UNIVERSITY OF CALGARY

Financial Feasibility of Village-Based Solar Projects: An Example in Burkina Faso

by

Spencer Illingworth

A RESEARCH PROJECT SUBMITTED

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN SUSTAINABLE ENERGY DEVELOPMENT

CALGARY, ALBERTA

AUGUST, 2018

Abstract

This research project identifies revenue generating scenarios for a small village-based solar project in Pa Village, Burkina Faso, and the impact they have on overall project economics. Assumptions and input values have been taken from industry experts, Pa Village survey and interview data, and other literature sources. These scenarios are researched and analyzed to calculate the revenue contribution to the project as well as the financial return profile of the entire project. With a project capital budget of $80,000 and annual profit of $5,350, the project realizes a payback period of 13.23 years and an Internal Rate of Return of 6.29%. The implementation of a Wifi sales scenario proves to have the most positive project financial return, while also being the riskiest due to uncertainty in the sales forecast. Further work on the project budget and Wifi sales assumptions will aid in mitigating the financial risks of this project.

Acknowledgements

I am very thankful for the overwhelming support and encouragement received from many people throughout the duration of this project. First and foremost, the team at The Strongest Oak, including Stace Wills, Puneet Mannan, Dan Rickard, and Marlene Ahern, must be thanked and congratulated for their work and continued dedication to this project and the improvement of life in Burkina Faso. In particular, I must thank Stace Wills for helping me through the details of this project and aiding me in hunting down answers to the questions I may have, good or bad.

I must also thank Dr. Irene Herremans for both agreeing to supervise my project as well as for aiding me through the development of the project. Dr. Herremans, your contributions to my project and to the project team as a whole added a layer of value and experience that would not have been achieved without your participation.

I was very fortunate to be partnered with Lucas Barr, Tinu Chineme, and Andrea Cosgrove on this project. My fellow SEDV students, your commitment and enthusiasm in helping to bring this project together, as well as providing a sounding board for my own project, was instrumental in the success of this report.

Finally, I would like to extend thanks to my parents, Graham and Janet, and my girlfriend Stephanie Duncan, who were always there to provide love and support through this entire program.

Table of Contents

List of Tables

List of Figures and Illustrations

List of Abbreviations

IRR: Internal Rate of Return

kWh: Kilowatt-hour

PAYG: Pay As You Go

SHS: Solar Home System

SVF: Solar Village of the Future

TSO: The Strongest Oak

Chapter 1: Introduction

1.1 Project Objectives and Scope

Given the extreme levels of poverty in Burkina Faso, one of the poorest African countries, how can an off-grid solar project in this region be financially and commercially feasible? The bulk of my research will be addressed towards answering this question. While this question deals directly with project economics, this project is inter-disciplinary as I have also looked at the environmental and energy aspects of this project.

The research completed and contained in this project will aid in assisting the development and feasibility of the Solar Village of the Future (SVF), a project being completed in Burkina Faso by the non-profit organization The Strongest Oak (TSO). Further, it will provide TSO with a tool that can be used to model future projects of a similar type. Given that a number of possible scenarios and uses for the electricity produced by the SVF have been modeled, TSO can alter the model to incorporate other uses to gauge financial feasibility of future projects with different uses and in different locations.

This research will contribute to existing research in the field of electrification and economic development of rural and remote villages, creating the opportunity to provide electricity to more of the global population in an economic manner. My research, working in conjunction with other SEDV students and their research areas, identifies the best possible model for the sale of solar energy produced in rural Burkina Faso. While my research dictates the most financially viable and economically feasible use of electricity by the SVF for TSO, other students' research considers the community implications and desires as well as what is technically

feasible. Combined, TSO has a clear picture of the potential impacts and considerations of implementing such a project in Burkina Faso.

1.2 Interdisciplinary Aspects

The economic aspect of this research project has been addressed through financial modelling and utilizing of assumptions gathered from our Burkina Faso partners, on-the-ground surveys, and other literature sources. A number of possible scenarios and business models have been tested to determine the most economically feasible use for the electricity generated by this SVF. The economic piece of this report is the most substantial and in-depth with other students directing their focus on other aspects.

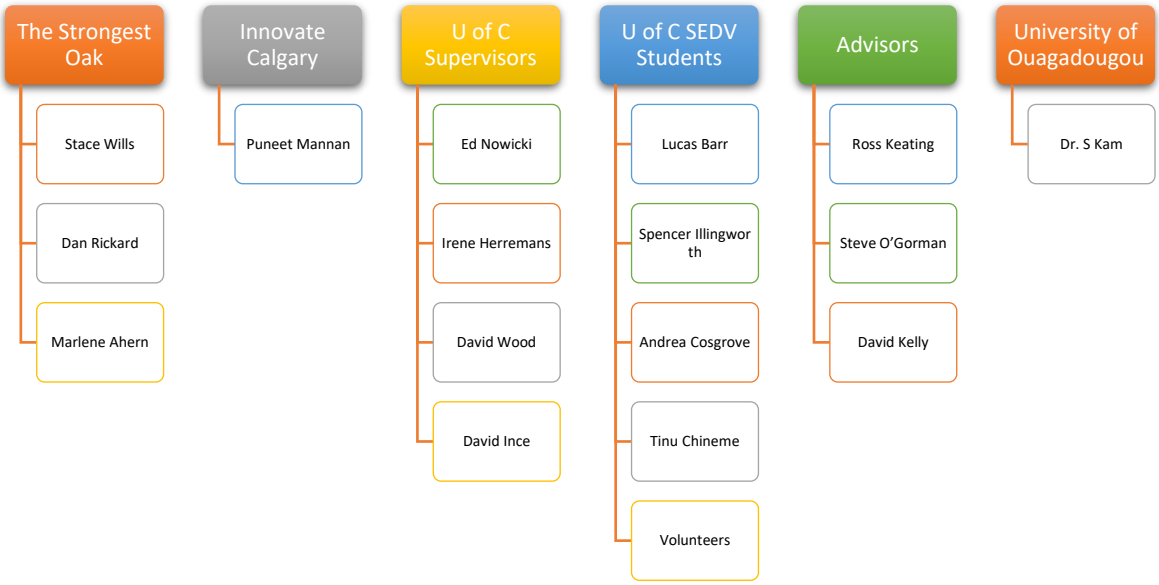
The energy aspect of this research project has been addressed through calculations of possible energy production based on solar insolation at the target location as well as SVF sizing. By utilizing a number of assumptions from the project team with regard to panel size and efficiencies and utilizing insolation values for the location of Burkina Faso, I have been able to calculate the average annual output of the solar facility and capacity factor.

The environmental aspect of this research project has been addressed through an analysis of fossil fuel emissions offsets that will be avoided through the implementation of the SVF. By researching data on Burkina Faso specifically, I have been able to calculate the emissions intensity of energy consumed in the country. By utilizing the energy output calculated in the energy section of this project, this report provides an amount of carbon dioxide emissions offset by the solar project when compared to traditional sources of energy in the area.

1.3 The Strongest Oak

For this project, four students from the SEDV program have partnered with TSO. TSO is an Alberta-based non-profit organization that supports the development of youth in Africa. TSO has already implemented rooftop solar projects in Burkina Faso, the target location for this project, on schools and in communities to improve learning opportunities for youth and bring light to communities (The Strongest Oak, 2017). TSO's next project is to bring a solar hub to a community in Burkina Faso, allowing for a larger community impact through increased levels of solar electricity generation. Solar electricity provides a low cost solution to rural electricity needs while also proving to be a clean energy source. The project name is the Solar Village of the Future (SVF). The entire project team comprises industry advisors, contacts in Burkina Faso, university faculty, and the students from the SEDV program itself. These students, myself included, have worked with TSO to identify four research projects that will contribute to the study of the SVF. The organizational chart can be seen in Figure 1.

Figure 1: SVF Project Members



(Source: Author, 2018)

This project is one of the four projects being complete and focuses on the financial feasibility of the project.

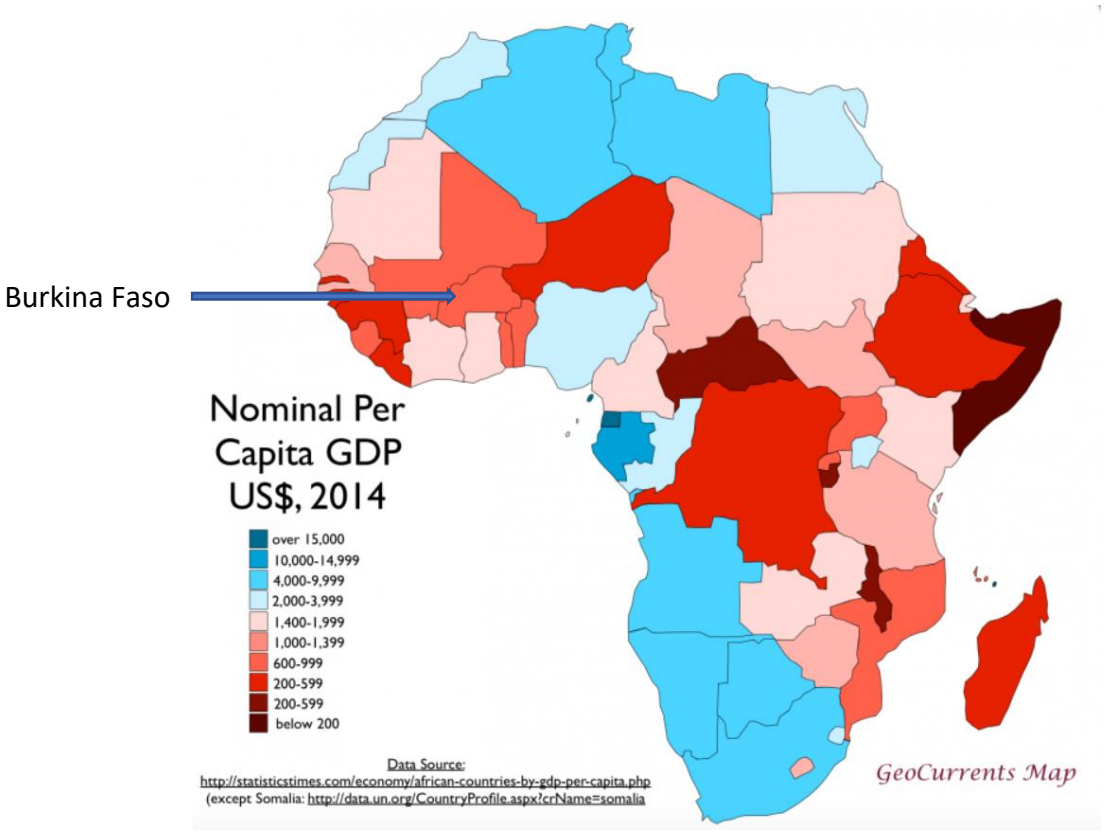
1.4 Burkina Faso

Climate change is an increasingly prominent theme in today's society and global discussions. While many countries have taken actions and have come together on a global scale to combat the amount of emissions produced by energy production and consumption, other countries still have the majority of their population living without any electricity at all. In 2016, the United Nations put into effect their Sustainable Development Goals. These goals serve as a series of targets meant to guide developmental policy through to the completion in 2030 (United Nations, 2018). These goals include No Poverty (SDG #1), Zero Hunger (SDG #2), Quality

Education (SDG #4), Affordable and Clean Energy (SDG #7), Decent Work and Economic Growth (SDG #8), and other targets aimed at improving the health of the planet and its citizens (United Nations, 2018). Burkina Faso is an example of a country which is targeted by each of these goals.

Burkina Faso is one of the most impoverished countries on the planet and as such presents an ideal target for an investment of this type. The country relies heavily upon subsistence farming, as it is lacking in natural resources and an industrial base. Burkina Faso has a population of 20 million, of which 14 million do not have access to electricity (Central Intelligence Agency, 2018). In rural areas, which will define our final target location, the country experiences electrification of 1%. The national GDP per capital for the country is approximately $1,900, with an unemployment rate of 77% and 40% of the population falling below the poverty line (Central Intelligence Agency, 2018). As can be seen in the following **Error! Reference source not found.**, Burkina Faso is amongst the most impoverished countries of Africa (GeoCurrents, 2016).

Figure 2: Africa GDP per Capita



(GeoCurrents, 2016)

Canada has also identified Burkina Faso as a candidate for foreign funding and increased levels of education. In February of 2018, Canada announced funding of $59.5 million for the improvement of public education in Burkina Faso aimed at improving access to quality education (Canada, 2018). Combining the federal government commitment to education in Burkina Faso and the United Nations commitment to its SDGs globally, Burkina Faso presents itself as an ideal opportunity for both humanitarian and development efforts as well as business opportunities. This project will aim to combine these elements, producing a project which aids

in economic and educational development in the area, while still proving commercially viable for social investors looking to recover their capital.

Chapter 2: Literature Review

There has been much work done on economically feasible off-grid solar installations across the globe, however much of this has been centered in areas other than Western Africa (Reichert & Trivella, 2015). In Burkina Faso specifically, research has been conducted on solar radiation, solar cooking, and solar photovoltaic competitiveness exclusively in Ouagadougou. No existing research exists surrounding the economic feasibility of off-grid solar generation in rural Burkina Faso.

2.1 Consumer and Customer Payment Mechanisms

When it comes to off-grid financing of renewable energy technologies, possible sources and options can be broken down into four main categories. These four categories include funds, down-stream financing, up-stream financing, and fiscal instruments (Rolffs, Byrne, & Ockwell, 2014). The area of down-stream financing focuses on the payment scheme or business model being proposed to recover costs at the consumer level. This is the area where most focus will be placed for this project, as the SVF must stand alone and be able to prove itself as a worthy business endeavor. Within this area of financial schemes, hire-purchase agreements, loans, and fee-for-service models have been most prevalent in development of solar home systems in sub-Saharan African countries (Rolffs, Byrne, & Ockwell, 2014).

Fee-For-Service

With a fee-for-service model, the solar home system itself is owned by the operator, technology partner, or other company responsible for providing and installing the hardware. Once installed, the customer is responsible for paying a monthly fee to ensure continuation of

service, allowing them to continue using the system. This scheme has been prevalent largely in South Africa, while also backed with government subsidies (Rolffs, Byrne, & Ockwell, 2014). Pay-as-you-go solar systems represent a subset or alteration to the typical fee-for-service model.

Hire Purchase

A hire purchase model operates through an agreement between an employer and a technology provider. Solar home systems are paid for through a hire purchase agreement, where the system is paid for through a deduction in the employee's salary (Rolffs, Byrne, & Ockwell, 2014). Payment periods vary between 6 to 18 months and typically have very high interest rates. This is a common way of purchasing goods in many sub-Saharan African countries (Rolffs, Byrne, & Ockwell, 2014).

Consumer Loans

Consumer loans are typically arranged between financial institutions and the customers themselves and show average interest rates between 15% and 38.9% (Rolffs, Byrne, & Ockwell, 2014). This arrangement is the simplest model included, as it represents a typical consumer loan that can be found across the globe. No level of innovation in the model has been employed and this would cause issues in more impoverished areas of the globe.

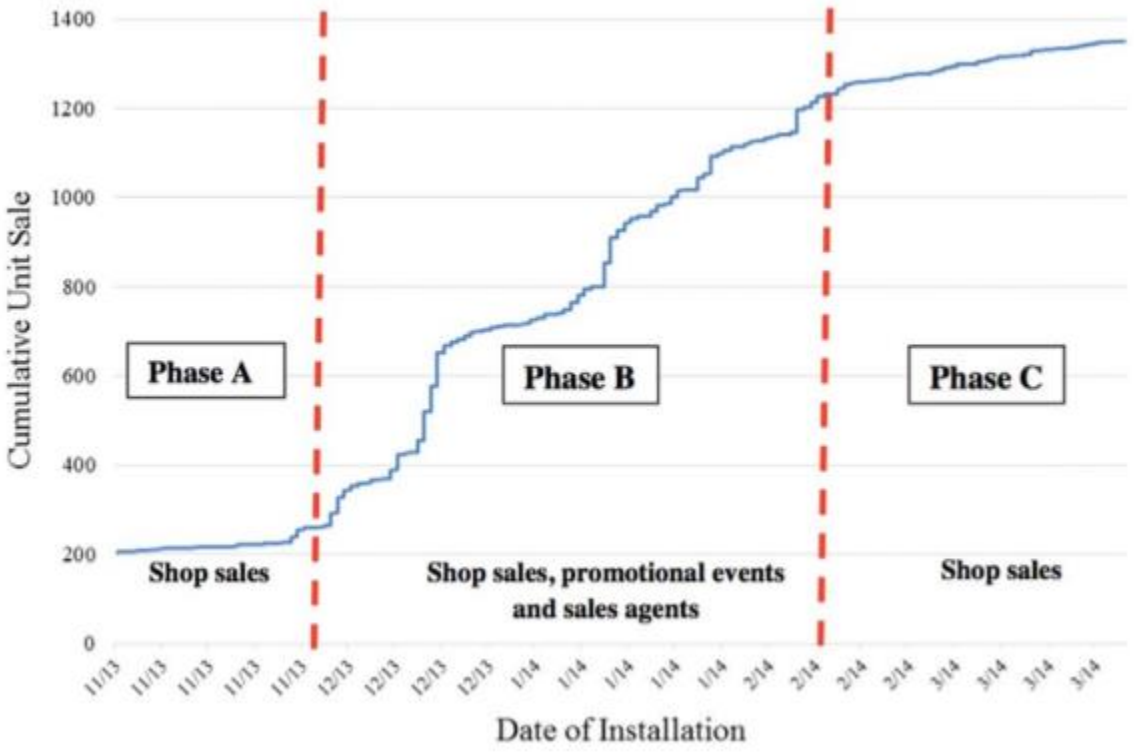
Mobile Pay-As-You-Go Credits

In Kenya, the rising penetration levels of mobile phones has allowed for the creation of a new kind of financing mechanism. By 2010, the number of people who had a mobile phone

subscription doubled the number of people who were connected to the grid or receiving electricity from a solar home system (Rolffs, Byrne, & Ockwell, 2014). The emergence of phones has allowed for a new type of fee-for-service system, whereby codes are sent via phone to the operator of the system to ensure continuation of service (Rolffs, Byrne, & Ockwell, 2014).

The models and mechanisms discussed by Rolffs, Byrne, and Ockwell (2014) provide an important and necessary look into the baseline understanding of current African solar systems, as well as possible funding schemes for the SVF. However, as identified by Barrie and Cruickshank (2017), the implementation of a successful marketing strategy is also of vital importance in order to garner interest in the product or service offering. In the case of solar home systems, a possible product offering for the SVF, an aggressive and thought out marketing scheme with demonstrations and sales agents was required in order to generate solar home system (SHS) sales growth in Central East Africa (Barrie & Cruickshank, 2017). The following ***Figure 3*** illustrates this growth over a 5-month period (Barrie & Cruickshank, 2017).

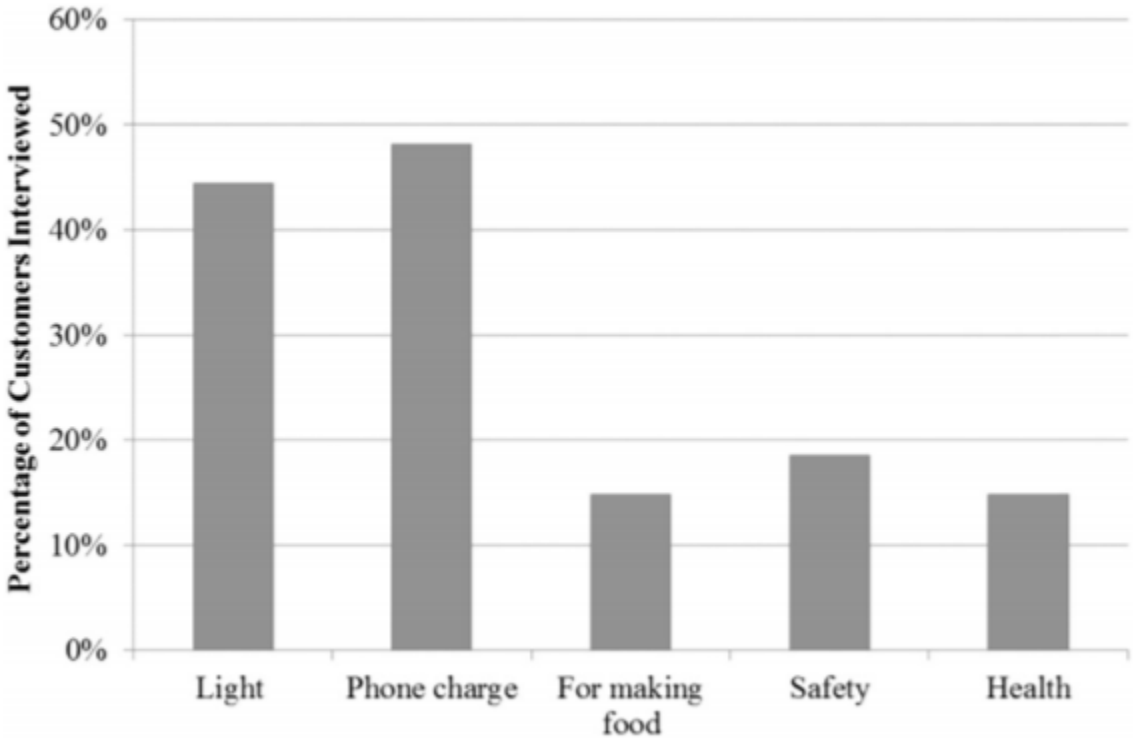
Figure 3: SHS Sales Growth in Central East Africa



(Barrie & Cruickshank, 2017)

Further, Barrie and Cruickshank (2017) went on to identify the reasons for which customers adopted their solar home systems. These reasons were broken out into light, cell phone charging, food production, health, and safety, with cell phone charging being the most prominent motivation. The interviews conducted obtained the results summarized in the following Figure 4 (Barrie & Cruickshank, 2017).

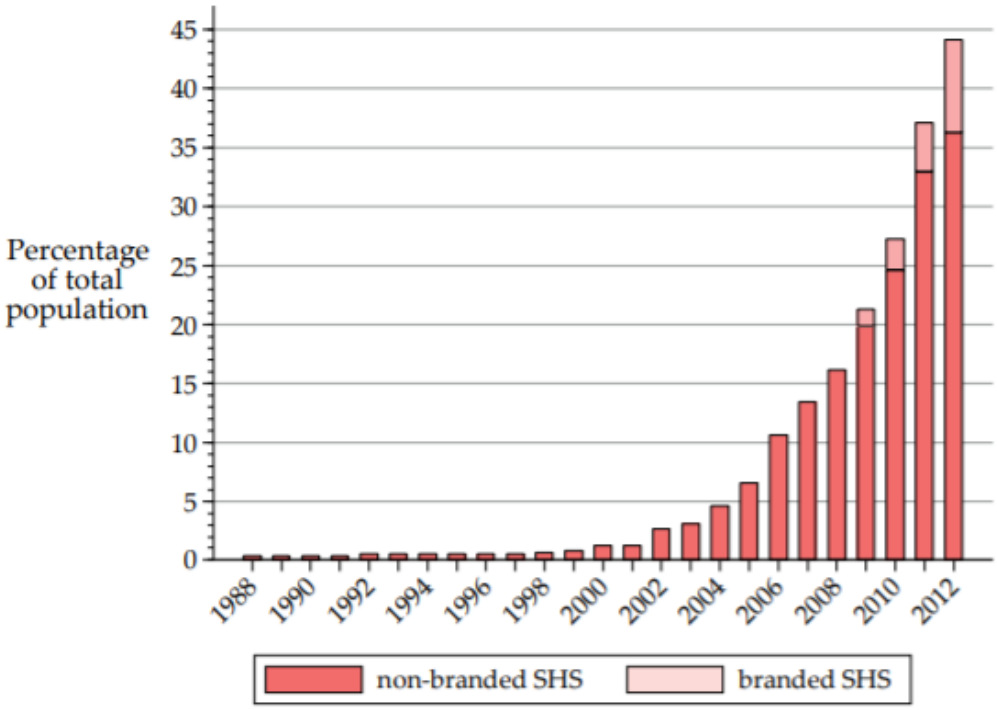
Figure 4: Customer Reasons for Adopting PAYG SHS



(Barrie & Cruickshank, 2017)

A study conducted in the western Kénédougou province in the Hauts-Bassins region of Burkina Faso looked at penetration rates of solar home systems in rural areas (Bensch, Grimm, Huppertz, Langbein, & Peters, 2016). This study found that the occurrence of solar home systems purchased in recent years has increased dramatically, as shown in ***Figure 5*** (Bensch, Grimm, Huppertz, Langbein, & Peters, 2016). This indicates a significant demand for such products.

Figure 5: SHS Prevalence in Kénédougou Province



(Bensch, Grimm, Huppertz, Langbein, & Peters, 2016)

In ***Figure 5***, the growth rate for the final two years of the survey averaged 6% per year (Bensch, Grimm, Huppertz, Langbein, & Peters, 2016). This helps to validate a business model of selling solar products at the project location.

2.2 Case Studies

While a number of small scale solar projects have been implemented in the regions surrounding Burkina Faso, no project incorporating multiple revenue sources and streams have been implemented in the country. These projects provide valuable information and insights into what is required to make a project commercially viable in Africa.

Urpelainen and Yoon (2015) conducted a field study in Uttar Pradesh, India, where they partnered with a for-profit industry player to establish an energy center in an unelectrified village. This energy center offered various solar products to customers, from solar home systems to water pumps (Urpelainen & Yoon, 2015). While India and Africa present two very different business landscapes, and the products offered were most likely larger and more expensive than what will be feasible for the SVF, there are certain learnings from this study that can utilized. The study itself identified that, while this project cannot reach or benefit the poorest individuals on the planet, it does provide a stepping stone from which we can learn and continue to improve upon (Urpelainen & Yoon, 2015).

Urpelainen & Yoon (2015) found that the $5,000 (USD) project was both feasible and successful, generating a profit in five of the six months of operation. The center serviced villages with an average household income of $170 (USD) per month. The most popular unit costed approximately $450 (USD), illustrating that the demand for access to electricity is high enough to warrant taking a loan and putting forward the limited resources available to these houses (Urpelainen & Yoon, 2015).

For every dollar invested into the energy center, $7 of revenue was generated over the 6-month time period (Urpelainen & Yoon, 2015). Throughout the project, a challenge around access to financing and the ability to afford these systems was prevalent. In all demonstration meetings with villages, questions were asked by villagers about access to loans and interest rates (Urpelainen & Yoon, 2015). The project developed a partnership with a banking institution, which removed a step required for customers and allowed an all-in-one product

offering for individuals interested in purchasing a system. This was identified as a key success factor for the project (Urpelainen & Yoon, 2015).

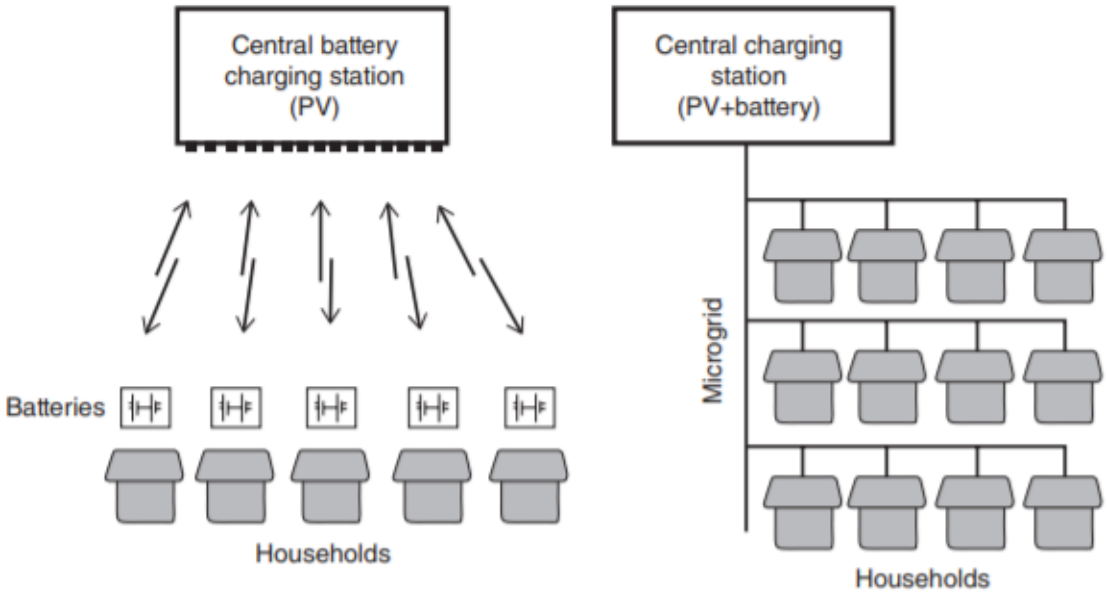
Munro et al (2016) conducted a study of a project which aligns closely with the SVF: a community charging station in Sierra Leone. This model has been adopted in several locations in Sierra Leone by a non-profit called Energy For Opportunity, and is examined in the context of commercial viability, financial and technological barriers, and lack of for-profit entities in the market (Munro, et al., 2016). This model relies on a small solar-powered kiosk, which is typically built near a community hub, marketplace, or other type of center. The kiosk serves as a "hub" for mobile phone charging, solar powered LED lantern rentals and sales, and solar home systems (Munro, et al., 2016).

The community charging station model relies on non-profit financing for initial funding but is able to self-sustain its operations through for-profit principles. Its products sold through the model are priced at market rates with margins of roughly 10% to 15%, with average payback periods of less than a single year for rental products (Munro, et al., 2016). It was found that 99% of project revenue comes from mobile phone charging, with the remainder coming from lantern and purified water sales. This discrepancy may be partially explained by the fact that lantern costs rival those of traditional kerosene lamps, however, lanterns provide a much higher light output without any harmful emissions. The expenses associated with the kiosk include salaries for attendants and the purchase of additional phone chargers (Munro, et al., 2016)

Munro et al (2016) found that, amongst the nine facilities in Sierra Leone, the main factors influencing the profit margin included rival charging stations, town population, phone reception, and proximity to electrical grid. One facility also had much higher expenses, due to the construction of a solar-powered water purification system. Every kiosk had a payback between two and three years and were profitable immediately after installation (Munro, et al., 2016). A large factor which influenced the success of these projects in Sierra Leone was the level of phone penetration, with 90% to 100% of households surveyed in each village owning at least one phone (Munro, et al., 2016).

Finally, a separate paper analyzed the economic and technical differences between a battery charging and leasing station, and two types of microgrid systems in India (D'Agostino, Lund, & Urpelainen, 2016). The difference between these two technologies is illustrated in the following ***Figure 6*** (D'Agostino, Lund, & Urpelainen, 2016).

Figure 6: Centralized Charging vs. Microgrid



(D'Agostino, Lund, & Urpelainen, 2016)

The two microgrids operated under different economic systems. One microgrid has its users pay a fixed monthly fee for their electricity, while the other allowed participating households to pre-pay for their electricity usage and only pay for what was used. Ultimately, the authors found that there is a tradeoff between economic viability and customer satisfaction (D'Agostino, Lund, & Urpelainen, 2016). Paying a fixed fee for the electrical service proved to be the most economic for the supplier while also having the lowest level of customer satisfaction. The customers simply did not have a need or desire for the amount of electricity that they were paying for (D'Agostino, Lund, & Urpelainen, 2016). The battery lease and charging stations struck a balance between economic feasibility and customer satisfaction, proving that such a model may prove feasible for TSO application with further research.

Chapter 3: Methodology

A different methodology and analysis was performed for each of the three aspects of analysis for the SVF: economic, environmental, and energy.

3.1 Economic Analysis Methodology

To analyze the economic feasibility of the SVF a financial model was constructed. This model utilizes a number of inputs and assumptions to produce an Internal Rate of Return, payback period, and other financial information for the project. The specific scenario calculations, inputs, and assumptions vary greatly from scenario to scenario, and are outlined in the following sections and can also be found in Appendix C.

Phase 1 of the SVF has been identified by the project team and includes a specified set of revenue-generating streams. As such, Phase 1 has been modeled first, with additional revenue generating scenarios identified for information purposes and for possible future iterations of the project. Phase 1 will include the following scenarios:

- Shea Milling and Butter Production
- Flour Milling
- Wifi
- Cell-Phone Charging
- Solar Product Sales

The financial feasibility of a scenario incorporating the above revenue streams has been considered as the base case and primary project.

A survey conducted by another student on the project, Tinu Chineme, has been relied upon as a source of primary information for the financial modelling of the SVF. Tinu's report has been referenced through this report can be found in the SEDV student project database.

3.1.1 General Project

A number of assumptions that related to the project as a whole were included in the economic analysis. These include the life of the SVF of 25 years, the Hub Manager's wage of $2,400 per year, and the Security expense of $2,760 per year. These numbers have all been received directly from TSO, with input from the project team consisting of industry contacts, suppliers, and advisors in both Canada and Burkina Faso. General project inputs can be found in Appendix A.

Further, the project team has put together a general project budget including all anticipated components and costs required for the base project, ranging from the container itself to engineering and fees. Given the constantly changing nature of a project in development, a specific budget has been selected and incorporated into this analysis. Version 9 of the project budget was received from TSO on July 10, 2018 and was utilized for the analysis. This budget worked out to be $65,458.36 to construct the solar hub and associated equipment, prior to the implementation of any revenue generating scenarios. The budget is continuing to evolve as the project team narrows the specific suppliers and technical specifications. The final budget can be found in Appendix B.

No overhead, administration, or general management fee has been modeled in this project as per guidance from the project team. This is a possible gap in the expense portion of the SVF. A projected inflation rate of 2% annually has been assumed for the project, based upon Burkina Faso historical and projected rates (Statista, 2018).

3.1.2 Shea Milling and Butter Production

Phase 1 of the SVF will be the implementation of shea milling equipment and partnership with the Pa Village women's shea butter cooperative, Sougrinooma. The cooperative currently produces approximately 30 kg of shea butter daily in their peak season, with a desire to double this production level to 60 kg per day (Chineme, 2018). This volume has been the one utilized for modelling purposes, resulting in 1,825 kg per month when averaged over 12 months.

Two pieces of equipment will be powered by the SVF to assist Sougrinooma in automating their production process. These pieces are a crusher and a paste-maker, quoted in Euros by the supplier at 810 € ($1,266.31 CDN) and 2,541 € ($3,893 CDN). Each piece of equipment consumes 1.1 kW of electricity. Further, the machines will require a control panel priced at 2,197 € ($3,434.66 CDN). This panel will also control the stone mill for the flour milling scenario but has been accounted for in this scenario. Additionally, a shipping fee of 1,530 € (2,391.91 CDN) has been quoted and also includes the stone mill for flour milling.

To calculate the revenue generating potential of this scenario, an estimate on monthly operating hours as well as an electrical tariff to be charged was provided by TSO. This estimate had operating hours of 144 hours for each piece of machinery with an electrical tariff of $0.54/kWh, resulting in monthly revenue of $171.07. The electrical tariff was calculated as half of the cost of diesel equivalent energy value in the region. In order to provide a more friendly and relatable number to the cooperative, this revenue number was converted to a price per kg of $0.094 CDN and rounded to $0.10 CDN which translates to approximately 40 West African CFA francs. This rounding increases the monthly revenue by just over $10 CDN to $182.50 CDN. A VAT of 18% has also been added to all items for this scenario. A sensitivity analysis illustrating

the effect of this revenue number has been calculated, with results located in Section **Error! Reference source not found.**.

3.1.3 Flour Milling

Phase 1 of the SVF will include a stone mill machine for the milling of various grains for Pa Village, aiding those with products other than shea nuts. This piece of equipment has been quoted by a supplier at 1,623 € ($2,537.30 CDN) and will consume approximately 750 watts. A VAT of 18% has also been added for this scenario. The community has indicated that other crops exist that can be milled such as sorghum, maize, rice, and beans, and that people of the village near the site will mill their products with the SVF if they can (Chineme, 2018).

Currently, families in Pa Village spend approximately 1,500 CFA or $3.69 CDN per week grinding food (Chineme, 2018). With 2,000 households in Pa Village, this equates to roughly $7,380 CDN being spent per week on grinding food. In order to provide an incentive and capture some of this market, the SVF has assumed that we will charge a reduced fee of 1,000 CFA or $2.46/week and that we will be able to attract a conservative 14 families to mill their food each week.

3.1.4 Wifi

Wifi offers a service which will allow the SVF to host an internet hot-spot and offer wifi service to customers at various rates (TamTam, 2018). These rates come in a variety of basic and premium packages for various durations. The difference between basic and premium products is internet speed itself, with basic being 512 KB/s and premium being 2 MB/s (Stace Wills, personal communication, July 12, 2018). The project team has made a variety of assumptions based upon traffic and number of devices in the area with regard to how many customers we

can expect to participate in the wifi hotspot. These assumptions, along with the package offerings and costs, are listed in the following ***Table 1***. Specific package costs and revenue margins have been obtained directly from TSO, who has communicated with a potential wifi supplier. The products being offered refer to length of wifi connection time for the purchaser.

Table 1: Wifi Assumptions and Package Options

	Basic			Premium		
Product	**# Monthly Clients**	**Cost per Pkg (CFA)**	**Total CFA**	**# Monthly Client**	**Cost per Pkg (CFA)**	**Total CFA**
1 hour	200	150	30,000	100	1,000	100,000
1 day	50	1,000	50,000	25	5,000	125,000
1 week	20	5,000	100,000	10	12,000	120,000
1 month	10	19,000	190,000	5	45,000	225,000

(Source: Author, 2018)

As the SVF reaches Phase 1 implementation, these assumptions can and will be altered and verified to ensure that the financial forecast is accurately representing cash flows.

The wifi package required to offer these services is anticipated to cost 2,000,000 CFA francs, or approximately $4,920 CDN (Stace Wills, personal communication, May 29, 2018). As part of the partnership with the supplier, the SVF will receive a 17% commission for the revenue generated from sale of wifi services, meaning that 17% of Total CFA sales in Table 1 will be attributable to the project (Stace Wills, personal communication, May 29, 2018).

3.1.5 Cell Phone Charging

Cell phone charging was identified as a significant opportunity for additional revenue generation given the significant penetration of cell phones in the area of Pa Village. According to a survey conducted by our team, the area of Pa has roughly 8,000 cell phones. All men in

attendance at our survey meeting owned at least one cell phone (Chineme, 2018). Further, the cost to charge a cell phone in Africa is amongst the highest in the world, particularly in rural regions (Akpablie, 2015). In Ghana, a country adjacent to Burkina Faso, rural residents pay at least 25 cents USD each time they charge their phone at a solar kiosk, not including transportation. Annually, this adds up to over 400 times what the average American pays to charge their phone (Akpablie, 2015).

In a follow up communication with the University of Ouagadougou, we were able to add additional detail to our assumptions. The residents of Pa Village currently charge their phones at home through PV systems or at the market for a cost of less than 100 CFA, or $0.23 CDN (K. S. Zacharie, personal communication, June 1, 2018). Further, these will often last 3 to 4 days before needing to be recharged (K. S. Zacharie, personal communication, June 1, 2018). Given this information, we have selected very conservative assumptions to ensure that our assumptions are not overly optimistic. We have assumed that we will charge 25 cell phones per day. This number could be greater as there are more than 8,000 cell phones, each lasting 3-4 days. We have also input a price of $0.10 per cell phone charge, which should result in cost savings for residents of Pa Village.

In determining corresponding capital costs, the project team was able to identify and price out a charging station. This station is solar compatible for the SVF and allows for charging of up to 10 devices through a USB connection. The station itself costs approximately $73 Canadian with no anticipated operations and maintenance costs.

3.1.6 Solar Product Leasing/Sales

Solar home systems are increasing in prevalence in Africa and specifically Burkina Faso (Bensch, Grimm, Huppertz, Langbein, & Peters, 2016). An opportunity exists for TSO to partner with a supplier of solar home systems and offer these products from the SVF in Pa Village. Currently no communication has been had with such a provider and as such several assumptions have been made for this scenario.

The survey conducted by our team indicates that the Pa Village region has approximately 2,000 homes (Chineme, 2018). The survey also concluded that residents would be much more interested in owning a solar home system or product than simply renting one (Chineme, 2018). Solar home systems are amongst households already in Pa Village, although we do not know the exact distribution percentage (Chineme, 2018).

A significant distributor of solar products of all types in Africa is SunnyMoney, who operates currently in Malawi, Zambia, and Uganda (SunnyMoney, 2018). They offer a range of products including solar lights for $13 CDN, solar lamp and phone charger combo for $46 CDN, and a larger SHS with 3 lights and multi-phone charging ability for $114 CDN (SunnyMoney, 2018). These products will be used as examples of possible products for sale the SVF. The initial assumptions around sales of these products are listed in ***Table 2*** below.

Table 2: Solar Product Sales Assumptions

Solar Product Sales			
Solar Products	**# Monthly Sales**	**Cost per Pkg (CDN)**	**Total CDN**
Solar Lamp	20	$ 13	$ 260
Lamp + Charge	15	$ 46	$ 690
SHS	5	$ 114	$ 570

(Source: Author, 2018)

Similar companies around the world in other developing countries use a commission rate of 5% on such systems, which will be utilized in our scenario (Stephanie Duncan, personal communication, June 26, 2018).

3.2 Energy Analysis Methodology

The energy analysis aspect of this project has been conducted by calculating the anticipated annual power production of the SVF, based upon solar irradiation data for Burkina Faso and project size.

For this calculation, average daily solar data for each month was gathered to produce the following **Table 3** (OpensolarDB, 2013).

Table 3: Daily Average Solar Data for Burkina Faso

Burkina Faso Solar Data — Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Solar Insolation (Daily avg MJ/m^2)	20.6	22.4	23.0	22.9	22.1	20.5	19.4	18.4	19.8	21.7	21.2	20.2	
Solar Insolation (Daily avg kWh/m^2)	5.7	6.2	6.4	6.4	6.1	5.7	5.4	5.1	5.5	6.0	5.9	5.6	
Monthly Isolation (Monthly kWh/m^2)	177.64	173.91	198.39	190.83	190.64	170.66	166.79	158.70	165.33	186.60	176.66	173.60	**2,129.75**

(OpensolarDB, 2013)

Additional assumptions surrounding panel area, efficiency, and miscellaneous losses were drawn from a panel analysis document provided by the project team for a 270 watt panel to

determine the annual power production and capacity factor of the SVF. To gauge the quality of the solar resource in Burkina Faso, the plant was theoretically moved in order to see the effect of solar irradiation on this plant in different parts of the world. The locations and insolation data are located in ***Table 4***.

Table 4: Insolation Data for Theoretical Plant Locations

Calgary, Canada Solar Data **Month**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Monthly Isolation (Monthly kWh/m^2)	30.65	50.09	93.00	135.33	162.75	167.41	181.34	150.35	102.00	66.99	36.42	25.40	**1,201.72**
LA, USA Solar Data													
Monthly Isolation (Monthly kWh/m^2)	86.80	100.80	148.80	182.99	198.39	197.99	220.09	201.49	159.00	130.20	96.00	80.60	**1,803.15**
Antofagasta, Chile Solar Data													
Monthly Isolation (Monthly kWh/m^2)	263.92	218.08	212.34	160.00	128.47	104.91	98.42	138.64	170.66	212.43	233.99	260.13	**2,202.01**
Freiburg, Germany Solar Data													
Monthly Isolation (Monthly kWh/m^2)	26.87	48.53	89.38	121.41	153.19	168.33	174.37	151.21	98.16	64.24	32.25	21.53	**1,149.46**

(OpensolarDB, 2013)

This data was gathered from the same source and four other locations in Canada, Germany, the United States of America, and Chile were selected to obtain a geographically diverse data set.

3.3 Environmental Analysis Methodology

The environmental analysis aspect of this project has been conducted by utilizing the annual energy output of the energy analysis to calculate greenhouse gas emissions avoided through the SVF. In order to calculate this, the emissions intensity of consumed energy in Burkina Faso has also been calculated.

In 2011, Burkina Faso generated 1.454 million metric tons of CO^2 from energy consumption (Burkina Faso Data Portal, 2015a). In that same year, Burkina Faso consumed approximately 0.027 quadrillion BTUs of energy (Burkina Faso Data Portal, 2015b). With this data, a calculation

of Burkina Faso's carbon emissions intensity for energy consumed has been conducted to determine the corresponding emissions offset by the SVF.

This analysis assumed no lifecycle carbon dioxide emissions of the SVF.

3.4 Risk Analysis Methodology

The assumptions made in the previous sections are accurate to the best of the project team's knowledge; however as with any project, it carries an inherent level of risk due to assumptions made in the modeling process and project unknowns as implementation, construction, and operation commences. This is particularly relevant in the case of the SVF, which is being considered a prototype and proof of concept, and as such many of the assumptions are untested and unconfirmed in an operating environment. A number of risks have been tested through sensitivity analyses to gauge the impact they have on project returns. The following aspects have been tested to identify their significance on project returns, including payback period and internal rate of return.

Capital Budget

Given the project location and size, the budget carries a level of uncertainty. A shift in the cost of the project will have consequences on all aspects of financial feasibility and returns. Scenarios have been tested where the budget has been shifted by 10% and 25% in both positive and negative directions.

Annual Wifi Revenue

For Phase 1 of the SVF, Wifi sales accounts for approximately 45% of the project revenue. Given the substantial weight this carries for project revenue, any fluctuation in the sales assumptions made for the SVF in Section 3.1.4 Wifi could impact financial feasibility substantially. Shifts in revenue assumptions of 25% and 50% in both positive and negative directions have been tested.

Annual Shea Milling and Butter Production Revenue

The possibility exists that both shea nut and water availability will be limited due to increased production capacity provided by Phase 1 of the SVF, given that the villagers would like to double production. As such, the revenue stream for shea milling and butter production may be influenced by factors outside of the control of the project. Sensitivity scenarios for a shift in revenue generation of 25% and 50% in either direction have been tested.

Annual Operating Costs

Currently, the only operating costs that have been assumed for the Phase 1 of the SVF include the Hub Manager and Security costs. Although these numbers don't carry as much uncertainty as other areas of the project, they are to be incurred for the entire 25 year project life. As such, the impact of a shift in these numbers would be long-lasting. A shift of 10% and 25% in both the positive and negative directions have been tested for annual operating costs over the life of the project.

Chapter 4: Results and Discussion

4.1 Economic Analysis

4.1.1 Phase 1

Phase 1 of the SVF includes a number of revenue generating scenarios and is the current TSO plan for implementation by the end of 2018. Based upon the assumptions made in Chapter 3: Methodology, the scenarios included in Phase 1 produce annual cash flows as per ***Table 5***.

Table 5: Phase 1 Scenario-Specific Cash Flow

Scenario Revenue		
Shea Machines	$	2,190.00
Flour Milling	$	1,791.12
Wifi	$	4,717.92
Cell Phone Charging	$	900.00
Solar Product Sales	$	912.00
Total	**$**	**10,511.04**

(Source: Author, 2018)

These scenarios produces just over $10,000 in positive cash flow to cover capital costs and operating costs. The operating costs of the SVF total $5,160 annually and comprise both the hub manager wage and security expense for the site. This leaves the project with $5,351 annually to repay the anticipated project cost of $80,658.81. This annual profit strains project economics, as TSO is aiming for a 10-year project payback. The current Phase 1 model does not meet the stated 10-year payback target prior to any financing schemes, as seen in ***Table 6***.

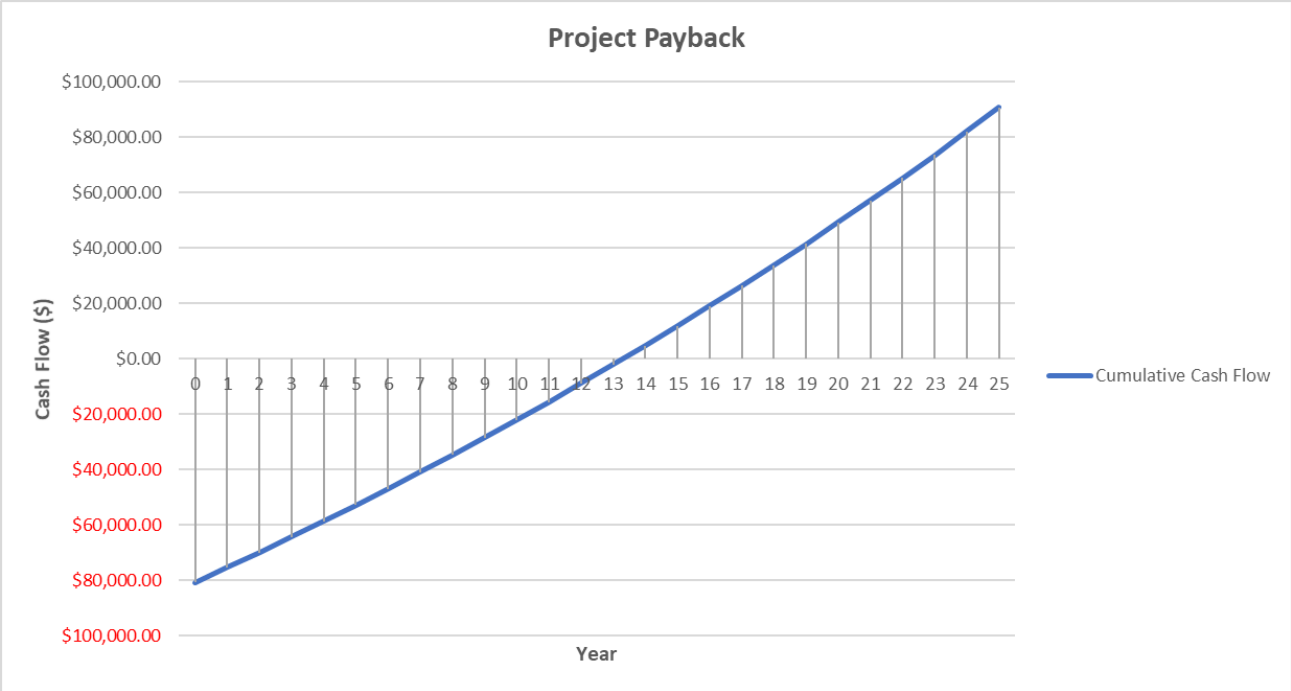
Table 6: Phase 1 Cash Investment Summary

Investment Summary (Cash on Cash)	
Payback Period	13.23
IRR	6.29%

(Source: Author, 2018)

With a payback period of over 13 years, the current assumptions that have gone into the Phase 1 model produce a financial result that is not satisfactory to TSO. ***Figure 7*** shows the cumulative cash flows resulting in project payback period for the SVF.

Figure 7: Project Payback



(Source: Author, 2018)

In order to produce a payback period of 10 years, the capital budget requires a reduction to approximately 72.6% of its current value from $80,659 to $58,599. Alternatively, an increase in

annual profit to approximately 137% of its current value from $5,351 to $7,356 will also produce this result.

Various shifts in the assumptions that have gone into this financial analysis have been tested, with the results in Section **Error! Reference source not found.**. The entirety of the financial analysis performed can be found in Appendices A, B, C, and D, with the financial output found in Appendix D.

4.1.2 Phase 1 Individual Scenario Analysis

In order to determine and analyze the revenue generating potential and financial feasibility of each individual scenario, each scenario has been analyzed on its own through a payback analysis for its revenue generation, operating costs (if applicable), and capital cost for that scenario specifically. The cost of the general solar product of $65,458.36 has not been included; only those costs attributable to the additional equipment required for generating revenue has been considered for each scenario.

Shea Milling and Butter Production

The Shea Milling and Butter Production scenario carries a capital cost of $12,626.53 CDN and includes the crusher, paste maker, control panel, shipping, and VAT. The control panel shipping costs also include the Flour Milling scenario, but have been assumed that these costs would not change with the exclusion of the stone mill and as such have remained the same. The annual revenue produced by this scenario is $2,190 CDN.

This scenario on its own carries the financial returns seen in ***Table 7***.

Table 7: Shea Milling and Butter Production Financial Returns

Investment Summary (Cash on Cash)	
Payback Period	5.51
IRR	18.97%

(Source: Author, 2018)

On its own and excluding all general project costs, this scenario realizes a 5.51 year payback period and a 18.97% IRR.

Flour Milling

The Flour Milling scenario carries a capital cost of $9,438.82 CDN and includes the stone mill, control panel, shipping, and VAT. The control panel and shipping values include the crusher and paste maker from the Shea Milling and Butter Production scenario, but have been assumed as unchanging with the exclusion of these two pieces of equipment. This scenario produces annual revenue of $1,791.12 CDN.

The financial returns for this scenario on its own are found in ***Table 8***.

Table 8: Flour Milling Financial Returns

Investment Summary (Cash on Cash)	
Payback Period	5.06
IRR	20.69%

(Source: Author, 2018)

On its own and excluding all general project costs, this scenario realizes a 5.06 year payback period and 20.69% IRR.

Wifi

The Wifi scenario carries a singular capital cost of $5,412.72 CDN for the package provided by a supplier to enable the sale of Wifi at the project location. The corresponding annual revenue generated based upon the sales assumptions is $4,717.92 CDN.

The financial returns for this scenario are found below in ***Table 9***.

Table 9: Wifi Financial Returns

Investment Summary (Cash on Cash)	
Payback Period	1.14
IRR	89.16%

(Source: Author, 2018)

On its own and excluding all general project costs, this scenario realizes a 1.14 year payback period and a 89.16% IRR.

Cell-Phone Charging

The Cell Phone Charging scenario carries a singular capital cost of $73.48 CDN to cover the purchase of the Charging Station. The corresponding annual revenue generated by the charging of 25 phones daily at a rate of $0.10 CDN per charge is $900.00 CDN.

The financial returns for this scenario are found in ***Table 10***.

Table 10: Cell Phone Charging Financial Returns

Investment Summary (Cash on Cash)	
Payback Period	0.09
IRR	1226.87%

(Source: Author, 2018)

On its own and excluding all other general project costs, this scenario has a payback period of 0.09 years, or almost exactly one month. The project also carries an IRR of 1,266.87%. This is due to the very low cost of the universal charger coupled with the comparably high revenue potential. However, it is important to note that this scenario still produces substantially less revenue than most of the other scenarios.

Solar Product Leasing/Sales

There are no capital costs associated with the Solar Product Leasing/Sales scenario, as the scenario was assumed to operate purely on a commission-based revenue model. The resulting annual revenue based upon the sales assumptions made is $912.00 CDN.

No financial returns are applicable on this scenario as there is no capital investment. As a result, the payback period is 0 years and there is no IRR.

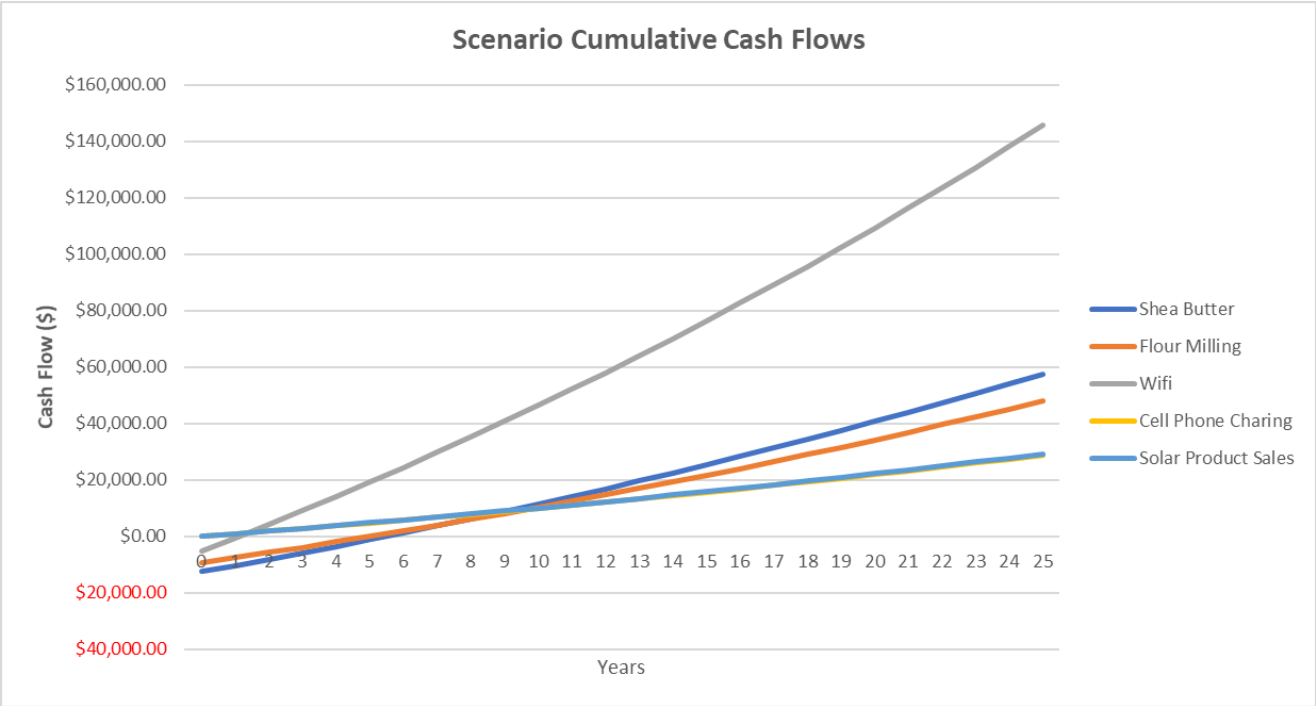
Scenario Analysis Comparison

While the financial returns provide a look at how the individual scenario operates on its own, it does not provide a metric by which to compare scenarios. This is due to the fact that payback periods and IRRs do not include a measure of dollar value magnitude in their metric and as such

a scenario with an IRR greater than 1,000% such as Cell Phone Charging may provide less value to the SVF than a scenario with an IRR of 20.69% such as Flour Milling. The units of years to payback and percentage IRR do not provide a complete understanding of the picture with regard to the magnitude of a scenario's contribution to the overall project revenue or cash flow.

As such, in order to better understand how each scenario compares based upon the cash flow provided to the project, the following ***Figure 8*** has been produced.

Figure 8: Scenario-Specific Cumulative Cash Flows



(Source: Author, 2018)

Figure 8 illustrates the cumulative cash flow for each scenario and provides an additional level of detail into the cash flow profiles of each scenario. As a result, it can be seen that the Wifi scenario provides the most cumulative cash flow to the SVF, despite having a capital

expenditure greater than both the Cell Phone Charging and Solar Product Sales scenarios. Further, we also see that the Shea Butter scenario, despite having a longer payback and lower IRR than the Flour Milling scenario, provides marginally more cumulative cash flow over the life of the project, even with a greater capital expenditure.

As a result of this analysis, it is apparent that Wifi proves to be the most important scenario to project cash flow, with Cell Phone Charging and Solar Product Sales being less important even though they require less up-front capital expenditure. The remaining two scenarios could be interpreted as the riskiest scenarios, as they require the greatest capital expenditure while not achieving cash flows equal to that of the Wifi scenario.

4.2 Energy Analysis

The results of the energy analysis provided output numbers for the year, based upon average solar insolation data for Burkina Faso. The calculations in ***Table 11*** were carried out to calculate this number based upon this data and other assumptions.

Table 11: Plant Output Assumptions and Calculations

Plant Output Calculations		Units
Panel Area	1.63	m^2
Panel Size	270	watts
Number of Panels	26	
Total Area	42.38	m^2
Efficiency	16.5%	
Misc Losses	10%	
Annual Average Insolation	2,129.75	kWh/m^2
Total Annual Output	13,403.44	kWh/year
Rated Plant Size	7,020	watts
Plant Capacity Factor	21.8%	

(Source: Author, 2018)

The 7.0 kW plant planned for the SVF will produce approximately 13,400 kWh per year based upon average Burkina Faso daily insolation data. The resulting capacity factor for this plant is 21.8%, which is an exceptional capacity factor when compared to the resulting capacity factor if this plant were located in other areas of the world. If the plant was relocated to other locations around the world, the effect of solar insolation has a dramatic effect on plant performance. ***Table 12*** illustrates the effect a shifting solar radiation value has on plant output in various diverse locations across the globe.

Table 12: Plant Output by Location

Locations	Insolation	CF
Pa Village, Burkina Faso	2,129.75	21.8%
Calgary, Canada	1,201.72	12.3%
Los Angeles, USA	1,803.15	18.5%
Antofagasta, Chile	2,202.01	22.5%
Freiburg, Germany	1,149.46	11.8%

(Source: Author, 2018)

This shows that Burkina Faso's solar resource one of the best amongst those identified, with the exception of Antofagasta. This translates into an increased plant output, having a positive effect on project economics and feasibility.

4.3 Environmental Analysis

The results of the environmental analysis provided data on the emissions avoided by the SVF when compared to a situation where this electricity was drawn from the Burkina Faso electrical grid. After calculating the Burkina Faso carbon dioxide intensity, I was able to determine the carbon dioxide emissions offset by the SVF. ***Table 13*** shows this calculation.

Table 13: Emissions Offset by the SVF

Annual Plant Output	13,403.44	kWh
BF Grid Intensity	0.184	kg CO^2/kWh
Emissions Avoided	**2,462.88**	**kg CO^2/year**

(Source: Author, 2018)

The results of this analysis show that the SVF would offset approximately 2,460 kg of CO^2 annually when compared to the electrical grid of Burkina Faso. In other words, if this project were to move ahead with a grid connection instead of electricity from solar panels, it would

emit 2,460 kg of CO^2 into the environment from the electricity consumed. At a carbon dioxide grid intensity of 0.184 kg CO^2/kWh, Burkina Faso's electricity is more carbon intensive than electricity generated in Canada (Bullfrog Power, 2015). Canada's carbon dioxide intensity is 0.15 kg CO^2/kWh (Bullfrog Power, 2015). If the SVF was located in Canada instead of Burkina Faso, the resulting emissions offset would be 2,010 kg CO^2 per year, illustrating that the SVF will have a larger environmental impact in Burkina Faso than in Canada.

4.4 Project Risk Analysis

The four risk areas identified in Section 3.4 Risk Analysis Methodology have been tested to determine the impact they have on the overall project economics for Phase 1. For this section, thresholds have been placed to highlight changes in scenarios which change payback periods to less than 11 years or greater than 14 years.

Capital Budget

The budget has a significant impact on financial return and is largely subject to change given the nature of a project in a remote and foreign geographic location. With all other Phase 1 assumptions remaining the same, the project budget was altered to determine its effect on project economics. The following ***Table 14*** was produced.

Table 14: Capital Budget Sensitivity Analysis

Capital Budget	-25%	-10%	0%	10%	25%
Payback Period	10.24	12.06	13.23	14.38	16.07
IRR	9.33%	7.35%	6.29%	5.38%	4.23%

(Source: Author, 2018)

Given TSO's stated goal of a 10-year payback, this analysis reveals that, all other assumptions remaining the same, the SVF would have to reduce its budget by 25% in order to approach this goal. Alternatively, any cost overruns would have significant impacts, pushing the payback period past 14 years for both the 10% and 25% cost overrun scenarios.

Annual Wifi Revenue

Given the significant weighting that wifi sales has on the revenue profile of Phase 1, it has been tested to determine the effect on overall project economics. With all other Phase 1 assumptions remaining the same, the revenue from was altered to produce the following ***Table 15***.

Table 15: Wifi Revenue Sensitivity

Annual Wifi Revenue	-50%	-25%	0%	25%	50%
Payback Period	21.67	16.42	13.23	11.09	9.54
IRR	1.31%	4.00%	6.29%	8.34%	10.24%

(Source: Author, 2018)

A swing of 25-50% in either direction has a significant effect on the financial returns of the SVF. On the extremes, a swing from a 50% reduction to a 50% increase in wifi revenue alters the payback period from 21.67 years to 9.54 years. This analysis reveals that, as the SVF

commences, any deviation from the assumptions used will have a substantial effect on the return and payback period of the SVF.

Annual Shea Milling and Butter Production Revenue

Given the uncertainties in water and shea nut availability, shifts in revenues provided by the shea milling and butter production scenario are a distinct possibility. All other Phase 1 assumptions remaining the same, shifts in revenue for this scenario produce the results in ***Table 16***.

Table 16: Shea Milling and Butter Production Sensitivity Analysis

Annual Shea Butter Revenue	-50%	-25%	0%	25%	50%
Payback Period	16.14	14.54	13.23	12.14	11.22
IRR	4.18%	5.27%	6.29%	7.27%	8.20%

(Source: Author, 2018)

A positive shift in the revenue provided by this scenario, even a 50% increase, does not result in Phase 1 achieving a payback period of less than 11 years. However, the negative scenarios have a more significant negative impact, pushing out the payback period to greater than 16 years if revenue were to decrease by 50%.

Annual Operating Costs

Phase 1 has annual operating costs of just over $5,000, almost half of the anticipated annual revenue. As such, alterations can have significant impacts, as seen in ***Table 17***.

Table 17: Operating Costs Sensitivity Analysis

Annual Operating Costs	-25%	-10%	0%	10%	25%
Payback Period	10.92	12.20	13.23	14.46	16.80
IRR	8.53%	7.21%	6.29%	5.33%	3.77%

(Source: Author, 2018)

A shift in the expenses occurred during operation have a greater impact when increased than when decreased. Despite the implication of these results, the assumptions that have gone into the operating costs portion of Phase 1 are not subject to as much risk as other areas of this analysis. The two elements to operating costs are a wage, determined by TSO, and security expense, the value for which was provided by the TSO contact in Burkina Faso. As such, the potential deviation in operating costs for Phase 1 is low.

Risk Summary

The above analyses have shown that the single most significant item in the current Phase 1 model is the revenue generated by the Wifi scenario. This is due to its significant weighting in the revenue profile. Prior to project implementation, it may be worthwhile for TSO to revisit the sales assumptions utilized in this model to ensure that they are comfortable with the numbers and the corresponding financial risk should those numbers prove to be unrealistic.

Chapter 5: Limitations, Future Research, and Conclusions

5.1 Limitations

A number of limitations existed in this research which might have limited accuracy as assumptions were made in their place.

The first limitation was access to information in Pa Village. While we were able to obtain information in the form of interviews and questionnaires, the ability to follow up, clarify details, and answer questions arising from this information was challenging. In certain instances, assumptions had to be made around the information provided by the village. These instances were identified within the report. Free and open access to the locals in the village could have provided clearer and more readily available information for the SVF; however, given the nature of the village and project country this was not a realistic expectation.

Other assumptions that were forced to be made through this project included certain project-specific assumptions themselves. These include information on the availability of shea nuts if processing capacity is increased, and the availability of water for production. Both of these items have been identified by the villagers as items which, from time to time, produce bottlenecks in the shea butter process. However, we have not considered that an increase in the processing ability provided by the SVF may cause an increased demand on these resources and therefore increased shortages and production outages. The availability of these resources is unknown.

When gathering solar data for Burkina Faso, the closest location to the SVF at which insolation data was available was Bobo-Dioulasso. While the two locations are relatively close in

geographic terms, around 100 km apart, it remains as a limitation to the accuracy of the solar data used in the energy analysis to calculate plant output.

5.2 Future Research

This report opens the door to areas of future research and further analysis into off-grid solar project financial feasibility. There are many other scenarios for revenue generation that can be examined, including but not limited to soap production, chicken farming, cold food and drink sales, cold storage, and others. Different uses of the electricity produced by this or a similar project could possibly be better financially put to use in these scenarios or others; however they were not considered in this report.

Further, given the prototype nature of the SVF, an opportunity exists for further research through revisiting the project at a later date to re-evaluate after operations have commenced. Forecasts could be re-adjusted and corrected with accurate figures to better understand the financial return profile of the SVF as well as future projects in similar locations.

Conclusions

This project set out to determine how an off-grid solar project could operate economically in Burkina Faso, one of Africa's poorest countries. The results of the analysis undertaken in this project illustrate that alterations are required to either the budget or the project cash flow, or both, in order for TSO to achieve the stated target of a 10-year payback. With the current assumptions included in the project financial analysis, the SVF realizes a 13.30-year payback period with an IRR of 6.23%. This result came about through the construction of the five

individual revenue generating scenarios, including Shea Milling and Butter Production, Flour Milling, Wifi, Cell Phone Charging, and Solar Product Sales.

The most important scenario to project cash flow is Wifi, followed in order by Shea Milling and Butter Production and Flour Milling, with Solar Product Sales and Cell Phone Charging being almost identical with the lowest cash flows. Wifi has the potential to provide the greatest impact to the project's feasibility, and as such the sales assumptions that have been made for this scenario should be further verified. TSO should be comfortable with a level of risk that includes the shifting of the Wifi sales figures in positive or negative directions prior to proceeding with the SVF.

References

Akpablie, P.-M. (2015, June 6). *Rural Africa is the most expensive place on earth to charge a phone*. Retrieved from Fusion.TV: https://fusion.tv/story/59726/rural-africa-is-the-most-expensive-place-on-earth-to-charge-a-phone/

Amankwah-Amoah, J. (2015). Solar Energy in Sub-Saharan Africa: The challenges and opportunities of technological leapfrogging. *Thunderbird International Business Review, 57*(1), 15-31. doi:10.1002/tie.21677

Approved Index. (2018). *ISO Container Price Guide*. Retrieved June 25, 2018, from Approved Index: https://www.approvedindex.co.uk/storage-containers/iso-containers

Barrie, J., & Cruickshank, H. (2017). Shedding light on the last mile: A study on the diffusion of pay as you go solar home systems in central east Africa. *Energy Policy, 107*, 425-436. Retrieved from http://www.sciencedirect.com.ezproxy.lib.ucalgary.ca/science/article/pii/S0301421517303002?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb&ccp=y

Bensch, G., Grimm, M., Huppertz, M., Langbein, J., & Peters, J. (2016). *Are Promotion Programs Needed to Establish Off-Grid Solar Energy Markets? Evidence from Rural Burkina Faso.* Ruhr Economic Papers. Retrieved from https://www.econstor.eu/bitstream/10419/147826/1/87225545X.pdf

Bullfrog Power. (2015). *Canadian Emission Factors for Grid Electricity.* Retrieved June 25, 2018, from https://www.bullfrogpower.com/wp-content/uploads/2015/09/2015_bullfrog_power_electricity_emission_calculator.pdf

Burkina Faso Data Portal. (2015a, February). *Burkina Faso CO2 Emissions from Energy Consumption 1980-2009*. Retrieved May 18, 2018, from Burkina Faso Data Portal: http://burkinafaso.opendataforafrica.org/bimqnwg/burkina-faso-co2-emissions-from-energy-consumption-1980-2009

Burkina Faso Data Portal. (2015b, February). *Burkina Faso Primary Energy Consumption (QUadrillion BTU)*. Retrieved May 18, 2018, from Burkina Faso Data Portal: http://burkinafaso.opendataforafrica.org/vlyfaaf/burkina-faso-primary-energy-consumption-quadrillion-btu

Canada. (2018, February 2). *Canada's new support for education project in Burkina Faso*. Retrieved from Government of Canada Website: https://www.canada.ca/en/global-affairs/news/2018/02/canada_s_new_supportforeducationprojectinburkinafaso.html

Central Intelligence Agency. (2018). *Burkina Faso*. Retrieved June 22, 2018, from CIA World Factbook: https://www.cia.gov/library/publications/the-world-factbook/geos/uv.html

Chineme, T. (2018). *Designing a Sustainable Development Project in a Western African Socio-cultural Environment; Burkina Faso Case Study.* Calgary: University of Calgary.

Collings, S., & Munyehirwe, A. (2016). Pay-as-you-go solar PV in Rwanda: Evidence of benefits to users and issues of affordability. *Field Actions Science Reports, 15*, 94-103. Retrieved from http://factsreports.revues.org/4189

Container Technology. (2018, January 11). *How Durable are Shipping Containers*. Retrieved from Container Technology Inc Corporate Site: http://containertech.com/about-containers/how-durable-are-shipping-containers/

D'Agostino, A. L., Lund, P. D., & Urpelainen, J. (2016). The business of distributed solar power: a comparative cast study of centralized charging stations and solar microgrids. *WIREs Energy and Environment, 5*, 640-648. doi:10.1002/wene.209

Dahir, A. L. (2017, March 13). *We could stop tons of food losses by scaling these African-made low-tech cooling units*. Retrieved from Quartz Africa: https://qz.com/929817/we-could-stop-tons-of-food-losses-by-scaling-these-african-made-low-tech-cooling-units/

DSV. (2018). *Reefer Containers*. Retrieved June 25, 2018, from DSV: http://www.dsv.com/sea-freight/sea-container-description/reefer-containers

Emerson Climate Technologies. (2012). *Making Sense Webinar Series.* Retrieved June 24, 2018, from https://climate.emerson.com/documents/webinar-08-%E2%80%8Bimproving-refrigerated-marine-container-management-pervasive-connectivity-en-us-2884860.pdf

EPRI. (2010). *Electric Refrigerated Container Racks: Technical Analysis.* Retrieved June 26, 2018, from https://www.massport.com/capitalprogramsattachments/M495-D1/M495-

D1%20Appendix%20A-%20EPRI%20Elec.%20Reefer%20Rack%20Technical%20Analysis_Dec2010.pdf

FreshBox. (2018). *Keeping It Cool*. Retrieved June 25, 2018, from FreshBox Corporate Website: https://www.freshbox.co.ke/keeping-it-cool/

GeoCurrents. (2016). *GeoCurrents Maps of GDP per Capita*. Retrieved May 29, 2018, from GeoCurrents Website: http://www.geocurrents.info/gc-maps/geocurrents-maps-by-topic/geocurrents-maps-of-gdp-per-capita

Maersk Line. (2018). *Containers for Sale*. Retrieved June 25, 2018, from Maersk Line Container Sales: https://maersklinecontainersales.com/searches/37c0d1e154f28a7936b1af060ed210b3

Mbindyo, J. (2017, October 29). *Creating Shared Value Prize*. Retrieved from Changemakers: https://network.changemakers.com/challenge/creatingsharedvalue/entry/freshbox-solar-powered-fresh-produce-storage-solutions

M-KOPA Solar. (2018). *Company Overview*. Retrieved June 26, 2018, from M-KOPA Solar Corporate Website: http://solar.m-kopa.com/about/company-overview/

Munro, P., Van der Horst, G., Willans, S., Kemeny, P., Christiansen, A., & Schiavone, N. (2016). Social enterprise development and renewable energy dissemination in Africa: The experience of the community charging station model in Sierra Leone. *Progress in Development Studies, 16*(1), 24-38. doi:10.1177/1464993415608080

OpensolarDB. (2013, September 22). *Extracting Solar Data*. Retrieved from OpensolarDB: http://www.opensolardb.org/db/extractcopypaste

Reichert, P., & Trivella, U. (2015). Increasing energy access: the rise of pay-as-you-go solar and innovative financing partnerships. *Enterprise Development & Microfinance, 26*(3), 248-261. doi:10.3362/1755-1986.2015.022

Rolffs, P., Byrne, R., & Ockwell, D. (2014). Financing Sustainable Energy for All: Pay-as-you-go vs. traditional solar finance approaches in Kenya. *STEPS Working Paper 59*. Retrieved from https://pdfs.semanticscholar.org/7f7d/f435d60e0535d239bd600649f7f44fd3d3f8.pdf

Schneider Electric. (2018). *Homaya USB charging station.* Retrieved June 22, 2018, from Schneider Electric Website: https://www.schneider-electric.com/en/product-range-download/64150-homaya-usb-charging-station#tabs-top

Solar Milling. (2018). Retrieved February 24, 2018, from Solar Milling Corporate Website: http://solarmilling.com

Statista. (2018). *Burkina Faso: Inflation rate from 2012 to 2022*. Retrieved 18 May, from Statista: The Statistics Portal: https://www.statista.com/statistics/449025/inflation-rate-in-burkina-faso/

SunnyMoney. (2018). *Home*. Retrieved June 26, 2018, from SunnyMoney Corporate Page: http://www.sunnymoney.org/

TamTam. (2018). Retrieved June 22, 2018, from TamTam Network Website: http://www.tamtam-network.com/index-english.php#contact

Taylor, M., & So, E. y. (2016). *Solar PV in Africa: Costs and Markets.* International Renewable Energy Agency. Retrieved from http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Solar_PV_Costs_Africa_2016.pdf

The Strongest Oak. (2017). *Our Program*. Retrieved June 25, 2018, from The Strongest Oak Website: http://www.thestrongestoak.org/what-we-do-and-why/our-program/

United Nations. (2018). *Sustainable Development Goals*. Retrieved March 18, 2018, from United Nations Development Programme Website: http://www.undp.org/content/undp/en/home/sustainable-development-goals.html

Urpelainen, J., & Yoon, S. (2015). Solar products for poor rural communities as a business: lessons from a successful project in Uttar Pradesh, India. *Clean Technologies and Environmental Policy, 18*, 617-626. doi:10.1007/s10098-015-1028-4

Appendix A – Project Excel Inputs Project Excel Sheet

	Drop Down List					
	Number Input					
	Text Input					
	Formula					
Project					**Scenarios**	
Name		Solar Village of the Future			☑	Shea Machines
Life		25	years		☑	Flour Milling
Location		Pa Village			☑	Wifi
Size		6.48	kW		☑	Cell Phone Charging
					☑	Solar Product Sales
Hub Manager Wage		$ 2,400.00	/year			
Security		$ 2,760.00	/year			
Overhead and Admin		$ -	/year			
Financing						
Project Budget						
	Project Budget	$ 80,175.06				
	Manual Input					
Grants/Subsidies						
Net Project Cost		$ 80,175.06				
Term		20	years			
Interest Rate		2%				
Inflation		2%				
% of Project Financing		100%				
Project Financing		$ 80,175.06				
Project Equity		$ -				
Misc						
CDN/CFA Exchange Rate		$ 0.0025				
CDN/USD Exchange Rate		$ 1.31				
CDN/Euro Exchange Rate		$ 1.56				

(Source: Author, 2018)

Appendix B – Project Excel Budget

Application	Quote	Line Item	Included?	Detail	Supplier	Quantity	Unit Price (CFA)	CFA	Euro	CDN
Base Project		Solar Panels (6.48 kW)	Yes			28	-	-	10,052	$ 10,836.00
Base Project		Lead Acid Batteries, 1 day autonomy	Yes			12				$ 6,723.60
Base Project		Meters	Yes			1				$ 435.00
Base Project		Charge Controller	Yes			1				$ 2,000.00
Base Project		Inverter	Yes			1				$ 2,300.00
Base Project		AC Power Distribution Panel	Yes			1				$ 500.00
Base Project		Comm Box	Yes			1				$ 350.00
Base Project		System Control Panel	Yes			1				$ 350.00
Base Project		Container	Yes			1	1,300,000	1,300,000	-	$ 3,198.43
Base Project		Container Transport	Yes			1	250,000	250,000	-	$ 615.08
Base Project		Cabling and accessories	Yes			1	300,000	300,000	-	$ 738.10
Base Project		Labour	Yes			1	350,000	350,000	-	$ 861.11
Base Project		Travel	Yes			1	150,000	150,000	-	$ 369.05
Base Project		Lamps	Yes			6	10,000	60,000	-	$ 147.62
Base Project		Corrugated Roof & Poles	Yes			1				$ 3,000.00
Base Project		Storage Shed	Yes			1				$ 1,000.00
Base Project		Structural Engineering	Yes			1				$ 3,000.00
Base Project		Hooded Vents	Yes			4				$ 600.00
Base Project		Evaporative cooling vent	Yes			1				$ 200.00
Base Project		Paint	Yes			1				$ 250.00
Base Project		Large Window and Awning	Yes			1				$ 500.00
Base Project		Small Window	Yes			1				$ 250.00
Base Project		Door	Yes			1				$ 500.00
Base Project		6 months security	Yes			0.5				$ 1,380.00
Base Project		Bar Fridge	Yes			1				$ 1,000.00
Base Project		Desk	Yes			1				$ 250.00
Base Project		Laptop	Yes			1				$ 1,000.00
Base Project		Printer	Yes			1				$ 500.00
Base Project		Shelving	Yes			1				$ 250.00
Base Project		Fencing	Yes			1				$ 2,500.00
Base Project		Student Travel - Needs Assess	Yes		UofOuaga	1	310,000	310,000	-	$ 762.70
Base Project		Site Visit October 2018 Install (1 engineer, 1 TSO)	Yes			1				$ 6,000.00
		SubTotal								$ 52,366.69
		Wire transfer/bank fees/currency fluctuation		5%						$ 2,618.33
		Contingency		20%						$ 10,473.34
		Base Project Total								**$ 65,458.36**

Application	Quote	Line Item	Included	Detail	Supplier	Quantity	Unit Price (CFA)	CFA	Euro	CDN
Flour Milling		Stone Mill	Yes			1	-	-	1,623	$ 2,537.30
Flour Milling		VAT/Import Taxes (18%)	Yes			1				$ 456.71
Shea Machines		Crusher	Yes			1	-	-	810	$ 1,266.31
Shea Machines		Shea Paste Maker	Yes			1	-	-	2,541	$ 3,972.45
Shea Machines		Control Panel with FCD & protections	Yes			1			2,197	$ 3,434.66
Shea Machines		Shipping to Ougadougou	Yes			1			1,530	$ 2,391.91
Shea Machines		VAT/Import Taxes (18%)	Yes			1				$ 1,561.21
Wifi		VSAT (wi-fi)	Yes			1	-	2,200,000	-	$ 5,412.72
Cell Phone Charging		Universal Charging Station	Yes	12V - 27 VDC		1	-	-	47	$ 73.48
		SubTotal								$ 21,106.75
		Wire transfer/bank fees/currency fluctuation		5%						$ 1,055.34
		Contingency		20%						$ 4,221.35
		Scenario Total								**$ 26,383.43**
		Project Total								**$ 91,841.80**
		Less: TSO members funding travel through airmiles and internal		$ (6,000.00)						$ (6,000.00)
		Less: Village contributions in-kind		$ (2,880.00)						$ (2,880.00)
		Less: Discount on Electrical Components??		50%						$ (2,786.74)
		Grand Total								**$ 80,175.06**

(Source: Author, 2018)

Appendix C – Project Excel Scenario Assumptions

SCENARIO ASSUMPTIONS

Shea Machines

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Operating Profile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monthly Revenue	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50	$ 182.50
Monthly Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Electrical Tariff	$ 0.54	/kWh
Monthly Operating Hours	144	
Peak Load	2.2	kW
Monthly Revenue (Tariff)	$ 171.07	
Current Peak Production	30	kg/day
Target Peak Production	60	kg/day
	1,825	kg/month
Cost per kg	$ 0.10	/kg
Projected Monthly Revenue	$ 182.50	

Flour Milling

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Operating Profile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monthly Revenue	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26	$ 149.26
Monthly Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

kW Usage	0.75	kW
Average Family Milling Expense	1,500	CFA/week
Charged Family Milling Expense	1,000	CFA/week
	$ 2.46	CDN/week
Estimated Weekly Customers	14	families
Projected Monthly Revenue	$ 149.26	

Wifi

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Operating Profile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monthly Revenue	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16	$ 393.16
Monthly Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Commission	17%

Expected Sales

	Basic			Premium		
Product	# Monthly Clients	Cost per Pkg (CFA)	Total CFA	# Monthly Client	Cost per Pkg (CFA)	Total CFA
1 hour	200	150	30,000	100	1,000	100,000
1 day	50	1,000	50,000	25	5,000	125,000
1 week	20	5,000	100,000	10	12,000	120,000
1 month	10	19,000	190,000	5	45,000	225,000

Projected Monthly Revenue	$ 393.16

Cell Phone Charging

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Operating Profile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monthly Revenue	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00
Monthly Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Cell Phones	8,000	
Monthly charging frequency	1	
Calculated Daily Frequency	266.7	
Phones charged per day	25	
Cost to charge	$ 0.10	CDN
Projected Monthly Revenue	$ 75.00	

Solar Product Sales

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Operating Profile	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Monthly Revenue	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00	$ 76.00
Monthly Expense	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Sales Commission	5%

Solar Product Sales			
Solar Products	# Monthly Sales	Cost per Pkg (CDN)	Total CDN
Solar Lamp	20	$ 13	$ 260
Lamp + Charge	15	$ 46	$ 690
SHS	5	$ 114	$ 570

Projected Monthly Revenue	$ 76.00

(Source: Author, 2018)

Appendix D – Project Excel Financial Metric Output

Project Information			
	Project Name		Solar Village of the Future
	Project Life		25 Years
	Location		Pa Village
	Size		6.48 kW
Project Cost			
	Equity	$	-
	Debt	$	80,175.06
	Net Project Cost	**$**	**80,175.06**
	Subsidies	$	-
	Gross Project Cost	**$**	**80,175.06**
Scenario Revenue			
	Shea Machines	$	2,190.00
	Flour Milling	$	1,791.12
	Wifi	$	4,717.92
	Cell Phone Charging	$	900.00
	Solar Product Sales	$	912.00
	Total	**$**	**10,511.04**
Investment Summary (Cash on Cash)			
	Payback Period		13.23
	IRR		6.29%

PROJECT CASH FLOW - CASH ON CASH	0	1	2	3	4	5	6	7
Scenario Revenue		$10,511.04	$10,721.26	$10,935.69	$11,154.40	$11,377.49	$11,605.04	$11,837.14
Scenario Expenses		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Personnel (Manager/Security)		$5,160.00	$5,263.20	$5,368.46	$5,475.83	$5,585.35	$5,697.06	$5,811.00
O&M								
Admin		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Line Items								
Net Annual Cash Flow	$80,175.06	$5,351.04	$5,458.06	$5,567.22	$5,678.57	$5,792.14	$5,907.98	$6,026.14
Cumulative Cash Flow	$80,175.06	$74,824.02	$69,365.95	$63,798.73	$58,120.16	$52,328.02	$46,420.04	$40,393.90
PROJECT CASH FLOW (100% FINANCED)								
Operating Cash Flow		$5,351.04	$5,458.06	$5,567.22	$5,678.57	$5,792.14	$5,907.98	$6,026.14
Blended Payment		$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24
Net Annual Cash Flow	$0.00	$447.80	$554.82	$663.98	$775.32	$888.90	$1,004.74	$1,122.90
Cumulative Cash Flow	$0.00	$447.80	$1,002.62	$1,666.60	$2,441.92	$3,330.82	$4,335.56	$5,458.46

8	9	10	11	12	13	14	15	16	17	18
$12,073.88	$12,315.36	$12,561.67	$12,812.90	$13,069.16	$13,330.54	$13,597.15	$13,869.10	$14,146.48	$14,429.41	$14,718.00
$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$5,927.22	$6,045.76	$6,166.68	$6,290.01	$6,415.81	$6,544.13	$6,675.01	$6,808.51	$6,944.68	$7,083.57	$7,225.25
$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$6,146.66	$6,269.60	$6,394.99	$6,522.89	$6,653.35	$6,786.41	$6,922.14	$7,060.59	$7,201.80	$7,345.83	$7,492.75
$34,247.23	$27,977.63	$21,582.64	$15,059.75	$8,406.41	$1,619.99	$5,302.15	$12,362.74	$19,564.54	$26,910.37	$34,403.12
$6,146.66	$6,269.60	$6,394.99	$6,522.89	$6,653.35	$6,786.41	$6,922.14	$7,060.59	$7,201.80	$7,345.83	$7,492.75
$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24	$4,903.24
$1,243.42	$1,366.35	$1,491.75	$1,619.65	$1,750.10	$1,883.17	$2,018.90	$2,157.34	$2,298.55	$2,442.59	$2,589.51
$6,701.88	$8,068.23	$9,559.98	$11,179.63	$12,929.73	$14,812.90	$16,831.80	$18,989.14	$21,287.70	$23,730.29	$26,319.80

19	20	21	22	23	24	25
$15,012.36	$15,312.60	$15,618.86	$15,931.23	$16,249.86	$16,574.85	$16,906.35
$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$7,369.75	$7,517.15	$7,667.49	$7,820.84	$7,977.26	$8,136.80	$8,299.54
$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$7,642.61	$7,795.46	$7,951.37	$8,110.39	$8,272.60	$8,438.05	$8,606.81
$42,045.72	$49,841.18	$57,792.55	$65,902.94	$74,175.54	$82,613.60	$91,220.41
$7,642.61	$7,795.46	$7,951.37	$8,110.39	$8,272.60	$8,438.05	$8,606.81
$4,903.24	$4,903.24	$0.00	$0.00	$0.00	$0.00	$0.00
$2,739.36	$2,892.21	$7,951.37	$8,110.39	$8,272.60	$8,438.05	$8,606.81
$29,059.16	$31,951.37	$39,902.74	$48,013.13	$56,285.73	$64,723.79	$73,330.60

(Source: Author, 2018)