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BRIEFING PAPER

OFF-THE-GRID ENERGY SOLUTIONS FOR SMALLHOLDER FARMERS IN AFRICA

INTRODUCTION

According to the World Bank, just over a quarter of people in sub-Saharan African have access to electricity.[1] The benefits of electricity—and conversely, the negative effects of not having access—are significant. Electricity can help smallholder farmers improve their yields (through better irrigation), earn more income (by engaging in value-added activities), and increase their access to information (by powering radios and mobile phones). Furthermore, access to electricity can improve health conditions by reducing pollutants from traditional fuel and increase livelihood opportunities for women and girls by freeing up time spent on time-consuming, manual labor.[2] Governments, donors, and the private sector can all play an important role in developing the infrastructure to expand access to electrical grids. Building power plants and laying down power lines, however, takes time and significant investment.

In the meantime, there are an increasing number of options that development organizations can use to help provide affordable energy to farmers who remain off the grid. Just as the mobile phone leapfrogged over landlines in much of Africa, off-the-grid solutions have a similar potential to deliver electricity to millions of rural, smallholder farmers throughout the continent. This paper focuses on what some of those solutions are, how they work, their potential benefits, and other considerations you need to make before choosing the right solution.

[1] The World Bank, Energy in Africa: Overview. (June 2012).
[2] UNDP, Fast Facts: Universal Energy Access. (July 2011).

THE BASICS OF ELECTRICAL POWER

Before looking at any type of off-the-grid solution, it is important to understand the basics of how electrical power works in regard to both generation and usage. All electrical energy has to be converted from another source of energy before it can be used to power an electrical device. The most common off-the-grid solutions rely on solar, biomass, kinetic (human/animal), wind, or hydro power. Off-the-grid energy solutions vary in terms of their efficiency at converting this energy input to electricity. Most solar panels, for example, range in efficiency between 10 and 20 percent. This means that up to 90 percent of the potential energy from the sun is lost in conversion. When using any type of electrical generator, obviously, the higher the efficiency rate, the better.

Before deciding on what type of solution is most appropriate for the needs of your beneficiaries, you need to determine the total amount of wattage they require. Many devices state the wattage, although some do not. To calculate the wattage, you will need to multiply the volts by the amps. For example, a laptop might have an output of 19.5V and 4.5A. This means that it would use a maximum of 87.75 watts per hour, although in reality it would likely use a fraction of that for typical usage. Once you have determined the wattage of the device you want to charge, you can multiply that amount by the number of hours you anticipate using it each day to determine the watt hours required. If you plan to use the laptop cited above for 8 hours a day, you would need a maximum of 702 watt hours to power it.

The other thing to understand is the total electrical output capacity of potential chargers. This is generally measured in watt hours (Wh) or kilowatt hours (kWh), and tells you the total number of watts or kilowatts expended or generated in one hour. The output can also sometimes be expressed in terms of milliampere hours (mAh), particularly on batteries. In order to convert mAh into Wh, you need to multiply the mAh figure by the voltage of the device, then divide by 1,000. For example, a solar charger with 12,000 mAh and a 19 volt output has the equivalent of 228 Wh. If your laptop runs on average at 40 watts, you would be able to get between 4-5 hours of battery life per full charge using that solar charger, assuming some degree of energy loss.

Wattage Estimates

Below is a list of some of the typical hourly wattage consumption for common electrical devices:

- Laptop – 50 watts
- CPU (and monitor) – 270 watts
- Stereo – 70-400 watts
- 27" television – 113 watts
- DVD player – 20-25 watts
- Mobile phone – 2-4 watts (when charging)
- Water pump – 250-1,100 watts
- Lightbulbs
  - LED – 6-12 watts
  - Incandescent – 60-100 watts

Sources: Energy.gov, Standby Power

EXAMPLES OF OFF-THE-GRID ENERGY SOLUTIONS

The following table includes a brief overview of likely solutions and things to consider for each. This is meant to be a point-of-entry guide, and you are encouraged to do your own due diligence before making any decision for your own project.

In most cases you will be able to store the electricity generated into batteries for later usage, so you will want to also consider the appropriate battery capacity to meet your needs. For each solution you will also need to instruct users on proper care and maintenance of both the generator and batteries. These systems often breakdown as a result of preventable causes.

Type	Overview	Things to Consider
Solar	Most solar chargers are photovoltaic, meaning that they convert solar radiation into direct current electricity. They are available in a variety of different sizes, efficiency levels, and outputs. Solar is the most common type of compact, affordable charger for consumer electronics and light bulbs.	**Sun insolation (or solar irradiance)** – This is the measure of solar radiation energy that is received on the surface of the earth at a given moment in time. It is measured in terms of $kWh/m^2/day$. In other words, the kilowatt hours per square meter that is received in a 24 hour period. The higher the number, the better the fit for solar power. The Solar Electricity Handbook has a helpful tool that shows the average sun isolation figures in a selection of cities/town for every country by month. Much of Africa receives high levels of sun insolation. **Efficiency** – As mentioned earlier, solar panels vary in their efficiency. High-efficiency panels are anything over about 20 percent.
Biomass	Biomass generators convert biological materials, such as wood or plant waste, into electricity. Most of them use thermal conversion, a process by which the heat generated from burning fuel is used to generate electricity.	**Fuel availability** – Any biomass generator needs a reliable source of compatible fuel. Before considering any biomass generator, you will want to check on the total volume of fuel needed to generate each kWh of electricity to determine if the required fuel source is available in such quantities.
Kinetic (Human)	The most common human-generated electrical systems are those that operate either by a hand-crank or a bicycle. This type of mechanical power has been around for decades, and is still a viable option in many cases.	**Efficiency** – Since you will be relying on the kinetic energy generated by humans, you need to make sure that the device you are using is efficient enough to generate the wattage required without becoming too burdensome for the user.
Kinetic (Animal)	Animal-generated power has been around for centuries. These systems operate in the same way as those that convert human-generated energy into electricity.	**Hidden costs** – Using animals to generate power requires more than just the hardware to harness this energy. It also requires continual upkeep and care of the animals you will be using. You will want to consider exactly what those ongoing costs are, and whether the animals might provide better value doing other tasks than turning a generator.
Wind	Wind turbines exploit the wind to generate electricity. Standard wind turbines are certainly not cheap, but micro-wind turbines that can generate up to 400 watts of electricity can be purchased for under $600.	**Wind area** – Wind turbines are optimized for one of the three different types of wind areas. Before purchasing a wind turbine, find out what the average wind speed is in the area you are working by checking with the national weather service.
Hydro	Pico-hydro systems, which provide under 2kW of electricity, can generate enough electricity to meet the needs of an average smallholder farmer and family in Africa. The total electricity generated depends on the amount of water flow and the vertical distance between the water input and the turbine.[3] On the community level, micro-hydro systems that can generate up to 100kW may also be an option, but they require much more logistical planning and community buy-in than household size pico-hydro systems.	**Water access** – Physical and legal access to a water source with sufficient flow is crucial to any hydro power system. You will need to find out what local permits or permission may be needed. **Water availability** – Stream flows can vary throughout the year, so make sure that whatever water source you are using has sufficient annual flow to operate the system.

[3] Department of Energy, Microhydropower Systems. (July 2, 2012).

DETERMINING THE APPROPRIATE SOLUTION

Determining which solution is most appropriate to your needs will generally depend on three things: how much electricity you need, your budget, and the local context. We have already discussed how to calculate the first of these. Having a solid sense of the anticipated electricity needs is crucial to making any decision. The initial and ongoing expenses associated with each solution type will also vary. Some may require greater upfront costs (such as solar), while others require greater ongoing costs (such as animal power). The last thing to consider is the local context. Some of these are obvious. For example, if there is limited sunlight then solar is probably not the best solution. Beyond environmental considerations though, you need to also consider things such as likelihood of damage or theft, capacity for local maintenance and repair, and whether there are any local beliefs that would inhibit the effectiveness of a given solution.

PROMISING EXAMPLES

Although some off-the-grid energy solutions require significant investment and infrastructure development, there are a growing number of affordable solutions for individual farmers. This section will look at some of those solutions that are already being used—or have potential to be used—on the ground in Africa. It is important to note that this is by no means an exhaustive list. Many other examples do exist, therefore you should do your own research before making any purchasing decisions.

Solar

Solar chargers are one of the most popular off-the-grid energy solutions. The cost of generating enough electricity from a solar photovoltaic panel to fully power a house full of modern appliances is still relatively expensive, as is the cost of protecting large solar panels from theft or vandalism. That being said, small solar chargers that can generate enough electricity to power a mobile phone, a radio, or a laptop can be found for a reasonable price. Lighting Africa, the joint IFDC and World Bank program, has done significant work in helping to promote off-the-grid lighting solutions in sub-Saharan Africa. Their goal is to mobilize the private sector to develop sustainable markets for these products to provide off-the-grid lighting to 250 million people by 2030. In fact, with advances in these technologies over the past few years, Africa is now on target to be the primary market for solar-powered portable lights by 2015.[4] Their website also includes a list of all of the products that meet their recommended performance targets, along with vendor lists in Kenya and Ghana. Many of these products are more than simply solar lamps, and include USB and mobile phone charger outlets for powering other devices as well.

In Uganda, mobile network operator MTN Uganda has introduced a solar solution, the Fenix ReadySet, to its dealers. The ReadySet can store up to 54 watt hours of power and includes two USB slots and two 12-volt car lighter ports. It also comes with an open standard input, meaning that it can be connected to any potential power source. MTN is using the ReadySet together with Fenix's 15W solar panel, although the company also produces a 100W kinetic generator that can be fit onto any bicycle. Besides using the ReadySet to generate their own electricity, MTN dealers are also using it to generate income. To date, MTN dealers using the ReadySet system earn an average of US$60/month in income by offering phone charging services and lighting.[5] The complete ReadySet solar kit retails for US$300 and includes the battery, solar panel, power adapter, LED light, and USB universal battery charger.

Biomass

The process of harnessing electricity from biomass has improved significantly over the past few years. Although low-cost options are not yet available in many markets, there are a couple of solutions that should be more widely available soon. BioLite, the makers of the portable CampStove, have been pilot testing a larger version called the HomeStove in Uganda, Ghana, and India. The biomass cook stove reportedly requires 50 percent less wood and gives off 94 percent less smoke than traditional wood burning stoves. Using a built-in thermoelectric generator, it can generate enough electricity to power an on-board fan and charge a mobile phone through its USB port. It is not yet known what the pricing will be for the HomeStove, but the smaller CampStove currently retails for US$129.

Another interesting, although larger scale, biomass solution comes out of Husk Power Systems in India. To date they have installed over 80 micro-power plants in villages in the state of Bihar each generating between 25 to 100 kW using rice husks. With plans to expand to another 10 to 15 countries over the next 10 years, they may be worth keeping an eye on if you are interested in larger scale power provision.[6]

Kinetic

There are dozens of examples of local solutions that harness the kinetic energy of humans or animals to create electricity. Besides the numerous do-it-yourself guides available online to create bicycle-powered and other generators, you will likely be able to find individuals locally who have already built their own solutions.

One creative solution in Afghanistan involved hooking up a pedal-powered generator underneath a desk so that students could power laptops by pedaling while they were using the laptops. [7] How long a student could continue pedaling while still being productive on the laptop is debatable though. In the Central African Republic and Democratic Republic of Congo, RFI Planète Radio has harnessed the power of oxen to turn a turbine to generate

[4] http://www.lightingafrica.org/about-us.html
[5] http://www.mtn.com/Sustainability/pages/CaseStudyFullView.aspx?pID=5

[6] Nerenberg, J. "Husk Power Systems Wants to Lead "a Revolution in Electricity" (January 5, 2011).
[7] OLPC Afghanistan's Pedal Powered Progress (October 12, 2009).

electricity to power community radio stations.[8]

In addition to these DIY solutions, there are out-of-the-box solutions that are human powered. One example is the Fenix Velo bicycle generator that can be hooked into the Fenix ReadySet. The company claims that 5 to 10 minutes of pedaling using this device can produce enough electricity to fully charge a mobile phone.

Etón and SOS Ready are two examples of companies that produce well regarded hand-crank lamps and chargers that can used to charge mobile phones and other low wattage devices. Prices can range from US$15–30 for such devices. There are also hand-crank and solar-powered radios available for as low as US$30 that can charge mobile phones as well.

Wind

In Kenya, Access:energy has developed a 700W wind turbine built using locally available parts with enough output capacity to power up to 50 rural homes. They are available on either a lease-hire basis or can be purchased outright for Ks250,000 (~ US$2,850). Although still new—their first customer was in February 2012—they may serve as a bellwether of the potential for locally built micro-wind turbines in Africa.

Hydro

A high preponderance of pico-hydro powered systems are found in Asia, particularly Vietnam and China. Pico-hydro systems have also been used in Africa, but hydroelectric power continues to be a relatively untapped source. According to a report prepared for the Water for Agriculture and Energy in Africa conference in 2008, only 5 percent of the technically feasible hydropower potential in Africa had been exploited.[9] One of the main challenges with hydropower, besides access to and availability of sufficient water, is the degree of skill required to install and maintain hydro systems. In addition, local availability of single family pico-hydro generators is non-existent in many countries.

Other

Another model of off-the-grid energy comes from EGG-energy, which is based in Tanzania. Dubbed as the "Netflix of batteries," EGG-energy operates battery charging depots from which individuals can rent a rechargeable battery for a subscription fee. Once subscribed, customers can swap out their battery for a fully charged one whenever they would like by taking it to a depot and paying a small swapping fee. The batteries they use reportedly have enough capacity to last about five nights in a typical household.[10] Earlier this year at the International Consumer Electronics Show in Las Vegas, a new fuel cell charger called the PowerTrekk was unveiled. It converts hydrogen intro electricity with only a tablespoon of water. It can be connected to a mobile phone using a USB charger and includes an internal battery that can hold 1,500 mAh. The charger retails for US$229 and the replaceable Pucks it uses for the conversion process cost US$12 for a three pack.[11]

LOOKING FORWARD

Before settling on any off-the-grid solution, do your research first to make sure that whatever you choose is locally appropriate. Also, rather than simply distributing off-the-grid chargers or generators to beneficiaries, consider exploring helping local entrepreneurs to establish their own electricity micro-enterprises. This model is already being applied in a number of places in Africa and elsewhere—and it need not be on a scale large enough to power an entire village. A micro-enterprise can use a smaller solar or hand-crank unit to provide mobile phone or radio charging services for a small fee to other community members.

Even where grid electricity does become available, it is worthwhile comparing the initial costs (of connecting to the grid vs. an off-the-grid solution), and the ongoing costs (cost per kWh, maintenance costs). In some cases, off-the-grid solutions may still be more cost effective than electricity from the grid, especially if the monthly electrical usage of the consumer is fairly limited.

This space is evolving rapidly, with solutions constantly being improved and new ones being developed. The box below includes resources that will be useful if you decide to explore this topic in more detail.

RESOURCES

Energy Sector Management Assistance Program http://www.esmap.org/

The World Bank, Photovoltaics for Community Service Facilities: Guidance for Sustainability. (2010)

World Bank Africa Energy Unit (AFTEG)'s website

Powering Agriculture: An Energy Grand Challenge for Development

Evans, P. "Rural Africa Looks Beyond the Grid," *Renewable Energy World Magazine.* (April 12, 2012)

USAID, Empowering Agriculture: Energy Options for Horticulture. (March 2009)

[8] http://www.rfiplaneteradio.org/pub/proj.php?idN=62

[9] Ministerial Conference on Water for Agriculture and Energy in Africa. Hydropower Resource Assessment of Africa. (December 15-17, 2008).

[10] http://egg-energy.com/what-we-do/

[11] Ulanoff, L. "PowerTrekk Offers Unlimited Water-Based Gadget Power" (Mashable Tech, January 8, 2012).

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