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"Use-Phase" Sustainability for Energy Development Projects

Completed by:

Jeff Jay
Will Kletter
Maite Madrazo
Josh Novacheck
Rory Pulvino

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Introduction

The goal of this project was to develop a model for “use-phase” sustainability of distributed energy resources in the developing world. Drawing from case-studies on related projects and our own field work installing a solar water-pump in Liberia, we derived valuable “best practices” related to ensuring the social, economic and environmental sustainability of distributed energy resources.

In recent years, the international community has shown great interest in increasing access to electricity throughout Africa using distributed energy systems such as solar panels. However, a wide-range of challenges have emerged, including a lack of funding post-installation, a dearth of technical knowledge required to maintain the system and even sabotage by parties who did not benefit from the system.

After taking best-practices and worst-case scenarios, we applied our findings to a project already underway involving a University of Michigan student group, Sustainability Without Borders (SWB), and the Liberian Agricultural Company (LAC), a large rubber plantation in Liberia. SWB and LAC had partnered together to construct a solar-powered water pump to deliver flowing water to a remote community located on LAC’s planation. The partnership hopes to bring the project to many more of its communities on the plantation. In addition to advising SWB and LAC on ensuring long term viability of the project, we educated a construction and maintenance team and created a student-run monitoring system to ensure ongoing sustainability. Armed with lessons learned from our fieldwork and case-study research, we have crafted a “how to” manual for “use-phase” sustainability.

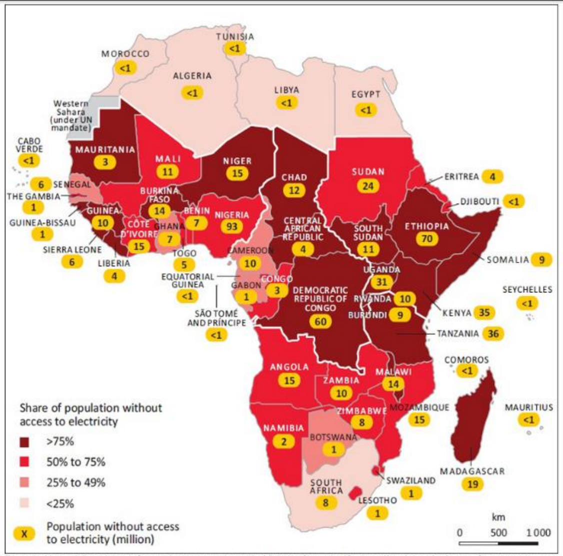
This paper breaks down the use-phase sustainability of energy development projects into three parts: environmental, social, and economic sustainability. Each section is intended to highlight key factors within that area that enable energy development projects to fully serve their communities. Additionally each section includes comments informed by our field experience of implementing an energy development project in Liberia.

Environmental

Overview of Electricity Access in sub-Saharan Africa

Access to electricity is increasingly recognized as an essential human right and a necessary component of meaningful global development. This is exemplified by the United Nation's Sustainable Energy for All initiative with its goal of achieving universal access to modern energy services by 2030. In launching the initiative, the Secretary General described sustainable energy as critical to efforts aimed at improving opportunities to work, learn and thrive economically.[1] The increased recognition of the need for increased electrification of developing countries can be seen in programs such as the International Renewable Energy Agency (IRENA), the African Development Bank's Sustainable Energy Fund for Africa (SEFA), and USAID's Power Africa initiative, as well as a growing number of non-governmental organizations focused on providing electricity access to developing countries.

Globally, nearly one in five people do not have access to electricity.[2] The lack of electricity access presents a continued obstacle for efforts to alleviate poverty, increase global health and promote sustainable development throughout the global south. The World Health Organization estimates that two million deaths each year can be attributed to the use of solid fuels for indoor cooking. [3] Electrification increases access to communication tools as well as enables better education through information access and the ability to study at night.



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Figure 1: Lack of Electricity Access in Africa (Source: IEA World Energy Outlook 2014)

In sub-Saharan Africa, the challenges posed by lack of access to electricity are especially acute (Figure 1). Thirteen percent of the world's population lives in sub-Saharan Africa and the region produces seven percent of the world's commercial energy, yet the region only accounts for four percent of the global energy demand.[4] Over forty percent of the regions energy demand comes from South Africa and Nigeria and two thirds of the total energy use is residential, mostly biomass for cooking.[5] Most importantly, over two-thirds or 620 million people in sub-Saharan Africa do not have access to electricity. The number without electricity access has increased by thirty million people since 2010 and is expected to continue to grow. Currently, the major energy source used to

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[1] United Nations, *Sustainable Energy for All*, Nov. 2011, http://www.se4all.org/wp-content/uploads/2013/09/SG_Sustainable_Energy_for_All_vision_final_clean.pdf.

[2] United Nations, *Sustainable Energy for All*, Nov. 2011, http://www.se4all.org/wp-content/uploads/2013/09/SG_Sustainable_Energy_for_All_vision_final_clean.pdf.

[3] World Health Organization, *The Energy Access Situation in Developing Countries*, Nov. 2009, http://www.who.int/indoorair/publications/energyaccesssituation/en/.

[4] International Renewable Energy Agency, *Africa's Renewable Future*, 2013, http://irena.org/DocumentDownloads/Publications/Africa_renewable_future.pdf.

[5] International Energy Agency, *Africa Energy Outlook*, Oct. 2014, http://www.worldenergyoutlook.org/africa/.

meet increasing demands in rural sub-Saharan Africa is diesel fuel generators. These generators are expensive to use as diesel fuel prices in many of African nations can be extremely volatile. Additionally, the generators produce significant pollution contributing to both local health problems and global climate change. However, in many places these generators are essential with no current viable alternatives.

By 2040, the International Energy Agency (IEA) estimates that $200 billion in investment will lead to 950 million people in sub-Saharan Africa gaining access to modern electricity services but 530 million will remain without access to electricity.[6] One of the biggest questions is how the increased demand for electricity will be met. The International Energy Agency estimates that seventy percent of the increased rural access will be accomplished by off-grid and mini-grid projects. Initiatives such as Sustainable Energy for All or Power Africa envision renewable energy systems meeting the demand for off-grid projects. However, the success of the systems will depend on a rapid increase in the technical knowledge and maintenance infrastructure throughout the region.

Needs and Concerns

In our case study, the diesel fuel generator served an important role in providing drinking water to the community. The Liberian Agricultural Company (LAC) owns an expansive rubber plantation, with about 14,000 ha of rubber trees; it is the second biggest rubber plantation in Liberia behind Firestone. LAC's land was originally acquired from local farmers and villagers through agreements with the government of Liberia. As part of the agreement to displace/relocate the locals and take ownership of the land, LAC must provide basic living requirements, such as shelter, food, and water. Though not yet required, LAC is preparing for new regulations requiring water to be accessible within or just outside of the home. To provide this service, wells will need to be outfitted with pumps.

There are three main options for pumping water: manual water pumps, a traditional diesel generator to power an electric pump, or solar panels to power an electric pump. LAC has begun the deployment of diesel-powered pumps in some of their camps. The initial capital investment for this system is cheaper than a solar powered system, but it also requires a constant supply of diesel fuel and significantly more maintenance. Additionally, diesel fuel is expensive and the price is very volatile in Liberia, making it difficult to budget these systems properly. While the solar powered system is a larger upfront investment, LAC understood it was ultimately a cheaper system when considering the entire life cycle costs. The challenge for LAC was the lack of knowledge surrounding these systems.

The obstacles that LAC identified in the installation of a solar-powered pump are identical to the challenges faced across sub-Saharan Africa. As the international community began to focus more intently on the need to provide electricity access to the region, NGOs and state sponsored initiatives began to provide funding for the installation of off-grid renewable energy systems. However, the funding was almost always limited to the purchase and installation of the systems. Throughout the region, renewable energy systems were installed but a severe lack of technical expertise needed for the

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[6] International Energy Agency, *Africa Energy Outlook*, Oct. 2014, http://www.worldenergyoutlook.org/africa/.

maintenance and repair of the systems remains. The lack of upkeep directly results in lower efficiencies for the systems and lower overall electricity provision. Without a more developed infrastructure capable of ensuring the productivity of these systems, companies such as LAC will continue to rely on the more expensive and polluting diesel fuel generators. IRENA envisions downstream energy-related services such as maintenance a major benefit of increased renewable energy deployment.

Social

Community dynamics

Understanding the organization of a community and the relationships within and without is critical in implementing sustainable development efforts and anticipating possible issues and concerns that may arise. Below we give a sample of critical questions to answer, identify critical areas for any project to consider, and use this outline to examine our own project. Of special note are the questions concerning the role of women in the community given the development potential when women are included in the decision making process.[7]

Sample Questions

- Who is the community that the project serves?
    - How many people are currently in the community?
    - How many people may be added to the community due to the intervention?
- Are there already community structures in place that would manage or interfere with project?
- How might the project impact the community's organization and productivity?
- What is the community's relationship with regional and national bodies that may interfere with project?
    - Is there an outside, unbiased third party that might be able to help manage disputes?
- Are there nearby support agencies that can be tapped?
- What are the needs of residents?
- What are the needs of women in the community?
- How are the needs of women/minorities in the community being considered?
- What is the role of women in the community?
- How important is this intervention to the community in relation to other needs?

Description of community

A complete description of the community allows for analysis of the community's needs and the potential impacts of a project. Such analysis then determines the tightness of fit between the project and the community's needs and potential. Accurate descriptions of a community helps with determining project scope, anticipating needs, and the potential for duplication or scaling up.[8]

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[7] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 61-66 ITDG Publishing (2003).

[8] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 56 ITDG Publishing (2003).

Figure 2 - LAC workers in the community (Source: Authors)

LAC is a large, foreign owned corporation which operates rubber plantations in Liberia. The plantations lands are owned by LAC having been acquired from local farmers and villagers through agreements with the government of Liberia in 1959. About 4,500 people work in some manner for LAC, but only 1,500 are actual employees of LAC, with the other 3,000 considered to be contract workers. The families of both LAC employees and contract workers live in camps of around 20 families within the plantation in permanent housing structures. LAC is required by the government to provide basic living requirements such as shelter, food, and water, to those living on the plantation. This government requirement includes access to water, yet the standard is fairly lax with hand pumps ranging from the center of camp to 1,500 yards away deemed sufficient. Though pumps rarely ran dry, collecting water generally consumes a substantial amount of the average African woman's time and energy.[9] By relieving some of the burden of collecting water for women we hope that they might have more time to invest in other productive activities improving the quality of community life.

Despite these anticipated benefits, this project did not evaluate community needs in determining what project to implement. An initial assessment was not completed because LAC requested the project from SWB in anticipation of a governmental push for its water provision mandate. Working under the assumption that LAC and the government identified water access as an essential community need, SWB went ahead with the project. However, a community needs assessment is planned for future work between LAC and SWB. Due to our group joining the SWB and LAC partnership midway, we were unable to emphasize the importance of such an assessment. Without an ex ante community needs assessment we are less able to anticipate the potential impact of the project given an incomplete baseline from which to compare.

The lack of community involvement in the project decision making process presents a moral hazard issue as there may be a lack of community buy-in when implementation is not linked with community needs.[10] Though the community's desire for the project is unclear, we can still predict how the implementation of the technology might alter community behavior by having a full description of the community organization. Furthermore, a complete community description takes on greater importance to ensure that the implementation of the technology falls along community dynamics and that a responsive, community sensitive system of governance is created to oversee the projects sustainability and success.

Community members often gathered water directly from nearby water sources such as rivers and creeks, leading to greater incidences of illness. While this project unfortunately does not provide reliably clean water, the community does have a more accessible source of water that they might more readily

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[9] "Public policies to ensure environmental sustainability," *Human Development Report 2003*, **UNDP** 123 - 124 (2003).

[10] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 89-93 ITDG Publishing (2003).

sanitize. Education and behavior change efforts are needed though to stress the importance of boiling drinking water to supplement this new technology. These education efforts should be tailored to the community's use of water and in anticipation of changes to their use of water given greater supply.

This community primarily used water for drinking, cooking, and washing. There is likely a limited amount of unmet need of water for these activities given that water was generally available before, but required more effort to acquire. With a greater supply of water then the community might begin to use the water in different ways than before. While many people bath directly in the nearby rivers and lagoons, a ready supply of water from a nearby tap may lead to community members bathing at home more frequently and likely reduce the frequency of illness from water borne parasites associated with bathing. How greater access to water may affect other community dynamics is less certain.

Figure 3 - Water spigot at the LAC facility (Source: Authors)

There are ample examples of the introduction of a localized water source significantly affecting the uses of water in the community and LAC should anticipate these changes.[11] Greater access to water might allow community members to engage in more water intensive activities such as growing household gardens or even bottling this water in reused bottles to sell to workers in camps without localized water systems. If the supply of water is greater than demand, then there might be substantial waste of the water, with community members leaving taps turned on and creating problems with flooding and standing water pools that might harbor mosquitos. LAC and the community must make sure that whatever the developments from increased access to water has community approval and to consider what might be done to mitigate any negative effects of increased water access. The current ownership structure of the project technology (LAC ownership) and the lack of land tenure or employment security for those living in the community raises a number of important and possibly troubling issues.

While the living conditions on the plantation are better than those found in other parts of Liberia, the workers on the plantation do not own the land or its resources. This divorce from land ownership decreases the community's incentives to properly care for the land.[12] Similarly, the community lacks ownership over the water system's materials and may not properly care for the system. LAC will need to monitor community care for the system and should increase community ownership of the project to ensure its proper care. Though LAC is required to provide basic living requirements, it is unclear whether residents have a right to demand the upkeep of this water system from LAC or whether the system are a benefit of willful employment. The limited reach of the technology may also create tensions between those that have access to the technology and those that do not. These potential conflicts may unfortunately parallel and add to already present contentions between LAC, employees, and contracted workers.

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[11] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 55-59 ITDG Publishing (2003).

[12] "Public policies to ensure environmental sustainability," *Human Development Report 2003*, **UNDP** 127 (2003).

LAC has two divisions of laborers: full employees and contract workers. Wage discrepancies between employees and contract workers have created a point of contention between LAC and the contract workers. Our team experienced this tension first-hand when presenting the technology; a community member used this public forum as an opportunity to air his protestations to LAC's employment practices. This employment situation creates a number of issues that should be resolved in order to avoid exploitation and the potential for conflict.

Hierarchy of community

The hierarchy of the community will determine who is responsible for the implementation and maintenance of projects. Without knowledge of who is responsible for what in a community, difficulties with project sustainability will arise as issues concerning project upkeep and development arise. Having clearly delineated roles and responsibilities for certain community members will ensure that as issues arise, the community as a whole knows who to hold responsible. This also requires that those responsible for certain aspects of a project have the skills and/or resources to deal with problems.[13]

However, having a grasp of community hierarchy and assigning responsibility is not enough to ensure sustainability. Rather, any assignment of responsibility must fit within cultural norms so as to ensure that the community feels comfortable with the structure and its enforcement. An assignment of responsibility means little if those the project is supposed to serve do not feel comfortable or are unable to enforce responsibility due to cultural norms.

To start, a camp superintendent is responsible for what takes place in the community. The camp superintendent generally maintains the area surrounding the camp, oversees the rubber growth and harvesting, and manages the human resources of the camp. The camp superintendent typically is responsible for multiple camps and lives in one of these camps. This is the highest position that a local Liberian can ascribe to as of now and may create a disconnect between the community and the higher levels of LAC leadership who are determining community conditions. Given the proximity the superintendent has to the community and her/his cultural ties to community members, protection of community members and this solar water project will most likely lie with the camp superintendent.

Above the camp superintendent are the plantation managers who are currently all foreigners. These plantation managers ensure that everyone on the plantation is doing his/her job and can be approached by individual workers as to any issues. Given the broader oversight mandate of the plantation managers, we expect them to help resolve any disputes arising between the camp receiving this technology and those camps not receiving this technology. Finally, the general manager oversees the plantations and is generally responsible for plantation productivity. Both the plantation manager and general manager live in larger homes closer to the on-site rubber factor and plantation central offices.

This organizational structure has been in place for a long time and the communities living on the planation are accustomed to dispute resolution through this chain. Community members then have a

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[13] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 97-98 ITDG Publishing (2003).

well-known structure through which they may bring complaints arising from inside the community or with outside communities. Challenges arise though if the community's complaint involves LAC control itself. The advantages of being an employee versus a contract worker create a conflict of interest for community members to bring complaints about LAC ownership and upkeep of the system to any third-party. A history of political instability and a lack of government responsiveness have also significantly dented the probability that an objective outside third-party might intervene in any disputes between LAC and community members. LAC should look to involve local NGOs that focus on community participatory methods or the local Liberian government in dispute resolution. Creating a system whereby community members are able to hold LAC accountable based on its technical ownership of the resource should be prioritized to ensure the project's sustainability. Risks of inadequate project maintenance can be at least partially mitigated through other power structures within the community.

Other than the regular chains of authority there are also construction, electrical, security, and equipment repair teams. Other than the security team, these teams are led by foreigners in the LAC project. Construction, electrical, and equipment repair teams are responsible for constructing new facilities to both serve the workers and the company as well as the upkeep of these facilities. These teams are more likely to be responsive to community demands because (1) of their proximity to the community and (2) that the team itself is made up of community members that benefit from the project and face internal pressures within the community. These teams provide a ready source of expertise in the repair and maintenance of the system. Diversifying knowledge of the technology of the project to those working on these teams can help to ensure that the project has a sustainable base of knowledge even if a single individual leaves the community. Our project incorporated education efforts to help with knowledge diffusion in the community.[14]

How we get community buy-in

As identified from a number of similar case studies,[15] community buy-in is essential to the long-term sustainability of any community solar project. Key problems identified in the research include: failure to appropriately set expectations for system performance, failure to engage community in ongoing operation of the system, and failure to fully understand local needs prior to system choice. For the implementation of the LAC system, the community needs were well identified prior to the installation and thus were not dealt with during the Dow Fellows engagement. However, the first two points represented areas of concern.

Figure 4 - Community engagement and education (Source: Authors)

During the site visit, it was deemed critical to appropriately set expectations for system performance. A rigorous education system was deployed to ensure appropriate understanding of the potential of the system and the resulting benefits to the

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[14] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 102-04 ITDG Publishing (2003).

[15] [15] *see* Schouten, Ton & Patrick Moriarty, *Community water, community management*, ITDG Publishing (2003).

community. After surveying the local community for appropriate influence points, it was determined that participation in regular community meetings would serve as the appropriate venue for disseminating this information. The meeting was also attended by the plantation's General Manager and other LAC management to underscore their commitment to the project. The primary point emphasized was water conservation, as the system was sized only to meet basic needs. This item also addressed a concern on the part of LAC that previous introductions of new technologies have resulted in significant waste.

Efforts were also taken to engage the community in the ongoing maintenance of the system. Specifically, a local high school graduate was trained in how to monitor system performance. This monitoring took the form of quantitative data-monitoring on power from panels and the speed of the pump, as well as qualitative interviews with community members to ensure satisfaction with the system. Communication protocols were established to relay this information back to the project sponsors in the United States so that necessary adjustments could be made.

Women & minority involvement

A key element in informing the "buy-in" strategies above were focus groups held with local women. Given the importance of engaging women in development efforts, it was deemed critical that they become active participants in the introduction of this new system. Their input was critical in guiding the implementation strategies described above.

Ownership and engagement

Projects need to enable the community's they aim to serve to adapt the system to community needs. This begins with engaging the community in the development of the project and creating structures in the community that are able to respond to issues with the project and to alter the project as the community itself changes. Community focus groups, community ownership and project oversight committees are proven ways to ensure the sustainability of projects by giving communities the tools to control projects.

Our project worked with LAC, the owner of the technology property as well as the community property, to design a community structure to oversee the project. By training a variety of individuals within the community over the project technology and its maintenance there are community members with an interest in the sustained success of the project. These individuals also face pressure from the community and LAC leadership for the system's upkeep. The smallness of the community and open relations between the community and LAC leadership should promote community engagement in the maintenance of the system.

LAC ownership of the actual system requires that community members feel comfortable

Issues and concerns given community dynamics:

- Given that LAC owns the land and the newly installed water system, there is concern that contract workers who receive less compensation and have less certain positions may have even less leverage in bargaining with LAC to ensure that it carries through on obligations to provide basic living requirements.

- LAC's ownership of the materials removes responsibility of its maintenance from the exact people who are using the system, the community. This may create issues of moral hazard as community members abuse/overuse the system since they do not face the full costs of its maintenance.
- Having a consistent and close source of water may alter the desirability of the camp and may possibly draw others from outside to the camp. How are these possible new individuals to be included in the system?
- Given a closer and more sustainable source of water how might those using the water alter their water use or the use of their time, i.e. might they use water in more commercially focused endeavors or engage in more commercial ventures as they save time from drawing water?
- Those who were previously responsible for retrieving water (women and children) will now have more free time. How will this free time be used?
- Without an initial community needs assessment and an understanding of the baseline of the community, measuring the impact of the technology implementation becomes more difficult.

Economic

In order for renewable energy systems to be truly sustainable, it is essential that they are economically viable. While certain places have government incentives or organizational support, this is not something that can be sustained in the long term, especially not in developing countries like Liberia. For these types of projects to truly take off and work, they need to be well thought out and implemented, and have a positive NPV. While feasibility has to be assessed on a per-project basis, there are certain things to consider in every case.

- What are the economics of the alternatives? (e.g. diesel)
- What are the benefits to the owner? (LAC)
- What are the benefits to the community?
- What are the possible costs of implementation of the project?
    - Are there potential changes to the community that may impose costs on the community or those outside the community?
    - Are incentives properly aligned for the upkeep and maintenance of the project?
    - What are possible costs due to LAC's ownership of the project?
- What are complementary services or systems that might increase the value of the project?
- What are potential business models that might make the project more attractive?

In the following section we will illustrate some of these points for the LAC solar water pump project and then explore new options to increase the value of these types of projects for the company and the community.

Economics of alternatives

In understanding what the best alternative is for an energy project, it's important to consider the economics of the closest alternative. In the case of water pumps in Africa, the closest alternative to a solar water pump is a diesel powered pump or the current manual pumps they use.

Diesel powered pumps consist of a diesel generator connected to a water pump, whereas solar water pumps consist of PV solar panels and an inverter connected to a water pump. The main difference, therefore, is the generation system.

While diesel powered generators present a lower up-front cost than PV panels, the lifetime cost is much greater because they require the constant purchase of diesel. Not only is diesel expensive, but the added costs of having to procure it is very high in places like Liberia, where the country's infrastructure was destroyed during 14 years of civil war. Overall, the cost of implementing a solar water pump system is a better investment over the project's lifetime.

Figure 5 - Installed Solar PV at LAC facility (Source: Authors)

With regards to manual water pumps, which were previously used at the LAC plantation to procure water, these are very time intensive and present a high opportunity cost for community members who could be harvesting rubber, completing other household chores, and educating themselves or their children. These pumps are cheap in terms of equipment, but are an inefficient use of time for the community and therefore create higher costs for the overall project.

Depending on location and geographical characteristics of different project sites, other alternatives like small wind turbines, run-of-river hydroelectric systems, or biofuel generators could also be considered.

Benefits to the Owner

LAC determined the solar-powered water pump was a wise investment in part due to impending government demands to increase ease of water access. However, we believe that even if that regulation were to change, this project is still worth the investment given the many benefits it presents to the owners. Some of the benefits include:

- Cost savings: as mentioned above, essentially no inputs are required to operate a solar water pump, which creates continued cost savings for the owner of the system in comparison to a diesel powered system or no pumping system at all.
- Better water management: solar water pumps, along with above ground water storage and a rainwater collection system allow the managers of the plantation to have much better water management. The previous system required water to be pumped manually and then carried back to the buildings where it was needed, which constantly resulted in water being spilled and wasted. Water reservoirs allow managers to better understand how much water is being used and for what, allowing them to also identify if water were wasted on a particular part of the plantation process. Therefore, having the proper pumping and storage systems will greatly increase the ability to properly manage the water resources available to LAC.
- Increased productivity: by installing these systems, the plantation will be more efficient and therefore more productive than before. Water will be better managed and community members will have more time available to perform other jobs instead of fetching water. This increased productivity could be further enhanced if better services were provided to the plantation workers who would in turn be happier with their jobs. We will touch on this further later in the paper.
- Easy maintenance: solar water pump systems have very few moving parts, which therefore makes the system easy to maintain and simple to operate.

Benefits to the Community

In the same manner, these projects can bring many benefits to the Cattle Barn Camp community. Some of these benefits include:

- Easier access to water: community members will benefit from having easier access to water as it will give them more time to perform other activities. Not only would they be more productive at work, but it can make their household work easier and therefore allow them to have more time to rest and spend time with their family.

- Easier irrigation process: by having water in an accessible place, the laborious task of irrigation will become easier.
- Reduction in illnesses: easier water collection leads to higher levels of hygiene both in the plantation and in the household, therefore families will suffer from fewer illnesses throughout the year.
- Possibility of obtaining more technical training: for a few members of the Cattle Barn Camp community, there is a possibility to be trained to be the technicians responsible for maintaining the systems. This allows them to further their knowledge, get better jobs within the plantation and possibly improve their quality of life.

Costs to consider

The implementation of new technologies into developing communities can have unanticipated costs as the community adjusts to the increased capacity brought about by the technology. Implementation of development projects should forecast possible changes to the community's organization and production, to changes in incentives for those inside and outside the community, and moral hazard considerations arising from the community organization and project ownership.

a. Community changes

While implementing a readily available water source within the community has a multitude of benefits, these benefits will create incentives for demographic and behavioral changes that should be considered to ensure that these developments do not inhibit future growth. Our project has a unique structure given that LAC owns the land on which the users of the technology live and attempt to control the migration of people within the plantation, although not always successful. Despite this control though, LAC must consider how this ready access to water for this community might impact the behavior of those within this camp as well as those outside the camp.

Ready access to water will likely increase the productivity of this camp through reductions in susceptibility to common illnesses such as diarrhea and dehydration and other benefits mentioned above. This increased productivity may lead the community to become more desirous for those outside the camp and thus increase pressure on LAC to allow others to move into the camp or to install such systems in other camps.[16] This may be a very serious cost in increased tension between community members that may be exacerbated by changes in production within the community receiving the technology. As mentioned above, with greater access to water the community may begin to exchange in the production of other goods such as household gardens or bottling water in reused bottles for sale to camps without such a ready source of water.[17] This increased productivity may displace farmers and those supplying water both inside and outside this community.

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[16] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 74-76 ITDG Publishing (2003).

[17] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 73 ITDG Publishing (2003).

Regardless of whether implementation of this technology results directly in changes to and increases in productive output, the technology will give those in the community previously responsible for collecting water with more time. How that time is put to use will determine much of the lasting impact of this project. Surveying how much time camps without the technology spend on water collection compared to those with the technology would give a good estimate of the time saving. This survey then can inform LAC as to the possible necessity of supplying other productive opportunities for those with more time.

b. Ownership

Ownership over this project gives LAC power in bargaining with those inside this camp and other camps that may desire this technology. Monopoly power over this project may allow LAC to draw concessions from camps and generally create distortions in the bargaining between LAC and those that work for the company. There are already contentious relations regarding the treatment of LAC employees versus contract workers. Employees currently enjoy much better working conditions and terms than contract workers. With control over this technology LAC may use this position to the disadvantage of contract workers. Moving ownership of the project to those within the camp would help to mitigate this possible distortion as well as to help address the possible moral hazard issues from LAC ownership.

LAC ownership distances those that benefit from the system from its upkeep and maintenance. Under the current ownership regime community members have little incentive to not overly draw on the system and can only be expected to not dismantle the system for personal gain as so far as there is a monitoring/security system in place to prevent theft.[18] With a ready source of nearby water that the community has been using prior to the system's installation, the community also has little incentive to not waste the resource.[19] Open taps may be a common occurrence with little incentive for community members to properly manage the resource. Though the small size of the project makes non-approved adjustments to the system unlikely and readily removable, the removal of parts in theft may be hard to monitor and prevent. This in part depends on cultural norms surrounding equitable distribution of resources between working camps and whether the parts of the system might garner higher valued uses elsewhere.

LAC might experiment with different ownership models to comply best with cultural and community values and needs. Integrating ownership of the system with those that use the system will likely help ensure the sustainability of the system and help to gauge the community's interest in the project.[20] Community ownership will also lower monitoring and maintenance costs for LAC. There are several different business models that can align with different ownership structures. The following models have proved successful with different types of solar projects in the past.

Potential business models

In order to ensure the economic sustainability of the project, LAC can consider different business models with which to finance and manage the systems. It is crucial that each project uses the best option given

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[18] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 107-108 ITDG Publishing (2003).

[19] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 109 ITDG Publishing (2003).

[20] Schouten, Ton & Patrick Moriarty, *Community water, community management*, 89-93 ITDG Publishing (2003).

its community dynamics, project objective and other specifications. Some of the business models that can be considered for different projects include:

a. Pay as you go or “Solar as a Service”

Solar as a service is a model that is currently used by most companies who provide electricity generated from PV solar panels. In its simplest form, the provider installs solar panel systems but does not charge the customer for the system, as it is fully owned by the provider. It charges the customer for the electricity used, in the same way a utility would charge for the electricity used from the grid. This allows customers to use electricity generated by the systems but not have to incur the high up-front cost. In a similar manner, LAC could decide to retain full ownership of the solar water pump system, use the water it needs for the plantation, but then also provide water to the houses of its workers (including contract workers). They could then charge a constant fee per liter of water consumed.

Advantages: would help to dis-incentivize the wasteful use of water and would make the system more profitable for LAC.
Disadvantages: could require the installation of metering systems in each house and could eliminate some of the benefits to the community by charging for something they might not be able to afford.

b. Community ownership (with financing)

The new water collection systems could be owned by all members of the community. This ownership would give them access to the water resources they need and also make them value the systems more. The details on how ownership would be divided and what that would entail would have to be designed for each different project. Given the high up-front cost of these systems, having cull community ownership would likely require LAC to provide financing which can be paid off by owners along several years of working in the plantation.

Advantages: vandalism could be avoided and safety ensured by having all owners invested in the proper functioning and constant maintenance of the system.
Disadvantages: could be complex to manage and to obtain buy-in from the majority of the community and LAC would have to determine how they can have access to more water resources for the operations of the plantation.

c. Leasing or “Rent to Own”

This business model is akin to car leasing or renting-to-own. Users in the community pay for the amount of water used throughout the month, but also pay a small additional amount to start “buying into” the system. After several payments they could then become owners of part of the system. This model is like a hybrid of the two mentioned above and presents most of the same advantages and disadvantages.

The decision on what type of business model to use will highly depend on the community dynamics, company ownership policies and the willingness of LAC to lose control over the system.

Potential complementary projects

In addition to the many benefits that this project can bring to LAC and the Cattle Barn Camp community, it opens the possibility to expand into other types of complementary projects and services that solar powered systems can provide. Additional solar panels could provide electrification for the plantation and the community, extending the productive hours of the day and improving quality of life in the household. This also opens the possibility of introducing charging outlets for those who have mobile phones, which could be implemented as a pay-as-you-go system as well. This type of service provision could become an additional profit generator for LAC and increase connectivity for its workers.

Thinking further about potential complements, this additional electrification can help to access internet services by installing the necessary equipment. This could then also help increase the plantation's productivity by being able to access operations optimization software, increasing communication with the supply chain, and allowing more connectivity for its employees. It would be important to consider that if a fully PV powered system is installed, battery banks would be necessary to be able to provide electricity without as much intermittency. Another option would be to install a hybrid system where both batteries and an emergency backup diesel generator can help smooth out the supply and demand curves for electricity and water throughout the day.

Conclusions

Long-term use-phase sustainability of community renewable energy systems is a critical component of the continuing electrification of sub-Saharan Africa. Successful incorporation of social, economic and environmental concerns will increase the viability of renewable systems as well as enhance community ownership and autonomy. While it is impossible to create a standard manual for successful project implementation, the same themes remain important and each successful project can act as a case study to provide guidelines for future projects. To be successful, each project needs to be tailored to specific characteristics including community dynamics, cultural differences, geographic location, resource availability, ownership structures and political environment. Through our research and on-the-ground experience, we were able to determine several key factors that can help ensure the environmental, social and economic sustainability of a project.

Ensuring use-phase sustainability of renewable energy projects demands that project implementers have a thorough understanding of community dynamics to ascertain system capacity and needs, create community buy-in for proper maintenance and account for the economic viability of the system considering the costs of alternatives and future community changes. If installed with little or no involvement from the community, a lack of ownership can lead to a distancing of community members from the responsibility of upkeep and maintenance. A system may also fundamentally alter the use of a resource or shift community dynamics in ways that strain or break the system. While many NGOs and international governmental initiatives are willing to provide the funding for these systems, each project will have its own unique costs and impact to be measured and weighed that inform system roll-out and development.

We have attempted to demonstrate the viability of a use-phase sustainability implementation program and have detailed the issues that should be considered in any future projects. The need for a focus on use-phase sustainability is clear and our hope is that others will use this project to continue the focus on the long-term viability of community renewable energy projects.

Acknowledgements

We would like to thank Sustainability Without Borders and the Liberian Agricultural Company for allowing us to partner with them on their joint effort to install solar-powered water pumps in the remote communities on LAC’s plantation. We hope the research completed here and the recommendations given can be used to increase the probability of long-term sustainability of the projects.

Appendix A – Manual for LAC's Use

Cattle Barn Solar Water Pump
Maintenance and Monitoring Manual
Updated: September 2nd, 2014
Prepared by: Josh Novacheck

Document Notes

Liberians frequently use the word "current" when referring to what American engineers call "electricity," a form of energy that travels in a conductor via the movement of electrons. "Current" for American engineers is a measure of the change in charge over a time, with the unit of Amps. This document will use "electricity" when referring to energy, and "current" when discussing the measure of the change in charge over a time.

Safety Note

The power produced by the solar panels and the power used by the pump is all Direct Current (DC), as opposed to the more common Alternating Current (AC). Both types of current are dangerous. The more important safety concern is the high DC current the solar panels operate at. The current from the solar panels can range between 0 – 10 Amps. Even a short exposure time to this current can be fatal. Whenever working with this system avoid touching exposed copper wire, and turn off the controller box before doing any electrical work.

System Design and Technical Specs

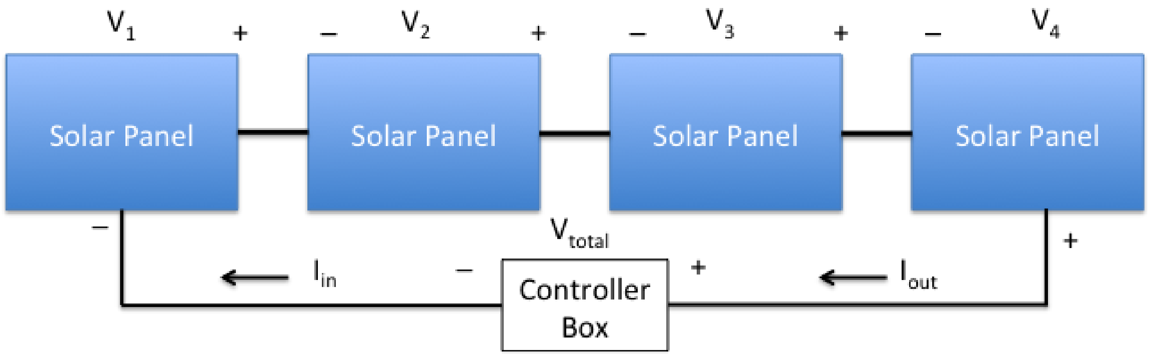
Solar Panel Array:

The purpose of the solar panels is to capture the energy from the sun and convert the energy into electricity. The solar panel array consists of 4 panels connected in series. Their basic specs are listed below:

Peak Power Rating: 265 Watts
V_{oc}: ~38V (Open circuit voltage)
I_{sc}: ~10A (Short circuit current)

These specs may be important when discussing panels with a manufacturer for troubleshooting/repair purposes.

The array is connected in series. In other words, the positive from one panel is connected to the negative of the next panel. Figure 1, shows a diagram of the connections. Both cables for the panels are colored black, so to find which end is the positive and negative look at the black plastic connector at the end of each cable (MC-4 connector). Each connection will have either a – (negative) or a + (positive) symbol. The voltage across the entire array will range between 130-140 Volts (depending on the solar intensity) when no load is attached to the array.



$$V_{total} = V_1 + V_2 + V_3 + V_4 \quad \text{(Voltage)}$$

$$I_{in} = I_{out} \quad \text{(Current)}$$

Figure 1. Solar Panel Array Diagram

The array is connected to the controller box. The positive end of the array is connected to positive terminal on the controller box, and the negative side of the array is connected to the negative terminal on the controller box. Ignore the MC-4 connector symbols on the cable that connects to the controller box. The cable that attaches to the positive terminal of the cable is colored red, and the cable that attaches to the negative terminal of the controller is colored black.

Figure 2. Two MC-4 connectors

Controller Box:

The controller box has a variety of functions. Its primary purpose is to convert the power coming from the solar panels into a form that can be used by the pump. Both the voltage and the current from the solar panels change depending on the solar conditions. The pump however, requires a constant voltage. The controller takes the input from the solar panels, and outputs the power to have a constant voltage. The output current is allowed to change as the power from the panels changes (because Power =

Voltage x Current). The controller also monitors the system and connects to the float switches in the water tank and the well.

The connections into the controller are shown in the pictures in Figure 3. In the upper right-hand side of the controller is the on/off toggle switch. For the toggle switch to work the controller box must be connected to the solar panels and the panels must be producing power. When the switch is on, the controller will start the pump if there is enough power, the reservoir is not full, and the well is not dry. When the toggle is off, the controller will not run the pump. **If work on the system is required always switch the toggle to the off position before proceeding with the work.**

In the lower left-hand corner are the two terminals for connection to the solar array. The red wire connecting to the positive end of the solar panels should be connected to the positive terminal in the controller. The black wire should be connected to the negative terminal. If electrical work on the solar panel array must be done, the wires should be disconnected from the terminals. First ensure the toggle switch of the controller is in the off position. Disconnect the wires by first disconnecting the red wire from the positive terminal and then the black wire from the negative terminal. **Never allow the two wires to touch!** This will cause the solar panel array to short circuit, potentially causing damage to the equipment. Also there is a risk of electrocution of whoever is touching the wires.

Figure 3. Controller Box

There are four wires that connect the pump to the controller. These wires connect to the lower right hand corner of the controller. The wires should be connected to the terminals according to color. The black wire connects to the terminal labeled “black”, the red wire connects to the terminal labeled “red”, and the yellow wire connects to the terminal labeled “yellow”. The green wire connects to the ground chassis to the left and below the other three pump terminals.

The other connections into the controller are for the two float switches. Both float switches connect to the GND and the RS terminals in the upper left-hand corner of the controller box. The black wire for both float switches connects to the GND terminal, while the colored wire (either brown or blue) connects to the RS terminal.

At the bottom of the control box is the ground chassis. A ground wire connects the panel frames to the chassis, and another wire connects the chassis to the grounding rod (6 foot copper rod) that is pounded into the ground near the base of the solar panel mounting structure. The grounding set up provides a path for high current to safely pass into the ground. This protects the system from damage due to lightning strikes, and electrocuting anyone who touches the equipment.

The dipswitches, which are located just to the left of the on/off toggle switch, control operation as well. A close up of the dipswitches and there positions when the system was installed are shown in figure 4. Switches 1 and 2 should always be in the down position, they control the logic of float switches in the reservoir and the well respectively. Switches 3 and 4 control how long the pump should delay before beginning to pump again after one of the float switches turns off (reservoir is no longer full or well is no longer low). The reason for a time delay is to ensure the pump will stay on for a period before filling the reservoir or drying the well again. The time delay will decrease on/off oscillations of the pump, which can damage the pump over time. Currently the 30-minute delay (switch 4) is on. These switches can be changed as desired. Switches 5, 6, and 8 are not used and their position does not mater. Switch 7 controls the display screen on the control box. In the up position the screen will continuously display the screen it was displaying when the switches was turned up. When the switch is down the screens will rotate between 5 different screens. The screens are explained in the “Monitoring System Performance” section later in the document.

Figure 4. Dipswitch position after installation of system

Float Switches:
There are two float switches incorporated in the system. One float switch is located in the reservoir and the other in the well. The float switch in the reservoir is a regular float switch and is used to ensure that the pump does not continue to pump once the reservoir is full, and therefore not waste water. When the water in the reservoir is high enough the float switch floats on the surface of the water. As the water rises, a small ball within the float switch will press into the float switch, completing a circuit and signaling the control box to turn the pump off. As water is drawn from the reservoir and the water level falls, the float switch will also fall and the ball will eventually fall away and open the circuit again. This will send a signal to the controller to turn the pump on again (with a potential delay depending on the dipswitch positions described earlier).

The switch in the well works in a similar fashion, but is smaller and does not actually float. The switch in the well is used to ensure the well does not go dry while the pump is on, avoiding potential damage to the pump. The switch is fixed just above the pump and senses whether or not it is submerged in water. When the water level drops below the switch, the switch sends a signal to the control box to shut off the pump. Once submerged again the float switches signals the control box it can turn on the pump.

Monitoring System Performance

The simplest method to monitor the solar panel array's performance is to record the power produced by the panels versus the speed of the pump and the water level in the reservoir. There is a linear relationship between the power and the speed of the pump. To ensure the system is operating properly, periodic measurements should be taken and compared to historical values. Kumei Allenton has been trained on how to properly record these values. It is recommended that the measurements be taken once weekly, for about 10 minutes. Measurements should be taken no mater the weather conditions (cloudy, partly cloudy, clear skies). The water level should also be monitored to ensure that water is not being wasted and the pump is providing enough water for the community. Communicating with the community will be vital to ensure they understand the system and are getting enough water for their needs. Finally there are various indicators of how the system is working on the controller box, including the display screen and LED lights, which are described in this section.

To take the power and pump speed measurements, it is necessary to open the control box and read the data from the display screen at the top of the box. The screen cycles through five different screens (staying on one screen for 5-10 seconds). The different screens are shown in figure 5. The speed of the pump is found on screen 3 in figure 5. The number that should be recorded is the number to the right of "RPM". The power from the array is displayed on screen 5, and is directly below "Power". When recording the pump speed and array power it is important to record the power that directly follows the pump speed as the screens change.

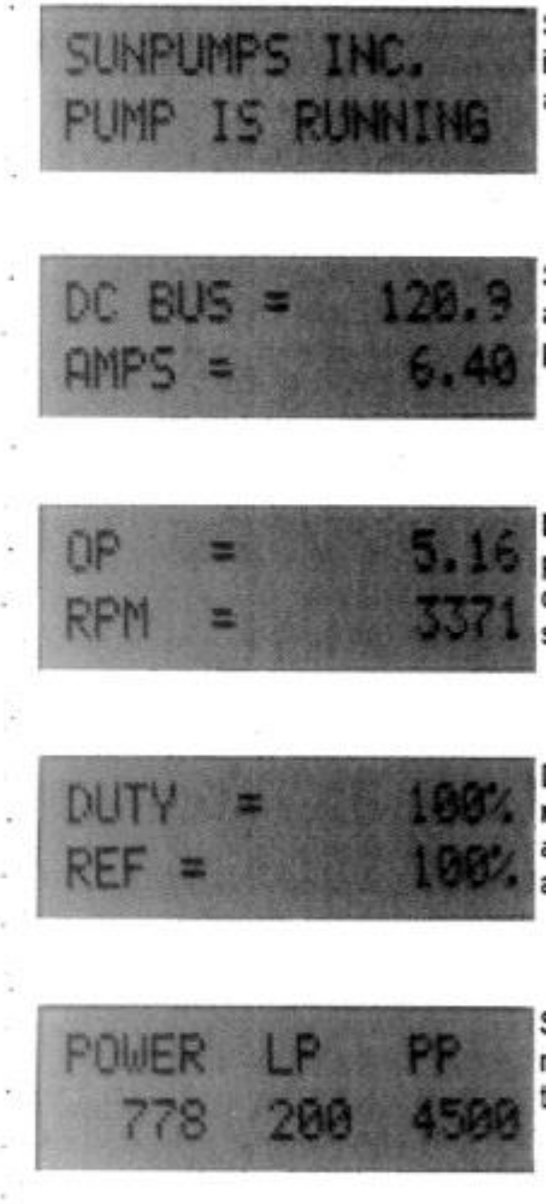
Display Screen:
The other screens also provide helpful information about the system performance. The first screen gives simple statements, such as, "Pump is on" and "Pump is off". If the statement is contrary to what is actually happening, then the different components of the system should be checked to ensure they are operating properly.

The second screen shows the array voltage and current. "DC Bus" is the voltage across the array and "Amps" is the current running through the wire. Multiplying these values will equal the power being produced by the solar panel array at that time. The power produced by the solar panels will change throughout the day and will depend on how direct the sun is and how clear the sky is. The current is more sensitive relatively to the changing solar conditions, ranging between 0 – 10 amps. The voltage is less sensitive and will generally range between 100 – 130 volts. When the pump is not running, the current will display zero, while the voltage will read a non-zero number depending on how clear the sky is.

Along with the "RPM" (speed of the pump), the third screen also displays the "OP", or operating parameter. This value does not have a physical meaning, but if there is a problem with the system and the manufacturer needs to be contacted, then they will likely want to know what the value is to assist with troubleshooting. The RPM value will cover a wide range of values and will depend on if the pump is running and the power provided to the pump.

The forth screen shows how close to full output the pump is working. "Duty" means at what fraction of full output the pump is running depending on the power from the solar panels. The number next to "Ref" refers to the maximum output allowed for the pump to operate, with a maximum of 100%. There should be no reason at this point to change this value.

The fifth screen shows the power the panels are providing the pump and the low power and peak power (max power) settings. "LP" refers to the low power setting and can be adjusted with the knob in the upper left-hand corner of the control box labeled "LP Adj". "PP" refers to the peak power setting and can also be adjusted using a small screwdriver to tighten or untightened a screw next to the low power adjustment knob. The screw adjustment is labeled “Peak Power Adjust”. There is no reason at this point to change the peak power. The low power determines at what minimum power the pump will turn on. A low setting for the low power means the pump will be on even in low sun periods, but will only pump a small amount of water. The advantage to operating with a low setting is the pump is able to operate even when the solar conditions are poor (very cloudy). A higher setting for the low power means the pump will only operate under good solar conditions and the pump will only operate at a large flow rate. The advantage to a high setting is the pump will be less likely to frequently oscillate on and off causing potential damage to the pump over time. However, oscillating will still occur. In the rainy season it is recommend to have the low power setting at a lower value (around 100 W). In the dry season, when it is more likely that there will be constant high quality solar conditions, this setting could be increased to decrease oscillations, but is not necessary.



```
SUNPUMPS INC.
PUMP IS RUNNING

DC BUS =   120.9
AMPS =      6.40

QP    =     5.16
RPM   =     3371

DUTY  =     100%
REF =       100%

POWER  LP   PP
  778  200  4500
```

Figure 5. The five screens the display screen on the controller box will cycle through.

LED Lights:
The LED lights on the central right-hand side of the controller box also provide insight into the performance of the system. There are seven different lights, indicating different operating states of the system. Figure 6 shows each of the lights.

The first light at the top is labeled “Power In”. This simply means that the solar panel array is connected to the controller box and providing power. Neither the pump nor the toggle on/off switch needs to be on for this light to be on. This light is colored blue.

The second light from the top is labeled “Run” and indicates the pump is running. This light is colored green. When this light is on, both float switches should be inactive (water tank not full and well not dry) and the solar panels should be providing more power than the low power cutoff (which is adjustable). This will turn on immediately when the pump turns on and will stay on until the pump turns off.

The third light from the top is labeled “MPPT” and is also colored green. MPPT stands for Maximum Power Point Tracking. This light will turn on shortly after the “Run” light turns on. It indicates the pump has started up completely and the controller is adjusting the current from the panels to maximize the power produced by the solar panels, known as Maximum Power Point Tracking. If this light does not turn on after the pump has been running for a time, take the measurements described above and check to see if the system is operating as expected.

The forth light from the top is labeled “RS Stop” and is colored orange. “RS” stands for remote switch and refers to the two float switches. This light will turn on when either of the two float switches is active (either the reservoir is full or the well is dry). When this light is on, the pump will be turned off so that pumping stops. If the reservoir is full or the well is dry, but the pump is still operating, check to see if this light is on. If it is not then check the connection and wiring to the two float switches.

The fifth light from the top is labeled “Low Power” and is also colored orange. When this light is on it means the maximum power that can be produced by the panels at that particular time is below the low power setting. When this light is on, the pump will not run. If the pump is not filling the reservoir fast enough, check to see if this light is on frequently. If it is, decrease low power setting by adjusting “LP Adj” knob as described earlier.

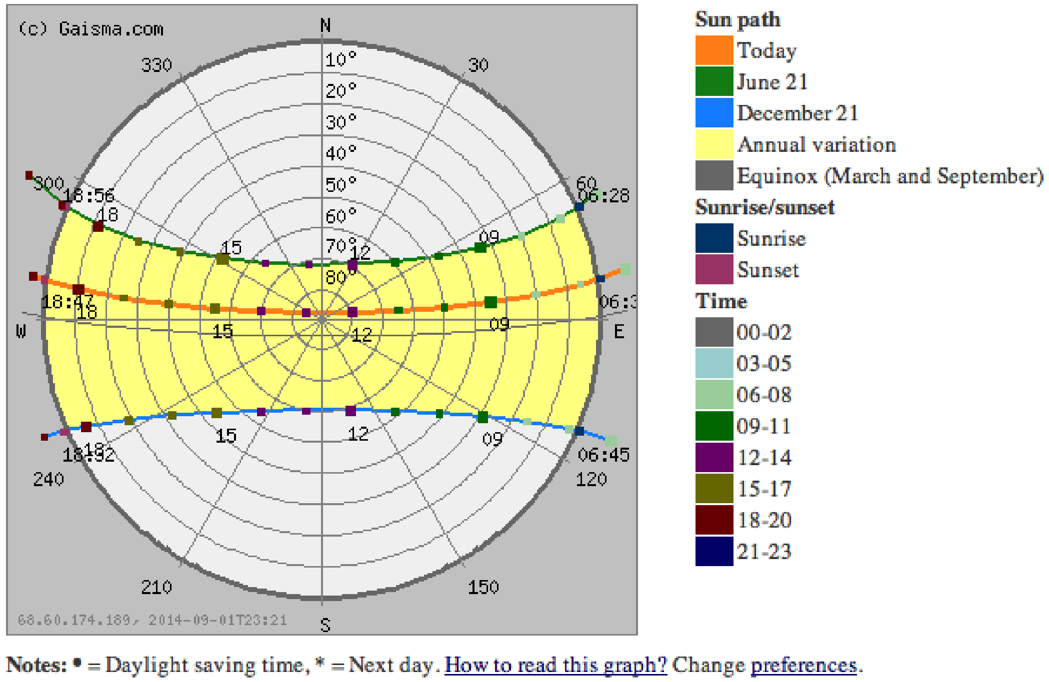
The sixth light from the bottom is labeled “Over Current” and is colored orange. When this light is on, it generally means the panels are not connected together properly and the control box is receiving too high of a current. When this light is on check the solar panel connections and ensure they are connected in series (as shown in figure 1).

The bottom light is labeled “Fault Condition” and is colored red. This most likely means that the wires of the system are not connected correctly. Turn the toggle on/of switch off and check all of the wiring to ensure all of the connections are correct.

Figure 6. Image of the LED lights on the control box

Solar Panel Array Orientation:

The solar panel frame was designed to allow for the direction of orientation of the array to be adjustable. The optimal direction for the panels to face changes between North and South throughout the year. The position of the sun in the sky throughout the year for Buchanan, Liberia can be seen in figure 6. To expose the panels to the most direct sunlight, it is best to orientate the panel to the North (towards the road) from the end of March until the beginning of September. The rest of the year the panels should be oriented towards the south (facing the lagoon). If moving the panels is challenging or risks damage to the equipment it is recommended to keep the panels facing North all year long. This is because during the dry season there will be plenty of sun and having the panels oriented to the south will likely not impact the pumps ability to fill the tank daily.   Whereas, in the raining season it is very important to have the panels oriented towards the North to maximize the panels' exposure to direct sunlight.



Notes: • = Daylight saving time, * = Next day. How to read this graph? Change preferences.

Figure 7. Position of the Sun in the sky for Buchanan, Liberia. Image obtained on 9/1/14 from: http://www.gaisma.com/en/location/buchanan.html

SWB Contact Information:

Josh Novacheck
Email: jnova@umich.edu
Telephone: (001) 612-708-1450

Jose Alfaro
Email: jfalfaro@umich.edu
Telephone: (001) 864-567-5142

Appendix B – Field Notes and Reflections

LAC Solar Water Pump Report

Intro

In this document I intend to address many of the questions brought up in the brainstorming document put together before my trip. This can be a working document so if there is something missing, bring it up and I'll address the question.

The trip was very successful. Everything that SWB was responsible for was installed, tested, and working well before leaving LAC's plantation. The taps at the homes in the camp were tested and water successfully flowed from the reservoir to the homes. There was some pipe leakage, which the LAC plumbers were planning on fixing in the days following my departure.

About 3.5 days were used for construction of the system and another 2 days were used for testing, education, and community outreach. Construction was done with the support of LAC's construction team. Even with this support construction took longer than hoped due to tools breaking down. Extra time was also taken so I could do some teaching to the construction team on solar energy, particularly safety considerations when repairing the system.

LAC's Motivation

LAC's plantation is expansive. With about 14,000 ha of rubber trees, it is the second biggest rubber plantation in Liberia behind Firestone. LAC's land was originally acquired from local farmers and villagers through agreements with the government of Liberia. As part of the agreement to displace/relocate the locals and take ownership of the land, LAC must provide basic living requirements, such as shelter, food, and water. Employment, however, is not guaranteed. About 4,500 people work in some manner for the plantation, but only 1,500 are employed directly. The other 3,000 are considered contract workers. Wage compensation and concession compensation for contract workers are less than what is required for direct employees. Thus LAC attempts to keep the number of direct employees low. This is a significant point of contention between LAC management and numerous contract workers that live on the plantation. In general, living conditions on the plantation are better than the conditions in most of Liberia.

The best analogy I can think of is LAC is similar to sharecropping in the South during reconstruction (after the civil war). Landlords own large portions of land and provide field workers basic living essentials, such as housing, and reduced wages.

I do not have a complete handle on the concession agreements with the government, but LAC is constantly concerned the government will require them to offer more. Accessible water is one requirement already in place, but a hand pump well a good distance away from the center of a camp is all that is required. However, LAC believes the government will soon require water to be accessible within or just outside of the home. To provide this, wells will need to be outfitted with pumps.

There are two main options for pumping water. Either using a traditional diesel generator to power the pump, or use solar panels. LAC has been beginning to deploy some diesel-powered pumps in some of their camps. The initial capital investment for this system is cheaper than a solar powered system, but it also requires a constant supply of diesel fuel and it requires more maintenance. Also, diesel fuel is expensive and the price is very volatile in Liberia. Therefore it can be tough to budget these systems properly. While the solar powered system is a larger up front investment, LAC views it as a cheaper system when considering the entire life cycle costs. The challenge for LAC was the lack of knowledge surrounding these systems. By working with SWB on a demonstration project LAC could train their employees on the system and monitor its performance.

Ownership of Materials/Security

LAC is the owner of the system and is responsible for maintaining it. It will be used to provide water for people living in the camp, most of who are only contract workers. But LAC views this as part of their concession agreement to the community and therefore will maintain ownership and responsibility of the system. SWB bought much of the material, but because of the difficulty of shipping the solar panels, LAC agreed to buy those locally (about 3-4 times more expensive than buying them in the US). For that reason, LAC also does have a significant financial commitment to the project.

LAC employs a security force on the plantation, and an officer is always present in the camp where the solar water pump system was installed. They have primary responsibility for security of the system. I met the head of the security force, a Liberian, and he offered useful recommendations and ideas to protect the system. In addition, the solar panels are raised about 15 feet in the air on a single pole. Around the frame of the solar panels, LAC installed barbed wire to discourage theft or vandalism.

Training and Performance Monitoring

I also spent time educating some of the community members and LAC management about the system. The camp's superintendent, who lives nearby to the camp and is responsible for what takes place in the community, the construction manager and the plantation's general manager (both expatriates), and one of the plantation's social workers, all meet with me at various times throughout my visit. In these meetings, I explained the basic functions of the system, safety, monitoring of system performance, and maintenance. People who received more in-depth training were the camp's superintendent, LAC's construction manager, and the plumper, who I worked with extensively during the project implementation. I also am completing a manual (which I will share with all of you) on the basics of the system, including potential maintenance.

I also worked closely with a recent high school graduate. He is 24 years old and is hoping to save money to go to college. He had to put off his education during the wars, but remained dedicated to getting an education, returning to school as soon as it was safe to do so. He was trained on the system as a whole, but also on how to record data on the system. The data is both quantitative (ie power from the panels, speed of the pump, etc.) and qualitative (interviewing community members on their satisfaction with the system). This information will then be sent back to SWB so we can keep track of the system's performance.

Community Involvement/Women Involvement

Along with the plantation's General Manager and various other LAC management staff, I met with the community that the system will serve. While all were welcome, I emphasized the importance of having the women attend the meeting, which the LAC management agreed with. In this discussion I gave a high level description of how the system works and how it would hopefully make life easier. I also emphasized water conservation, as we only sized the system to provide basic needs. In the past, LAC has experienced high amounts of waste (either water or electricity) when new technologies are introduced into the camps.

Future Projects

LAC is so far very pleased with the system SWB installed. They are hoping to install and additional 15 systems next year with SWB's help. LAC also wants to partner with SWB to bring other renewable energy projects to the plantation, including various solar and biomass electricity projects. LAC has agreed to buy all material for future projects. This however, may need to be put on hold due to concerns over the ebola virus and ebola related civil unrest.

From SWB's perspective the partnership is very exciting, however, we would like to better engage the community at LAC to get their perspective. We need to do a better job to ensure we are sticking by our mission to serve communities, and not simply the LAC management.