A network of informal transportation that involved shade-covered box cars.

Informal Settlements - an area where houses and communities have arisen where that the occupants have no legal claim to.

EXHIBITION MATERIALS

Blue Gas

Exploring an Accessible Transition to BioGas in Kisumu

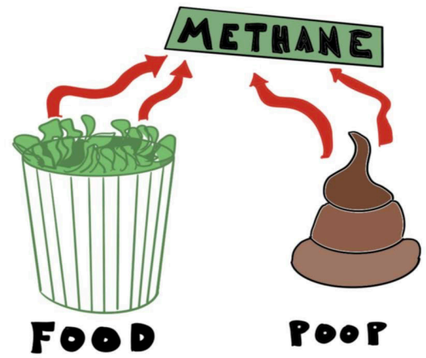
Project by Jeff Bennett
Masters student at Lund University

What is BioGas?

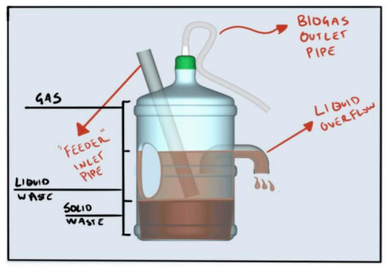
Biogas is a renewable, clean source of fuel. In it’s purest form, biogas is methane **and is produced from the breakdown of organic material like compost and excrement.**

Biogas has been around for a long time and is present in spirit and in practice is Kisumu, but the average citizen is far away from being able to use this abundant fuel for free or even at a low cost.

The biggest barriers are cost to invest and exposure to a working system.



How do I make it?



The process to create biogas is relatively simple. You'll need an airtight container and supplementing hardware.

The one-time activation usually takes 1-4 weeks depending on the size of the digester.

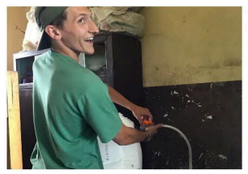
General rule of thumb: in 24 hours you can create as much biogas as the size of your container**. A 250L digester can normally produce enough gas to cook for one hour/day.** This size digester can be sourced and constructed for approximately 5,000 /=

How can I get it?

There are seven BioCenters with BioGas initiatives around Kisumu, and while all have different capacities, BioCenter Obunga has enough BioGas to service 300-500 people per day, but currently services approximately 10**.**

With Zingira Community Crafts and Obunga BioCenter, we created a first working prototype of what affordable biogas harvesting could look like in Kisumu.

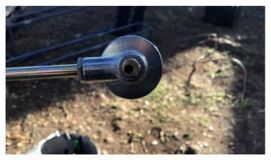
Otherwise, construction of your own biogas digester can supply your needs.



How do I use it?

The Polypropylene bag is outfitted with a valve to allow for safe harvesting. It can plug directly into any gas source, fill up and be transported to your cooking stove where it can also be plugged in directly. The bag displayed can cook for 12-15 minutes and easily make two cups of tea.

BioGas requires a particular kind of stove burner - one with a larger nozzle than those made for gas cylinders. But with a 3mm drill bit you can modify any burner to fit your biogas needs.



Why should I use it?

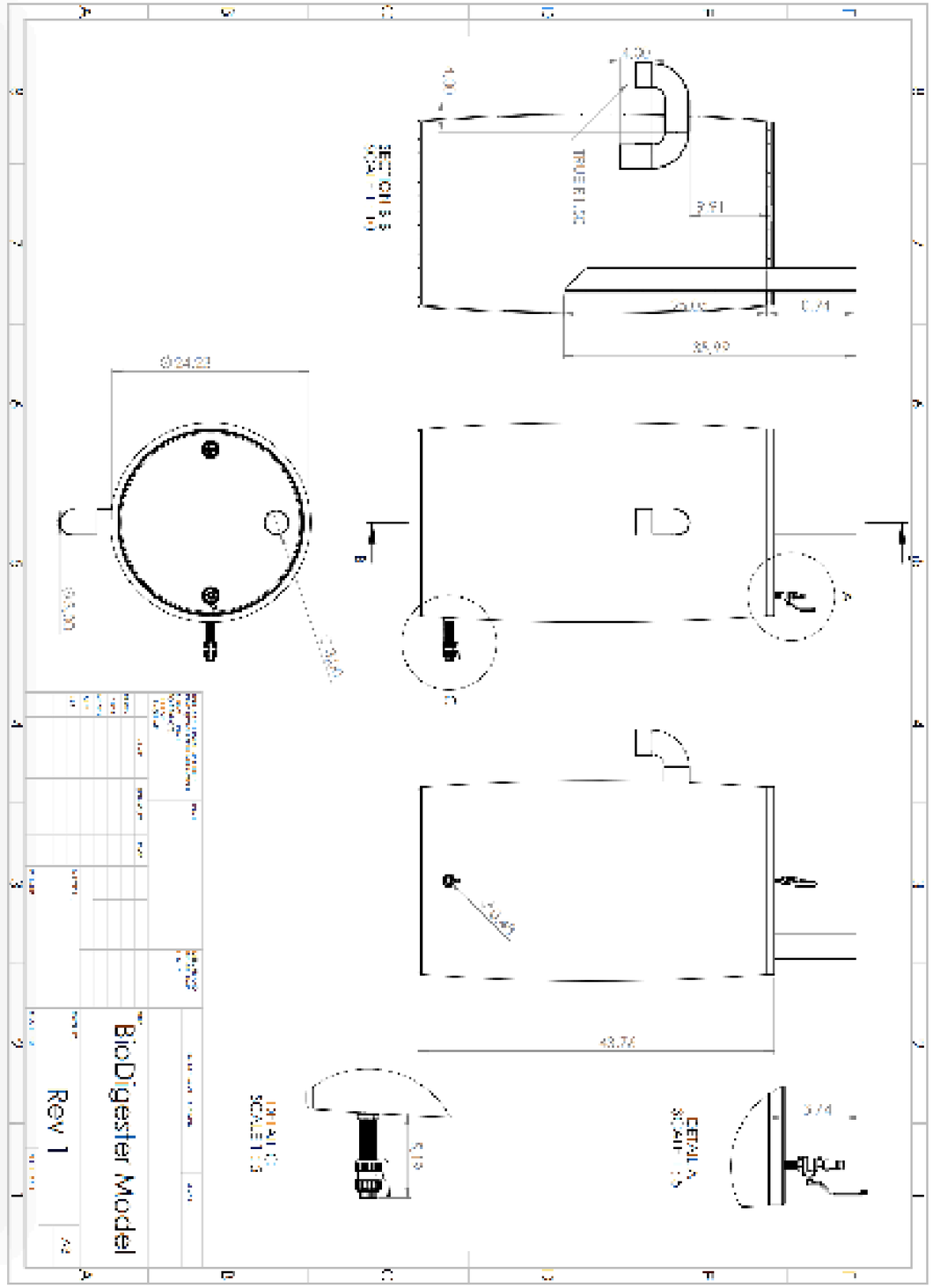
Charcoal can cost upwards of 2500/= per month**. Gas costs 1100/= to refill after a 6000/= investment. Investing in and cooking with biogas can** save you thousands of schillings over time. **Not to mention the negative affects of kerosene, charcoal and firewood in the home kitchen on the livelihood of those who cook.** Millions die every year from slow exposure to unhealthy cooking environments**, but biogas is a safe gas and is completely green.**

HOMEBIOGAS TECHNICAL SHEET

Technical Spec Sheet
HomeBiogas 2.0

Item	Value
Total Volume of the System	2.1 [illegible] / 534.8 Gal
Volume of Biodigester	1900 L / 217 Gal
Volume Gas Tank	900 [illegible] / 187.5 Gal
Maximum Amount of Food Waste	Up to 2 L / 31.7 Gal
Maximum Amount of Animal Manure	Up to 36 L / 9.5 Gal
Daily Nominal Biogas Output	300 L / 79.3 Gal
Nominal Gas Pressure at System Outlet	10 Mbar
Cooking Time (One Burner)	Up to 3 Hours Daily
Total Amount of Fertilizer Produced	Same Amount as Waste Input
Typical Daily Power Output	1.4 kWh / 5.4 mega-joules
Dimensions of Assembled System	130 [illegible] 230 / 130W (cm: 51 [illegible] 90 W (in)
Dimensions of Shipping Box	88 [illegible] 100 / 42W (cm; 12 [illegible] 90 / 17 24 kg / 53 lbs
Distance to Cooking Stove	Up to 20 m / 66 ft
Daily Temperature	
Best Performance	[illegible] C (+77 F)
Good Performance	+20 C (+68 F)
Requires Heating	+20 C (+68 F)

TECHNICAL DRAWING: BIODIGESTER



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