A PV system for remote power and Shea nut processing in Burkina Faso

Stace Wills[1], Dan Rickard[1], Andrea Cosgrove[1], Tinu Chineme[1], Pep Margets[2], S. Zacharie Kam[3], David Wood[4]

[1] The Strongest Oak Foundation, 61 Valley Woods Way NW, Calgary, Canada T3B 6A2
[2] Seine Tech Solar Milling, Alemanya, 58 Pol. Ind., 08700 Igualada, Spain
[3]Dépt de Physique, UFR/Sciences Exactes et Appliquées, Université Joseph Ki-Zerbo, Burkina Faso
[4] Dept Mechanical & Manufacturing Engineering, University of Calgary, Calgary, Canada, T2N 1N4

Abstract

This project developed a photovoltaics (PV) power hub for a remote village in Burkina Faso consisting of (1) a 1.5 kW array providing internet connection and WiFi hotspot, cell phone charging, office services (photocopy, scan/print, computer), and cafeteria (fridge, coffee machine) and (2) a separate 5.0 kW array with no batteries for a novel PV application: the grinding and milling of flour and shea nuts, as well as the production of shea paste by the village women's co-operative. Shea "butter" – the paste mixed with water - is used in soap and cosmetic manufacture worldwide and is one of the major cash crops of the region. From June each year, the women work many hours per day to collect the nuts, and then to de-shell, roast, dry and mill them. Traditionally these time-consuming tasks are done by hand and often last until the following February. The largest uncertainty in designing the system was in estimating the usage of the milling equipment, so the project includes an internet-gateway to provide data on PV production and energy usage to be analyzed by researchers and students at the University of Ouagadougou to improve the design of future systems.

Keywords: remote power systems, photovoltaics, shea butter, women's co-operative, rural development

1. Introduction

The non-profit organization The Strongest Oak Foundation (TSO: http://www.thestrongestoak.org/) has been working in Burkina Faso for four years providing photovoltaic (PV) powered lighting for schools and teachers' residences in the municipality of Pa, an agricultural district located three hours west of the capital city, Ouagadougou. The co-founders of TSO's local non-profit partner, Association Monde Meilleur (AMM), all originate from Pa but live and work elsewhere in the country.

Burkina Faso has a severe energy challenge in that around 14 million people (95% of the country's rural population), are not connected to the national grid, Mona-Girona *et al.* (2016). Diesel generators are commonly used to supply power to small businesses in rural areas, but the high cost of diesel fuel and the CO_2 emissions are significant impediments to mass adoption. Several solar micro-grid projects have been built or are underway, e.g. Bensch *et al.* (2018), but they typically require large capital investment, have very long-term paybacks, and do not provide power in remote regions. Decentralized, containerized systems for remote power represent an emerging opportunity in Africa and the global market is projected to grow by 8% per year to $US500 million by 2025 (https://globenewswire.com/news-release/2019/02/20/1738265/0/en/Containerized-Solar-Generators-Industry-Global-Market-to-Touch-Revenue-of-Over-US-500-Mn-by-2025-QY-Research-Inc.html).

TSO and its partners' vision is to create a smart network of Power Hubs across Burkina and West Africa that convert clean, solar energy into sustainable village wealth, as well as generate an economically-viable return on capital within a 10-year payback period. The low capital/equipment costs and multiple potential revenue streams offered by the Power Hub will be attractive to not only government agencies, large NGOs, and corporate social responsibility initiatives of large international enterprises, but also to traditional capital providers like banks and social venture capitalists. This enables the Power Hub project to potentially scale rapidly in the near future, with the right partners alongside.

doi:10.18086/swc.2019.32.03 Available at http://proceedings.ises.org

In 2015, AMM invited TSO to partner with local stakeholders to develop PV systems for schools and teachers' residences in the Pa district by maximizing the use of local contractors and TSO-sponsored youth interns ("Oaks"). In the following three years, five villages were provided with solar lighting and power. In October 2017, TSO conducted site inspections of the five solar installations. During the visit, TSO solicited input from local stakeholders, including the Sougrinooma women's cooperative and the University of Ouagadougou, to explore how the district might benefit further through the deployment of a custom-built, containerized PV system. In May 2018, a needs assessment was conducted by TSO and the University of Ouagadougou to explore the viability of a launching a groundbreaking project for economic development and women's empowerment in Pa village: the Power Hub, which was designed to help a local shea butter co-operative to automate some of their production processes, increase productivity, and generate higher incomes. Containerized PV systems from several global suppliers were considered for the project, but all were determined by TSO to be either too expensive, or not sturdy enough to meet the rugged environmental requirements of Pa district in terms of extreme heat, dust, wind, and periods of intense rain.

In October 2018, fabrication of a 6.5 kW, containerized, prototype solar hub commenced in Ouagadougou. In December 2018, the 20-ft. container was delivered and installed in Pa village, close to the main road. Solar-powered shea and flour processing machines were installed in January 2019 and the women's cooperative have been processing their nut and grain supplies nearly every day since the Power Hub's launch on January 16.

Shea nut collecting and processing is a well-researched activity in Africa, eg Elias (2015) and Rousseau *et al.* (2015). It is a major cash crop in much of Burkina Faso and is often managed by local women's co-operatives such as Sougrinooma in Pa. The season usually starts in June with the collection of the nuts from trees surrounding the village. The nuts are then cooked for about 2 hours followed by further drying in the sun. The shell is then removed by hand and the flesh dried again in the sun. The dried flesh is then ground to a fine paste, also by hand, which is the most time-demanding part of the process. Water is added to the paste to make Shea butter which is then sold. Shea butter production usually lasts until February the following year and the women typically work 10 hours a day or more in collecting and processing during this period. This is time taken away from their other responsibilites of child raising, cooking, etc. In Pa, the cooking is by burning scarce timber and is an important element in deforestation in the region. TSO and its partners intend, at some point in the future, to develop a solar cooker to replace burning timber.

The co-operative sometimes supplements its supply by purchasing nuts and would do this more often if faster processing was available. The co-operative has recently extended its activities to include soap production which brings a bigger income.

Other shea production units in Burkina Faso are mechanized. For example, the Yona co-operative supported by the Semafo Foundation (https://fondationsemafo.org/cause-view/karite-butter-production/?lang=en), which is about 50 km from Pa, uses a total diesel power of 25 kW for grinding, milling and paste making. Other means of producing shea butter are described by Yonas et al. (2015). As far as the authors are aware, no PV-powered system has been used for shea production. The aim of the present project is to combine the PV-power to lessen the most labour-intensive loads of shea butter production with a power hub for the more common uses of cell phone charging, computer use, refrigeration, coffee making etc. TSO engaged Seine Tech (www.seinetech.com, www.solarmilling.com) a Catalonia-based company with experience in solar milling to provide the milling machine, grinder, and paste maker. This was the first use of these machines for shea butter production.

The remainder of this paper is organized as follows. Section 2 describes the system design and construction. The next section describes the operation of the system over its first five months, and Section 4 discusses our investigations of the impact of the system on the village. The final section sums up the experiences with the project and describes further plans, as well as listing the conclusions.

2. Description of the System

Figure 1 shows the topology of the Power Hub and Figure 2 is a photograph of the system. For simplicity, the smaller PV system, labeled Section 1 in Figure 1, was kept separate from the solar milling system, Section 2. The power from Section 1 is used for cafe services (coffee and refrigerated beverages), photocopying and other office services, WIFI hotspot, and cellphone battery recharge. The main components of Section 1 are: a 6×250W Horonya PV array feeding a Schneider MPPT 66-150 charge controller rated at 2.5 kW. This connects to a 24V battery and a Schneider

Conext SW 2524 2.5 kW inverter. Section 2 comprises 20× 250 W Horonya PV modules feeding three frequency controllers followed by a grinder, a paste maker, and a grain mill. For system monitoring and performance evaluation, a communication box connects both sections with a Cachelan internet gateway and modem, (http://tsop1.solarvu.net/green/solarVuLive.php?ac=tsop1&dr=tso.

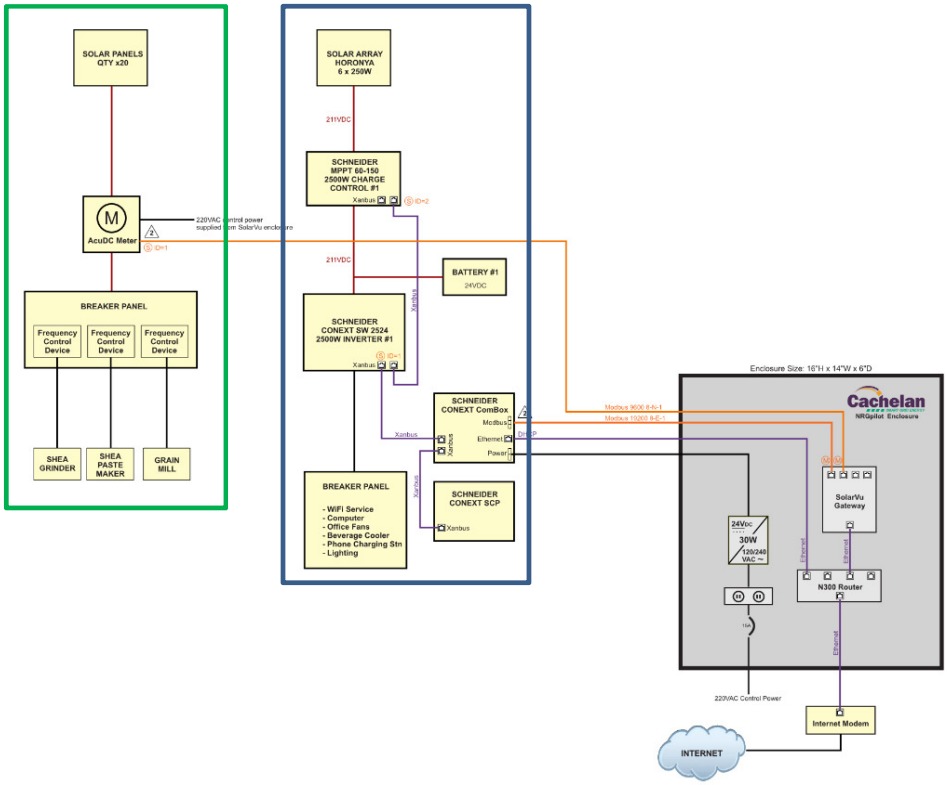

Fig. 1: Layout of the PV system. Section 1 is shown in the blue rectangle. Section 2 for the solar milling is in the green rectangle. The internet gateway is shown on the right.

A possible problem with the separation of the two sections is that there is no alternative use of the PV power provided by Section 2 if the machines are not used which would lead to significant waste of solar energy. For that reason, it was considered essential that the system be monitored and that the performance data analyzed to track PV production and machine usage. Ideally, the individual modules would be controlled by a power conditioner and their individual performance monitored, partly because the modules, produced in Mali, and easily available in Burkina Faso, are guaranteed only for five years. Individual control, however, was not economic and the site is unshaded so it was decided to use a string inverter for Section 1 and Seine Tech's recommendation of a standard frequency controller for the machines.

3. System Operation

The Power Hub was commissioned in January 2019, well in time for the 2019 shea nut season. Nearly 2 MWh of solar energy has been produced in that time. Figure 3 shows typical data from the gateway with the red blocks indicating no internet connection, a common problem in developing countries. The lack of internet access through a Telecom Afrique satellite has been a continuing problem which has not yet been satisfactorily resolved. The consumption of Section 1 has been steady and near capacity. However, the consumption by Section 2 has been decreasing slowly each month since January and there is currently a 3-day waiting period for customers to process their nuts or grains. Two possible reasons for the underperformance of the Primary Load are:

- The solar mills produce a high quality powder that is good for niche buyers, but the throughput is extremely slow (10x less than a standard electric mill), and
- Increasing cloud as the mid-year rainy season is approached. When customers must wait, they are likely they go elsewhere to process their nuts and grains, or else they revert to manual techniques.

Fig. 2: Photograph of the PV system showing the solar milling equipment on the shaded concrete floor.

To address the above issues, Solar Milling is developing a new solar mill for grains that is significantly faster than the current mill used at the Power Hub. The mill is still in development and expected to be ready in the coming months. In the meantime, TSO plans to alleviate current bottlenecks by acquiring a new electric mill (see Section 5: Project Development) that will be powered by a grid connection until the solar mills are available for purchase.

Fig. 3: Shea butter production

In addition, TSO is exploring potential designs for the next version of the Power Hub (v2.0) that will add battery storage capabilities to Section 2 so that the machines can be operated during cloudy days or evenings.

Café sales have exceeded expectations and they represent half the current total revenues. WIFI sales have underperformed due to technical issues with the satellite telecom supplier and their equipment, which has yet to be resolved. Lamp sales, battery charging and office services have underperformed. TSO is planning to discontinue the lamp sales and adjust prices for the latter two services. TSO's WIFI suppliers and design will be reconsidered in v2.0. The Hub is currently generating net revenues of CAD$275 per month, which is roughly 33% of the original budgeted amount. Roughly CAD$800 to $900 per month is required for the Hub to achieve break-even, which includes a monthly contribution of net profits to a Sinking Fund for future maintenance, repairs, and depreciation/equipment replacement.to ensure long-term financial sustainability.

The Hub employs four full-time staff members including the overall Hub Manager, a milling/solar technician, an IT technician, as well as a night watchmen. 8 part-time personnel – mostly women from the Sougrinooma cooperative - work at the Hub from time to time in roles such as serving (cafe), cashier, and treasury/bookkeeping

In June 2019, TSO and Sougrinooma launched its first line of finished goods, believed by TSO to be the world's first soap produced by a combination of solar milling equipment and manually-driven equipment (such as a stamping machine below, used for branding the soap), Fig 4. Sougrinooma manufactures three types of soaps – all using shea butter as a primary ingredient -- for retail sale across Burkina: Green Clay, Honey, and Neem. Neem comes from a drought-resistant, exotic tree commonly found in Burkina Faso. Locals maintain that neem soap acts as an antibacterial and that it is an effective treatment for skin rashes, acne, and eczema, as well as effective relief of muscle tension.

To prepare for the soap launch, Sougrinooma members received training from the Semafo-sponsored Yona Cooperative. Sougrinooma can now supplement their incomes and capture more of the value chain, rather than selling just shea butter as a commodity. Figure 4 shows a Sougrinooma woman using a tool to stamp the words "Sougri-Nooma" to the face of each soap bar. Then, each soap bar is packaged and labelled, and then made available for sale in local shops.

In addition to the Yona soap training, a one-week workshop in Entrepreneurial Thinking was delivered to the women's cooperative by two instructors from the University of Ouagadougou. The intent of the training was to increase the women's familiarity with key business and marketing concepts, to improve their financial literacy, to improve efficiencies and productivity within their cooperative, and to inspire individual members to launch new businesses that could increase their incomes and self-confidence.

Many Sougrinooma cooperative members are illiterate, which meant that TSO and the University of Ouagadougou had to develop a "train-the-trainer" concept to focus the entrepreneurial training on Sougrinooma's leaders. In turn, such leaders would be responsible for training other members outside of the workshop so that the knowledge could be transferred.

Transfer of ownership of the Power Hub and its equipment from TSO to Sougrinooma is expected to conclude in August 2019. TSO's Burkina partner, AMM, will continue to support and advise Sougrinooma in the management and oversight of the Hub. The project is governed by a Project Steering Committee consisting of representatives from Sougrinooma, AMM, and the village. The parties have agreed that net profits from Power Hub activities will be divided as follows: 50% Sougrinooma, 30% AMM, and 20% towards the Sinking Fund.

Fig. 4: Final steps in the making of shea butter soap

4. Impact on the Community

In June 2019, TSO collaborated with a Pa resident (the English teacher at the local school) to conduct an Impact Assessment on the Power Hub project. The Impact Assessment was a follow-up to a comprehensive Needs Assessment that was completed by TSO and its partners one year prior.

The Impact Assessment had four major goals:

1. Demonstrate the impact of the intervention on the target community (Pa)
2. Demonstrate the value of the intervention to donors and stakeholders.
3. Aid internal decision-making and continuous improvement
4. Share learnings with other NGOs who can benefit from our experiences

In addition, TSO's longer term goal was to evaluate improvements in the self esteem of the women's cooperative members, and empower more female leaders in the Pa communiity. Dr. David Wood, a project team member, reported on his return from a Pa site visit in May 2018 that: "The thing I felt most when we were at the village and talking to the women was…. they were in the courtyard of the mosque and the row of men were sitting with their back to the mosque… there was that distinction from the beginning. I found it hard to engage the women…. there is possibly a need to reinforce their voice so that the decisions are not just made by the men." The Impact Assessment intended to evaluate not only if women's incomes increased, but also their self-confidence—confidence to voice opinions, start new businesses, and pursue dreams.

Success parameters for the Impact Assessment were defined as follows:

1. Grains and shea nut are processed using milling equipment
2. Portable devices are conveniently charged
3. A women's "house" is made available for women to converge and innovate
4. Residents have easy access to information and entertainment (based on TV and radio request)
5. Internet connectivity to residents is increased
6. Power Hub inspires the creation of social enterprise in Pa
7. Technological and business expertise is transferred

Based on the success parameters, the impact assessment was designed to evaluate three main concerns;

1. Is the Power Hub profitable and how profitable is it?
2. Did the Power Hub impact beneficiary families positively (or negatively)?
3. Is the Power Hub stimulating entrepreneurial thinking and/or promoting business start-ups?

Table 1: Proposed Impact Assessment

Evaluation Questions	Observation	Questionnaires	Interviews
1. Is the Power Hub **profitable** and how profitable is it?	**Interviewer** (via report, pictures, Skype)	Sougrinooma Coop and Power Hub staff	• Coop President • Alima Sawado • TSO Oaks
2. Did the Power Hub impact **beneficiary families** positively (or negatively)? How?	Same as above	Sougrinooma Coop and Power Hub staff	• Coop President • Alima Sawado • TSO Oaks
3. Is the Power Hub stimulating **entrepreneurial thinking** and/or promoting **business start-ups**?	Same as above	Male and Female residents of Pa (10 each)	• Coop President • Alima Sawado • TSO Oaks

The assessment was originally proposed as a video conferenced interview with an interpreter who spoke English, French, and the local language (Mossi). However, this was not possible because of time constraint, associated costs, and intermittent internet connectivity at the location.

Table 1 provides a summary of the planned assessment approach. The strategy was implemented as a survey conducted with printed copies of the questionnaire shown in Table 2. Forty (40) Pa residents, 29 women and 11 men, were individually interviewed in-person and their responses recorded and forwarded via the internet to Calgary for analysis. Of the forty respondents, twenty-four were between the ages eighteen to thirty-five i.e. 60% of those surveyed are thirty-five years old or younger. Major highlights from the survey include:

Table 2: The Questionnaire

Questions	Yes	No
Q 3: Are you directly employed or involved in running the Power Hub?	46%	54%
Q 5: Are you a member of the Sougrinooma Women's Cooperative?	85%	15%
Q 6: Did you want the Power Hub in your village BEFORE it was constructed?	100%	0%
Q 7: Do you want the Power Hub in your village AFTER it has been built?	100%	0%
*Q8: How has the Power Hub benefited you personally?	75%	25%
Q 9: Have you attended a TSO training course?	57%	43%
Q 11: Have you used what you learned from the course(s) in your day-to-day activities?	60%	40%
Q 12: Were you trained by TSO to train others i.e. Train-the-Trainer?	20%	80%
Q 13: Have TSOs activities helped in increasing your confidence in what you can personally achieve?	80%	20%
Q 14: Did you start up a new business because of the Power Hub or training provided by TSO?	10%	90%
Q 15: Do you use the WIFI service from the Power Hub?	10%	90%
Q 18: Has the Power Hub improved your ability to provide an education for your children?	65%	35%
Q 20: Has your time at the Power Hub enabled you able to find new solutions to old challenges? Do you think of challenges differently?	72.5%	27.5%
Q 21: Is the Power Hub delivering on the promises made?	52.5%	32.5% (+ 15% Not all the time)
Q 23: Does the Power Hub make it easier for you to charge your personal portable devices? E.g. lamps, cell phones etc.	100%	0%
Q 24: Does the Power Hub provide you with consistent and easier access to information and entertainment?	25%	75%

*Responses are categorized by “no benefits” as a “No” and “benefitted” as a “Yes.”

1. 100% of respondents endorsed the Power Hub at inception and currently still favour the project
2. 75% have benefitted financially or otherwise by the project
3. 60% were able to apply the classroom training to their daily activities.
4. 80% of respondents have improved self-esteem
5. 10% started up new businesses as a result of TSO provided training
6. Low literacy levels and intermittent internet connection contributed to only 10% use of the WIFI service
7. 100% of respondents endorsed the Power Hub at inception and currently still favour the project
8. 65% are better able to provide an education for their children because of wages made at the Power Hub

9. Thanks to the Power Hub and training conducted, 72.5% have a new understanding of challenges and have discovered solutions to old problems
10. The current slow speed of the milling machines and the sporadic internet service are the primary concerns affecting user adoption.
11. Portable electric device charging is considered a succes.

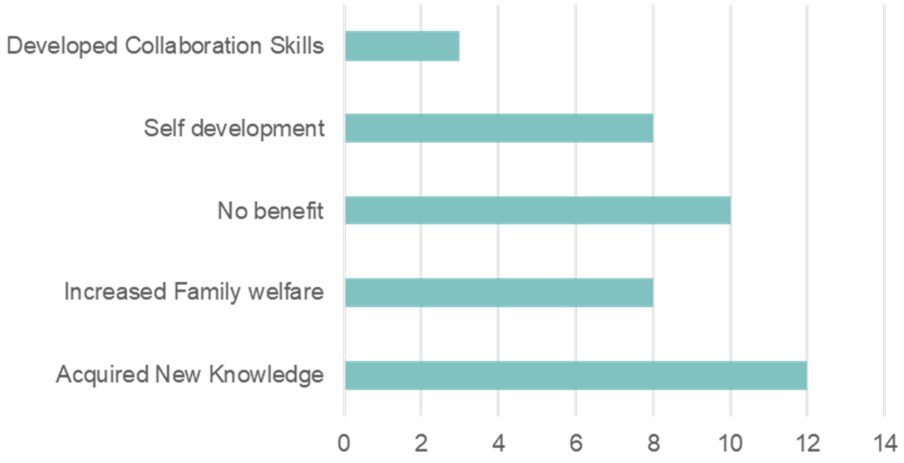

Fig. 5: Power Hub Impact Categories

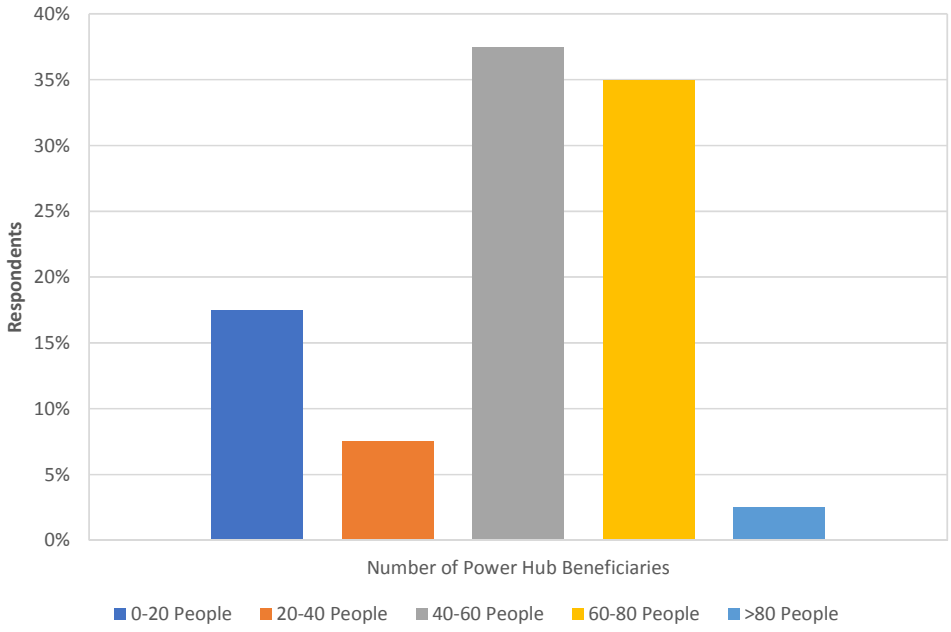

Fig. 5: Power Hub Beneficiaries

A summary of the "Yes" or "No" category questions from the questionnaire are represented in Table 2. Further analysis of respondents' answers provided valuable lessons to the project team. For example, respondents were asked "How has the Power Hub personally benefited you"? Figure 5 shows thirty percent (30%) acknowledge the Power Hub contributing to knowledge acquisition, while 20% attribute self-development to the project.

Respondents were also asked: "Have you used what you learned from the course(s) in your day-to-day activities?" Sixty percent (60%) of respondents identified course learnings that they were inspired to apply at their jobs and businesses, or in their day to day activities. Comments included:

- "It helped to have another view of work"
- "It helps in our daily business"
- "Help organize myself"
- "My daily work is now organized" and
- "Performance at work"

Another question posed was " Did you start up a new business because of the Power Hub or training provided by TSO?" Empowered by the training from TSO and the University of Ouagdougou, four respondents started up new businesses; two began milling and producing "Sumbala", a local condiment prepared from Néré (Parkia biglobosa) seeds or soybeans, while one started a trading business.

Respondents were asked: "Has your time at the Power Hub enabled you to find new solutions to old challenges? Do you think of challenges differently?" One respondent felt empowered to find solutions for herself as well as others. "I can work for myself and help others at work . Another respondent cited a change in an approach to work; "In the past, I did not use to organize my activities, but now my work is different"

Weekly Power Hub income (on an individual basis) varied with approximately forty percent (40%) of the respondents earning more than CFA 5000 (CAD$11.42) each week. Some respondents were unable to provide an estimate because they were not in control of their finances, Figure 6.

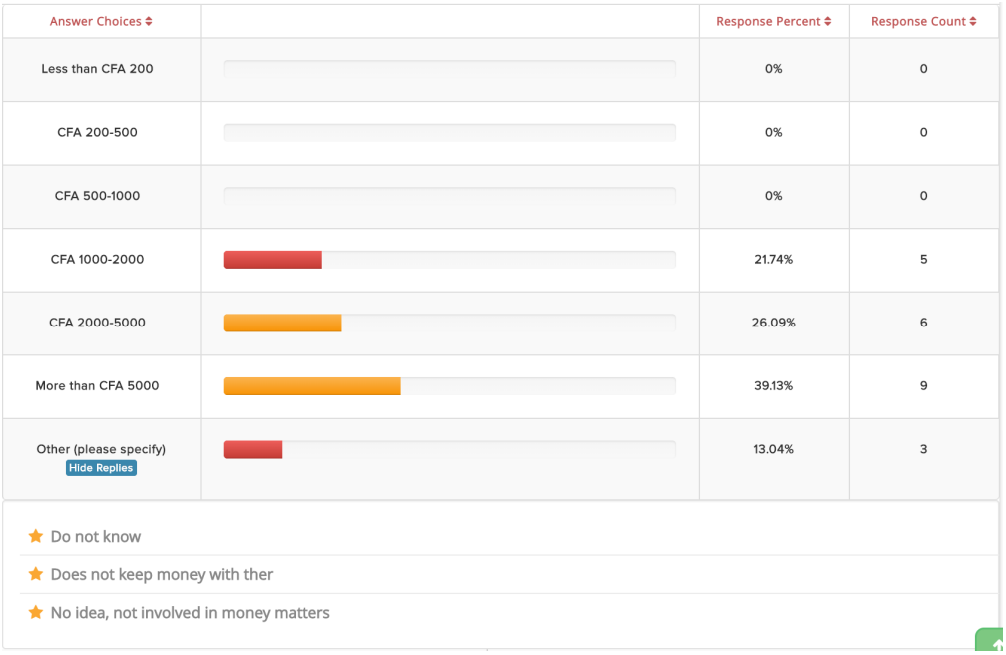

Fig. 6: Beneficiary Income from the Power Hub

The improvements required by the respondents from the Power Hub include:

1. Faster working and more powerful milling machines
2. Re-evaluation of the solar lantern rental; revenue stream is "slow and not beneficial"
3. Consider the use of a supplementary energy source for days when solar panels do not generate enough energy
4. Unstable and slow internet service (Wi-Fi)

Despite the suggested improvements, the respondents are requesting more milling machines, another Power Hub, and additional assistance for the men and women in the community. Improvements like a supplementary energy source and faster milling machines are currently being implemented.

5. Project Development

To achieve the original budgeted net revenues, reach profitability, and ensure long term sustainability, TSO is funding additional equipment:

- 5500 W Dehusker (projected to add between $350 to $600 per month in additional net revenues, which should bring the project to break even)
- 1500 W electric mill (10 x faster than the original mill)
- Soap press, soap cutter, soap packaging / labelling (which helps the Sougrinooma co-operative convert its shea commodity into higher margin, finished goods).

Overall, we view the Power Hub as a tremendous success, as it has achieved the major goals of local economic development, women's empowerment by inspiring entrepreneurial activities and launching new business, as well as reducing the workload on the women processing shea nuts. The quality of the butter they produced with this unique PV-powered system is high and we have demonstrated to our sponsors the ability to carry through important projects like this one.

Dozens of Sougrinooma women, 12 full and part-time Power Hub employees, and 6 contracting service provider firms, have directly benefitted from the Project so far. In addition, hundreds of Sougrinooma family members, clients, suppliers, and other villager stakeholders have benefitted indirectly from Power Hub activities. Perhaps most compelling, the Power Hub has become a community gathering point, especially for women. It has proven to provide a safe and supportive environment for women to learn from each other, socialize, share new ideas, and fulfill dreams.

Once the transfer of ownership is complete and the abovelisted equipment has been purchased and installed, TSO intends to re-engage its partners to consolidate the lessons learnt from this first installation and then to commence designs for launching the next version of the Power Hub in early 2020. The location has yet to be determined. Upon validation of Power Hub v2.0, TSO plans to replicate the solution, in partnership with others, across Burkina Faso and beyond. The future is bright for off-grid African communities, given the projected emergence of containerized solar generator solutions like the Power Hub.

6. References

Bensch, G., Grimm, M., Huppertz, M., Langbein, J., & Peters, J. (2018). Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso. Renewable and Sustainable Energy Reviews, 90, 1060-1068.

Elias, M. (2015). Gender, knowledge-sharing and management of shea (Vitellaria paradoxa) parklands in central-west Burkina Faso. Journal of Rural Studies, 38, 27-38.

Moner-Girona, M., Bódis, K., Huld, T., Kougias, I., & Szabó, S. (2016). Universal access to electricity in Burkina Faso: scaling-up renewable energy technologies. Environmental Research Letters, 11(8), 084010.

Rousseau, K., Gautier, D., & Wardell, D. A. (2015). Coping with the upheavals of globalization in the shea value chain: The maintenance and relevance of upstream shea nut supply chain organization in western Burkina Faso. World Development, 66, 413-427.

Yonas, G. A., Shimelis, E. A., & Sisay, A. F. (2016). Effect of processing factors on Shea (Vitellaria paradoxa) butter extraction. *LWT-Food Science and Technology,* 66, 172-178.