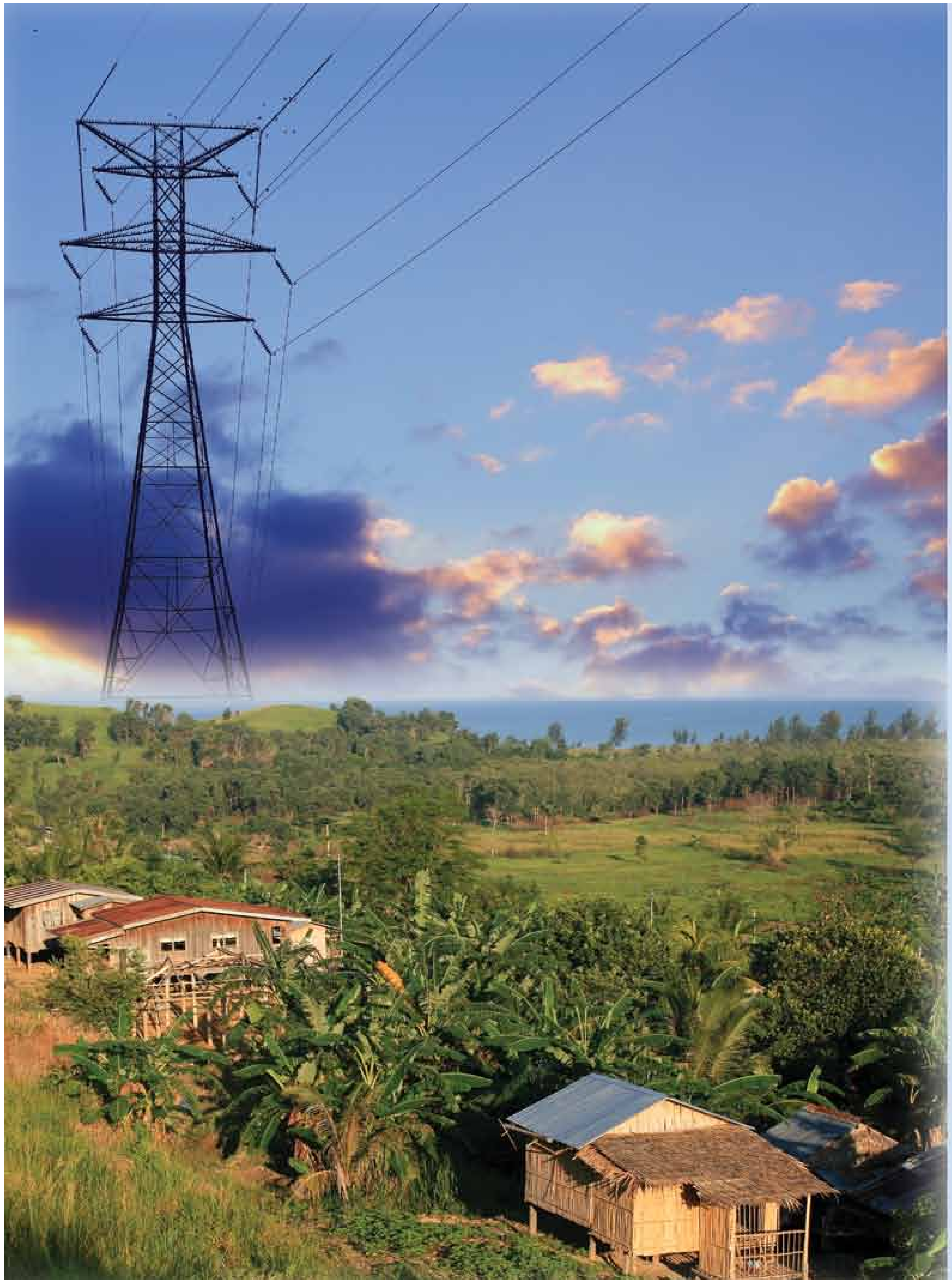

Affordable Energy Solutions for Developing Communities

By R. Podmore, R. Larsen, H. Louie, P. Dauenhauer, W. Gutschow, P. Lacourciere, R. Parigoris, S. Szablya

Energy Poverty

The World Bank estimates that roughly 1.6 billion people—nearly one out of every four people on the planet—do not have regular access to electricity. This form of energy poverty disproportionately afflicts people living in developing countries. For example, in sub-Saharan Africa excluding South Africa, 75 percent of households, some 550 million people, have no access to network electricity. In South Asia, 700 million are similarly not connected to the electricity grid.

The conditions are not likely to change soon. Based on current approaches to providing energy, the International Energy Agency predicts that 1.4 billion people will still lack access to electricity in 2030. Electrification through centralized grid expansion in most cases has failed to make meaningful progress in eliminating energy poverty. There are numerous causes of failure, including high capital and fuel costs, which are often discovered only after systems have been deployed. The remote and only sparsely populated areas in which most poor people live further raises the barrier to electrification.

Energy poverty directly correlates with world poverty, and its ramifications are profound. A telling relationship unfolds when the United Nations Human Development Index (HDI) is plotted with respect to per capita electrical energy consumption for various countries (Figure 1). The HDI accounts for a country's GDP, education levels and mortality rates.

The observed asymptotic relationship is partially due to the normalization of the metric, but it is also clear that the greater the consumption of energy—or ability to consume—the higher the HDI. This suggests that when provided with access to energy, communities are likely to invest this energy in actions that improve their quality of life. The trend also suggests that increasing consumption by a modest amount could dramatically increase HDI.

A lack of electricity impacts almost every aspect of human existence: economic, social, health and education. Without electric lighting most human enterprises are limited to daylight hours. Household chores, homework, reading, and conducting business are stifled. Without electricity, people have only kerosene and candles for cooking and lighting. There are significant safety and health problems associated with kerosene and candles. In 1998, there were 270,000 deaths from fire related burns in developing

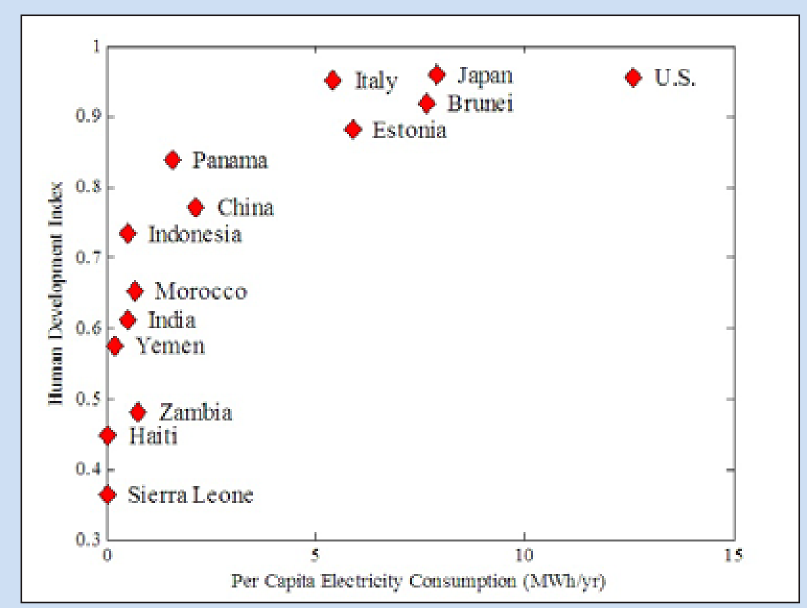

Figure 1. Human Development Index as a function of per capita electrical energy consumption

countries. In India, 2.5 million people suffer burns each year mainly from overturned kerosene lamps.

Energy poverty also tends to disproportionately affect women and children. Without electricity, it is the women that usually collect wood, pump or fetch water, and are exposed to the dangerous kerosene and candles that are used for cooking, lighting and heating. For 780 million women and children, inhaling particulate-laden kerosene fumes is equivalent to smoking two packs of cigarettes a day.

Market-Based Solutions

Ending poverty of any type is wrought with challenges. Massive government aid and donations from private charities have made little impact on ending poverty, despite the US$2 trillion in foreign aid investments since the 1950's. Many have argued that these subsidy-based aid models fail because they create aid-dependent states, promote corruption, stifle competitive markets and discourage entrepreneurs. Subsidy models drive tragedy-of-the-commons scenarios, in which rational, but single-minded entities deplete a shared resource, even though it is clearly not in anyone's long-term interest to do so. This lack of stewardship and trained community ownership has been cited as a reason that donated tractors and drilled wells quickly fail and fall into disrepair.

A contrasting approach to eliminating poverty has been proposed by Jeffrey Sachs, author of The End of Poverty, and key figure in establishing the United Nations Millennium Development Goals. Sachs posited that with proper management, market-based entrepreneurial economies and democratic governance could eliminate the worst of world poverty, along with the key root causes that trap a helpless underclass in unconscionable conditions of preventable misery. Sachs stressed that eliminating poverty was in the best interests of all parties globally and would pose a very modest cost on developed nations for a relatively short number of years. At the forefront is the expansion of market economies as a solution.

Market-based entrepreneurial models have also been championed notably by Paul Polak and Dambisa Moyo. The model recognizes that the approximately one billion people earning around US$1 per day constitute a billion-dollar-per-day market. These people can lift themselves from poverty if products and services that ultimately increase their income are made accessible to them using market principles. Given the close relationship between access to electricity and quality of life and productivity, there are compelling humanitarian and economic reasons to market electricity to the poor.

Demand for Electricity

Travel to any developing community and it will not take long see how electronic devices—mainly cellular phones and radios—have proliferated worldwide. Cellular phones, for example, have a penetration rate of over 61 percent in the developing world. Far from luxury items, the cellular phones and radios are often used for economic, social, health and educational reasons. In poor rural areas, cellular phones are a lifeline for all community members to help one another survive, whether for the next meal, medical emergency, or finding the best place to sell produce; while radios convey news and medical alerts.

Against this backdrop of electrical device proliferation is a seemingly incongruent inaccessibility to basic electricity. For example, fifty percent of the eight million rural Zambians possess electronic devices, while only four percent of rural Zambians have access to electricity. Rural residents must pay a merchant generator to charge the device or walk to the nearest electrified town, which may be many kilometers away. In rural Zambia, the cost to charge a cellular phone is approximately 1000 Kwacha (US$0.20). Assuming a nominal 5Wh cellular phone battery, this translates into astonishing US$40/kWh—nearly one thousand times the rate of electricity in parts of North America. Similarly high rates are common in rural developing communities around the globe.

The demand for electricity in developing communities and its humanitarian benefits of improved quality of life and social justice are apparent. What is missing is the means to launch market-based, self-sustainable and scalable programs to provide electricity to the impoverished.

Community Solutions Initiative

In 2008, the IEEE Foundation together with the United Nations and Vodafone Foundations formed a three-year pilot study program called the Humanitarian Technology Challenge (HTC). The HTC's goal was to have a major impact on alleviating global poverty using technological solutions. The efforts are focused on three key challenges in impoverished areas: Communications Interconnectivity, Reliable Medical Records and Reliable Electricity.

For the Reliable Electricity challenge, one team focused on new technology, and another team focused on using existing technology but with innovative community-scale implementation using strategic Non-Government Organization (NGO) partnerships. This team was formalized as the Community Solutions Working Group, which would later become the Community Solutions Initiative (CSI).

The Community Solutions Initiative is now a not-for-profit member group of the IEEE. It is a volunteer committee organization composed of IEEE and non-IEEE volunteers, including students, industry practitioners, principals of non-profits, academics, and retirees. CSI brings together appropriate technology designs, with sustainable business models and scalable implementation to eliminate energy poverty.

Whenever possible, CSI uses existing technologies, or simple modifications to existing technologies. The final product should be appropriate for the local community and designed based on the tenets of extreme affordability, expandability and scalability. CSI has worked and continues to work on a family of products based on these principles. The products currently in the advanced design, test, or deployment stages are summarized in Table 1.

The CSI products are designed from the concept of a Community Charging Station (CCS). The CCS concept is inspired by the already accepted method of walk-up cellular phone charging: a small centralized power station is patronized by customers dropping off batteries to be charged and retrieving them some time later. This mode avoids fixed wires and other expensive infrastructure components. It can be scaled from community to community, and is expandable by adding additional power inputs, such as photovoltaic panels, wind turbines or human-powered generators as load grows (see sidebars *Why Not Wind?* and *Pedal Power* on page 97).

The business plan associated with a product or service is devised with the world's most poor—those living under US$2 per day—as its target customers. The customers are families, businesses or organizations within the local community. The market for electricity grows if quality-of-life improving devices are made available to the customers for lease or purchase. For example, the market can be expanded beyond cellular phone charging by making available affordable, safe, and high-quality lighting solutions (see sidebar *Lighting Up the World* on page 98). The long-term plan is for the business to be sustainable without the on-going need for donations or subsidies.

To make a significant impact on energy poverty worldwide, the implementation of the business plan and technology must be widely scalable. CSI has found success in using strategic partnerships with local NGOs to design and implement the business plans. NGOs often have an embedded presence, and are familiar with the communities. The most mature design, business plan and implementation of the CSI products is the SunBlazer, a portable solar-powered generating station currently deployed in Haiti by NGO partner Sirona Cares Foundation.

Table 1. CSI product status summary.

Product	Description	Stage
SunBlazer	1.5 kW photovoltaic charging station to service 40 homes to full charging capacity daily **Note: Actual field usage data suggests can easily double to 80 homes per unit*	<u>Manufactured Units Deployed</u> **Six units deployed in six different communities under contracted entrepreneurs in Haiti since June 2011 **Nine more units in construction scheduled for delivery February 2012 **Assembly plant in Haiti underway
Home Battery Kit	17Ah integrated battery with two, 4W LED sockets, switches and wiring lighting kit and second appliance load or cell charging adapter for home use; delivers 100Wh per day maximum (50% discharge limited)	<u>Manufactured Units Deployed</u> **240 units deployed in Haiti since June 2011 **360* more units scheduled for 2012 **Note: Number of Home Battery Kits will be doubled to 80 per unit in 2012 by NGO partner Sirona-Haiti.*
Wind Turbine	Sub-kilowatt wind turbine for auxiliary input to SunBlazer via installed AC converter	<u>Initial Prototype Testing</u> ** First prototype tested in Zambia in 2011 ** Additional field testing scheduled for 2012 ** Plan to test with SunBlazer 2012
LightCycle	Biomechanical powered generator	<u>Initial Prototype Testing</u> **Design refinement stage in U.S. **Pilot test with SunBlazer as LightStick charging option planned in 2012
LightStick	<1W LED lighting device	<u>Initial Prototype Testing</u> **Prototype designed, tested **Sample Pilot units to be deployed for field test with SunBlazer owners in Haiti in 2012

SunBlazer

The flagship CSI product is branded as the SunBlazer (see sidebar *SunBlazer Logos* on page 96). The SunBlazer is a portable, community-scale, solar-powered Community Charging Station. Six SunBlazers have been deployed in Haiti since June of 2011. A franchise style business plan using local entrepreneurs is being used to operate, manage and develop the customer base for the SunBlazers. A strategic partnership with the NGO Sirona Cares Foundation was formed to implement the program. A new Haitian for-profit entity, Sirona-Haiti, has been formed to spearhead the in-country business including manufacturing.

Technology

The SunBlazer is a mobile, self-contained 1.5kW solar-powered generating station built from a trailer chassis. A summary of specifications and costs is provided in Table 2. The basic design is straightforward but many details have to be optimized for both performance and extreme affordability. The SunBlazer is powered by six 245W solar panels, arranged in two parallel banks of three. There is a charge controller, auxiliary rectifier, four "house" storage batteries, and 20 sub-chargers for 40 customer Home Battery Kits. The 12V, 200Ah house batteries are sized to provide a buffer in case of prolonged periods of low solar irradiance. These batteries are used to charge the smaller Home Battery Kits. Figures 2-7 show the SunBlazer floor plan, finished assembly, road configuration, major components and schematic diagrams.

Figure 8 shows the CSI-Sirona and Haitian Community Team celebrating the first SunBlazer deployment at St. Etienne on June 23, 2011. Five more SunBlazers were deployed successfully in the following week.

The SunBlazer chassis carries 40 portable customer Home Battery Kits, each consisting of a 12V, 18Ah portable battery pack. These kits are leased by the customers. Each Home Battery Kit is accompanied by a prefabricated lighting kit of two 4W LED white globes and chain-pull wall or ceiling mount sockets with 15 ft. (5m) of wiring.

Table 2: Summary specifications & cost estimate.

SunBlazer 40- & 80-Home Systems			
Component	No./ Sys	Specifications	Cost USD
Trailer	1	5x8x1.5' chassis 1- axle w/spare tire, 3 stabilizing jacks, 6-solar panel array, 3200lbs GVW	2,600
Solar Panels	6	245W ea., 2 parallel columns of 3 ea, nominal output 60V	2,400
House Batteries	4	12V 200Ah units in series for 48V	1,400
Sub-Chargers	20	48-12V home battery chargers, 3 stage program for 3 hr charge per bank of 20	1,700
Home Battery Packs	40	18Ah 12V battery pack with LVD limiter, auxiliary source, 108Ah 50% capacity per charge	3,200
Home Lighting Kits	40	2 – 4W LED globes, 2 pull-chain sockets, 15 ft wiring harness installed w/ 12V plug	2,400
Solar Charge Controller	1	MPPT controller	550
AC source aux. charger	1	Converter-regulator accepts 220VAC for aux charger power from turbine, diesel or grid	550
Wiring & breakers, misc.	1 set	Chassis wiring harness, breakers assembly, misc fittings	200
Total-40		40-Home System USD	15,000
+40 Home Packs	40	Battery Packs + Lighting Kits	5.600
Total 80		80-Home System USD	20,600
Initial Capital Cost/Customer		40-Home System: 15,000/40 80-Home System: 20,600/80	375 258

The Home Battery Kit itself is a converted commercial automobile jump-start kit. There are two automobile cigarette lighter-style outlets for auxiliary loads such as a 12V cellular phone charger or other small electronic devices. A low voltage discharge limiter circuit board has been added to prolong battery life. The circuit allows approximately 50 percent of the battery capacity to be used per day before cutting off. A fully charged kit can power a single 4W LED room light for 31 hours and two lamps for 14 hours. Other Home Battery Kit conveniences are a push-button state-of-charge meter, and a flashlight for use when walking at night. The rear access panel is modified with tamper-resistant screws and instructions in three languages (see sidebar SunBlazer Logos). All batteries are SLA (Sealed Lead-Acid) requiring no handling of hazardous fluids.

The SunBlazer contains twenty 48V-to-12V converters to charge the forty Home Battery Kits in two banks of twenty every day if needed. The solar panel array has a peak capacity to fully charge all Home Battery Kits, even on a day with the lowest seasonal average irradiance in Haiti.

The SunBlazer is equipped with an AC converter / regulator to allow connection of an external source such as a wind turbine, emergency diesel generator or, if one should become available, a grid connection. An auxiliary source can be invaluable in emergency service in critical applications such as a clinic, operating room, school, computer lab or emergency communications system. The first six SunBlazers were constructed in the U.S. The next set of nine will be assembled in Haiti.

Making a Business Work for People earning US$1-2 per day

The highly challenging business model for the SunBlazer was refined into a viable plan by the NGO Sirona Cares Foundation. Sirona has experience developing small businesses in Haiti that provide an extra income for small acreage farmers. Working through cooperatives, Sirona has empowered approximately 1000 farmers through their Jatropha plant growing program for bio-fuel production, and are well embedded in Haitian business culture. A for-profit entity called Sirona-Haiti was formed to implement the business model and raise the investment funds needed to take it to a large scale. These capabilities are vital for any future technolo-

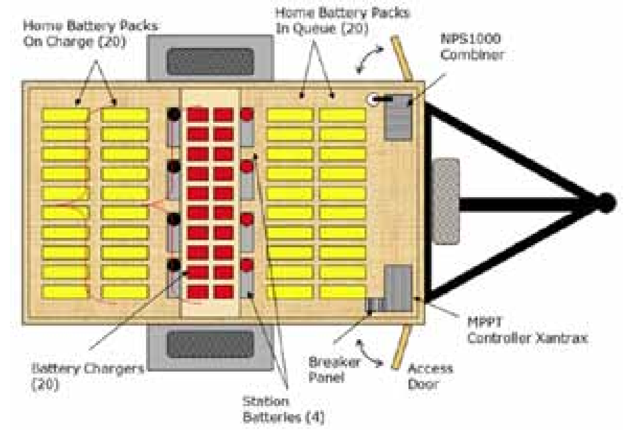

Figure 2: SunBlazer Floor Plan


Figure 3: SunBlazer in Production Mode, Station & Home Batteries & Controls Secured


Figure 4: Trailers on arrival in Grand Goave, stowed position. Note Boxed Lighting Kits on Front Deck


Figure 5a: Home Battery Kit Trailer Charging bay


Figure 5b: 48-12V Chargers

gy model to succeed and give a blueprint for expansion beyond Haiti.

The business model was developed based on the results of a market survey, as summarized in Table 3. There are four layers to the business plan: lenders and investors, NGOs (Sirona-Haiti), operators (franchisees), and customers. Lenders and investors supply money to Sirona-Haiti. Sirona-Haiti in turn oversees the procurement and construction of the SunBlazers. Franchisees operate the SunBlazers. The franchisees are selected from the local communities and trained in the business and basic technical aspects of the SunBlazer. The operators are responsible to develop business for the SunBlazer in the form of customers that lease Home Battery Kits. The local operators in turn provide a guaranteed service to the home owners.

Each customer has the right to have his or her Home Battery Kit recharged as frequently as once per day in return for paying HTG260—around US$6.50—per month. The franchisees collect the fees from the customers and make a fixed monthly lease payment to Sirona-Haiti, which oversees all future operations and maintenance. The difference between income and lease payment is the franchisee's profit for running the business. There is no up-front cost for either owner or operator other than a security deposit.

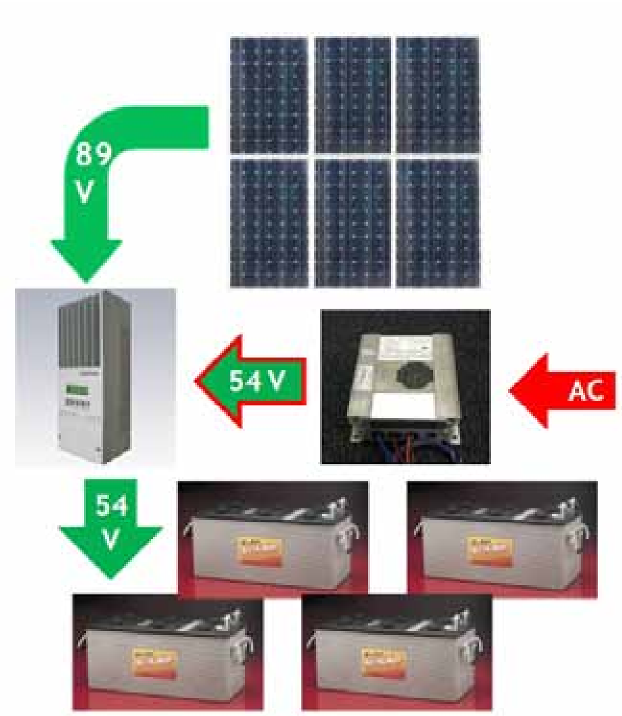

Figure 6a: PV Solar & Optional Auxiliary AC Station Battery Charging Circuits

Figure 6b: System Load Schematic to Home Packs

Figure 7a: Home Battery Pack and Lighting Kit

Figure 7b: First Light at Anse à Veau, Haiti

Figure 8: First SunBlazer Deployment in Haiti

Implementation

Sirona Cares Foundation developed the local entrepreneur teams to take ownership of the first six SunBlazer units. Entrepreneurs were found through its ongoing connections with the church and farming communities. Potential franchisees must first pass a screening, conduct a formal market survey in their community and secure customers who agree to lease a Home Kit.

After three months of operating experience in six communities the business report card was near-perfect (see Table 4). Early indicators show that the whole community benefits—families with Home Battery Kits often place their lights in areas where others in the community gather (see sidebar Home Battery Kit Testimonial). In addition, most Home Battery Kits have been underutilized, suggesting that each SunBlazer could serve twice as many customers. The next nine SunBlazers to be deployed in early 2012 will be equipped with double the number of Home Battery Kits, 80 per SunBlazer. These next nine will reach 720 new homes or an estimated 4300 more people, depending on family size.

The 15 SunBlazer units (six currently deployed and nine to be deployed in 2012) in the pilot phase of the program were seed-funded by several IEEE entities and supported by CSI member pro-bono labor. The approximate construction cost of a unit with 40 Home Battery Kits in the US with volunteer labor is US$15,000. This will be reduced considerably in high volume production. The next nine trailers will be shipped empty and components installed in Haiti, and all further units will be completely procured and assembled in Haiti.

Sirona-Haiti must now raise major capital to scale the business at a rapid rate beyond the pilot program through long term loans or investment. They are off to a good start with a USAID grant for bridge funding to equip a factory as well as to build, deploy and service the first run of SunBlazer units built in Haiti. The Sirona-Haiti goal is to raise funds for 300-500 new SunBlazers by the end of 2012 to be on track to reach a million people by 2016.

With double the number of home kits, this goal may be met much sooner. CSI volunteers will continue advisory and technical support as needed.

Table 3. Haiti market research summary.

	Min	Max	Median
Willing to Pay Per Month for Electricity (HTG)	15	1000	150
Income Spent on Electricity (%)	10%	52%	15%
Cost to Use Charging Station (HTG)	10	275	50
Cost to Charge Cellular Phone (HTG)	5	75	15
Price of Generator Fuel (HTG/gallon)	100	350	200
Monthly Cost of Candles (HTG)	20	550	100
Monthly Cost of Kerosene (HTG)	20	2000	170

40Haitain Gourdes (HTG) = US$1

Table 4. Status update of SunBlazer deployment (Sirona Haiti Data).

Location	Months in Operation	Fully Subscribed?	Payments on Time?	Families on Waiting List	Home Battery Kit Recharge Time	Security Issues?	Equipment Issues
Marmelade	3	Yes	100%	80+	Not Reported	None	1 bad battery pack; 3 bad lamps
Anse au Veaux	3	Yes	100%	20+	3 Hrs	None	Minor water leak
Deuxième Plaines	3	Yes	100%	100+	3 Hrs	None	8 lamps need replacement
Jérémie	3	Yes	100%	200	3 Hrs	None	2 bad battery packs; minor water leak
St. Helène (Les Cayes)	3	Yes	100%	100	3 Hrs	None	None
St. Étiènne	3	Yes	100%	100	3 Hrs	None	None

The Road to Global Outreach

The IEEE Community Solutions Initiative (CSI) is working to eliminate energy poverty through appropriate energy system designs, sustainable business plans, and rapidly scalable implementation. The success and lessons learned with the SunBlazer allow CSI to move on to promote the Haiti model in other regions with IEEE and trusted NGOs starting with Africa and India, with the aim of raising significant seed funding through a new IEEE Foundation Fund called the IEEE PES Community Solutions Initiative for Affordable Energy Fund. The Fund will make appeals to IEEE Members, corporations and private citizens for support.

As demonstrated in Haiti, community-scale solutions can be achieved, but it requires dedicated individuals, NGOs, and entrepreneurs to make it happen. As a volunteer organization, CSI seeks individuals and organizations willing to donate their business and engineering talents in order to make real change in the world. Continued support from IEEE and leveraging through partnerships including Engineers without Borders USA are also critical. Readers interested in becoming involved in CSI are encouraged to visit www.communitysolutionsinitiative.org to learn more about the organization and www.sironacares.org to learn specifically about the pioneering ongoing venture in Haiti.

SunBlazer System Logos

Product branding is as important for developing communities as it is for the developed world. The triangular logo was modified for Sirona-Haiti to include the logos of all the major sponsors, the national colors of Haiti and the motto in three languages, "Rural and Village Electrification Project". Also shown are a Community logo and Home Battery Kit rear panel instructions in English, French and Creole.

Figure 9: SunBlazer Trailer Logo with Donor Logos; Community Logo; Home Pack Operating Instructions

Home Battery Kit User Testimonial

"I put one light in my house and one outside so that others could share in the light. Now they all gather in front of my house at night to talk, children play, it is wonderful. Our kerosene lamps made our ceilings black, the fumes were hard to breathe, our clothes smelled... our life is changed by this light. We used to need to buy kerosene, buy matches, and in the dark we would find the gas, fill our lamp and light it; the lights are so easy for us, we just turn them on. We breathe so much better. People in the city have lights, and now we do. We are very proud. Our children can study now with good light. If I am reading a book and it gets dark, I can continue to read at night."

– *Customer in St Etienne*

Why Not Wind?

Considerably more energy worldwide is produced each year by wind turbines than by photovoltaic (PV) panels. Megawatt-sized generators to augment grid systems are well established. However, in rural off-grid applications, PV panels are the renewable generation source of choice. Since wind power is dominant in grid-connected utility-scale generation, why is it not also dominant in off-grid rural electrification?

Since wind turbines are mechanical in nature, there is a tendency to view them as "low tech" power producers. However, this actually can be an advantage in rural electrification: wind turbines can be constructed without sophisticated fabrication plants, mostly local or easily obtainable materials are needed, and their operation and field repair is feasible.

CSI is working to determine the feasibility of constructing sub-kilowatt sized wind turbines that could be integrated into the community charging station business model. It is based on the homemade wind turbine designs that have been steadily improved upon since the 1970s. These designs generally use poly-phase, axial-flux, direct drive permanent magnet synchronous generators.

Figure 10. 700W Wind Turbine Prototype Under Test in Zambia

High grade NdFeB rare earth magnets are used to create the requisite magnetic flux. The windings can be embedded in a resin cast. The generators can be made in a shop equipped with basic wood and metal working tools. The output voltage is converted to DC via a common, inexpensive diode rectifier or used as a supplementary input to a SunBlazer.

For sub-kilowatt capacity turbines, blade lengths are typically between two and six feet. They can be carved from wood or shaped out of high strength PVC, though there are durability concerns when using PVC. For smaller wind turbines, the tower structure can be simple, for example, repurposed borehole piping or rebar towers.

To demonstrate the proof-of-concept, a 700 W wind turbine was test deployed in Chikuni, Zambia by CSI volunteers. The blades and a 20 foot tower were constructed in country, using locally available parts and materials. The generator was constructed in the United States, and assembled in Zambia. The team is now designing a more affordable, small scale 100 W wind turbine.

For wind power to be a more plausible alternative or auxiliary source to PV panels, advances are needed in: eliminating or reducing the need for the expensive, and sometimes difficult to obtain rare earth magnets; co-optimizing wind turbine electrical, mechanical and tower designs; and performing quick, low technology and inexpensive wind resource assessments.

Pedal Power

Low labor rates and high unemployment in many developing communities make for the profitable opportunity to use human power to generate electricity. Humans can generate 40 watts of power for a period 60 minutes by pedaling.

The CSI LightCycle is a pedal-powered generator that can be constructed for approximately US$240, including a small charging station. A standard bicycle is temporarily connected to drive a 12 volt DC generator. The generator can be used to charge a 12 V lead acid battery and several banks of six 1.2 volt NiMh batteries in series. The bicycle can be inserted into and removed from the LightCycle stand in less than a minute, so that it is readily available for transportation.

A reading quality task lamp can be built for US$5 that draws only 0.2 watts (see sidebar Lighting Up the World). After accounting for losses, one hour of pedaling can provide one hour of light for around 80 homes. If a fee to charge a 5Wh cellular phone battery is US$0.20, the LightCycle operator can generate income of US$2 per hour.

Still in the prototype testing phase, the LightCycle could fill a niche market by lowering the barriers for the startup of small independent power producers to less than a few hundred dollars.

Figure 11. LightCycle Prototype Under Test

Lighting Up the World

Rural electrification in developing communities can be a chicken-and-egg paradox. Demand for electricity must be sufficient to justify electricity generation; but people are discouraged from purchasing devices unless electricity is readily available. CSI has found success in integrating life-improving devices with a supply of energy to power those devices. The SunBlazer and Home Battery Kits are one example. The Home Battery Kits that are leased to the customers with lighting kits, which have a plethora of economic, health and safety advantages over kerosene and candles. The value proposition of leasing a kit is easily communicated: customers are not paying for electricity, they are paying for an improved quality of life. This is similar to the approach used in the early 20th century when utilities would sell appliances to stimulate consumer demand for electricity.

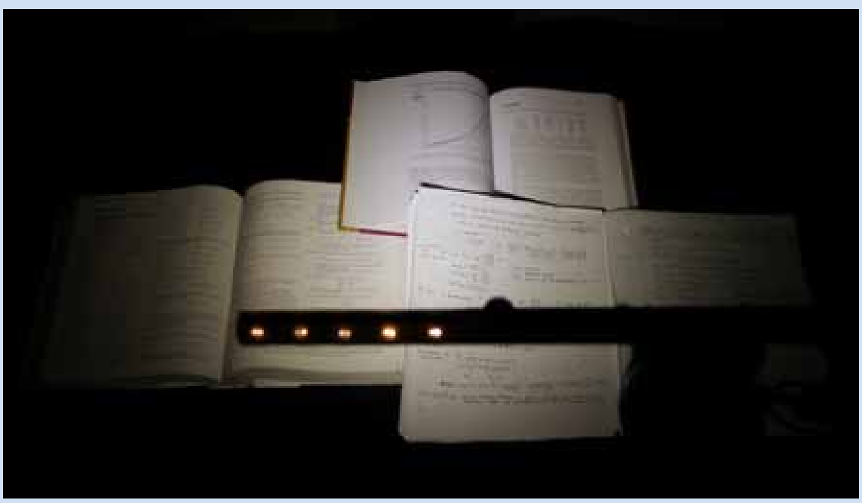

Figure 12. Light Stick Prototype Under Test

With the need and demand for electric lighting and in the pursuit of extreme affordability and expandability, CSI is developing an entry-level lighting solution known as the LightStick. It will be field tested in Haiti beginning in 2012. The LightStick is a battery-powered LED lighting device that can be built for approximately US$5 including three AA rechargeable batteries, and recharged by customers for US$1 per month. At these prices it will be compelling for people to switch from kerosene and candles.

The LightStick nominally utilizes three rechargeable AA batteries and five white LEDs. It can be inexpensively made using common materials such as PVC pipe and copper tape. They can be constructed in under one hour, using minimal tools and with little technical proficiency. The tubular container can be adapted to contain batteries of different capacities, such as AAA, AA, C and D sized. AA batteries are currently priced in the range of US$0.70 each for 900 mAH capacity to US$2.50 each for 2400 mAH batteries. For general home applications the 900 mAH batteries will suffice. For more critical applications such as midwifery, the 2400 mAH batteries are preferred.

The LightStick's linear design is easily extended. LEDs can be placed to light up different areas and surfaces. Several LightSticks can be assembled into simple but highly effective LED based flashlights, desk or task lamps and ambient room lights. In contrast, LED lights that are imported and mass produced, typically have an appealing form factor, but can be wasteful on battery power, may provide uneven lighting and may use unreliable LEDs.

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Community Solutions Initiative, http://communitysolutionsinitiative.org/

Sirona Cares Foundation, www.sironacares.org

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