Desert Water: Feasibility of Bioethanol Production from Cassava as an Alternative Cooking Fuel in the Bo Region of Sierra Leone

Project Partner: Martin Kailie
D-Lab I Team: Matthew Bridges, Dana Armstrong, Peter Nasielski
I. INTRODUCTION

Almost all of Sierra Leone’s 7.2 million inhabitants prepare their food over wood-burning fires. This practice leads to high rates of pulmonary disease, increased risks for women who collect firewood, and severe deforestation. The rapid deforestation for cookstove fuel is additionally contributing to greater irregularities in regional climate, including severe droughts and flash floods, which in turn further lowers the resilience of the rural population. At the same time, cassava has been recently hailed as a strategic, climate resilient crop as it can withstand long periods of drought and will not wash away during floods. The tubers can remain underground for up to 2 years, thus allowing for a steady output. The starchy tubers can be processed into many value-added products such as gari, fufu, paper and beer. In the Bo region of Sierra Leone, cassava is already starting to be more intensively grown by women in cooperatives.

Here, we explore the feasibility of creating a market for cassava-based ethanol in the Bo region of Sierra Leone, the regional expertise of our in-country partner, Desert Water Social Enterprise. We explore the introduction of the stoves in urban areas, where inhabitants are already having to purchase fuel. One bundle of firewood costs $5-10 USD depending on the time of year and lasts a family for about one week. We explore the idea of replacing this wood consumption with locally sourced cassava-based fuel produced from a high-fiber, high-yielding strain (identified by the Sierra Leone Ag Research Institute), grown by women in cooperatives. Similar initiatives have been implemented in Mali, Nigeria and Mozambique to varying levels of success. We are optimistic about Sierra Leone as a strategic location because of its land availability, the high price of firewood and its already-organized women’s growers cooperatives who are eager to be part of this project.

The specific outcomes of this project are to:

1. Establish a market in the urban center for cookstoves and ethanol
2. Establish efficient, environmentally sustainable ethanol production systems
3. Establish a sound transportation system for harvest-to-production and product-to-market
4. Empower and further develop the farmer cooperatives that produce cassava

After some background research and analysis, we have determined the following targets:

1. Introduce 1,000 households (0.01% of the population) to cassava-ethanol as an alternative fuel source. We estimate one family uses about 3 liters of ethanol per week\(^1\) (Murran and Debebe 2006), so:
2. We plan on building ethanol production plants that can produce 156,000 liters annually. This can take the form of one plant that produces at least 500 liters per day, or ten micro-breweries that produce 50 liters per day.

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3. We propose to contract farmers on 50 hectares to farm a high-yielding strain of cassava that produces 20 tons/ha for a total of 1 million kg (1000 tonnes) per year. Several cooperatives already exist and have expressed interest in the initiative.

We have identified and recommend cassava strain TMS 30572 (among about five equally legitimate contenders) as a high-starch, high-yielding variety possessed by the Sierra Leone Agricultural Research Institute (SLARI), who may be willing to donate stems for this initiative. Because it grows identically to the current cassava, no new farming practices will need to be introduced. Additionally, we have identified a cookstove supplier who has agreed to donate stoves for a mini-pilot study, to test the market and acceptance of the product in Sierra Leonean kitchens. Our on-the-ground partner is Martin Kailie of Desert Water Social Enterprise. Martin is from Sierra Leone and is familiar with farming cooperatives and value-added cassava initiatives, as well as an expert in the local cultural norms and practices. We are a team of UC Davis Students in International Agricultural Development and Industrial Design, with knowledge and experience in ethanol production and cassava cultivation.

If successfully implemented, we believe this project will result in substantial economic opportunity, providing women’s empowerment through their production of value added cassava, and jobs in ethanol production and distribution. Our client’s project could also reduce reliance on wood as the sole source of cooking fuel, therefore reducing the amount of wood that is harvested, and reducing deforestation.

II. METHODS AND EVALUATION TOOLS
We employed a variety of methods and tools to better outline the role of Desert Water. Each tool presented a different way framing the multifaceted project, with valuable insights shared below.

A. SWOT Analysis:

The SWOT analysis presented on the following page is resulting from our team’s research, partner engagement, and stakeholder engagement. Strong external partnerships are the main strength of the project. The main weakness is the need for major start up investments for each leg of the project and the interdependence of each of these investments. Meanwhile the presence of experienced and well organized cassava farmer cooperatives represents a major opportunity. The most significant threat to the project is the potential for unforseen costs.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Dynamic organizational leader</td>
<td>• High start up investment required for building ethanol production facility</td>
</tr>
<tr>
<td>• licensed to operate in California</td>
<td>• Each leg of the project relies on the other-- fuel market is needed for cassava production, but intensive cassava production needs an end point/destination market</td>
</tr>
<tr>
<td>• In-line with FAO and IIITA mission; probable support from existing ethanol plant</td>
<td></td>
</tr>
<tr>
<td>• Startup stoves and sticks already donated (need to confirm)</td>
<td></td>
</tr>
<tr>
<td>• Existing Connections to farmer cooperatives</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Women Farmers are already familiar with growing cassava</td>
<td>• Alcohol/ethanol may be a taboo in some rural areas</td>
</tr>
<tr>
<td>• High demand if produced affordably</td>
<td>• Minimal infrastructure: roads, electricity, water</td>
</tr>
<tr>
<td>• Similar initiatives begun in other countries</td>
<td>• Seasonal fluxes: droughts (may lower cassava production) and floods (roads may be impassible and harvest will be hard)</td>
</tr>
<tr>
<td>• Existing ag business centers potential base for farmer collaboration and cassava purchase</td>
<td>• Other stove fuel sources -- solar?</td>
</tr>
<tr>
<td></td>
<td>• Non-cooperation of Makeni/Sunbird biofuel plant?</td>
</tr>
<tr>
<td></td>
<td>• Potential for unforseen project costs</td>
</tr>
</tbody>
</table>
B. Logframe Flow Chart:
Several versions of logical frameworks exist, however, we have created one that lays out the suggested scope of the project in full. Listing the general sequence for suggested implementation can give an idea of the investments and outcomes as one moves forward. The initial proposed methodology begins by identifying critical inputs: stoves donated by CleanCookAB, high-yielding cassava sticks provided by Sierra Leone Ag Research Institute, ethanol provided by Mikeni (formerly Addax) Bioenergy, possible collaboration with students at Njala University, and participation from UC Davis students to run pilot tests on stove reception and technologies. Assuming successful completion of summer initiatives, the latter half focuses on establishing market for stoves, construction and beginning function of ethanol plants, and establishing further trainings and benefits for participating farmers. This flowchart can aid in planning out a Gantt Chart (in recommendations) and other critical sequential implementation considerations. A similar methodology can be found in Appendix 1, which is a production chain of the full proposed product.

**Program:** Cassava Ethanol Logic Model (uses text boxes: add/change boxes and arrows as needed)

**Situation:** 95+% wood-burning stove use in Sierra Leone results in pulmonary disease, deforestation and gender equity issues and necessitates a need for fuel alternatives. Cassava-based ethanol burns clean and can be a value-added opportunity for crops already grown by women in cooperatives.

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**Inputs**
- 50 stoves donated by Project Gauss and SHL, ethanol donated by Addax Bioenergy
- Student funding provided by Jalibb &Brun
- UCD faculty may serve as advisors
- Possible participation/ collaboration with students from Njala University
- High-yielding cassava sticks provided by SLARI
- Further funding needed

**Outputs**
- Summer: stove Mini pilot study & survey with urban households
- Summer training on importance of forestation and dangers of woodburning
- Summer area mapping of target markets, supplier firms and geographic assessment (HCO etc)
- Summer: introduction of SLARI variety sticks through cooperative training & meet
- Rural training on importance of trees to reduce extreme weather events

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**Assumptions**
There are enough farmers and fallow land (500 ha) to adequately produce and process 20 tons of cassava.
Future sizeable infusion of funds for ethanol plant construction
Sufficient water available for ethanol production

**External Factors**
Government & country remaining peaceful
Weather not being too severe
Other similar initiatives possibly coming in/starting up infrastructure and possibility of roads
C. Monitoring & Evaluation Logframe:

A template for monitoring and evaluation has been developed and shared here. This is different than the above flow chart as it identifies specific values for the purposes of assessment.

The monitoring and evaluation logistical framework was created to serve the need of measuring progress. Major grants are likely to require a structure dictating how major project objectives will be implemented, in order to uphold accountability. Our three project objectives encompass the entire scope of the project, presumably in the first year of our timeline. Here, the possibility of building medium scale ethanol plants is explored. However, the client is also encouraged to pursue partnership with an existing bioethanol company (see “Recommendations”). The three project objectives were based off of the client's vision for addressing deforestation and women's sovereignty in the countryside of Sierra Leone.

The quantitative estimates offered are derived from the following logic: Our team determined a 6:1 ratio of fresh cassava tubers to 1 liter of ethanol,\(^3\) we determined that if we invest in the high yield of cassava we will get an average of 20 tons per hectare.\(^4\) Our client estimates rural farmers are currently getting around 9 tons per hectare. Assuming that if a family uses 3 liters of ethanol per week, in order to provide 156,000 liters of ethanol per year we need 1 million kilograms of cassava. 1,000 metric tonnes of cassava per year is therefore needed to provide 156,000 liters, and this amount can be grown on only 50 hectares of land if the high-yield variety is introduced.

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**Project Goal:** Reduced deforestation and livelihood improvement through use of cassava based ethanol stoves

**Project Outcomes:** Sustainable market for biofuel for stoves; sustainable provision of feedstock for ethanol production; sustainable production of ethanol

**Project Objectives:**

1. Develop Cassava Production/Processing System (cooperatives, women farmers)
2. Develop ethanol Production system
3. Develop market for ethanol-based stoves

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### Objective 1: Development of cassava production and and processing system

<table>
<thead>
<tr>
<th>Output 1: 1 million tons of fresh cassava tubers produced annually on 50 ha</th>
<th>Indicator</th>
<th>Target Value</th>
<th>Tool/Method</th>
<th>Frequency of Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>counting number of trucks that carry X tonnes of cassava</td>
<td>50 hectares of land, at least 1 m kg of fresh tubers</td>
<td>Weigh fresh tubers, measure total number of ha</td>
<td>each time land is acquired up to 50 ha; every harvest for measuring tubers</td>
<td></td>
</tr>
<tr>
<td>Output 2: Higher yielding strain introduced to farmers</td>
<td>Farmers can productively produce high yielding strains</td>
<td>80% success rate, 95% success for production of any cassava (high or low yield)</td>
<td>trainings on how to farm new varieties</td>
<td>every four months and after any training/enrichment</td>
</tr>
<tr>
<td>Output 3: Resilient, engaged farmer base</td>
<td>High retention of farmers participating in program and who remain satisfied and productive</td>
<td>90% retention rate of participating farmers and 80% reported satisfaction with participation</td>
<td>Monthly meeting with cooperative leaders and desert water staff to ensure cassava production metrics are met and more</td>
<td>every four months and after any training or enrichment</td>
</tr>
<tr>
<td>Output 4: Robust tuber processing facilities established</td>
<td>Existence of sufficient shredders, presses, dryers and laborers to process tubers</td>
<td>90% of tubers successfully processed</td>
<td>count each unit of processing equipment created</td>
<td>each time a new piece of equipment is required</td>
</tr>
</tbody>
</table>

### Objective 2: Build a sustainable ethanol production system

<table>
<thead>
<tr>
<th>Output 1: Build one medium size processing plant</th>
<th>Indicator</th>
<th>Target Value</th>
<th>Tool/Method</th>
<th>Frequency of Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>construction and operation of a functioning plant</td>
<td>one plant that produces 500 l/day of cassava-based ethanol</td>
<td>Recording amount of ethanol produced</td>
<td>Every month for the first year, bi annually after that</td>
<td></td>
</tr>
<tr>
<td>Output 2: train staff to work at the plant</td>
<td>competency assessment, ethanol production target is met, no injuries</td>
<td>ten trained members; six in plant operation, 2 in feedstock procurement, 2 in product marketing and transport</td>
<td>performance assessment of each employee</td>
<td>intensive assessment upon hiring and beginning; every three months the first year; twice a year after</td>
</tr>
<tr>
<td>Output 3: Packaging and transportation</td>
<td>barrels for transportation; families can purchase a container for weekly filling or trade-in</td>
<td>3 one-liter bottles per household/week, 1000 households participate</td>
<td>account sheets of bottles sold, where and to who</td>
<td>with each transaction</td>
</tr>
</tbody>
</table>
### Objective 3: Develop Market for Ethanol Based Stoves

<table>
<thead>
<tr>
<th>Output 1: Design or select an appropriate stove model</th>
<th>Indicator</th>
<th>Target Value</th>
<th>Tool/Method</th>
<th>Frequency of Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stove metrics: Fuel type, efficiency, maximum heat, etc</td>
<td>approval rating/metric in household surveys</td>
<td>rice cooking likeness to traditional method</td>
<td>once a week over the course of one month</td>
<td></td>
</tr>
</tbody>
</table>

| Output 2: Develop sourcing and distribution system for stoves | Stoves are sourced and able to be sold at same cost of local kerosene stove | 50 pilot, 1000 for phase 1 | report from distributors | each month |

| Output 3: Set up distribution system for ethanol | Price of ethanol, ease of access | less than cost of kerosene and firewood | market analysis | each month |

| Output 4: Distribute/Sell Stoves to households | Number of households using ethanol | 50 pilot, 1000 for phase 1 | report from distributors | each month |

| Output 5: Mini-pilot study | Determine likelihood of adoption of ethanol and stoves for everyday cooking with costs | satisfactory approval rating to pay for and use ethanol and stoves, identify optimum user price for ethanol which is higher than Desert Water production cost | qualitative household interviews, quantify amount willing to pay per liter over the course of one month | once per week per household, over the course of one month |

### D. Risk Analysis:

Here we address some of the complications associated with this project, but first we reframe the necessity that the project rests on. The aim of Desert Water is to build a dependable base of cassava farmers, who are compensated at a price more competitive than what they might get if cassava was put toward making other products. On the opposite end, Desert Water aims to provide ethanol consumers with ethanol at a price that is cheaper than wood. The aims of serving the consumer and producer are interdependent: we don’t want to build a demand for cookstoves that run on ethanol that can’t be supplied; likewise, we don’t want to employ rural farmers to grow starchy cassava if there is no market for their product.

We brainstormed possible risks to the project success and laid them out in a graph that assesses their likelihood of happening and their detriment to the project if it were to happen. Risks which Desert Water has the potential to reduce or control are within red boxes. We discuss some of these risks below.

1. Ethanol presents a serious fire hazard both in the home and during storage and transport. At this point the review recommends production of 98% ethanol, because it’s very efficient to burn and is currently most compatible with the stove model that has been identified. However, other projects have pursued 50% ethanol or ethanol gel. These options are less efficient, requiring families to have to buy fuel more often as they’ll go through the canisters faster. However, it’s much safer in the home as it won’t

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burn when spilled on a surface (and in the case of gel, can’t really “spill”). It also may not require as robust and careful of care in packaging and transportation for this reason. Fuel grade assessments can be considered as part of the summer pilot study.

2. An almost inevitable risk we will face is the misuse of ethanol. Consumption of ethanol is almost unavoidable. In the United States, methanol is added to ethanol to make it essentially poisonous to people so they don’t drink it; we encourage our client to look into the feasibility of this option.

3. Passability of roads is one of the most concerning threats. See appendix B for a map which details the current major roads and functioning cassava transport routes in Sierra Leone. Our recommendation is for students to conduct community and regional mapping, with the goal of determining efficient transportation routes, and the ideal location of a medium sized ethanol plant.

4. Our ability to maintain supply of CleanCook stoves relies on the efficiency of a transport system between Nigeria and Bo, as well as import or tariff laws regarding the cargo. Our suggestion ultimately is to begin producing stoves in-country, providing jobs to Sierra Leoneans. However, this will be more feasible five years into the project, once the market is established. In the meantime, we have identified two backup stove technologies (ChinaBest and Malawi Superblu) in case CleanCook importation gets disrupted.
III. RESULTS AND DISCUSSION

*Ethanol Partnerships*

Ethanol is produced from cassava in several parts of the world, most notably in Thailand, China and Brazil for the purposes of “gasohol”-- ethanol to mix in with gasoline for vehicles. Ethanol plants exist throughout Africa, but mostly use sugar cane or molasses. Addax Bioenergy was built in the Mikeni region of Sierra Leone to process and export sugar-cane bioethanol to Scandinavia. It was later sold to Sunbird Energy and now functions as Mikeni Bioenergy. Mikeni Bioenergy has begun pursuit of a cassava-based ethanol initiative, with hopes of expanding as an out-grower agreement program. This initiative aligns with Desert Water’s scope, and the team’s thoughts on the matter can be found in the ‘recommendations’ section below. More details on the Mikeni Biofuel outgrower program and other current initiatives can be found in the Stockholm Environment Institute report on the matter. It is extremely important that Desert Water be aware of the major impacts of the Addax bioenergy project on surrounding communities. Many communities lost their fertile land and were disappointed when promises for employment didn’t pan out as expected. We recommend Desert Water exercise great care in its dealings with the Makeni project due to the history of exploitation on the surrounding communities.

*Ethanol Stoves*

There are 5 ways to burn ethanol fuel in a cookstove application and of these the evaporative stove technology is the most appropriate for this project. Evaporative stoves work by inducing the evaporation of liquid ethanol fuel which mixes with air in a chimney before actually combusting directly above the fuel canister. As the chimney grows hot, more ethanol evaporates, and convection pulls more air in providing the ideal air-fuel mix in a self-pressurizing environment. This technology is efficient because the ethanol is stored as a liquid but burned as a gas. The definitive evaporative stove design was produced by NewFire for dissemination in Mozambique between 2012 and 2014. The stoves were immediately popular but the Mozambique ethanol project ultimately failed when local ethanol production plant couldn’t keep up with the fuel demand. This stove is still being produced in Nigeria by CleanCook AB and supplied to several communities globally through the work of Project Gaia.

*Producer Cooperatives and Cooperative Enterprise*

The word “cooperative” has been used throughout our team’s discussions with the client. It is important that this word carry weight, especially if grant proposals discuss the implementation of cooperative business and farmer organization structures. Here, we provide a brief summary of the cooperative principles as outlined by the International Labor Organization.

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Members are users and owners of the cooperative (1) Through participation of capital, labor, and delivery of produce, (2) decision making, and (3) profit sharing. Profit sharing often happens through a patronage fund, which allows profits earned by the enterprise to be re-distributed based on the respective contributions of each member. The seven major principles of a cooperative include: (1) voluntary and open membership (2) democratic member control (one member, one vote – all members have equal say) (3) member economic participation (members provide resources/money to operate business, benefits received are in proportion to business conducted, not capital invested) (4) Autonomy and independence (in the case that cooperatives enter agreements with governments, or receive support from external sources, cooperative autonomy and maintaining democratic member control is the priority) (5) cooperation among cooperatives, (6) education, training, and information provided to members and managers) and (7) Concern for the community.

A deeper look at cooperatives and associated literature can be found in the Bridges 2018 D-Lab Sector Paper9. The ILO has recently produced a straightforward cooperative feasibility guide in 201810, as well as, in 2010, a comprehensive project design manual11 for cooperative organizations. If our client determines that running Desert Water as a cooperative is feasible, these aforementioned resources will be of use in grant applications and organization planning.

Policy Considerations

In our research we found data on current prominent energy and trade policies in Sierra Leone12. Energy policies are important to be aware of, as they will affect the cost of operating a business, as well as the demand for Ethanol, sourced from the Mikeni bioethanol plant, in turn influencing the availability of ethanol for cooking. According to a recent World Trade Organization Policy report, Sierra Leone has electricity tariffs of $.28 per kilowatt hour, which is twice the average in Africa. As of September 2016, the government has a tax rate on electricity of 15%. This is coupled with the current “Sierra Leone Energy Revolution” which is being pushed by the government and the NGO “Power for All”13 to introduce solar power to every part of Sierra Leone. Widened electricity access could change small business prospects in relation to farmgate cassava processing and ethanol production in the future.

Trade policy will affect the feasibility for Desert Water to make a profit in the case of exporting cassava or ethanol to other countries. A 2.5% export tax exists on certain crops and a 40% tariff on agricultural imports. Businesses in the agriculture sector are allowed tax deductible expenses for research and development, training, and export promotion. The Local Content Policy of 2012 mandates that organizational staffing is mandated to be 50% nationals at the managerial level and 100% nationals at the junior level.

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9 Bridges, Matthew. 2018, D-Lab Sector Paper
https://drive.google.com/file/d/1AzNlx3zuC8LR0ZrhygmcHqINDCPyp5yN/view?usp=sharing


11 The ILO Project Design Manual:


IV. FINAL RECOMMENDATIONS

Based on the methodologies above and additional research conducted, we put forward the following recommendations:

A. Partner, rather than build infrastructure

Desert Water’s founder is a man with many initiatives, of which this is just one. Therefore, the review team recommends he create as few new structures as possible. Experts already exist in Sierra Leone in cassava production (women’s cooperatives), ethanol production (Mikeni Bioenergy), and stove technologies (CleanCook AB and others). We suggest the most appropriate role for Desert Water would be to serve as a liason or project manager between expert parties. We suggest the following parties in the map below:

Note on Mikeni Bioenergy: as of recently, Mikeni bioenergy has made contact with the consulting team and expressed interest in fulfilling the role of ethanol production. As the construction of ethanol plants is likely to be the most expensive and complicated element to this project, we highly recommend furthering the conversation with Mikeni Bioenergy to explore how their objectives align with this project’s.
B. Conduct an in-country feasibility study

We recommend the client to design and conduct a market validation study in the Bo region. The main function of this study will be to confirm that ethanol stoves and fuel are marketable in the proposed market. This study will likely involve providing stoves and fuel to select households in urban Bo and monitoring their use over the course of a month or longer. Standard Interview and data collection methods should be employed to attain the required data. Specific additional goals of the study include:

- Assess whether stoves will be accepted for daily use, which in some countries may fail due to cultural or aesthetic reasons
- Assess the marketability of stoves, by determining the feasible price point and developing layaway programs for piecemeal payments for stoves
- Determine how much ethanol one family uses in a week (current hypothesis is three liters, though similar studies have shared two or four).
- Determine how much people will pay for ethanol.
- Conduct community and regional mapping to assess who will be growing cassava and where the ultimate ethanol market will be; this will allow us to determine the most strategic location for ethanol plant production location and minimize travel distances, therefore minimizing likelihood of road impassibility.
- Identify partners in the city of Bo to sell stoves and ethanol in partnership with Desert Water.

Preparation for the proposed market validation study will require sourcing and allocation of stoves and ethanol, composition of interview questions, identification of urban households to target, and design of an implementation plan. D-lab 2 poses an opportunity to test small scale ethanol production using donated cassava and home brewing equipment. It may also be possible to conduct stove tests with local focus groups. This would aid in the design of questions and interview methods proposed market validation study.
C. Integrate the Proposed Desert Water Organizational Plan:

We recommend that our client implement the below staffing structure and work allocation. The diagram suggests a hierarchy where the Executive Director is the ultimate decision maker, with three reporting staff, each of which are focused on a critical sector of Desert Water's objectives. These three critical staff are supported by administration and accounting staff, who also support the executive director. This model provides flexibility, since as Desert Water increases in size and capacity, each critical staff person will have the ability to hire assistant staff which can then report directly to the “critical staff”.

Cooperative Business Models

The suggested organizational structure (above) is set up as a Social Business Enterprise model, not specifically as a cooperative business model. While a cooperative model may be advantageous as a social innovation, and for cooperative specific grants, it may also become a burden when cultural hierarchies counteract with cooperative principles. We recommend that the client review the principles of a cooperative, as established by the International Labor Organization, in order to decide if the cooperative model is feasible for Desert Water.

As a reminder, we encourage the reader to visit the above “results and discussion” section for a review of cooperative principles.
D. Consider implementing project according to the proposed Gantt Chart:

E. Build An Accurate Budget

Despite the analysis above, the consulting team was not able to confirm a feasible budget for the project, due to both the uncertainty of prices and the variety of ways the program could move forward, specifically with ethanol production. Operational costs for ethanol production in a rural West African setting have not been quantified: due to lack of numbers for the pricing of water, combined with the accumulated pricing and use of diesel for generators to heat the boilers has yet to be fully understood and quantified. Alternatively, partnering with Mikeni Bioenergy may save costs and present itself as a single line-item expense rather than estimating each step of the brewing process. Until we can put more accurate numbers to this project lynchpin, we are unable to confirm with certainty that ethanol can reliably be produced below our goal of $3 USD a liter. Thus, the in country market feasibility study will need to contain a price exploration component, enabling an accurate budget to be created.

V. REFERENCES


(9) Bridges, Matthew. 2018, D-Lab Sector Paper https://drive.google.com/file/d/1AzNlx3zuC8LROZrhy3mcH9INDCPy5SyN/view?usp=sharing

V. APPENDICES

A. Production Chain Chart
B. Cassava Map
C. Existing Contacts

a. Production chain chart: After assessing the landscape and identifying stakeholders, we considered what the production chain for our project would look like in full, with minimal restrictions. We used this tool to make sure we didn’t miss any step of the production chain as we thought through our implementation procedures, which will be addressed later on. It is a large chart, epitomizing the complexity of the project. The primary direct/optimal production path is highlighted in yellow.
B. Major Cassava Transport Routes and Infrastructure in 2016

Figure 39 Local cassava production and trade flow map, Sierra Leone

Note: FEWS NET Production and Trade Flow Maps provide a summary of the geography of marketing systems that are relevant to food security outcomes during an average marketing year or season. The maps are produced by FEWS NET in collaboration with stakeholders from local government ministries, market information systems, NGOs, and private sector partners, using a mix of qualitative and quantitative data.


C. Existing Contacts

<table>
<thead>
<tr>
<th>Contact</th>
<th>Organization</th>
<th>Email</th>
<th>Expertise</th>
</tr>
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<tbody>
<tr>
<td>Ted Örbrink</td>
<td>CleanCook AB</td>
<td><a href="mailto:ted.orbrink@cleancook.com">ted.orbrink@cleancook.com</a></td>
<td>Ethanol Stoves</td>
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<tr>
<td>Harry Stokes</td>
<td>Project Gaia</td>
<td><a href="mailto:hstokesoffice@gmail.com">hstokesoffice@gmail.com</a></td>
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</tr>
<tr>
<td>Chido Munangagwa</td>
<td>Project Gaia (US Office)</td>
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<td>Joe Obueh</td>
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<td><a href="mailto:jobueh@projectgaia.com">jobueh@projectgaia.com</a></td>
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<td>Cassava varieties</td>
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</tbody>
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14 [https://www.fews.net/sites/default/files/documents/reports/Sierra%20Leone%20MFR_final_20170228_1.pdf](https://www.fews.net/sites/default/files/documents/reports/Sierra%20Leone%20MFR_final_20170228_1.pdf)
<table>
<thead>
<tr>
<th>Joseph Brima (Representative)</th>
<th>FAO Sierra Leone</th>
<th><a href="mailto:Joseph.Brima@fao.org">Joseph.Brima@fao.org</a></th>
<th>Current cooperative and farmer business initiatives</th>
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<tr>
<td>Richard Bennett (CEO Sunbird)</td>
<td>Mikeni Bioenergy</td>
<td><a href="mailto:rb@sunbirdbioenergy.com">rb@sunbirdbioenergy.com</a></td>
<td>Ethanol Production, possible partnership for outgrower program</td>
</tr>
<tr>
<td>Staff in Sierra Leone</td>
<td></td>
<td><a href="mailto:rajiv.bali@sunbirdbioenergy.com">rajiv.bali@sunbirdbioenergy.com</a></td>
<td></td>
</tr>
<tr>
<td>Rajiv Bali (CEO)</td>
<td></td>
<td><a href="mailto:andy.gee@sunbirdbioenergy.com">andy.gee@sunbirdbioenergy.com</a></td>
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<tr>
<td>Andy Gee (Director)</td>
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