Infrastructure from the Bottom Up

AN OVERVIEW AND ASSESSMENT OF THE MILLENNIUM VILLAGE PROJECT ENERGY AND INFRASTRUCTURE SECTOR AFTER FIVE YEARS

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Executive Summary

THIS REPORT an attempt to document progress and lessons learned from the first five years of the Millennium Village Project (MVP) with a focus on investments in infrastructure and services related to energy, transportation, communications and piped water supply. The broad goal of this component of the MVP was to address some of the constraints that a lack of infrastructure and related services had placed on health, agriculture, education and economic activity in a rural, poor setting. The interventions were designed based on a combination of accepted development practices and community priorities.

The objective here is not to test or report on the impact of specific interventions such as roads or electricity access on people's welfare or health—which is complex—but rather to understand the issues surrounding the selection, prioritization, procurement and cost effective implementation from a set of proven interventions in settings where technical capacity constraints are significant. The report documents what was done, and suggests future directions. It is aimed at an audience of development practitioners and intended as a resource to learn from and contribute to. It will become a "living document" on the Internet.

The interventions that emerged as most critical in the first half of the five year effort were, first, the need to repair and build more clinics and health posts, schools, classrooms and water access points; and introduce needed services and infrastructure, such as electricity for health facilities, ambulances for emergency transport, sanitation services, efficient cookstoves at schools and accelerated expansion of mobile telephony coverage. In the second half of the five year period, the interventions consisted of repairing bridges and culverts, rehabilitating roads and paving some crucial road links, improving access to irrigation pumps, expanding electric grids where appropriate, installing solar powered pay-as-you-go mini-grids in other dispersed or smaller settlements and promoting household cookstoves, solar lanterns, and ICT services for health management.

Improvements in energy, transportation, ICT (information and communication technologies) and irrigation can aid in the achievement of all the Millennium Development Goals, particularly poverty reduction. Small-scale irrigation pumps have helped farmers in Potou, Senegal, and Tiby, Mali increase their incomes. Improved cookstoves have helped reduce the amount of time and effort spent to collect fuelwood in multiple sites. Solar lanterns in Mwandama, Malawi, have replaced kerosene lighting. A modern electricity connection via SharedSolar is helping a tailor in Uganda work longer hours. A community-run vehicle in Koraro has reduced the cost of transporting farm goods, an urgent intervention that was followed by a better road that has now dramatically enhanced transportation access through private providers. Improvements in roads and electricity services have occurred at every site. Dozens of additional schools and health clinics have been constructed, increasing access for residents that once lived far from such facilities. Almost all the health facilities that did not have power five years ago now do, and a similar effort can hopefully be undertaken for schools.

Infrastructure and related services contribute to other MDGs, benefitting sectors from health to education, from business to government. Access to telephony enables connectivity between family and friends and opportunities as well as information and communications that could prove vital to health and incomes. There has been a dramatic increase in voice coverage over the last five years through a combination of market forces and assistance from Ericsson, a mobile network equipment provider. Access to a water supply can reduce time burdens and allow larger volumetric use, and with other interventions, could reduce disease. Drinking water access is steadily improving through a combination of local efforts and donations from JM Eagle, a pipe manufacturer. Irrigation also increases profits for farmers while reducing the risk of crop loss. Adequate lighting can facilitate education by enabling children and adults to read and study and have a greater awareness of the world and their own empowerment.

However, developing large-scale energy, water, transportation and ICT infrastructure alone will not fulfill the MDGs; the ability of infrastructure to reduce costs, increase reliability and equity of access is what matters to end users. For example, establishing an electric power line, a mobile phone tower and an improved road near a clinic do not, alone, improve health services. A reliable, low-voltage electricity connection or an LPG refrigerator that is regularly supplied with fuel is required to maintain a vaccine cold-chain. Similarly, a community health program needs mobile phones (with consistent access to electricity) as well as a functioning health system with which workers can keep and share important records. An ambulance helps improve access to emergency healthcare, but so does a phone system that enables a response to emergency calls and a working health center to serve patients. While new water points are useful, unless a community member can call and report a broken pump, and a system for maintenance is in place, the value of the investment is severely curtailed.

Our lesson from the first five years is that we need to now address the management and maintenance of such infrastructure. Using information technologies and working closely with local governments, we must build a combination of human resources and information chains that connect them to deliver the services.

Structure of the Report

Chapter 1 explores the importance of infrastructure and energy to meeting the MDGs, with special emphasis on their importance across multiple sectors. **Chapter 2** offers specific lessons and broad policy recommendations from the implementation of energy and infrastructure programs in the Millennium Villages (MVs) and the programs' associated scaling-up. **Chapter 3** discusses the operational design of projects and the issues related to the implementation of large and small infrastructure programs in a multi-stakeholder context. **Chapter 4** presents a set of proven technical solutions implemented in many of the Millennium Villages, including grid electricity extensions, road improvements, water (piped drinking water and irrigation), solar LED lanterns and improved biomass cookstoves. **Chapter 5** introduces novel tools developed and piloted within the MVP to solve complex and persistent problems in developing country contexts, many of which are now being scaled-up or implemented beyond the Villages. **Chapters 6 through 9** detail the energy and infrastructure profiles of four Millennium Villages: Bonsaaso, Ghana; Potou, Senegal; Sauri, Kenya and Ruhiira, Uganda. These chapters provide insights into the specific interventions undertaken in each setting; the progress, lessons learned and future challenges. **Chapter 10** offers a discussion of project maintenance and the implications for sustainability. ■

Girl Gathering Water,
Tiby, Mali

CHAPTER I

Energy, Infrastructure and the MDGs

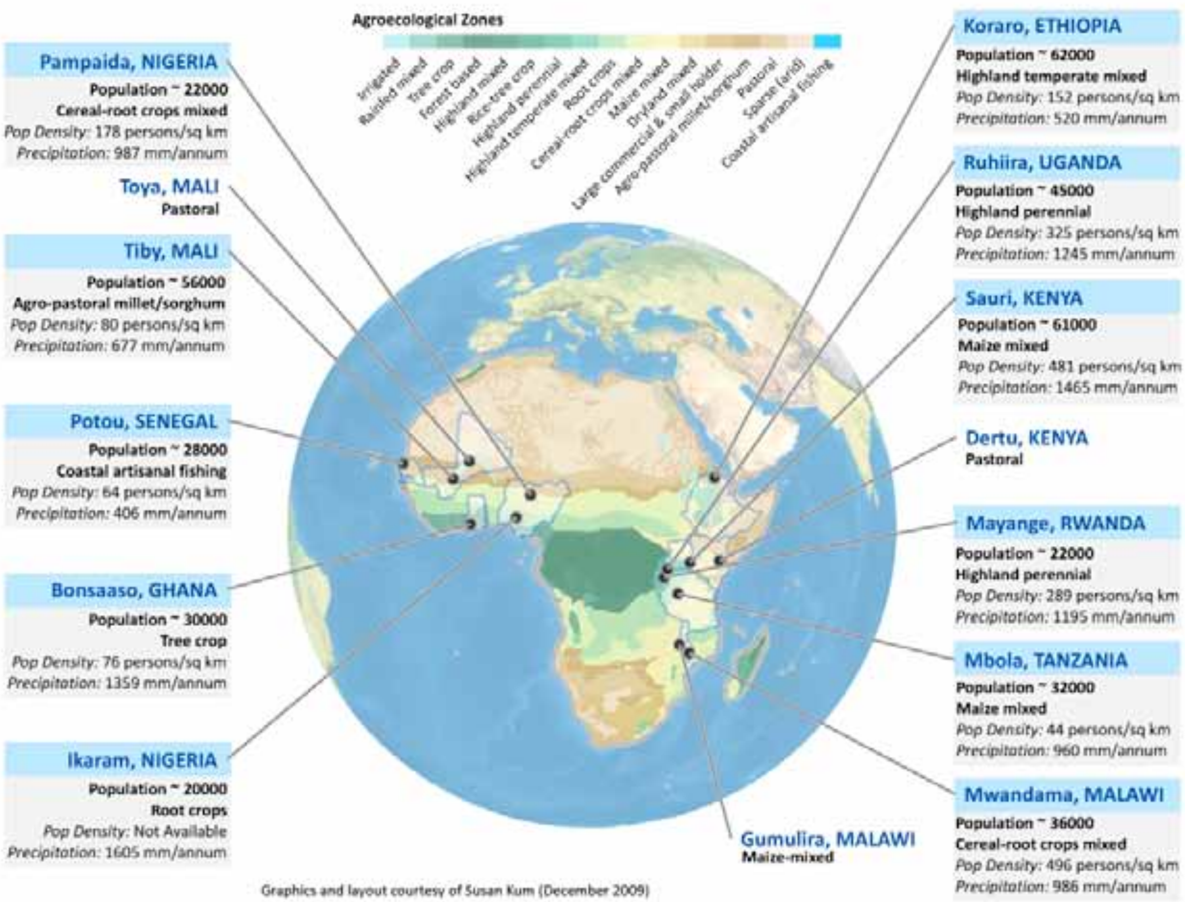
The Millennium Development Goals (MDGs) and the Millennium Village Project (MVP)

At the United Nations Millennium Summit in September, 2000, world leaders placed development and poverty eradication at the heart of the global agenda by adopting the Millennium Declaration. This led to the Millennium Development Goals (MDGs): concrete, time-bound objectives for dramatically reducing extreme poverty in its many dimensions by 2015 —income poverty, hunger, disease, lack of infrastructure and shelter—while promoting gender equality, education, health, and environmental sustainability. Soon after, UN Secretary General Koffi Annan tasked the UN Millennium Project, a research body led by economist Jeffrey Sachs under the auspices of the UNDP, to propose a practical path, with budgets and timelines, for the world to achieve the MDGs by 2015. The Millennium Project's conclusion, outlined in a series of sector-specific documents, was that the world has at its disposal the knowledge, tools and resources to achieve the goals under existing international commitments made at the Millennium Summit, the Monterrey Conference on Financing for Development, and the World Summit on Sustainable Development in Johannesburg[1].

Then as now, despite many challenges facing various parts of the world, Sub-Saharan Africa—with its many small, land-locked countries and weak transportation and communications infrastructure—is, in many ways, the epicenter of the global poverty crisis. It has the planet's lowest rates of electricity access, a singularly high disease burden and hundreds of millions living below the poverty line. Thus, the Millennium Villages Project (MVP) was initiated in Africa—in the village of Bar Sauri, in western Kenya, in 2004—as a practical effort to demonstrate that the goals could be achieved in this quantitative and time-bound fashion, and to test the cost predictions of the Millennium Project, and investigate the best existing and most novel technical and operational approaches to support this goal. The project expanded to include 14 village "clusters," in 10 countries, throughout all major agro-ecologies spanning Sub-Saharan Africa. The villages comprised a total population of around 500,000, all residing in "hunger hotspots".

From the beginning, the project was intended as an integrated, multi-sectoral effort. The challenge for the infrastructure investments was to cost-effectively address all critical bottlenecks. Teams in each site follow a common framework of MDG-related objectives in a range of sectors, including agriculture, health, education, environment and infrastructure. These broad goals are adapted to local conditions and become site-specific targets. This report describes the efforts related to building construction, energy, roads, ICT and piped drinking water where such systems have been deployed. Smaller-scale water interventions and activities related to landscape restoration for water management and storage were part of the agriculture and environment focus.

Figure 1.1: Millennium Village Project (MVP) Sites, by agroecological zone: 14 locations in 10 countries.



INFRASTRUCTURE AND THE MDGS

The MDGs themselves are expressed primarily in terms of outcomes for human health and welfare, and rarely mention infrastructure[2]. However, investments in energy, roads and transportation, ICT and water infrastructure are important enab lers of communities and nations in achieving the Goals.

ENERGY

Improved energy services are necessary for meeting almost all the Goals. Electricity is critical to providing basic social services, including health and education. Reliable energy in clinics enables sterilization, access to clean water, and the refrigeration of essential medicines. Power in schools supports instruction, administration and teacher retention. The lack of electricity that is common to poor, rural areas can act as a disincentive for skilled workers to stay, further limiting local economic development.

Household energy services—including lighting, cellphone charging, and basic media, such as radios –are a substantial part of household budgets for poor families. Lighting from kerosene wick lamps and disposable batteries can be twice as costly on a per unit basis as light from solar rechargeable lanterns, and at least

1. The Earth Insitute, Millennium Promise, UNDP. Millennium Villages. http://millenniumvillages.org/ (accessed June 2011).

2. UNDP. The Millennium Development Goals. 2011. http://www.beta.undp.org/undp/en/home/mdgoverview.html (accessed June 2011).

ten times as expensive as light powered by a central electricity grid. Cooking with fuelwood and crop residues has been associated with a significantly higher disease burden due to indoor air pollution, and means added time and labor spent on fuel collection by women and children. Greater efficiency of cooking fuels and technologies, combined with programs to enhance local biomass fuel availability, can reduce these burdens, freeing up time for education and income-generating work, and lessening pressure on fragile ecosystems.

Machinery powered by electricity, fossil fuels, or renewable energy (water, wind) can support income-generating opportunities such as irrigation, agricultural processing and light manufacturing. Productive uses of mechanical power, especially those that benefit women, can provide social and economic benefits.

ROADS AND TRANSPORTATION

Transport networks and services are critical to economic growth and the efficient delivery of essential social and health services. High transportation costs affect the rural poor severely through adverse impacts on farm incomes. Farmers in remote areas receive less for their products at the farm gate, simply because it is costly for buyers to reach them. Poor transport also limits market access—and thus bargaining power. Finally, poor transport raises the risks of damage and spoilage while transporting crops. Those without access to good transportation pay higher prices for inputs, because it is more difficult to get to them. The poor typically travel further—over more difficult roads—for essential services. Motorized transportation depends on the density and quality of road networks; the cost and availability of fuel, vehicles, maintenance and repair; and the risk of accidents, which is higher where roads are poor. All of these factors tend to be unfavorable in poor areas, thus transportation costs can easily be higher for rural Africans than for residents of developed countries.

ICT

Most people in rural Africa now have access to a mobile phone. Being "connected," by voice and increasingly with data services, is transforming the lives of the poor. Until recently, access to ICT other than radio was achieved only rarely due to the expense of connectivity, hardware, energy and maintenance. Mobile phones allow people to connect instantaneously over long distances. This allows a farmer to quickly access crop prices in distant markets and represents a lifeline for a woman who needs to call for help. Mobile phones also provide a platform for improved service delivery in agriculture and health. Community health care workers (CHWs), armed with basic mobile phones, can register the children they care for by simple SMS. Mobile phone based payment systems promote savings and have allowed for innovative new financial services tailored to the poor, such as micropayments for electricity over mobile phone enabled microgrid systems. Mobile phones will become more critical as they become increasingly integrated into the delivery of vital services for the rural poor.

WATER AND SANITATION

Infrastructure plays an important role in ensuring that clean water-- fundamental to human health and welfare—can be obtained from improved sources such as boreholes and protected springs, then stored, transported and delivered in a manner that is efficient, reduces household labor, and ensures that it remains clean. Sanitation, through interventions such as clinic incinerators and improved latrines, plays an important role in preventing infectious diseases.

Infrastructure at the Start of the Millennium Village Project

The scarcity and generally poor condition of infrastructure in the MVs at the start of this project in 2005-06 was representative of rural Sub-Saharan Africa (SSA) and other areas of extreme poverty. Market centers, social infrastructure (health and education

Table 1.1: Linkages Between Infrastructure and the MDGs

Infrastructure Sector	1: Poverty & Hunger	2: Primary Education	3: Gender Equality & Women's Empowerment	4, 5, 6: Health	7: Environmental Sustainability
MDG					
Energy	Modern energy services increase productivity of human labor, while enabling enterprise development & income Energy can raise productivity and help reduce post-harvest losses More efficient energy use (cooking, lighting) reduces expenditures on less efficient energy resources Improved cooking can reduce fuel and related labor demands	Electricity and lighting enables studying and educational tools and services in schools (computers, projectors, etc) and promotes teacher retention More efficient cooking can reduce time spent fetching wood	Improved cooking can reduce time/labor burden and reduce indoor air pollution Street lighting improves women's safety	Permits cold chain for vaccines, reagents, sterilization, operation of essential laboratory equipment and operating theaters Modern energy can be safer Electricity enables pumped clean water and purification Increases hours of facility operation / nighttime services Helps retain qualified staff	Efficient cooking and switch to modern fuels (LPG) can reduce demand for charcoal or other biomass sources reducing pressure on local ecosystems from fuel collection More efficient agriculture (including fertilizer, mechanization) can reduce need for additional land clearing Improved cooking can reduce greenhouse gas emissions and black carbon
Transport	Facilitates market access and reduces costs of trade, inputs prices , and monopoly power of agricultural middlemen Reduces social / family travel costs	Can improve students' access to school, reducing drop-our rates, particularly for girls	Reduces time and transport burden and eases independent movement for women Can save time, and increase access of women to health services	Increases access to health facilities Reduces emergency response times Improved roads can be safer for drivers and pedestrians	Improved public transport services reduces overall environmental impact
ICT	Increases access to weather, market and income-related information Enables extension, outreach and other training for increased incomes (agriculture, business)	Enables distance learning, access to educational media and communications Aids in teacher retention Improves record-keeping and school management	Reduces isolation of working in home, enables education at home Enables emergency communication and reporting of violence	Increases access to emergency care Supports improved medical information systems (ChildCount), 'distance medicine', and access to health education media Improves access to and quality of public and community health systems	Improves natural resource information gathering, mapping and monitoring
Water and Sanitation	Irrigation (combining improved water access and energy) can dramatically raise agricultural productivity	Rainwater harvesting can reduce water gathering labor for schools by children Reduced water-borne disease, improves school attendance	Improved/piped water sources or systems reduces women's time/labor burden of fetching water	Clean water is essential for health services Cleaner drinking water reduces water-borne diseases Safe disposal of medical waste prevents spread of disease	Increased availability of water and sanitation can improve local environments

facilities) and households frequently had little or no access to "network" infrastructure (electric grids, piped water and all-weather roads) or mobile telephony, for which voice coverage was spotty and data service non-existent. The sites lacked affordable, reliable stand-alone power and water systems. The poor paid a premium for low quality services to meet their basic needs: Rural households paid the equivalent of $10 per kWh of electricity for low quality lighting from kerosene or disposable cells; cooks used inefficient, traditional three-stone fires; poor farmers paid nearly 50 cents to transport one ton of produce one kilometer, nearly three times the average rate of rural India.

- **Institutions:** The number and capacity (size and services delivered) of schools and clinics was inadequate for the population they served. Most of those lacked drinking water, sanitation services and reliable electricity. Grid connections were extremely rare, and off-grid power sources— such as solar photovoltaic or diesel generators—were improperly sized and poorly maintained. Essential needs such as nighttime lighting, vaccine cold-chain storage and clean water in clinics went unmet or required costly substitutes. Record keeping was almost entirely on paper, making data difficult to collect and drastically limiting its use and reporting throughout health, education and other government systems. Although institutions were usually located near all-weather roads, there were often seasonal blockages, especially in heavy rains. Schools that served meals used inefficient three-stone fires, often relying on schoolchildren to collect fuelwood.

- **Market centers and businesses:** Most lacked grid electricity, raising basic service costs and preventing other income-generating activities such as refrigeration, television, carpentry and welding. Many markets lacked mobile phone network coverage, and none had Internet service. Mobile phones and vehicle batteries were recharged using expensive diesel gensets, and most grinding was done at market diesel mills. Access to paved road and transport services varied widely.

- **Households and smallholder farms:** Even in communities served by a central electricity grid, household connections were virtually nonexistent. Cooking was generally done on three-stone fires using collected biomass, while lighting was via kerosene wick lamps. Small electrical appliances (radios, flashlights) were powered by disposable batteries. Mobile phone ownership was rare, and phones were often left unused due to the high cost of power and the lack of network coverage. Less than one-third of the population lived within two kilometers of an all-weather road. Piped water and irrigation systems were rare.

Such are the infrastructure challenges of rural sub-Saharan Africa, due to poverty and low population density. The high cost of project implementation relative to the populations can prohibit investment by governments, donors, and the private sector. In addition, thin value chains for technologies—with few vendors and post-sales support—result in the perception that systems are unreliable. Yet overcoming energy, transportation, and communication challenges are crucial to progress.

The Strategy for Improving Infrastructure

The broad objective of the MVP infrastructure program is to reduce by half the number of people without access to modern energy, transportation, communication services and water and sanitation by 2015. Access is defined as a presence in the household or the community, meaning within two kilometers. The targets and strategies to achieve them vary:

- Energy interventions focus on electric grid extension, increased access to off-grid electricity, mechanical power and improved energy for cooking. A key objective has been to support and collaborate with governments and utilities to extend the electric grid "backbone" to more than 50% of a cluster's villages, providing power to markets and social infrastructure (schools, clinics, and government offices). In some

MVs, household connections are being promoted by limiting connection costs to $50, with the help of loans or installment plans. Where grid extension is not feasible, SharedSolar micro-grids (small systems serving 10–20 households) have been installed, and the project has invested in commercial supply chains for portable, rechargeable light emitting diode (LED) lanterns, which can also charge mobile phones. The project has supported the testing and introduction of efficient improved cookstoves by directly investing in large stoves for schools and establishing commercial supply chains for smaller household models.

- MVP aims to improve access to transportation, and to ensure that at least half of the community is within two kilometers of an all-weather road. It supports spot improvements, including installing culverts at water crossings and grading and surfacing dangerous slopes, with a focus on rehabilitating main village roads that connect the MVs to national networks. The MVP collaborates with governments, while engaging community members for improvements and maintenance. The MVP also implements community-managed transportation services, such as a community truck, emergency vehicles, and other vehicles for market transport. The MVP uses a model that manages the recurring costs, repairs and reinvestments of revenue arising from community-managed transport, with communities benefitting from and contributing to increased access.

- In ICT, the MVP supports access to mobile phone networks within two kilometers of 80 percent of households and basic data connectivity to key institutions (schools, clinics, and ICT kiosks) while introducing mobile phone-based health services. These objectives have been facilitated by partnerships with regional network operators, which have helped to expand and strengthen GSM network coverage. The MVP also aims to increase access to computers and the Internet in schools and communities, for instance, through the purchase of low-power and other technology innovations such as ChildCount (see Chapter 5).

The budget for the above interventions was $11 per capita per year ($5 for Energy, $5 for Transport, and $1 for ICT). This means that a cluster of villages with a population of 5,000 had an "infrastructure" budget covering these three categories of interventions of $55,000 per year, or $275,000 for the entire five-year project.

- MDG-related water and sanitation projects—improved drinking water access and irrigation—are administered in a site-specific manner. At some, a donation of piping has made possible piped water systems that supply clean water from boreholes to community taps. Most sites have programs to improve drinking water access by protecting springs from contamination. Irrigation programs have focused largely on the market-based provision of small diesel pumps that farmers can rent or buy, thereby contributing to a revolving fund for the future purchase of more pumps. The sanitation interventions have involved establishing incinerators at health facilities and improved latrines, primarily at schools.

The water activities were separately budgeted at $3.75 (roughly $4) per capita per year, or $18,750 per year for a village of 5,000. Over five years, the total water and sanitation budget for this population would be $93,750 (roughly $100,000). ■

CHAPTER 2

Lessons Learned and Policy Implications

Background / Introduction

Infrastructure planning and implementation involves specific issues of scale, timing and sequencing and relationships between planners, the community and collaborators; between infrastructure and other sectors it enables, and among infrastructure projects.

Some may simply be stand-alone equipment or products. For example, a community health worker might be given a cell phone and a solar lantern for fieldwork. A health clinic might require a few lights, a vaccine refrigerator, a microscope, a centrifuge, a small water pump for an overhead tank, a charging outlet and possibly a computer. A school meals program may benefit from fuel-saving cookstoves in kitchens with improved ventilation. As these examples illustrate, energy, water, and other "infrastructure" technologies often support activities in other sectors and must respond directly to those sectors' needs in terms of size, technologies chosen and the prioritization of their implementation. Other stand-alone technologies, such as a solar micro-grid, portable lanterns, or household cookstoves, may respond less to other sectors' needs, but may require collaborator support in areas such as business development.

Projects with increasing scale and functionality—such as large health centers, schools with computer learning centers, boreholes and larger market centers—tend to depend upon supporting infrastructure with greater capacity and scale, such as road networks, piped water systems, electricity grids, and mobile phone towers and antennae. These may involve higher implementation questions, such as collaboration with entities such as government or the private sector; implementation over long timeframes with multi-stage, phased construction; and coordination of larger systems, such as electricity and water pumping.

Recurring costs, maintenance, and sustainability are important issues from the outset. Even small systems that function largely in isolation usually require maintenance and recurring costs. Larger systems may initially plan features such as fee-collection systems and government partnerships for maintenance.

Lessons have emerged from the first five years of the MVP as crucial to the implementation of energy and infrastructure programs. Some are applicable at the community level, while others inform broader policy applications.

Lessons Learned from Field Implementation

The following ground-level lessons may be useful for planning and development teams working at roughly the district level, possibly in projects operating in several regions simultaneously.

1. Community linkages and institutional / governmental partnerships are crucial to an accurate and detailed understanding of the area, its needs and existing systems:

- Projects should work with community structures and government demographics and statistics offices to map and assess all settlements, infrastructure systems, and facilities (giving each facility a numerical ID). (See Appendix 1 for a GIS assessment tool)
- Projects should work with existing agencies, NGOs, governments at all levels and national utilities; learn local government systems and identify potential partner organizations to leverage skills, knowledge and government efforts.

2. In the first year, aim for immediate "quick wins" while doing assessments and planning new construction and basic services.

- Equip health workers with cell phones, chargers and portable solar lanterns. Health facilities should have minimum power required for essential services.
- Note gaps in health and education services: areas with poor access to health facilities, low coverage by health workers and poor coverage or overcrowding of primary schools. Plan new facility construction in a manner that leverages procurement at scale and employs low-cost designs.
- Plan school construction to provide the appropriate number of classrooms and gender-segregated latrines.
- Address long distances to cereal grinding/milling (>2km) by working with community/business structures to establish mechanical power services.
- Assess critical gaps in year-round drinking water access. This is the single most challenging task, and requires a combination of community, government and outside expert consultant expertise.

3. Following "quick wins", focus on medium-term project management and design, prioritizing:

- Establish an information management system to share infrastructure project information with multiple participants.
- Work with telecom operators to fill critical network coverage gaps.
- Identify community road and transport problems. Assess whether critical blockages make major roadways periodically impassable. Work with district road officials to prioritize repairs or new construction (culverts, bridges, spot improvements). Where transport services are inadequate, establish a "village vehicle" or similar transport service.
- Consider installing improved stoves in school kitchens to make meals programs more efficient.
- Initiate quick responses to drinking water issues, for example: protect spring catchments, shallow wells or boreholes. Address issues of effective water storage (particularly sub-surface), irrigation and drinking water as a single package.

4. Identify the primary drivers of income growth as high priorities to guide infrastructure planning. For example:

- Integrate electricity planning with plans for irrigation, agro-processing or refrigeration.
- Include transport planning—both roads and services—to ensure access to essential inputs and markets, and health services.

5. Encourage and facilitate standardization and modularization of electricity needs for health/education facilities.

- Difficulty and delay is often caused by an iterative dialogue across multiple specialists to estimate specific electricity needs for numerous, yet fundamentally similar, facilities, then design custom systems for each. An example is the practice of unique and detailed solar PV system specification for each clinic or school.
- Instead, encourage health and education sectors to identify categories of facilities (e.g., health post, dispensary, clinic) with common needs, then modularize the system design by category. Alternately, for facilities of variable size, such specifications would be tied to a clear metric associated with the facility, e.g. the number of classrooms.
- This modularization makes system provision tractable and efficient: Systems can be quickly specified, procured in bulk at a lower cost, and installed with known equipment lists, unit costs and timelines.
- Once such standardized needs and systems are identified, planning at larger scales (district, region or country) becomes easier, particularly with the aid of decision support software that allows data to be easily analyzed or visualized.

6. Local procurement vs. least cost international bulk procurement for solar modules, batteries and associated electronics.

- There are pros and cons to the local procurement of electricity systems (such as standalone or mini-grids). While local procurement supports local businesses, it can also increase costs, particularly in areas where markets are thin and local supply chains are not developed. High costs can force implementers to curtail the number of facilities served, reducing health, education and other MDG-related benefits.
- International bulk procurement, particularly of modularized systems, can reduce unit costs, increasing a project's impact. Moreover, the installation services, local construction materials, and maintenance services can still be locally procured.

7. Regional oversight of infrastructure projects is essential for fast implementation and lasting success.

- Infrastructure planning, especially of novel or unusual technologies, requires skills that may be of limited availability in rural areas, or needed only periodically and for short durations. Hiring experienced engineers/supervisors to oversee infrastructure work at multiple locations can increase effectiveness.

8. The following approaches can help finance initial and recurring costs.

- Public financing is generally necessary for construction of social infrastructure such as clinics, schools and roads. Anticipate the challenge of budgeting and planning for maintenance, since technical staff and transport can be rare and costly in rural settings.
- Local cost recovery is often possible for some portion of the initial expenses (e.g. household fees for electricity connections) and certainly for recurring costs (e.g. electricity tariffs or volumetric pricing of drinking water).
- Innovative ways to provide essential basic services—such as a minimum amount of free potable water or small quantities of electricity at reduced rates (using a "lifeline tariff")—should be investigated and implemented.

9. Planning and budgeting ongoing maintenance.

- Funding maintenance varies by location, sector, and project.
- In principle, grid electricity infrastructure is maintained by a utility, which recovers this cost through tariffs.
- For roads, this modality is generally not feasible, so one might need to budget as much as 10% of the

initial cost as an annual recurrent expenditure. Where possible, local support (particularly government ministries) should be enlisted for future maintenance. Where necessary (i.e. local support is not sufficient) budget should be allocated for continued support of large infrastructure even after the project ends.

- For water infrastructure, especially drinking water, key challenges are obtaining information on quantity of use and system condition, and ensuring timely repair of pumps that can be numerous, dispersed and difficult to reach. Here, novel information and communication technologies (as discussed below) can be vital.

10. New information and communications technologies enable improved infrastructure planning, data collection and management.

- Portable technologies such as smartphones and "tablet" computers that often connect to wireless networks (WiFi, mobile phone) can streamline and accelerate data gathering. These can be combined with data management systems to improve data compiling, monitoring and reporting. Examples include: ChildCount, Open Data Kit (ODK), and the SharedSolar Gateway.

- Planning and decision support tools, such as NetworkPlanner, can help to cost-effectively plan systems to meet infrastructure needs with strong geospatial components, such as electricity networks, or water kiosks.

Policy Implications

Many important issues relate to balancing objectives of, on the one hand, provision of key services and, on the other, establishing a sound basis for economic growth. Given the limited resources of development practitioners, tradeoffs must be considered in prioritizing physical facilities for social needs (schools and clinics) versus systemic infrastructure such as roads, ports, energy and irrigation. Local politics may advocate infrastructure for social services as a visible sign of local progress, since often governments or parastatals have failed to deliver on systemic infrastructure, even after the supposed investments have been made. This is especially true in places where the rural poor are the primary beneficiaries and recognize the immediate necessity of the services provided by schools and clinics, and there is hope that those facilities will in turn bring teachers and health workers.

Systemic infrastructure, on the other hand, can serve as an engine of broad economic growth, potentially lowering transport and processing costs, and allowing for—at least in principle—the idea that such infrastructure for electricity can be well maintained by a utility and hence lower energy costs. The argument is that with raised income levels, populations are better able to feed themselves, the nation can generate internal resources to fund wider facility construction, and the infrastructure makes it easier to attract skilled personnel for the provision of social services. Furthermore, the creation of systemic infrastructure reduces the costs of stand-alone systems.

Given the urgency accorded to health and education in the MDGs, a rapid roll-out of a stand-alone system is sometimes seen to provide an immediate solution, particularly since progress in systemic infrastructure has proven sluggish.

Alongside electricity, roads and water networks, information and communications infrastructure is growing rapidly. The latter includes not only mobile telephony and mobile data, but also systems for mobile exchange, banking and credit, as well as data gathering and software for information tracking and data management. These new systems are becoming increasingly important to enhance opportunities for the poor and improve the efficiency and transparency of the development processes.

The following policy lessons are drawn both from experience gained from on the ground implementation and in working with governments, utilities, international banks and donors, and other key participants and stakeholders.

ENERGY

Electric power has historically been the most difficult infrastructure to implement in Sub-Saharan Africa (SSA), despite leaders in government and international development banks recognizing its critical importance to development. Electricity is among the most politicized sectors. Moreover, the pervasiveness and rapid expansion of cellular telephony have raised expectations for governments to deliver high-quality electricity services to rural areas of SSA.

Africa faces a double disadvantage when it comes to grid extension. The density of demand is low, due to low population densities and the often dispersed nature of settlements; and the unit cost of deployment is high due to thin markets, emerging industrial capacity and the high cost of transport. Implementers must take advantage of high densities where they do exist, while at the same time addressing cost reductions through proper design and procurement.

Rural households are willing and able to pay for reliable electricity: A common assumption is that the poor cannot pay for power. However, initial household survey work in the MVP shows that a significant proportion of rural households might be willing to spend as much as $5 per month on electricity if each household had a wire to the home. Instead of a large backbone of transmission lines, one option is to explore a more decentralized generation option paired with low voltage distribution lines. This approach allows the early deployment of low wattage "micro-grid" systems (less than an amp or so at 220V), which are modular and can be scaled up as demand grows and investment capital becomes available. An intermediate-scale investment in small micro-grids creates an "incremental infrastructure" approach that is smaller and more automated than typical diesel mini-grids, making management easier and more cost-effective.

Good Management and Recovery of Recurrent Costs: Many countries have split vertically integrated electricity monopolies, separating them into 1) power generation, 2) power transmission and 3) power distribution, as is the widely accepted best practice today. Ensuring that recurrent costs are recovered can ensure financial health of utilities. Cost control and the accelerated rollout of electrification, especially in dense areas, can further strengthen utilities.

Develop Regional Linkages for Cross-Border Electricity Distribution: Africa still has substantial low-cost energy sources, such as hydro and geothermal sources that are yet to be developed. In addition, new developments in technology and learning allow energy sources to be tapped with a much lower environmental impact than decades earlier. These hydro and geothermal resources necessarily require multi-country transmission systems. The World Bank and the African Development Bank have been successfully working towards increasing regional connectivity through encouraging dialogue and developing some important regional linkages. Stronger cooperation among countries will lead to lower cost electricity for both the power supplier and the recipient countries.

Address the factors limiting IPPs in Africa: Independent Power Producers (IPPs) have the potential to flourish in Africa, provided that uncertainty and long waiting periods for new energy projects can be reduced, providers can have more autonomy in tariff setting, and assistance with project preparation can be provided. Removing such barriers would enable increased private sector engagement in IPP contracts, working together with small franchisees, allowing numerous "medium scale" (10 MW to 200 MW) power generation projects to come online to meet rural power needs. The following could enable this process:

- **Create a Core Team of Specialists to Facilitate the Entry of IPPs:** There is a need for a "broker" between the government and the private sector that does the due diligence of assessment, project preparation and economic analysis. This assistance could be provided by a team—or "project preparation facility," at an organization such as the World Bank or AfDB—that would build planning capacity and develop projects in countries throughout SSA, preferably in the form of prospectuses for energy sector wide programs. The proposed team would work closely with national energy ministries, utilities, and other relevant planning entities to gather national and multi-country data, then deploy software and decision support tools to assist planning. Currently, valuable time and financial resources are lost contracting for these skills. Moreover, electricity planning work gets repeated without a deeper accumulation of knowledge or capacity building at the national level. In contrast, the proposed "facility" would have the institutional longevity to build a base of experience and knowledge, both regionally and in individual countries, while establishing local partnerships in universities and research institutes.

- **Medium-Scale IPPs can be Attractive Investments when Costing is Done Correctly:** There are many potential "medium scale" hydro, wind, solar-hybrid and biomass projects on the African continent whose construction and technical implementation can be done quickly, but which face lengthy and complex start-up processes. Though they are "medium scale," the processes and scrutiny for these IPPs are similar to those of larger projects. This results in high transaction costs relative to the project's size, fostering reluctance to adopt IPPs. In effect, upfront investment of money and time is squelching potential opportunities. These medium-sized projects could be designed with the technical assistance of the team or "facility" proposed above in order to reduce the risks and costs that the private sector faces in gathering all the information to determine the viability of these IPPs. These medium-scale IPP projects start to look financially attractive when it's not forced to bundle in reinforcements of existing transmission systems, and when it's allowed to locally charge higher tariffs for electricity in more remote areas. Project viability would be further improved by incorporating technologies that improve cost-recovery, such as the best tamper-proof distribution, prepayment meters, and efficient end-use appliances.

Urban-Rural Linkages are Crucial: While much of the discussion about solving solving agro-processing and energy challenges is about rural areas, an urban focus is also important. Urban areas are engines of non-agricultural growth, and entrepreneurial activities in these areas tend to be much higher. In this vibrant setting, it is critical that industry, manufacturing and services all have reliable infrastructure and services, since unreliable electricity, water and transport can hinder competitiveness. Urban-rural linkages are also crucial for rural areas, creating opportunities for rural investment, income generation, acquisition of new skills and talent. However, network infrastructure expansion into rural areas should be supported by other necessary improvements, such as added generation capacity to supply electricity demand in rural areas.

Modern Household Energy Technologies Can Be Introduced To Rural Areas Through Market-Based Programs: Experience in the MVs shows that small, household-scale modern energy products can be distributed through market-driven systems.

- **Households will pay full cost for solar rechargeable LED lanterns.** Multiple manufacturers offer portable LED lighting devices with solar panels, a rechargeable battery and charge-discharge control circuitry at a total retail cost of less than $50, which provides more light at the same or lower cost relative to kerosene lighting. Households have purchased these at full price and used them for durations of a year or more, giving consistently favorable reports of usability and quality.

- **Households will pay for improved stoves with some subsidy.** Improved, imported cookstoves, with high quality control in manufacturing, offer fuel savings of roughly 30-35% relative to the traditional three-stone fire. MVP programs have verified that households will purchase these stoves, typically at ~50 percent subsidy.

- **Supply chains are the primary challenge:** Availability, not cost, has been the key limiting factor in sales of both lanterns and stoves. For sales to scale rapidly, supply chains for sales and service (including battery replacement and warranty fulfillment / replacement for faulty appliances) require rapid scale-up to reach beyond towns and cities all the way to the village level.

- **Favorable tax policies for these technologies are a key factor in maintaining affordability:** Import duties, VAT, and similar costs add up quickly to make lanterns and stoves unaffordable to many village-level consumers. Exemption of household energy products from these costs can help sales expand rapidly.

ROADS AND TRANSPORT

- **Spot improvements are typically a cost-effective manner of improve road networks:** Targeted improvements toward specific infrastructure (culverts, bridges) or impassable segments of roads can improve transport quickly and cost-effectively.

- **Planning Must Account for Maintenance Costs:** In rehabilitating and constructing roads in the MVP, it is clear that roads projects do not stop after the original investment. Roads need to be maintained, and these maintenance costs are generally about 10% of the total cost of the road.

- **Particularly for remote localities, interventions that fill gaps in transport services can have important impacts at relatively low costs:** A “village vehicle” that offers cargo transport services can reduce costs to reach distant markets and improve incomes for villagers while recovering some costs through user fees. Other transport services that can advance the MDGs include time-saving means to get to school; ambulance services for medical emergencies; or less burdensome means of local transport (such as “intermediate” technologies like carts or bicycles)

WATER AND SANITATION

- **Governments in sub-Saharan Africa typically lack funds for capital investments** to meet the water- and sanitation-related MDGs, and most countries rely heavily on donor financing to fill this budgetary gap. But conditions placed on donor funds may require African governments reprioritize their own budgets and workplans, sacrificing control over projects and budgeting[3].

National and local governments have a number of alternatives when drafting water supply development plans. Appropriate solutions vary tremendously from place to place, depending on numerous factors, such as water resources, socio-economic standing of the users, existing infrastructure, availability of energy and topography. This high variability means that there is typically no simple method based on demographic data alone to estimate the costs or type of water infrastructure. In most cases, local expert knowledge is required to evaluate the multiple variables that will inform the choice-of-technology.

- **Technology now Exists to Make Lifeline Tariffs Viable:** Historically, “lifeline tariffs”—provisions to supply a certain minimal quantity of water daily at little or no cost -- have been difficult to implement at existing kiosks due to the high costs of monitoring. Now, emerging technology that allows for remote monitoring of consumption can reduce costs and increase the feasibility of creating lifeline tariffs at water points.

Role of information management

Though often overlooked in infrastructure deployment, information management can enable project planning, implementation and management, by, supporting efficient communication between all levels of

3. Campos, Ed and Pradhan, Sanjay, Budgetary Institutions and Expenditure Outcomes: Binding Governments to Fiscal Performance (September 1996). World Bank Policy Research Working Paper No. 1646

Bicycles as an intermediate form of transportation, Mwandama, Malawi

development organizations, governments and the public, and facilitating transparent financial management within projects. Greater access to information and communication technologies (ICT) has demonstrated numerous livelihood benefits. Information technologies—such as mobile phones, Internet connections in schools and community centers and radio—can enable training of health, education, agriculture, and water personnel. They can allow better management of health delivery systems. Timely information on markets and prices, weather, and off-farm labor can also aid livelihoods. ICTs can be used to improve access to credit and remittances, as well as information on creating and managing businesses. Health benefits may include more timely access to emergency medical transport and services as well as better health information. Radio instruction and Internet access can further education while better access to communications empowers people, increasing the impact of stakeholders' voices. These benefits are often inter-related, and may involve more than one ICT technology. For example, a community radio program links listeners to the Internet in response to requests from callers using mobile phones. Electricity can be supplied using prepaid electricity transactions with a "pay-as-you-go" model that does not regressively penalize small purchases. A Web-based system can provide status of maintenance complaints and real time performance statistics. ■

CHAPTER 3

Project Operations

Project management structure

The project management structure for the MVP is based on a partnership model involving three institutions, each playing a complementary role: the Earth Institute at Columbia University, Millennium Promise, and the United Nations Development Programme (UNDP). The Earth Institute (EI) is the lead partner responsible for the development of the project's strategy. The EI has two Millennium Development Goals (MDG) Regional Centers, one in Bamako, Mali covering West and Central Africa and other located in Nairobi, Kenya covering East and Southern Africa.

Millennium Promise (MP), an international NGO, managed private and public sector donors. MP also provided management, operations, and logistical support.

The UN Development Programme (UNDP), World Agroforestry Center (ICRAF) and Millennium Development Ethiopia (MDE): UNDP has been instrumental in the financial management, administration, contracts and procurement aspects of project implementation through its offices in eight of the ten MVP countries. Two international research institutions, MDE and ICRAF, perform similar roles in Ethiopia and Kenya, respectively.

THE INFRASTRUCTURE TEAM IN THE FIELD

The MVP field team has a leader who is responsible for planning, budgeting and implementing activities. He/she receives technical support from the MDG regional centers and the Earth Institute in New York and operational support from UNDP and MP. Each site has a senior infrastructure coordinator, and most sites also have a senior water coordinator. They work in close collaboration with staff for other sectors (health, education, community development, etc.). As infrastructure activities expanded, the MVP incorporated two regional infrastructure coordinators, based in Bamako and Nairobi, to assist with procurement, logistics and technical issues. These regional coordinators have been instrumental in expediting the implementation of large civil works projects. In addition, consultants were hired to support sites in areas that required short term but highly specialized expertise (lanterns, stoves, SharedSolar off-grid programs, etc.)

IMPLEMENTING AN INFRASTRUCTURE PROGRAM

Infrastructure programs in the MVP have generally been implemented in five phases:

1. SITE ASSESSMENT AND GEOGRAPHIC SURVEY

The first step was to carry out a detailed assessment and geospatial survey, including: key qualitative questions regarding prevailing technologies and local practices (types of fuels and stoves used for cooking, etc.); quantitative information generally applicable locally (such as retail prices of different energy technologies and carriers); and a detailed specification for the collection of spatial data using a combination of maps, local knowledge, and hand-held GPS units. The information included population points, markets, institutions (schools, clinics, government offices), roads, electricity lines, water points, and other existing infrastructure, key resources, or locations of importance.

Consulting with the government and tapping into complementary local knowledge greatly improved results, since detailed assessment may have been already collected. With the rapid development of mobile applications, data collection tasks and mapping are becoming easier even in remote rural areas. Once a good map of the area was completed, there was an initial assessment of existing infrastructure (type, standards, quality, condition, ownership, etc.) to create a solid baseline for planning. The MVP team was then ready create a five-year overall plan that was reflected in the subsequent annual work plans and budgets.

2. PLANS AND BUDGETS

These are developed annually by the MVP site teams in consultation with partners and communities.

Annual budgets have three points of reference:

- MVP model budget annual allocation by sector (see table below)
- EI technical advice on MDG-related targets and best practices
- Adaptability to local circumstances (consultations with community and local partners)

Teams have consultations with communities and local partners facilitated by a team leader. Ideally, they coordinate with local governments to make the most effective use of limited resources, particularly for ex-

Table 3.1: Financial Allocation by Sector

MVP Financial Guidelines: Allocations by Sector		
Sector*	**Percent Allocation (%)**	**Per Capita Allocation ($)**
1. Agriculture and Nutrition	15%	$7.50
2. Education	15%	$7.50
3. Health	35%	$17.50
4. Water and Sanitation	7.5%	$3.75
5. Environment	2.5%	$1.25
6. ICT	2%	$1.00
7. Energy	10%	$5.00
8. Transport	10%	$5.00
9. Community	3%	$1.50
Sub-total: Interventions	100%	$50
Sub-total: Management	—	$10
Totals	—	$60

tension of infrastructure (roads, electricity and water). However, the focus on multi-sectoral, MDG-related objectives implemented on an accelerated timeline, and the small geographic area targeted may not coincide with those of the local government. Some MVP strategies to overcome this include:

- Developing contingency plans in case government contributions are delayed or not forthcoming (i.e. SharedSolar as an alternative to grid extension).
- Working with governments on their efforts to meet "natural" targets, while addressing other areas that are less of an official priority.
- Train community members for labor-based implementation where appropriate.

3. TECHNICAL DESIGN

It is crucial to include documentation defining the technical, economic and institutional framework of projects, including ownership, operation and maintenance plans. When possible, the designs for MVP have been done by the local infrastructure coordinators with support from the government engineers. Sometimes external consultants have been hired to complement local expertise. The primary challenge the MVP has encountered is overdesign. This is often caused by an effort to meet high national standards, or the perception that as an international NGO, the expectations and budget of MVP must be extremely high. Technical design should, of course, be based on sound standards, but it also must be adapted to local circumstances as well as the priority of reaching the largest possible population for a given investment. For example, spot improvements of roads (i.e. fixing culverts, steep slopes and other problems that prevent access) is an excellent, cost-effective strategy for rural areas. The construction standards of schools, clinics and staff houses is sometimes overly ambitious. The MVP has tried to adapt to local circumstances in order to strike a balance between efficiency and economic feasibility.

4. PROCUREMENT OF EQUIPMENT AND CIVIL WORKS

There is a need to balance the priorities of ensuring transparency and accountability and the timely and efficient execution of projects. When conducting procurement and awarding of construction or civil works projects, the basic thresholds used by the UNDP, have been:

- Up to $30,000 → Invitation to Bid (ITB) Simplified process
- $30,000—$100,000 → Open bid, nationally advertised (three quotations needed)
- More than $100,000 → Open bid, internationally advertised

Delays in procurement have mainly occurred during the evaluation of the financial and technical capabilities of bidding companies. The limited capacity and/or experience of various participants together with the tight regulation of some of these processes have resulted in long delays. One partial solution that has sometimes worked well is to conduct a prequalification of companies so they are effectively pre-vetted and, for a period of time, can bid with simplified checks mostly based on economic offer.

Regarding the procurement of international equipment such as water pumps, solar panels, batteries and LED lanterns, weak supply chains, customs delays and high transport costs are still very common in the MVP intervention areas, resulting in high prices and long delays in delivery. The MVP has found that bulk international procurement reduces costs and delivery time by almost half. The MVP has started to purchase most of these items internationally and send them in bulk containers to sites, reducing costs and expediting the implementation of projects.

5. IMPLEMENTATION/OVERSIGHT

In most cases, infrastructure and water coordinators, with support from the district engineers, have acted as project supervisors for infrastructure projects. In countries like Mali, an external consultant reinforced the supervision and quality control of all the civil works construction.

Quality Control of Materials: To ensure the use of good quality materials for the civil works, suppliers and manufacturers were asked to provide certificates of test. Where such certificates are not available, representative samples of the material were tested to ensure quality.

Cost Control and Payments: The MVP Infrastructure Coordinator is responsible for the assessment of the economic, technical, administrative and financial effectiveness in the use of resources on civil works projects.

Coordinating Community Labor-based Implementation: Community contribution gives beneficiaries a greater sense of project ownership. Tasks include maintaining small feeder roads, digging trenches for water pipe installation, brick making and constructing facilities.

Dilapidated school, since replaced by MVP, in Sauri, Kenya

Maintenance and Sustainability

As with most projects targeting poor, rural areas, maintenance and sustainability of interventions are two of the MVP's biggest challenges. Where possible, the MVP is handing over maintenance and existing infrastructure to communities, local governments, utilities or other authorities. For public works such as roads, clinics and schools, funds must be in place to ensure their proper maintenance and function. Since there is little capacity at the local level for tax collection, most of these funds have to be gathered via government transfers. The MVP and other projects should lobby the government on behalf of the site to ensure that adequate funds are allocated for new facilities. When necessary (i.e. local support is not sufficient,) budgets should be allocated to the continued support of large infrastructure works.

In the case of water and electricity, local cost recovery is possible for both initial costs (e.g. households' fees for electricity connections) and recurring costs (e.g. electricity tariffs and user fees for drinking water). Building capacity for small operators or local communities is key for the long-term sustainability of the infrastructure. New mobile applications can help to improve collection of payments as well as the provision of lifeline services for the poorest. ■

CHAPTER 4

Technical Solutions, MVP Infrastructure Program

The Millennium Village Project aimed to improve the lives and livelihoods of rural populations by undertaking a range of infrastructure interventions. Electricity services (grid connections, solar power), roads, water (irrigation, pumping and piping), improved cookstove programs and solar LED lantern programs were implemented across sites. The nature and scale of the projects depended on the needs of the site, as identified by the site team, and the available budget. The following details the strategy, process and progress of each of the energy and infrastructure sector technical solutions.

This chapter frequently makes references to data obtained from various sources, one of the most important being the MVP household surveying program. Summarized briefly, the MVP survey effort included a baseline and two follow-up surveys of households in each MV cluster, using several structured household questionnaires covering several sectors (health, agriculture, energy and transport, etc.) More information about the MVP surveying efforts can be found at: http://millenniumvillages.org/progress/monitoring-evaluation/ .

Electricity in the MVP

Reliable, modern energy services, particularly dependable, affordable electricity, are key to improving the health and welfare of the world's poor. Electricity in homes enables lighting for children's studies and home-based income generation. Power for markets and communities supports various income-generating activities and provide a lower-cost alternative for high power demands such as pumping for irrigation or drinking water and motive power for grinding, milling, and other agro-processing2.

However, the poorest, especially in rural areas, typically have access only to costly and unreliable energy. Essential household needs, such as lighting or mobile phone charging, are usually met by technologies that are dirty and expensive, such as kerosene wick lamps and torches powered by dry cell batteries. Compounding these issues, access to these energy sources may also be available only at substantial distances. Off-grid electricity systems—such as diesel gensets or solar photovoltaic systems in health facilities, schools, and markets—often suffer from a range of problems related to improper sizing, unmet operating and maintenance costs and poor management.

Figure 4.1: Grid Extension Mbola Cluster

The MVP has defined the following targets:

- Community-level electricity service to all markets and 50 percent of cluster households (defined as grid access to the home or within two kilometers).
- Social infrastructure (health facilities, schools, community centers and other public buildings) outfitted with electricity as deemed necessary by those sectors, in coordination with government ministries.

To achieve these objectives, the MVP has employed three primary electricity strategies targeting homes, marketplaces and social infrastructure:

1. EXTENSION OF THE ELECTRICITY GRID

The cost of grid extension, and thus the viability of electricity access programs, varies greatly, depending upon factors such as population density and settlement patterns, household electricity demand, efficiency and the effectiveness of utilities in construction and cost-recovery, the availability of key materials and equipment within the country. Table 4.1 shows the cost range for medium voltage (MV) and low voltage (LV) line per km in the projects where MVP contributed substantially to funding, or solicited cost estimates to do so.

Table 4.1 Cost of Grid Extension for Medium (MV) and Low voltage (LV) line, $ per Kilometer

Site		MV (Avg: 33/11 kV)	LV (220 V)
Country	Cluster	US$ / km	US$ / km
KEN	Sauri	$25,600	$8,500
MWI	Mwandama	$ 29,000	$ 16,000
RWA	Mayange	$ 48,046	$ 18,000
TZA	Mbola	$ 33,520	$ 19,633
UGA	Ruhiira	$ 40,000	$ 20,000
GHA	Bonsaaso	$ 13,000	$ 10,000
MLI	Tiby	$ 28,500	N/A
NIG	Pampaida	N/A	$ 9,868
SEN	Potou	$ 17,688	$ 15,477
AVERAGE		$ 29,419	$ 14,685
MAX		$ 48,046	$ 20,000
MIN		$ 13,000	$ 8,500

Table 4.2: Estimated Percent of Population with Grid Access at the Community Level (within 2 km): Baseline and Year 5.

Site	Percentage of population with grid access at community level (within 2 km of household)		
	Baseline	Year 5	Notes
1. Koraro	30 %	> 80 %	
2. Dertu	0 %	0 %	Grid deemed infeasible for this site
3. Sauri	60 %	80 %	
4. Gumulira	0 %	0 %	Budget limits prevented grid extension
5. Mwandama	< 10 %	50-60 %	
6. Mbola	30 %	35 %	(SharedSolar being implemented)
7. Ruhiira	0 %	13 %	(SharedSolar being implemented)
8. Mayange	20-30	60 %	
9. Tiby	0 %**	0 %	(SharedSolar being implemented)
10. Bonsaaso	0 %	70-80 %	
11. Potou	0 / 30%	50–60 %	
12. Toya	0 %	0 %	Grid deemed infeasible for this site
13. Pampaida	20 %	50 %	
14. Ikaram***	> 90 %	> 90 %	

*A gridline existed in Potou, but was not yet electrified at the start of the project

*A diesel mini-grid system provided inconsistent service to roughly 20% of the cluster at baseline.

**Grid coverage was nearly universal in Ikaram at the start of the project.

These data are insufficient for a detailed examination of all the factors influencing grid extension costs in various countries. Nonetheless, it is important to note that—particularly if planning covers a long (10-20 year) timeframe and a sufficiently large scale and population (roughly the district level or above)—unit costs for widespread electrification can be reduced substantially through what is sometimes referred to as a "mission-oriented" approach. This approach emphasizes features such as bulk procurement to reduce equipment costs, lower connection fees to raise penetration rates and better metering and management to improve the recovery of operating costs for dramatic overall cost reduction. Important examples in Tunisia and South Africa (among other countries) have carried out national electrification programs at remarkable rates, in a cost-effective manner.

In rural areas, population densities and consumption levels are such that the initial costs of grid electrification can be as high as $1000 per household. In such settings, while connections to households and businesses should be achieved where possible, it may be most cost-effective overall to target grid connectivity in key markets and trading centers, and social infrastructure such clinics, schools and government offices.

In much of Sub-Saharan Africa, if the distance to extend the grid is on average less than two kilometers per community, and each community averages 2,000 people, and extension costs are below $25,000 per kilometer of MV line, then an initial investment of $50,000 per community represents a $25/capita initial investment. This is a reasonable investment for the benefits of a low cost, load-following, scalable electricity supply, even if reasonably reliable grid power is available. With tariffs typically between $0.10 - 0.25 per kWh, the recurrent costs in terms of actual electricity supply costs for such an investment are affordable.

Unfortunately, in much of Sub-Saharan Africa, access

Figure 4.2: Solar Electrified Clinic Mbola

to modern energy services remains limited. This trend has been reflected at all the Millennium Villages except Ikaram, Nigeria. Thus, a central part of the MVP energy strategy has been to support the extension of the electricity grid to communities, households and key demand points such as social infrastructure in three ways:

First, MVP encourages grid extension indirectly, through non-grid related investments in communities, such as in the construction of clinics and schools and a range of interventions that promote higher incomes. Such investments in public facilities and programs raise the benefits of grid extension by enabling government ministries to improve the quantity and quality of related services. Meanwhile, investing in household income-generation raises the benefits of grid extension for utilities by strengthening and expanding their client base of household ratepayers.

Second, the MVP supports grid extension directly, by funding in full or in part the extension of both low and medium voltage grid lines. This strategy can be particularly important in extending the grid to key demand points, such as water pumping or agro-processing sites, or to small population centers, which may not be part of government or utility grid extension plans. The strategy targets larger and/or more aggregated population centers where grid extension will have the most impact. Crucially, MVP strategy holds that grid extension should be complemented by other technologies, such as off-grid power systems and portable lanterns, particularly for household electricity needs in areas where grid extension is not cost-effective.

Third, where the grid is extended, a related aim is to promote electricity connections to households and businesses by reducing fees and administrative barriers. This may mean financial support for communities or individual customers (households, businesses) or assistance in community organizing and sensitization efforts. Whatever the specific strategy, a key goal toward increasing penetration rates has been to reduce connection costs for the consumer to about $50.

Furthermore, energy projects were designed to reduce the time and effort spent on grinding grain and other agro-processing activities, as well as lifting water for drinking or irrigation. These MVP energy interventions reduced the time-labor burden on women and encouraged economic growth through increased agricultural yields.

Table 4.3. Cost of Institutional Solar Photovoltaic Systems (US$ per peak Watt installed)

Country	MVP Cluster	Year	Number of Systems	Average Cost (US$/Wp)
Senegal	Potou	2007	6 systems	$ 17.85
Ghana	Bonsaaso	2007	6 systems	$ 9.59
Ethiopia	Koraro	2008	15 systems	$ 26.78
Mali	Tiby	2007	7+ systems	$ 15.72
Tanzania	Mbola	2008	7 systems	$ 22.54
			ALL SITES HIGH	$ 26.78
			ALL SITES AVERAGE	$ 18.50
			ALL SITES LOW	$ 9.59

2. OFF-GRID STANDALONE SYSTEMS FOR KEY SOCIAL INFRASTRUCTURE

While modern energy services provided by grid electricity should ideally be available to all communities and households, in many locations a grid connection is simply not cost effective in the next 5-10 years. Under these circumstances, off-grid approaches can provide reliable energy for essential services—particularly for urgent health needs—without delays.

For initial demands of less than 4 kWh per day, which is likely at small clinics and schools, the most likely choice is a solar PV system with battery storage. For every kWh of daily use, an approximate upper limit for a small clinic, the expense is about $5,000 in initial system costs (see Table 4.3 for costs in practice).

Off-grid approaches that rely on high initial cost per unit capacity (e.g., solar systems) will need to ensure that operations, maintenance and reinvestment (particularly in batteries) are planned and budgeted. Related concerns include ensuring the proper training of site personnel, choosing the type and number of electric appliances to ensure demand is manageable and ensuring a thorough understanding of cold chain requirements.

At consumption levels above 4 kWh per day, or in locations with poor solar insulation (such as coastal areas of West Africa), other options, such as hybrid solar-diesel options, or relying on gensets during peak load times, should be considered.

3. MICRO-GRID (SHAREDSOLAR) FOR HOUSEHOLDS, MARKETS, AND OTHER OFF-GRID SITES

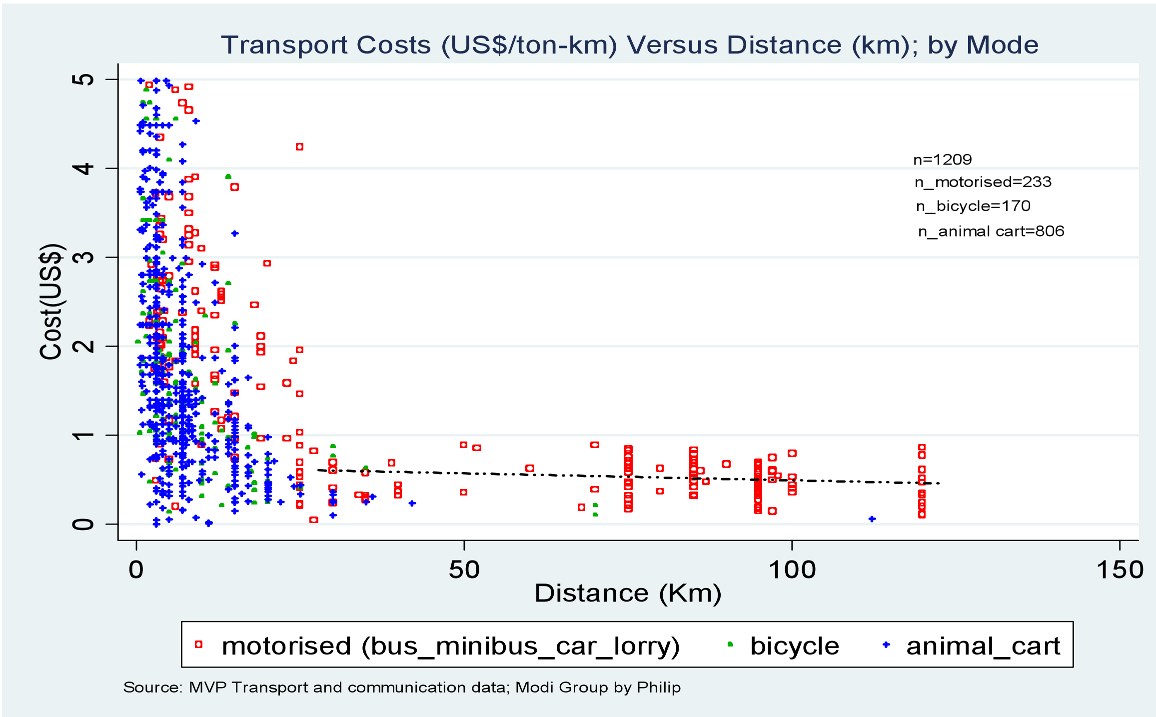
Solar home systems have typically been unaffordable for most households in the MVP locations and typically provide too little power for business needs. Generators, while popular in shops, are typically used only for limited applications, due to high fuel costs and the short operating life of very small petrol engines.

In response, MVP has taken two complementary approaches. For very small power needs in households (room lighting and mobile phone charging), MVP has developed distribution programs for portable, solar, rechargeable LED lanterns, generally with bulbs and panels of roughly one watt. For higher wattage needs in homes and businesses, MVP has introduced a novel electricity technology, SharedSolar, employing solar photovoltaic electricity generation coupled with an automated metering and payment system in which users purchase scratch cards and receive prepaid, metered power in their homes on a pay-as-you-go basis. (see Chapter 5.) Diesel mini-grids, particularly when implemented with careful metering and attention to the efficiency of end-use devices, is another option, as are portable batteries, recharged centrally and carried to the home.

These technologies are considered transitional in that they provide rural areas with an increased range of electricity options, at various costs, for immediate scale-up until access to the power grid becomes locally viable, as is likely with economic and population growth, or gradual grid expansion nearby. The low up-front costs of such solutions are key in that they allow them to be easily replaced. The higher recurrent costs of such technologies are less of an issue since consumption levels are likely to be low during this transition. For example, the generation and fuel costs of diesel-based electricity do not exceed $0.40/kWh if diesel costs are below $1/liter. Even at this relatively high generation cost, the recurrent electricity expense is still lower than the recurrent cost of kerosene for lighting currently being shouldered by many rural poor.

It is important to note that as population, incomes, costs and technologies change, other technologies may become more cost effective. Renewable energy technologies, particularly solar photovoltaic with battery storage, may be the cheapest option in conditions where power demands are small and fuel is hard to obtain reliably. Decentralized energy systems may also permit the use of local biomass to produce electricity (e.g., via biomass gasification). If such systems can be scaled down to one or several households and made low-maintenance, they could potentially become the preferred electricity source for rural areas

Figure 4.3: Transport Costs (US$/ton-km) Versus Distance (km) by Mode



Roads

TRANSPORTATION SERVICES

Transport in most poor, rural areas means walking long distances carrying heavy loads. Some modern transport services that are widely recognized include motorized ambulance services for medical emergencies; faster means of getting to school and less burdensome means of carrying goods to market, or just to the roadside. These interventions often rely upon motorized vehicles, but may, be intermediate transport technologies, such as carts or bicycles. Road improvements themselves are crucial.

An analysis of the MVP transportation data and patterns shows, the costs of transport are high and highly variable for distances up to 10 kilometers and reduce gradually for longer distance across all modes. Non-motorized transport is mainly used for distances up to 20 kilometers, while motorized transport is mostly used for longer trips, at a much lower and stable price of around $0.65 per ton-kilometer. The cost of moving commodities is high—above $2 per ton-km for distances up to 5 km but below $2 for distances above 5 km. The implication of these findings is that the market/trade for non-grain goods is localized while that of grains is diverse.

ROAD ACCESS

Road improvements can both enhance transportation and build local capacity. Villagers' participation in planning, constructing and maintaining road works can build local knowledge and capacity while establishing links and influence with local government.

The MVP has defined the following targets:

- Community-level road access to all market centers and (50-80%) of households (an all-weather road within 2 kilometers of the home)

Table 4.5: Costs of Moving Grains and Non-Grain Commodities

	Average costs in in US$ per ton-km with standard deviation (in parentheses); and n, number of observations									
Goods Transported	0-5 km		5-10 km		10-15 km		15-20 km		>20 km	
	Costs	n	Costs	n	Costs	n	Costs	n	Costs	n
Grains/Cereals	2.79 (1.15)	99	1.58 (0.77)	89	1.29 (0.81)	37	0.66 (0.25)	17	0.65 (0.61)	65
Fruits/Veg/Nuts	2.56 (1.13)	218	1.69 (0.88)	77	1.48 (0.51)	13	1.35 (0.47)	4	0.71 (0.71)	42
All goods	2.63 (1.14)	317	1.63 (0.82)	166	1.34 (0.74)	50	0.79 (0.40)	21	0.70 (0.63)	197

- All-weather road access for social infrastructure (health facilities, schools, community centers and other public buildings) as deemed necessary by those sectors, in coordination with government ministries.

Main interventions for this sector:

- Construction of new facilities: This reduces the distances that villagers need to travel for essential services. Also, the investment by MVP increases the likelihood of government maintenance.

- Provision of transport services: This may include a cargo truck that functions as a "village vehicle" to improve market access, or a program to introduce "intermediate" technologies (carts, bicycles, etc.) for local transport.

- Construction and rehabilitation of roads: While this typically includes some new construction, the majority of the Project's work follows a "spot improvement" approach.

Data on MVP roads rehabilitation projects provide the following information on costs per kilometer. Generally, these refer to gravel roads six to seven meters wide, including culverts and small structures and side drainage. Key factors affecting costs include local topography, thickness of gravel layer and quality of materials.

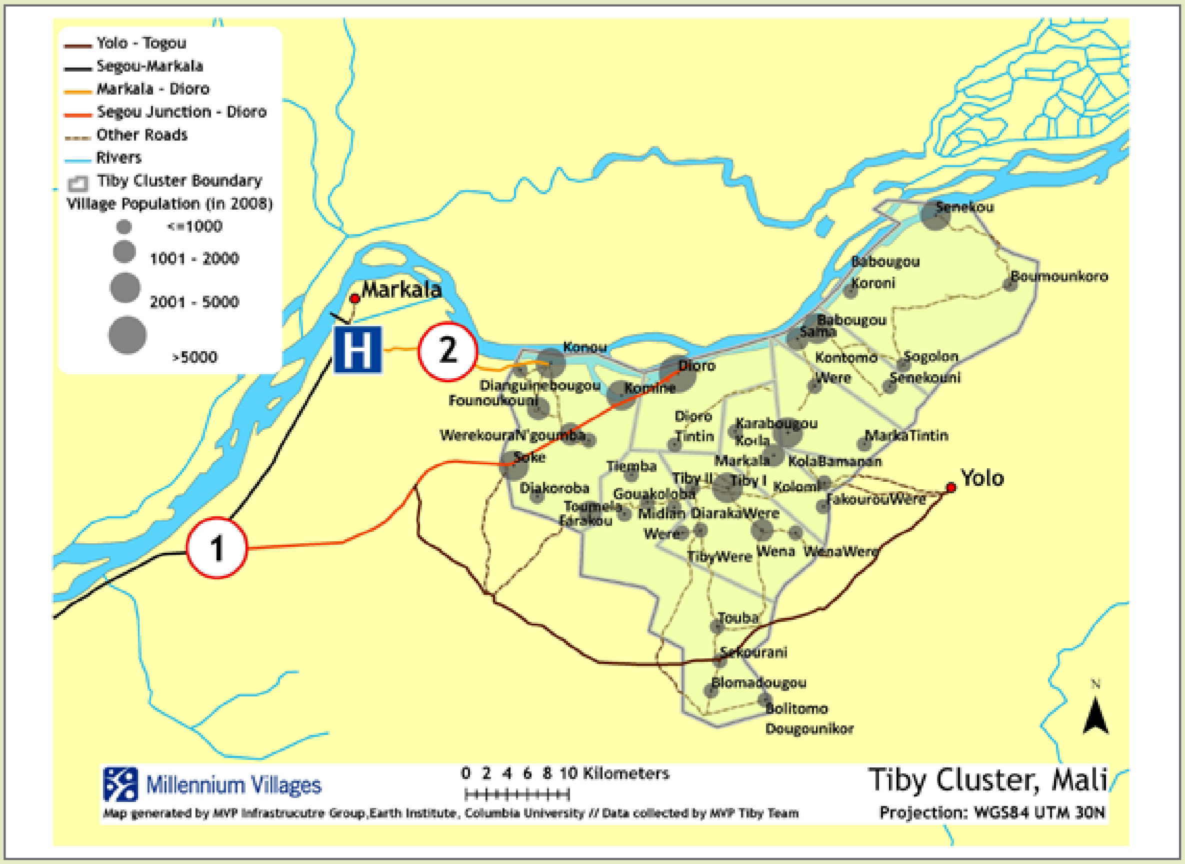
Table 4.6: Road Rehabilitation—average cost per km

Country	MVP Cluster	Year	Kilometers of road rehabilitated	Average Cost ($/km)
Senegal	Potou	2009	18 Km	$ 17,590
Ghana	Bonsaaso	2011	17 Km	$ 18,775
Ethiopia	Koraro	2010	23 Km	$ 30,435
Mali	Tiby	2010	65 Km	$ 13,500
Tanzania	Mbola	2010	13 Km	$ 21,154
			ALL SITES HIGH	$ 30,435
			ALL SITES AVERAGE	**$ 20,291**
			ALL SITES LOW	$ 13,500

Village Vehicles in Koraro and Dertu

At baseline, the lack of available transportation to nearby towns was one of the main problems for villagers of Koraro, Ethiopia, and Dertu, Kenya. Transport of farm produce, animals, materials such as building supplies, and people were all severely limited, and, when it was available, it was expensive. To improve this problem in Koraro, in early 2006, MVP helped obtain a community-run NPR ISUZU truck. The truck is managed by a Track Managing Committee, a driver and permanent assistant. In year five, the truck continues to run between Koraro and local towns, provides free services to emergency patients and is available to all residents on a fee-for-service basis, depending on the distance traveled. For villagers in Dertu, the combination of the community vehicle and the road rehabilitation has reduced costs per ton of cargo transport by 50 percent. The fee-for-service model allows the community-managed transport to generate revenue that covers the recurring costs of the service. The communities benefit from increased access and have been able to save money toward major repairs. ■

Village Vehicles in Koraro, Ethiopia (bottom), and Dertwu, Kenya (top).



New Road Connects Tiby to Markets

In April 2009, the Millennium Villages Project completed construction of a new road connecting the Tiby, Mali, cluster to the major nearby town of Markala. By connecting the villages of the Tiby cluster to health services and a major market center, the new road is helping to achieve the income and health Millennium Development Goals.

Top: Map of situation of the Tiby cluster area
Bottom: New Road to Markala

Before construction of the new road there was no direct route from the Tiby cluster to Markala. Patients with medical emergencies had to travel 70 km—more than an hour's drive (map point 1)—to reach the referral hospital in Markala. Now, the new road along the Niger River provides a shortcut to the hospital (see map point 2), reducing the travel distance to 30km—less than a half hour drive.

With one of the only bridges in the region, Markala also attracts people from either side of the Niger River to create a bustling market center with internet cafes, fish markets and much more. The new road connects these services to people in the Tiby cluster, creating a broader market for their products. ■

Figure 4.4: Water Pump for School Facility (left); Public Tap (right), Tiby, Mali

Water and Sanitation

Access to safe drinking water and adequate sanitation, in conjunction with good hygiene, are key factors in the health and development of rural communities and for agricultural production. As of 2004, 322 million people in sub-Saharan Africa lacked access to an improved drinking water source.

Governments have several alternatives when drafting water supply development plans to meet the MDG for drinking water access, which will require building infrastructure and providing access to an additional 28.8 million people annually until 2015.[4] Appropriate solutions vary tremendously from place to place depending on water resource availability, setting, socioeconomic standing of the users, existing infrastructure, availability of energy, topography and other factors. There is no single accepted system based solely on demographic data to estimate costs or the best type of water infrastructure to provide. In most cases, local expert knowledge is key to evaluating the multiple variables that inform the choice of technology.

For improved water supply, the options employed by the MVP include protecting water sources such as springs, boreholes and piped water systems. A generous donation of piping from JM Eagle has been essential for providing improved water access for more than 120,000 people in MV sites in Senegal, Mali, Ghana, Uganda, Tanzania, Malawi, Kenya and Rwanda. The first, in Potou, Senegal, provides an example of the overall approach.

The site team in Potou drew up technical plans to construct a system throughout the cluster. Potou was chosen to be the first recipient of the piping donated by JM Eagle, as the local government and national water agency there were concurrently completing a complementary system in the project zone. The site team received and installed approximately 67 miles of PVC piping and public taps in 2008. Since October of that year, some 13,000 people in more than 80 villages have used the system. It is managed and operated by the community with technical support from the public water agency.

Following the success of this system, similar projects were initiated at seven other sites. Table 4.8 provides an overview. Fifty-five containers with more than 260 miles of PVC piping) are currently in the process of being installed in the MVs.

While the piping for these projects was donated, an estimation of its value is presented in Table 4.9 along with the costs of installing drinking water systems, other infrastructure and the total cost per capita of the systems. Note the costs do not include irrigation.

4. WHO (World Health Orgaziation), UNICEF. Meeting the MDG Water and Sanitation Target: The Urban and Rural Challenge of the Decade. Geneva, Switzerland: World Health Organziation, 2006.

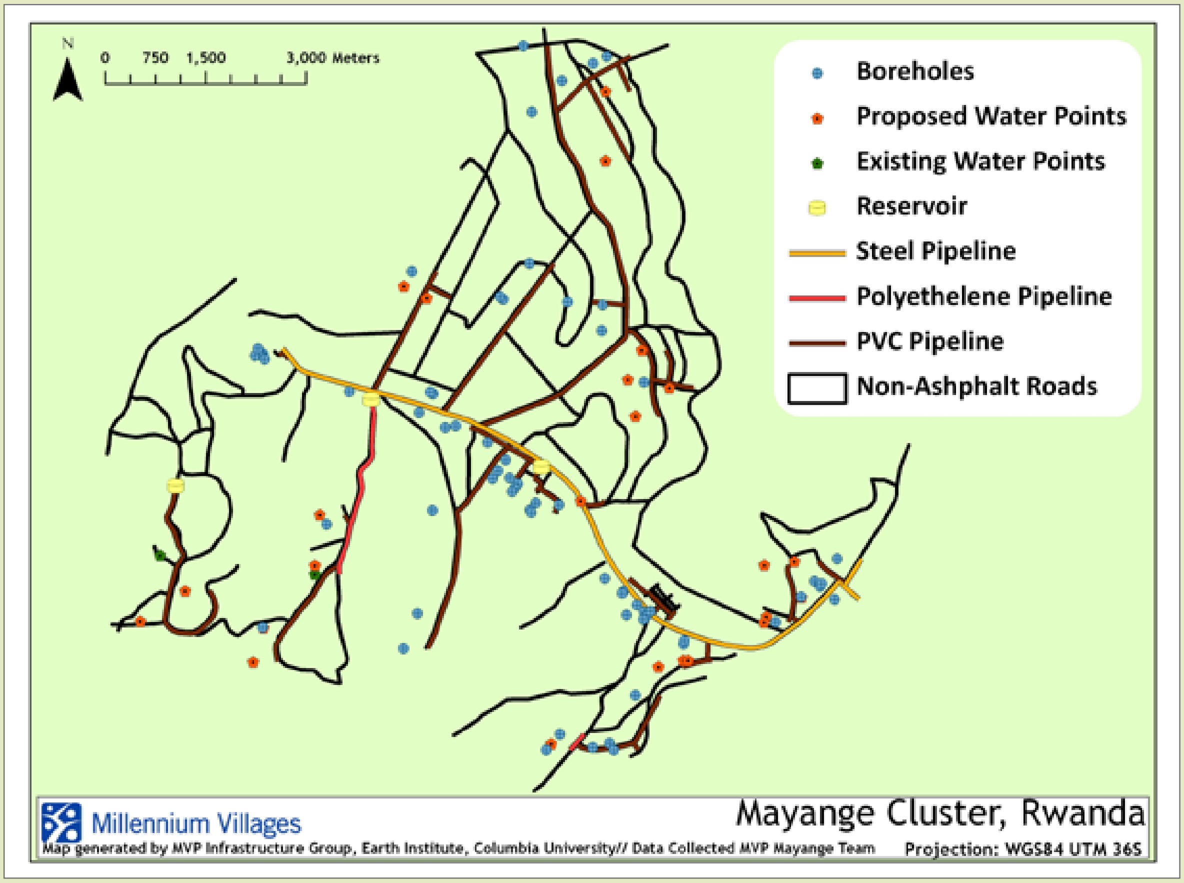
Figure 4.5: Health Clinic Water Storage Tanks; Potou, Senegal

Table 4.8. Piping Projects: Technical Overview and Project Timeline

Site	No. of Taps	Drinking water length (miles)	Irrigation length (miles)	Total length of piping (miles)	Start Date	Completion Date
Bonsaaso	66	58	0	58	Early 2011	End of 2011
Mayange	70	37	4	41	Early 2011	End of 2011
Mbola	26	22	3	3	July 2010	Mid 2011
Mwandama	27	9	0	9	Mid 2010	Mid 2011
Potou	85	67	0	67	Early 2007	End of 2008
Ruhiira	311	71	5	75	Early 2011	End of 2011
Sauri	15	20	3	23	Early 2011	Mid 2011
Tiby	91	62	0	62	Early 2011	End of 2011
Totals	**691**	**345**	**15**	**360**		

Table 4.9. Water Piping System Initial Costs: Total and per capita, for all MVP Sites (Estimated)

Site	Population to be served	Piping Costs (Value of JM Eagle Donation)		Non-piping Costs		All Costs (piping and non-)	
		Pipe Value	per capita	Tower, Gensets, etc.	per capita	Total	per capita
Potou	13,500	498,780	37	340,000	25	838,780	62
Bonsaaso	16,633	379,790	23	902,000	54	1,281,790	77
Tiby	38,921	526,490	14	1,296,000	33	1,822,490	47
Mayange	18,900	117,360	6	236,000	12	353,360	19
Ruhiira	21,922	291,770	13	2,506,000	114	2,797,770	128
Mbola	5,660	146,700	26	200,000	35	346,700	61
Mwandama	2,666	88,020	33	95,000	36	183,020	69
Sauri	3,500	58,680	17	128,000	37	186,680	53
Totals	**121,702**	**2,107,590**	**21**	**5,703,000**	**43**	**7,810,590**	**64**

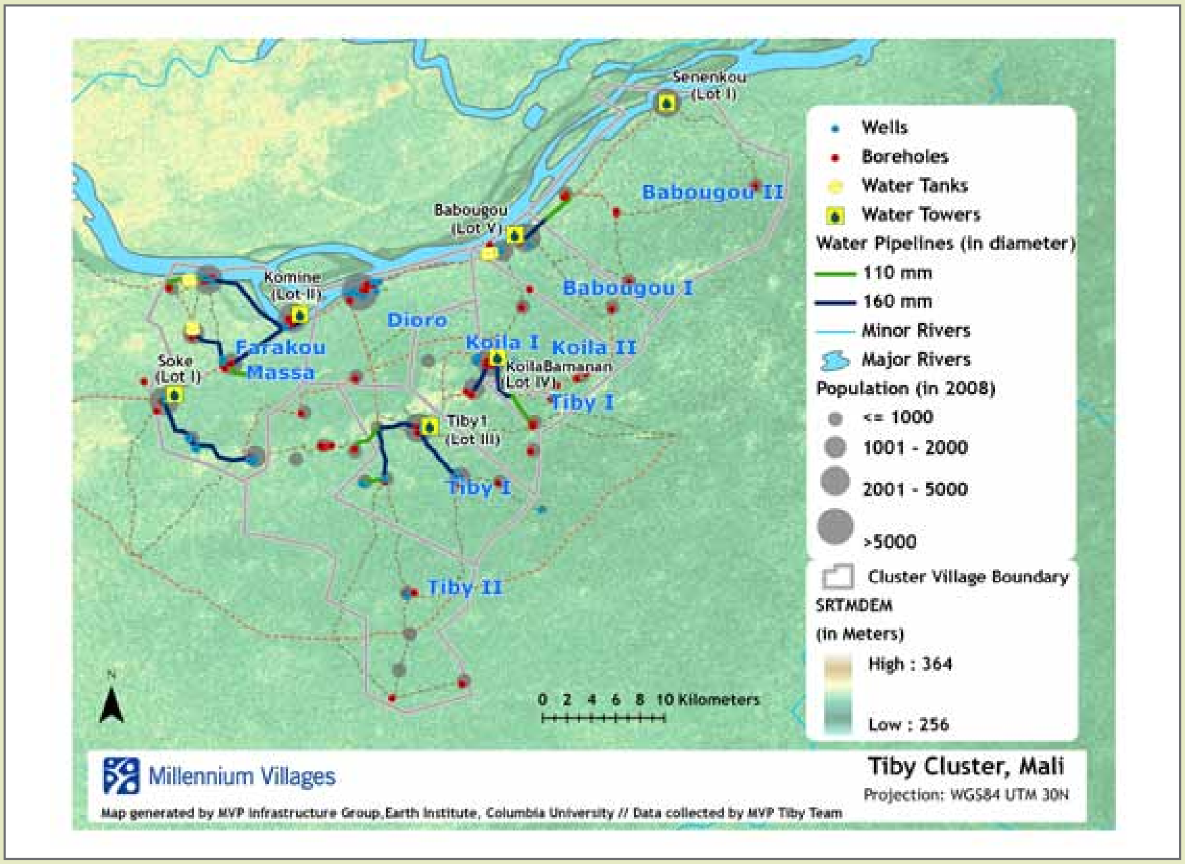


Lessons in Shared Infrastructure—Water in Mayange

Village Vaehicles in Koraro, Ethiopia (top), and Dertu, Kenya (bottom).

The MVP site of Mayange, Rwanda is an example of local government and the Millennium Villages Project collaborating to provide benefit to both the local water district by creating more infrastructure and service points for increased revenue but also to MVP in helping to reach the Millennium Development Goal of improved access to safe, clean water. Prior to the Millennium Villages Project, the Mayange sector had few public water points available through the existing piped water system that were located on the main road running through the sector. Villagers would have to travel as far as 4km over steep gradients to reach the few public taps.Since the implementation of MVP in Mayange, several new boreholes with hand pumps have been developed, creating more access to groundwater.

Now, an extension of the piped and treated water system is taking place. Nearly 60 of piping will be installed when the project is complete and a total of 70 new water points will be constructed where water will be sold. The expanded system will provide 20 to 40 liters per capita per day of clean water to the 18,900 villagers of Mayange. The population coverage of the new system is expected to be greater than 90%. ■



Piped Water in Tiby

Before the Millennium Villages Project, the prospect of a centralized, multi-village piped water delivery system was unheard of in rural Mali. Most Tiby cluster residents relied on local wells, many of which dried up during Mali's long dry season, forcing women and children to walk miles for water. The lucky few with access to an improved water source—who at baseline comprised just 16 percent of its 64,000 residents—drew it from local boreholes, many of which had broken pumps, or delivered contaminated water. To meet the MDG of improved access to safe, clean water, the MVP team initially considered adding handpumps to the boreholes but determined instead that it would be cheaper and faster to link many villages to one water source. When completed, the new, piped water system will connect six existing boreholes that access—each outfitted with a solar or diesel powered pump serving a 15-meter water tower -- which in turn connect to a 65 mile long piped water distribution system that reaches all residents, who can draw from a water kiosk for a small fee. ■

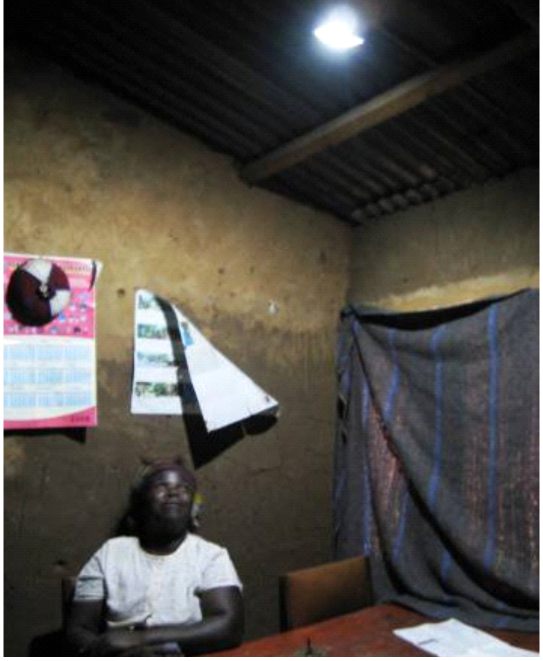


Figure 4.6: Solar Lanterns in the MVs

Lanterns

Rural populations in the poorest parts of the world typically rely on inefficient, expensive lighting options such as kerosene, candles, and low-quality electric lanterns powered by disposable, dry cell batteries. While cell phone penetration even in rural parts of the developing world has risen rapidly in recent years, these communities often lack grid electricity, making phone charging difficult and expensive.

According to the MVP baseline survey, the most common energy source for lighting is kerosene, which was reported as the primary or secondary energy source by an average 85 percent of households across the sites, followed by dry cell batteries, at 39 percent, and candles, at 21 percent. The exceptions were Dertu (KEN), where households also relied heavily on dry cell batteries—perhaps reflecting a reliance on flashlights consistent with the pastoralist population—and Ikaram (NGA), which had significant grid coverage.

Across all MV sites, households spent an average $58 per year on fuels and $17 per year on batteries. Of these energy expenses, $21 was for cooking and $41 was for lighting and electricity. Kerosene accounted for the bulk of fuel expenses across the villages, followed by fuelwood and charcoal.

Table 4.10: Total Fuel Expenses Per Household Per Year (USD)

	Kerosene	Fuelwood	Charcoal	Candles	All other fuels	Sum
Bonsaaso (GHA)	51.37	5.69	2.93	18.53	1.52	80.04
Ikaram (NGA)	48.81	15.35	6.98	1.90	0.00	73.04
Mayange (RWA)	11.66	24.22	0.00	1.69	0.59	38.16
Mbola (TZA)	33.10	5.45	4.47	0.35	0.59	43.97
Mwandama (MWI)	12.08	3.97	1.88	7.31	0.40	25.64
Pampaida (NGA)	48.62	16.44	0.25	0.48	2.17	67.95
Ruhiira (UGA)	15.10	4.83	2.09	2.44	0.70	25.16
Tiby (MLI)	55.80	41.66	9.39	1.16	4.10	112.11
Average (all sites)	**35.72**	**35.86**	**8.81**	**8.33**	**9.90**	**58.26**

Table 4.11. Lantern Programs in the MVs

Site	Program Start Date	Total Sales (Units)	Price to end user	Vendor Margin
Mwandama, Malawi	May, 2009	1000	$38	$3
Bonsaaso, Ghana	April 2010	402	$38	$3
Ikaram, Nigeria	October 2010	256	$36	$2
Pampaida, Nigeria	April 2011	56	$36.80	$3
Potou, Senegal	November 2010	168	Novas: $39 Kirans: $15	$3
Tiby, Mali	January 2011	139	Novas: $35 Kirans: 17.5	Novas: $3.5 Kirans: $1.70

Cutting Household Kerosene Expenditure: Solar LED Lantern Program in Malawi

In 2009 an improved LED lantern program was launched in the MV cluster of Mwandama, Malawi. Prior to purchasing lanterns, most households in the cluster were spending between US$2-4 monthly on kerosene to light their homes. Surveys conducted in 97 households who bought the lanterns -- first one week after purchase, and then again three to five weeks after—showed large decreases in expenditures on less efficient lighting options. Among lantern buyers, the average annualized drop in household lighting expenditures was $47 per household with a median of $37. Taking into account these avoided recurring expenditures, the majority of customers paying $29 for the LED lantern on cash basis had an average "payback period" of less than one year. Each lantern is expected to last several years, and return visits to households 12-14 months later showed that not only were lanterns generally still working well, but many households had purchased additional units. The cluster site team is still working to establish a system to allow for battery replacement after 1.5 years , extending the devices useable lives by years at low cost (<US$5 per battery). ■

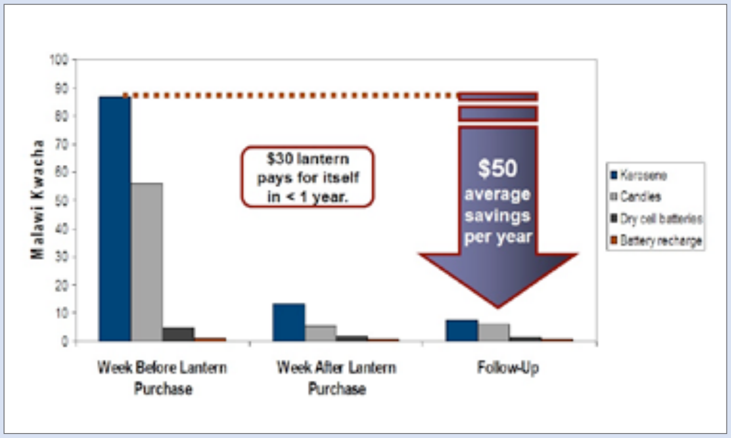


Photo 4.7: Lanterns Charging; Bonsaaso, Ghana

Figure 4.8: Controlled Cooking Tests in the MVs

In this context, portable, solar rechargeable lanterns with efficient LED bulbs offer rural households a cost-effective technology that delivers more light at lower or equal cost to kerosene. The MVP approach of introducing rechargeable LED lanterns is market-based, in which village-level vendors sell lanterns at full-cost (no-subsidies), spurring entrepreneurship at the local level. The first trial lantern program implemented in the Mwandama, Malawi, MV site showed significant benefits to households, who decreased purchases on kerosene and batteries by 90 percent, and vendors, who increased their income.

Based on the Mwandama pilot, the MVP has launched six lantern programs in five countries. A seventh program will launch in Tanzania in 2011. The programs employ the same basic approach, with adaptations for local conditions. Lanterns were tested by EI in New York to identify those with high technical performance, then imported from international suppliers and tested to identify preferred models. These were shipped to the MV sites and sold via a private sector led effort, in which margins were added at each step in the supply chain and lanterns were sold to villagers at full-cost (no subsidy). The ultimate goal of the MVP lantern program is to spur a self-sustaining commercial supply chain via a phased approach in which the initial technical support and oversight can be replaced by strong commercial supply chain. Village businesses should have a stake in continuing the program, with the wholesalers and retailers profiting from each sale.

The cost of each MVP lantern program varied, based on the length of the consultant's stay and the amount of original investment. The general costing: three months of consultant salary and expenses, and an initial investment of $20,000 in lanterns to be used as a rotating fund. Additionally, several sites hired local household energy program managers for one year and also budgeted for promotional activities. These additional expenditures proved crucial to the programs'

Table 4.12: Lantern Program Cost

Expense	Per-month	3 Month Launch
Consultant Salary	$5,000.00	$15,000.00
Consultant Expenses (including travel)	$2,000.00	$6,000.00
Initial lantern investment (rotating fund)	$20,000.00	$20,000.00
Suggested Expenditures		
Marketing	$600.00	$1,800.00
Household Energy Program Manager	—	$12,000.00
Total		$54,800.00

sustained success. The budget in Table 4.12 provides a rotating fund with the capacity to provide 100 percent lantern coverage to the cluster.

KEY LESSONS:

- **High demand for lanterns at a low price:** Data demonstrates that rural villagers are willing to pay market price for a lantern. Studies of lantern pricing at MVP sites show that 70%–80% of respondents are interested in purchasing the lanterns for $40–$50, while demand drops to 10%–20% at $70–$80. Projects must therefore keep prices low to maintain demand.

- **A Range of Benefits:** these appliances can save households money and time, allowing owners to forego travel of 5–10 kilometers for phone charging or purchase of kerosene or dry-cell batteries, and lanterns increase the quality of lighting. A decrease of 85–90 percent in kerosene expenditures among households who purchase the lanterns (this equates to a 6–9 month "payback" period) .

- **International Supply Chains Remain the Most Important Challenge:** Results suggest that a private sector led approach can be sustainable and scalable. However, this requires national and international supply chains, which in most countries are weak or absent. Efforts are underway to strengthen these chains. Lantern manufacturers are meanwhile working to establish regional distributors, and the availability of lanterns to rural populations will ultimately depend on their success.

Improved Cookstoves

Roughly half of the world's population burns solid biomass fuels—predominantly collected fuelwood and charcoal—for cooking and heating. Throughout poor, rural areas of the developing world, biomass is the dominant fuel, and cooking is usually performed using a simple three-stone fire (or "open fire"), often in poorly ventilated structures. The inefficient and incomplete combustion of these fuels without good ventilation produces indoor concentrations of health damaging pollutants. Moreover, women and children, who are primarily responsible for gathering fuelwood for cooking, may spend many hours searching for it each week.

An analysis of MVP baseline data revealed that the two most commonly used cooking fuels were wood and farm residue, at 74 percent and 12 percent respectively. Fuelwood was primarily used and mostly collected by women.

The majority of fuelwood used in households across all MVP sites (79 percent) was acquired via collec-

The MVP Stove Program:

The MVP Improved Cookstove Program model recognizes that cooking practices, biomass composition and locally cooked foods vary by country and region and that all of these can impact a stove's efficiency. In order to select the stove best suited to local conditions, the MVP conducts Controlled Cooking Tests (CCTs) and surveys to determine stove fuel efficiency and user preference. Using these results, the MVP launches demand-driven stove programs that spur entrepreneurship and encourage the adoption of efficient cookstoves in the MVs.

- Conducted CCTs at eight sites across seven countries to test locally made stoves, Envirofit stoves, and StoveTec stoves against the three-stone fire.

- Launched results-based household stove programs in five sites across four countries: Uganda (Ruhiira), Ethiopia (Koraro), Mali (Tiby), and Nigeria (Ikaram and Pampaida).

- Sold over 7,000 household stoves at a 0%-50% subsidy.

Figure 4.9: CCTs: Simultaneous Cooking Tests on Multiple Stoves (left); Weighing Fuelwood Consumed (right)

tion, whereas 18 percent was purchased. The highest reported percentages of fuelwood purchase were seen at the MVP sites with the lowest annual precipitation: the two Sahelian sites, Potou (SEN) and Tiby (MLI), as well as Dertu (KEN), all of which have rainfall below approximately 700 mm/year.

Fuelwood gathering requires, on average, six hours per gatherer per week, (ranging from 2.9 hours per week in Mwandama (MWI) to 10.8 hours per week in Potou (SEN)).

The Controlled Cooking Test (CCT) is designed to assess the performance of the improved stove relative to stove type generally in use (typically the three-stone fire). Stoves are compared as they perform a standard local cooking task. In parallel, a qualitative survey of local cooks was conducted to determine which stove each preferred, and which factors influenced that choice. The MVP CCT protocol can be found online at: modi.mech.columbia.edu. As of May, 2011, the MVP stove program has performed CCTs at seven sites across six countries using eight different stoves.

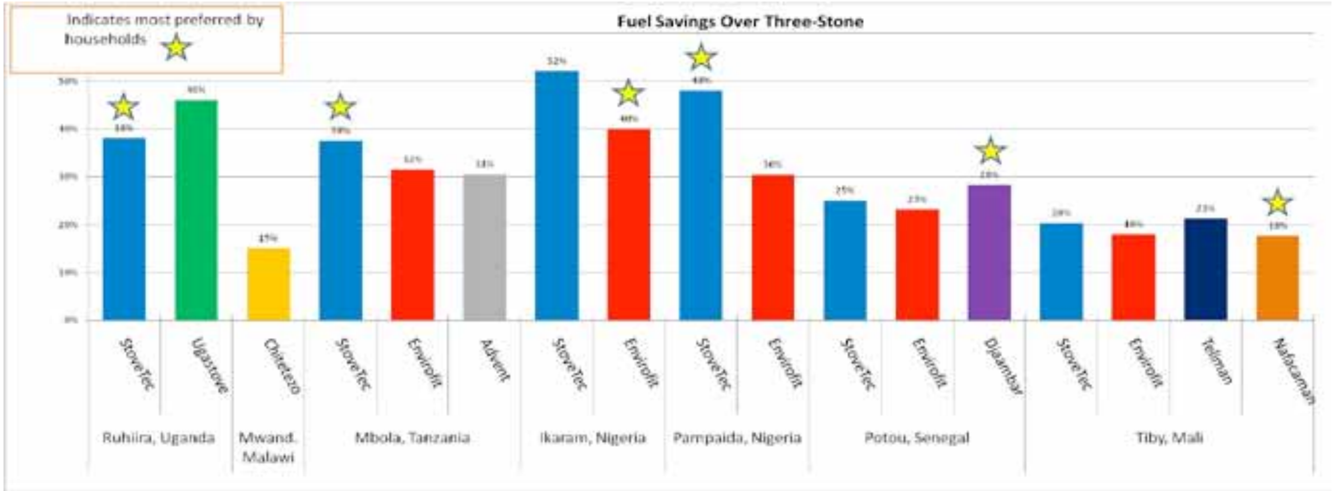
The cost of the MV stove programs varied based on the length of the consultant's stay for program launch and the amount of original investment of stove stock.

Table 4.13: Fraction of Cooking Done With Various Fuels (Average Across Seasons and Households)

	Fuelwood	Farm residue	Kerosene
Bonsaaso (GHA)	0.76	0.09	0.12
Ikaram (NGA)	0.74	0.00	0.19
Mayange (RWA)	0.92	0.04	0.01
Mbola (TZA)	0.64	0.19	0.11
Mwandama (MWI)	0.66	0.30	0.03
Pampaida (NGA)	0.61	0.20	0.15
Potou (SEN)	0.71	0.04	0.03
Ruhiira (UGA)	0.84	0.13	0.01
Tiby (MLI)	0.77	0.08	0.10
Average (all sites)*	0.74	0.12	0.08

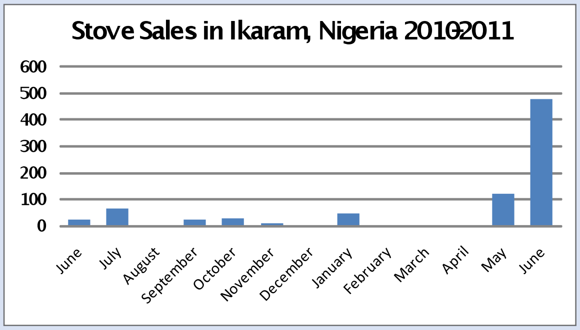
* In this table and all subsequent tables the phrase "average (all sites)" indicates a simple average of the numbers in the column above, and is not weighted in any way to reflect the populations, household sizes, or other factors particular to each site.

Figure 4.10. Results of CCTs and Surveys for Stove Preference from 7 MVP Sites.



Infra-fuelwood consumption tests for preparation in Ruhiira

Environment Week in Ikaram, Nigeria



In the Ikaram MVP, there was initial reluctance to buy cookstoves because of the plentiful wood supply in the cluster. In response, the site team introduced Environmental Week to educate the community on the importance of conservation. The week started by meeting community leaders, after which a stove rally reinforced these points and highlighted the role of stoves in conservation. By the end of the first three days, 121 stoves had been sold. ■

Selling Stoves on Credit: Improved Biomass Cookstoves in Pampaida, Nigeria

Despite surveys indicating high demand for improved stoves in Pampaida, sales began slowly, with only 43 stoves sold in the first two months, primarily because households lacked money pre-harvest. Adopting a successful fertilizer finance model from the MVP in Malawi, the Pampaida site team offered the stoves on credit: Customers put N300 ($2) down and take a stove home, an account was created, and the stove had to be repaid in full, N2500 ($16.70), over the next three months. Sales accelerated rapidly: over 500 were dispersed in under ten days. The cooperative-based system of sales continues, wherein each Co-op vendor gets N150 ($1) per stove, and only those vendors who have collected 100% of their outstanding balances receive commissions. Nearly one year later 744 stoves have been sold, 80% fully paid and the remaining 20% being repaid in increments. The Pampaida program is the only MVP stove program operating on credit and serves as an example for household's wiliness to pay when costs are distributed over time. ■

Figure 5.1: CHWs at work

CHAPTER 5

Innovations

New technologies and innovative solutions are changing the way energy and infrastructure planning and project implementation is executed in developing countries. Alongside more traditional technologies and projects, the MVP Energy and Infrastructure sector has developed new solutions to common development challenges. This chapter profiles four innovations that have had shown an impact at the village level and are now being scaled to the national level.

ChildCount

Reducing child and maternal mortality by 66% and 75% respectively are core MDGs. In much of sub-Saharan Africa, 10 to 20 percent of children die before turning five, while the death of women during childbirth, a rare event in industrialized countries, occurs far too frequently.

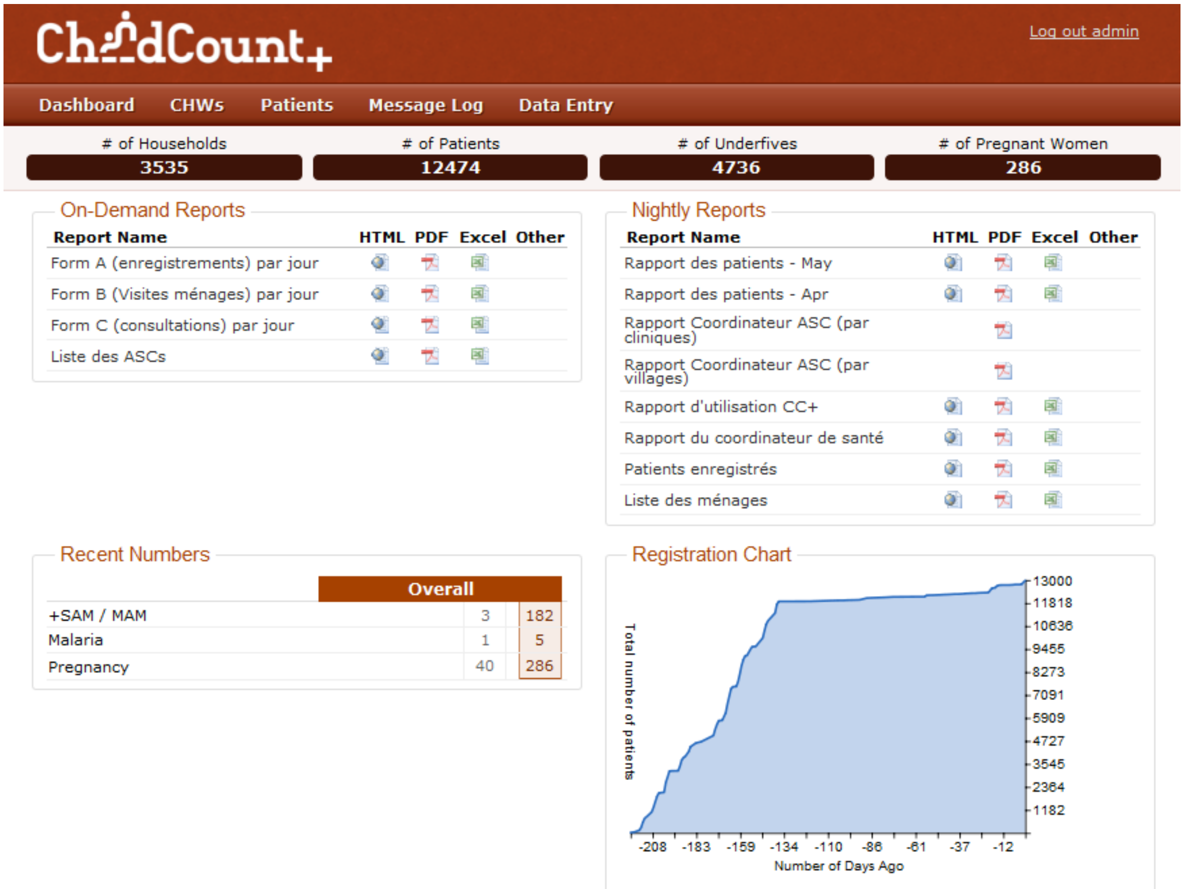
There is substantial evidence that several simple, cost-effective interventions can greatly increase maternal and child survival rates, including vaccinations, oral-rehydration therapy and insecticide-treated bednets as well as strengthened antenatal and delivery care and the integrated management of sick children [1–4].

The MVP aims to address these gaps through the co-ordinated delivery of proven health and development interventions in 14 sites in 10 countries. In the health sector, the MVP emphasizes the integrated delivery of free maternal-newborn-child health services, with the goal of achieving universal coverage through inputs to referral hospitals and primary care clinics, alongside providing direct household support via a cadre of paid-professional community health workers (CHWs). Evidence suggests that CHWS can be effective in reducing maternal and child mortality and improving health outcomes.

In the MVP, CHWs—who number nearly 800 across 14 MV sites—are salaried secondary school graduates—generally from the local community—who are trained in a minimum set of core competencies. There is approximately 1 CHW for every 100–200 households, depending on geography and population density, and each household is visited at least once per quarter. By taking healthcare from clinics directly into vulnerable households, the goal is to improve on disease prevention as well as the early detection, treatment and referral of sick individuals.

While CHWs can provide life-saving interventions, they can also deliver vital household health information. During routine household screening visits, CHWs can generate collect data on the registration of

Figure 5.2: ChildCount Dashboard



community health events, including recent births and deaths; the burden of illnesses such as acute malnutrition or malaria; and the prevalence of essential interventions such as immunizations, antenatal care and skilled delivery.

This collection of household information is greatly facilitated by new advances in mobile communications technology. Each MV CHW is provided with a cell phone. Through a partnership with Ericsson, nearly all MVs have high levels of cell phone coverage. The MVP is piloting the use of electronic mobile phone systems to collect health information at several sites. For example, in Sauri, Kenya, a new program called ChildCount has electronically registered 90 percent of children under 5, who will then be monitored via a text message-based system for nutrition, immunizations, and signs of common childhood illnesses (see www.ChildCount.org).

This project includes a scalable model for the delivery and monitoring of critical maternal-newborn-child health interventions in regions of the world where effective strategies to address health-related MDGs are urgently required.

IMPLEMENTATION

Currently, ChildCount has registered more than 140,000 people. It is used in vaccination campaigns, to accurately gauge the coverage of a vaccine, and flags children for follow up who have not been immunized. It helps CHWs to spot malnourished children during home visits by providing support regarding upper arm circumference measurements (MUACs), and reminds them to check up 48 hours later on any child referred to a clinic for care. The system also produces reports for CHWs, helps them plan future activities and enables them to see at a glance the status of all those under their care. It produces reports for CHW managers to assist in performance monitoring and counseling for those who need improvement as well as reports with detailed indicators for health section heads, to help them see where interventions have been successful and make broader program decisions.

Modular components for ChildCount+ are also designed for specific cases. For instance, the PMTCT (Prevention of Mother to Child Transmission of HIV) module provides enhanced antenatal tracking for pregnant women and tracks childhood health visits for children under 18 months. The module, which is currently in use in Sauri, Kenya and Bonsaaso, Ghana, reminds CHWs when a pregnant woman or child has an upcoming appointment and prompts her to visit the the client's home for a reminder and to emphasize the importance of regular antenatal care. It notifies the CHW if a woman misses an appointment. It also prompts him to go over an expectant mother's birth plan with her three weeks before her due date to help ensure delivery by a skilled birth attendant. Presently, some 400 pregnant women have used the program, and utilization increases monthly

RESULTS

The program has encouraged CHWs to expand and improve their work by helping managers balance their workloads and give spot training when necessary. Sites can install additional models to to expand the capabilities of ChildCount+. It currently tracks over 40,000 children across the Millennium Villages. It empowers CHWs to perform their tasks more efficiently and helps deliver high quality community-based health care. It has successfully aided health workers in peri-urban settings as well as nomadic herding communities; using both paper-based and SMS centered deployments. ChildCount+ has helped improve the detection and systematic monitoring of childhood deaths, malaria and cases of malnutrition. ChildCount+ has contributed to a number of other improved health outcomes across the spectrum. A few examples from the Sauri cluster: The percentage of infants under seven days old receiving an in-home checkup went from 31% at the outset of the program to over 80%. These results are not exclusively due to ChildCount+, but it has been an integral part of the CHW program.

Open Data Kit Collect

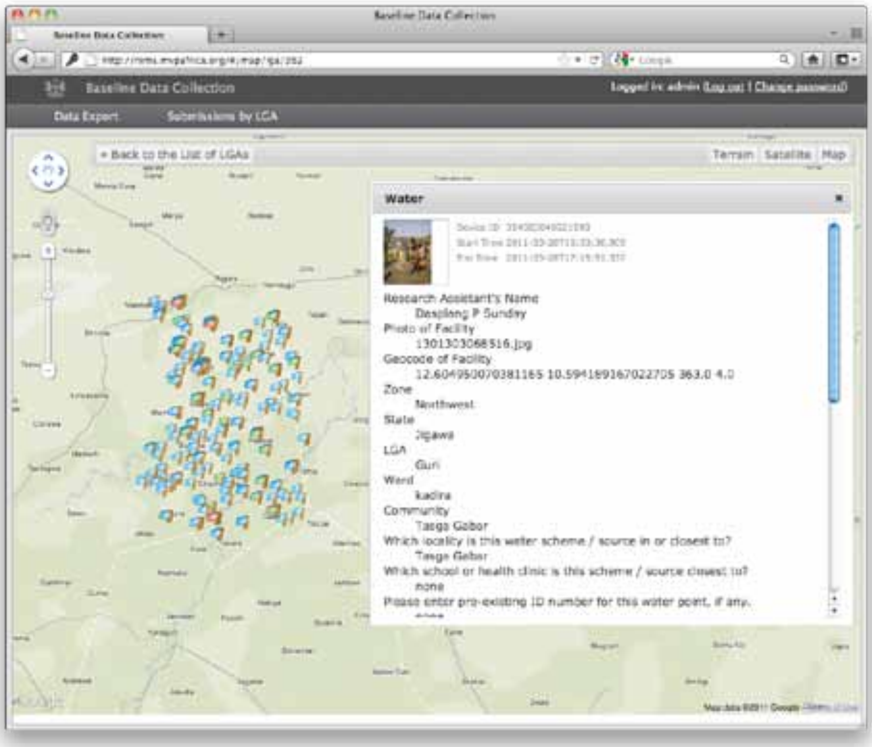
ODK (Open Data Kit) Collect is an open source Android application for collecting survey data in developing countries that was originally created at the University of Washington. Since ODK Collect is designed for the Android operating system, surveys can be collected using consumer-grade Android OS smart phones. Surveys for ODK Collect are written as XForms following the OpenROSA specification.

ODK Collect is easily installed on an Android phone using the Android Market application. By opening Market and searching for "ODK Collect", one can quickly install and use the application. Survey forms are stored on the SD Card in a folder called "/odk/forms/" and survey data is stored in a folder called "/odk/instances/". The major features of ODK Collect can be found at: http://opendatakit.org/

In a January 2010 study in which researchers at the Modi Lab at Columbia University surveyed around 300 farmers in rural Mali were surveyed, data collection took place using smart phones running ODK. This approach allowed for immediate digitization of data for analysis and remote monitoring of the collection progress. It also facilitated the gathering of data and eliminating the need for paper surveys, thereby

Figure 5.3: Surveying

Figure 5.4 Screen Shot of Data View



significantly reducing survey times. Enumerators were quickly able to navigate the touch screens, and within just a few trials the time required to conduct interviews was reduced by 50 percent. Frequent phone contact between field researchers and researchers in New York allowed for instant feedback to the field, permitting immediate notification of progress and irregularities. The success of this trial led the Modi Group to adopt the approach more generally.

CURRENT PROJECTS USING ODK COLLECT

The Earth Institute and the Nigerian government worked together to run four large-scale surveys using ODK Collect. ODK Collect was used to collect a facility inventory of 40 out of 774 Local Government Areas (LGAs). Data on schools, health facilities, and water distribution points were collected. This allowed for a detailed and comprehensive picture of development in Nigeria.

The next major planned survey is an in-depth household survey on malaria. By collecting detailed information on all household members, with a particular focus on the most vulnerable populations—children under five and women ages 15—49—and bed net usage, this survey will provide very detailed data informing how to best combat the disease.

Coordinating such large-scale surveys typically requires significant preparation and work. Training 210 surveyors in how to use ODK Collect and maintaining the hardware takes about a week of five people working full time.

WRITING SURVEYS FOR ODK COLLECT

Columbia University's Modi Lab has developed tools for authoring surveys for use with ODK Collect as well as those for storing and displaying data collected using Android smart phones. When programming surveys for ODK Collect, lab staff members found that the existing Web-based interfaces would require significant copying and pasting of question information and would not allow for the necessary customization the surveys required. Developers in the Modi Lab created a Python computer code library for writing XForms for use with ODK Collect. Below are the major features of the library pyxform that set it apart:

1. Easily convert Microsoft Excel files into XForms for use with ODK Collect—Pyxform allows users to write surveys offline, using a familiar spreadsheet format, and then compile that spreadsheet into a survey for use on the phone.

2. Dynamic question types—It is easy to add new question types to pyxform and to add response constraints timeframe or units.

3. Multiple choice questions with an “other” option—ODK Collect does not have an easy way to enter “other” into multiple choice questions. Pyxform offers an easy syntax for creating these two questions at once.

4. The ability to include xls and json templates—Pyxform allows the author to break a survey up into multiple templates and then include those templates in a base template.

STORING DATA FROM ODK COLLECT

The Modi Lab has also developed its own tool for receiving data from ODK Collect. We have written a pluggable Django application called XFormManager. This application receives XML and media files submitted from ODK Collect and stores them in a database. By making this application modular, we have made it easy for other Web developers to add ODK support to their Django projects. To illustrate how these tools are being used, see a screenshot of survey data:

The tools created by the Modi Lab have increased the utility of ODK. Working with Google docs, pyxform allows developers to quickly collaborate with survey writers. Survey authors can focus on the wording and flow of the survey, while developers ensure that the skip logic and data constraints are in place. The xform manager Web application allows data analysts to monitor survey activities in real time. Watching surveys appear on a map as they are submitted allows users to at once see the big picture and gain perspective on the finest details.

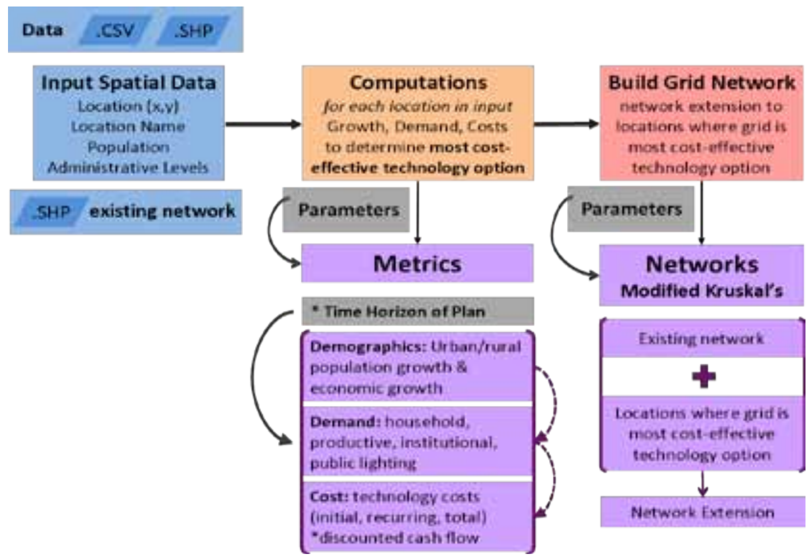
Network Planner

Network Planner is a decision support tool for infrastructure planning. Broadly stated, the tool’s purpose is to help planners determine the most cost-optimal type and placement of infrastructure to serve populations over a given time horizon, in a manner that promotes transparency and the participation of multiple stakeholders in the planning process. This fills an important need, since traditional infrastructure planning is often inefficient, non-transparent, or too limited in scope to guide the equitable and rapid scale-up of essential services required to meet the MDGs.

Network Planner was designed to provide key decision makers—utilities, planners, governments and communities—with the outputs they need to make rapid, iterative, and data-driven assessments on infrastructure costs at various administrative levels (national, district, and community). The system incorporates spatial data (i.e. location of populated places, existing infrastructure, and administrative units); key modeling parameters (population growth and demand, costs of technologies and financial variables) and cost-optimizing geospatial algorithms to provide the most cost-effective, long-term infrastructure plan. The system has potential application in a number of other planning efforts, such as water resources and distribution.

Network Planner helps answer questions such as how best to provide electricity to settlements that currently lack access. To evaluate the options, the tool uses a three-stage process (see fig. 5.5 below):

Figure 5.5: Concept Diagram of Network Planner Tool



1. **Data gathering**—First, geospatial data is collected on populated centers as well as utilities (grid lines) and social infrastructure (health and educational facilities), market centers and government offices. Various modeling parameters are added. For example, electricity demand in various sectors (domestic, commercial, industry, agricultural); cost metrics for grid and off-grid electricity systems (equipment, installation, fuel, operations and maintenance) and socioeconomic data (economic and population growth rates and electricity demand elasticity).

2. **Least-cost electricity system optimization**—The model projects future electricity demand at each point (accounting for such factors as economic growth, population growth, electricity demand elasticity). It computes the technical requirements (such as system sizing) and costs (fixed and recurring) of meeting each location's estimated power demand by grid extension as well as standalone technologies such as diesel mini-grids and solar systems. Finally, the system uses this cost and technical information to create a cost-optimized electricity plan for the system as a whole, for both grid and off-grid power systems.

Figure 5.6 Network Planner Input and Output Interfaces

3. **Data rich outputs**—Network Planner supports the presentation of results in a "prospectus" framework, with detailed cost reporting. Results may be summarized by specific geospatial area (nation, region, district, etc.), by energy technology (solar PV, grid, minigrid), or other key planning categories, as needed.

Important aspects of the model's value are the speed, geospatial specificity and quantitative detail. The model's standardized algorithms rapidly produce plans with a long-term vision, including access targets and financing requirements, with rigor and accuracy that leads to the kind of quantitatively credible project documents that are essential for major funders and donors.

The system is also user-driven and highly dynamic, allowing all input data, assumptions and equations to be viewed and changed by users. This facilitates rapidly collaborative and participatory planning in which users modify settings and quickly produce detailed results. These rapid results provide immediate feedback, allowing users to quickly fine-tune results in successive model runs.. At a more fundamental level, the system is transparent regarding the underlying logic and calculations it performs and allows revisions in its basic computational methods.

Another benefit of this approach is that it improves the participation of multiple stakeholders in the planning process. Government officials will only sanction a plan with a clear approach to meeting national targets. Financiers require clear details on the investment required. Utilities will only extend their services if they have an understanding of the costs of service delivery (e.g., labor and material costs) and the additional services (energy, water) that their networks must provide. Engineers require drafts of where demand for services is highest as a basis for more detailed technical assessments and design work. Finally, communities and customers want to know when and how services will be supplied, and how communities can and will be expected to contribute. All these stakeholders can contribute valuable inputs to the model.

Moreover, this tool and approach can be integrated into planning activities at international development banks, national ministries and utilities in a manner that builds capacity and develops institutional memory so planning can be localized. The automated and algorithmic aspects of the model promote speed and objectivity, while its adaptability ensures relevance to local standards and priorities identified by local planners, utilities, ministries and stakeholders, rather than relying on international consultants. Finally, the model described here need not be limited solely to the analysis of electricity infrastructure. Other issues involving rural infrastructure design, such as water and communication networks, or determining the location of new health care and educational facilities, could also benefit from this approach to maximize penetration and cost effectiveness of service delivery.

APPLICATION

In practice, Network Planner has been used in electricity planning as described above and also to perform detailed sensitivity analyses on the impact of key variables, such as demand growth and the relative wealth and poverty of sub-national areas, on electrification plans for Kenya, Senegal and Ghana.

SharedSolar

SharedSolar is architecture for delivering solar electricity to remote areas where grid extension is not feasible. The electricity is provided via a prepaid payment model that is widely used for the purchase of mobile phone time. Currently, each SharedSolar generation system supplies up to 20 households with electricity and communicates with a central server.

SharedSolar provides a near grid quality connection without the capital cost of grid extension or requiring large consumer investments. Research throughout the Millennium Villages has shown that the rural poor pay as much as $5 per month for kerosene, batteries, and other energy inputs for power that could be more efficiently and cheaply supplied by electricity from a centralized source. This $5 per month of energy use is equivalent to about 1.5 kWh. Thus, the poor are paying often in excess of $10/kWh for inconvenient energy sources. A detailed analysis of grid connection costs has shown that extending the grid to reach the rural poor typically requires more than $1000/household, and even then would only connect the few who reside near existing infrastructure (roads). Furthermore, traditional post-pay metering is too expensive given the low energy use levels these populations can afford, and the variability of their use.

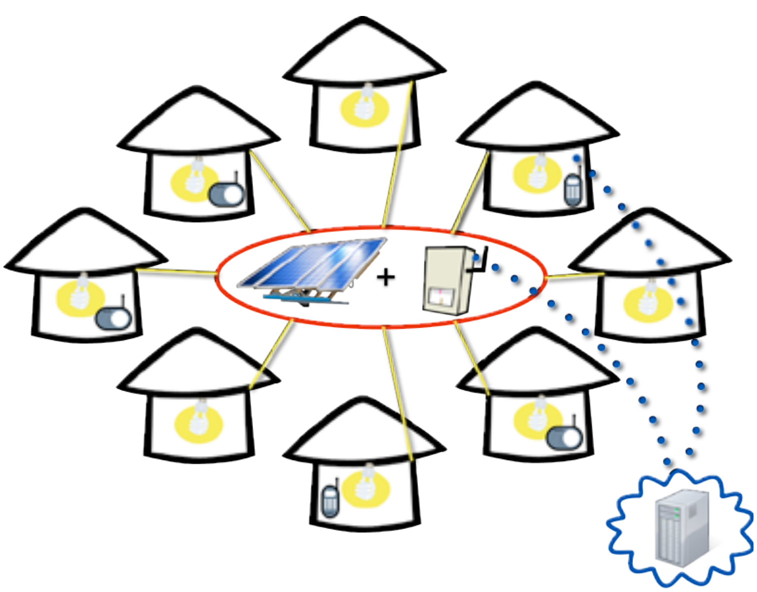
Currently, the poorest are paying the most for the lowest quality energy, but more efficient and reliable alternatives require a capital investment that is out of the reach of these customers. The vision of SharedSolar is making high-quality electricity available in small purchase amounts, bringing a better electricity source to the consumer while lowering the initial cost barrier.

THE INNOVATION

Prepaid metering utilizing manually keyed codes or RFID cards on the meter is a technology that has been employed in traditional macro-utility managed grid-based systems in India, China, South Africa and other places. Similarly, aggregated sub-metering or meter circuit metering has been utilized in a wide variety of applications. Mobile telephony providers have also developed a profitable prepaid business model throughout the developing world that supplies an analogous pattern of service—a low amount for highly variable use. Furthermore, small (1 kW), stand-alone power technologies such solar PVs or diesel-solar hybrids are well understood and highly flexible thanks to their modular characteristics, and often provide better reliability than local grid services.

The marriage and modification of these four mature technologies provides a compelling solution: small-scale (1 kW) micro-grids with prepaid, aggregated metering and semi-automated management (as shown in figure 5.8.) This solution clears two barriers to energy access, upfront cost and credit risk. By creating a robust system that can be managed remotely and amortized confidently, a utility can comfortably invest in expensive solar power generation costs. This leaves the much lower initial investment of home wiring and light bulbs to the consumer. The prepayment mechanism allows for the purchase of electricity in small amounts at irregular intervals. This avoids the problem of non-payment that is common with post-paid billing. This architecture could provide a business opportunity for a utility.

Figure 5.7: Micro-grid Star Topology and Remote Server (Payment Gateway) Communicating with Meter over Mobile Network

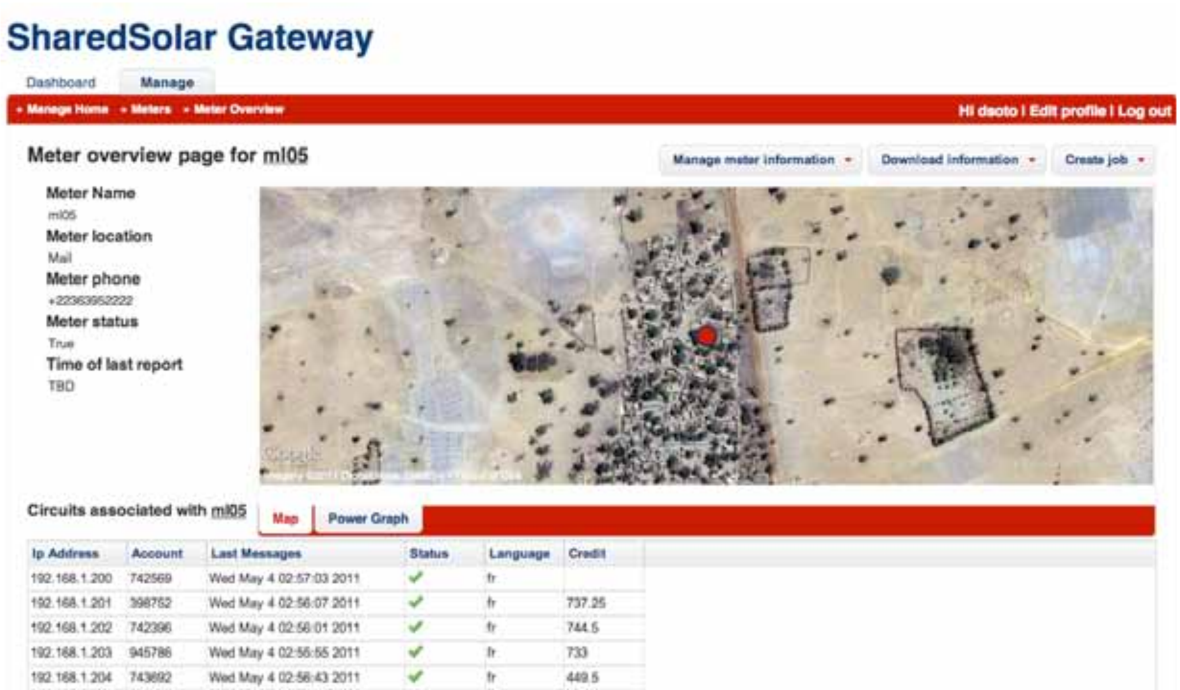


SYSTEM DESCRIPTION

Connected households buy scratch cards from local vendors, similar to those purchased for prepaid airtime, and send the revealed codes via SMS to credit their accounts. The text message reaches the payment gateway server via HTTP. The gateway communicates, also via SMS and HTTP, with power meters connected to each household. When the customer's credit is exhausted, the meter shuts off his circuit.

Through remote management, the metering costs of SharedSolar are significantly minimized, while automated dispatch further drives down the expenses of monitoring and maintenance. These specially designed meters allow for the low loads that are typical of such energy customers. System modularity provides flexibility and even a path toward eventual grid

Figure 5.8: Screenshot of Web application for Monitoring SharedSolar Installations



connectivity—users can increase electricity use as incomes rise, and additional systems can be deployed in areas with demand growth.

The risk of tampering is also eliminated—the wire leaving the centralized meter is the property of the household that it powers.

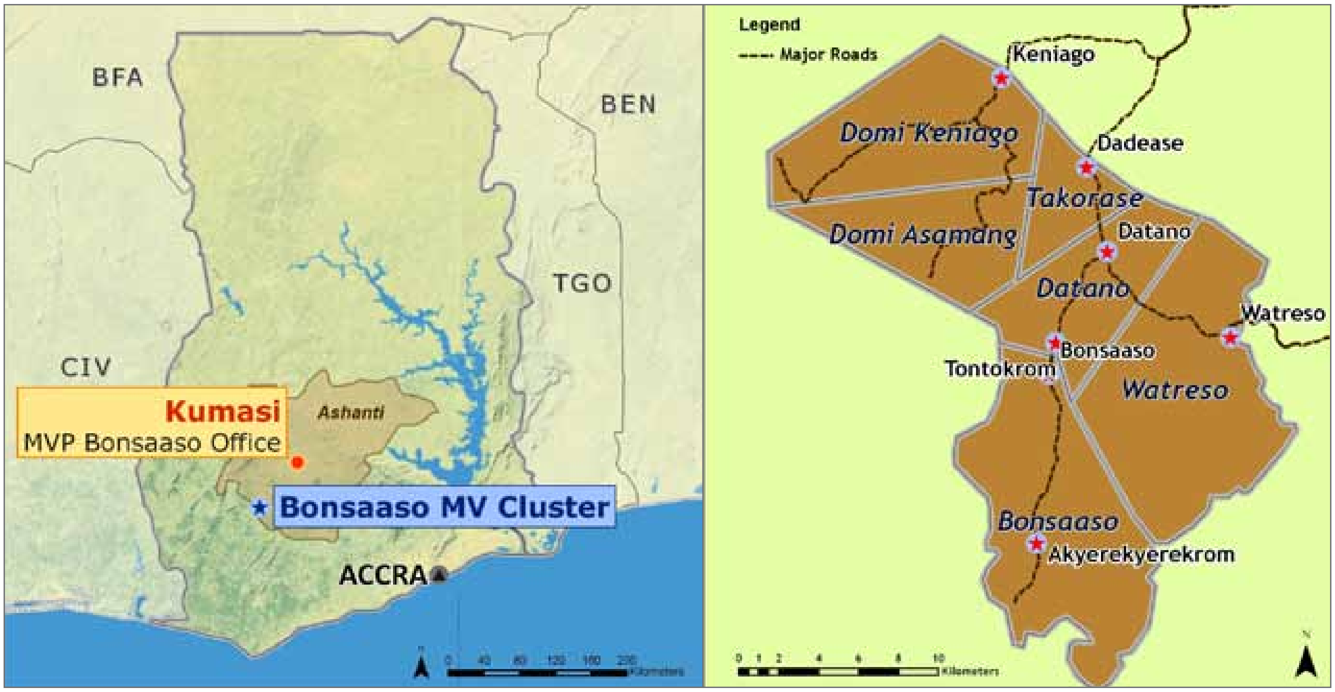
RESULTS

A pilot system in Pelengana, Mali was initiated in late 2010 to test the technology. At this writing, two systems have been commissioned at sites in Tiby, Mali, and one in Ruhiira, Uganda. This system includes software and hardware at the metering site as well as a server that aggregates information from multiple meters (Figure 5.8). The project has contracted with local telecommunications providers for access to their infrastructure.

Early results have confirmed predicted use patterns: Consumers are happy to replace their kerosene and dry-cell purchases, enjoying the significantly improved light from efficient electric lighting and find electric outlets useful for charging their mobile phones and powering other small appliances. Figure 5.9 shows the difference in lighting quality. Lighting is typically 20-50 watt-hours per household per day, while household with televisions consume up to 150 watt-hours per day.

CHAPTER 6

Site Profile: Bonsaaso, Ghana



Summary of Infrastructure Outcomes and Lessons Learned

- Strong government and donor support resulted in grid connectivity in most markets, institutions (health, education, community) and many households.
- Ghana's program of reduced connection costs (<$10 each) greatly increased grid penetration rates, justifying MV grid build-out.
- The energy utility made improvements to equipment and buttressed service in forested areas to address community complaints about spotty grid reliability.
- Recurring costs remain an issue for both grid and off-grid electricity customers, particularly in schools, school staff quarters and ICT learning centres.
- The contributions of visiting consultants were key to the success of some interventions, particularly those involving technologies that were unfamiliar locally, such as solar LED lanterns.
- Designing and installing piped water systems to include plans for substituting grid-connected pumps for diesel pumps could potentially reduce energy costs and improve sustainability.
- A substantial government commitment was also key in the roads sector (for main road rehabilitation), while MVP invested primarily in one major spot improvement (paving a steep slope).

Figure 6.1 (left to right): Increased taxi service to Datano is one sign of increased economic activity; a new ECG meter in a Datano household installed after grid extension; a village shop sells rechargeable solar LED lanterns.

- The coordinated planning of water piping systems and electricity grid extensions will permit the replacement of diesel pumps with cost-saving electric ones in the near future.

Energy in the Bonsaaso Cluster

BASELINE

At the start of the MVP, access to modern energy technologies and supplies in the cluster of villages surrounding Bonsaaso was extremely limited, and villagers relied almost exclusively on inefficient, dirty, expensive fuels like kerosene and dry cell batteries. There were no national electricity grid lines in the cluster; social infrastructure buildings rarely had any electricity; solar systems were small and poorly maintained. Business owners in off-grid communities said in interviews that they primarily used kerosene and dry cell batteries for lighting at a cost of $5-$50 each month, and some used generators spending about $80 - $330 per month on fuel. Household energy expenditures averaged ~$86 per year, mostly on kerosene ($44), dry cell batteries ($28). A small amount ($3.25) was spent by the 3 percent of households who paid to recharge mobile phones. These villagers reported traveling an average of 3.2 kilometers to access energy to charge their phones.

Some areas were not targeted because local conditions and practices did not suggest that they would yield important benefits. Cooking and stove interventions were not prioritized because fuelwood is abundant; irrigation was not targeted because the Bonsaaso cluster has abundant rainfall; and mechanical power for grinding and milling was not a focus of interventions because the local diet is not cereal based, and grinding mills are prevalent throughout the cluster.

MVP Target: 50% Grid Electrification	Community-level access to all markets and 50% of population; Connections to schools and clinics as specified by those MVP sectors
Status at Project Launch: 0%	No communities or social infrastructure buildings were electrified at the start of the project
Outcome at 5th Year: 100% of public institutions 70% community access	~58 km of MV line constructed to reach 16 communities; 21 buildings were grid-connected; estimated 70% of homes will be electrified
MVP expenditures: $39,000 total	$19,000 for solar in 3 computer learning centers; $20,000 for LV poles, connections to social infrastructure
Partner / government contribution: $1.2 total (estimate)	Estimate: $1.2-$1.3 million (primarily for MV electricity grid “backbone”)

Figure 6.2: A typical phone charging business in the Bonsaaso cluster before grid extension.

Figure 6.3 (left to right): A customer with a new meter; clearing trees for grid construction; a transformer in Dawusaso; a Datano business using refrigeration.

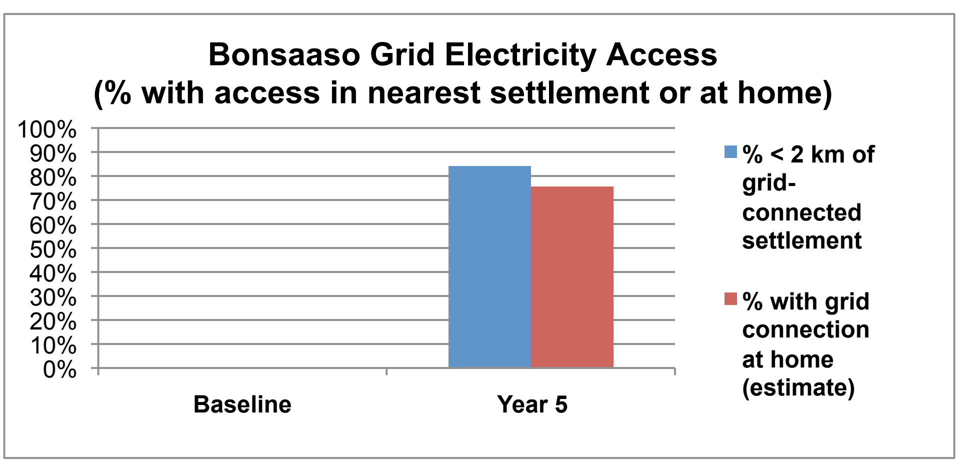
Grid Extension to Markets and Households

Bonsaaso MVP approach to grid extension: Grid extension in the Bonsaaso cluster was undertaken by national programs funded by the Ghanaian government and international donors (JICA, the Chinese government and others). The MVP promoted grid access in the following ways:

1) Provided cross-sectoral investments—in clinics, schools, etc.—justifying the use of limited donor funds to extend the grid specifically to the Bonsaaso cluster.

2) Appealed directly to Ministry of Energy; assisted the community with applications and lobbying; and provided transportation and staff support for government surveys.

Figure 6.4: Grid electricity access in the Bonsaaso cluster (the percentage with grid at home is estimated, assuming 85% penetration rate in grid-connected settlements)



3) Contributed to the community's share of Ghana's Self Help Electrification Program (SHEP), mostly by purchasing low-voltage poles.

4) In communities approved for grid extension, MVP helped mobilize households and businesses to quickly apply for connections raising penetration rates and increasing the base of rate-payers.

Costs for government grid extension projects were not shared with MVP, but are estimated at ~$1.2–1.3 million, including: $18,000 per kilometer1 for 58 kilometers of MV extension ($1.04 million), plus 15–20 percent ($150,000–$200,000), for LV extensions. Direct MVP expenditures on the grid (primarily for LV poles) were relatively low (estimated at $20,000, or less than 2 percent of the total grid extension cost).

The electrification process varies by country. In Ghana, the grid MV "backbone" is extended according to a national electrification master plan. The process for connection of communities is as follows :

1 **Identification of communities:** Communities within 20 kilometers of the network backbone apply for connections, and if approved, communities are surveyed for construction of LV line and connections to all structures.

2 **Preparations for connections:** Residents and institutions have six months to apply for highly subsidized connections (fees of ~2.50 GH¢/$2). MVP assisted local assemblymen in this process. Internal wiring costs (~50-60 GH¢/$40) are paid by customers. These low connection costs encourage high penetration rates (at least 90 percent).

3 **Grid extension and connections, utility builds database:** Contractors perform grid extension and once a household is connected it may use power immediately. Later, the utility installs meters and builds a customer database.

4 **Billing:** A customer's first bill includes two parts: a) estimated use during an unmetered period of up to six months (which can total ~185 GH¢/~$120, difficult for some to afford), plus b) a metered bill for the most recent month, usually 10-20 GH¢ / ~$6 – 15.

5 **Later connections:** Applications for connections after the initial six-month window must be submitted individually to the utility, at a greater cost and delay (the Ghanain MoE estimates connection costs at ~GH¢450 ($300) plus GH¢1,500 ($1000) per LV pole required).

At the project's start, there was no grid in the cluster. Since then, a variety of contributors and programs—including the Ghanaian government, the China International Water and Electric Corporation (CWE), the MoE's Self Help Electrification Plan (SHEP) and the Japanese International Cooperation Agency (JICA)—funded separate projects resulting in over 50 kilometers of MV grid extension (plus transformers, LV line and connections) to most homes and shops in 16 communities. The MVP staff anticipates ~70 percent electricity access in the cluster by the five-year mark or soon thereafter. Only one large community remains off-grid, Akeyrekyerekrom (pop. ~900), which currently has solar systems in its clinic, school and ICT center. MVP is submitting a separate proposal for grid extension.

Table 6.1: Recurring costs for grid power, based on a sample of Bonsaaso ECG bills

Recurring Cost Category	Rate or Average cost (GH¢)	Cost in US$
Service Charge	1.50—4.50 Gh¢ (monthly flat rate)	1.00—3.00
Electricity Tarif	~0.12 - 0.17 / kWh (estimate from bills)	~0.08 - 0.12
Street lighting, levy, etc.	Additional 0.0003 per kWh	(negligible)

Figure 6.5: Map of grid extension projects: completed (in red) and underway (in blue, 1 & 2), plus one solar project (3).

Note: The population figures shown on the map are from 2006 Ghana Census
Credits:
Data Provided by: MVP Site Team, Bonsaaso Cluster, Ghana
Map Created By: MVP Infrastructure Group at The Earth Institute, Columbia University
Map Created On: Feburary 25, 2011

Some issues related to grid connections:

- **Electricity in households:** Villagers are pleased to be connected, but many complain of high first bills (200 GH¢/$130), including a 185 GH¢/$120 charge for estimated use over the preceding months, plus 10–25 GH¢/$6-$16 for the most recent month's use.
- **Electricity in shops and markets:** Grid in villages such as Datano enabled commercial uses of electricity such as refrigeration and electric lighting in small shops and restaurants which pay electric bills of $5–$10 per month. In informal interviews, vendors who refrigeration report selling, on average, 4 to 5 times more on days when grid power is working than during outages. Some business owners complained about a) a recent tariff increase b) power cuts (occur weekly and last a day or more) and c) service fees that must be paid regardless of use or blackouts.

Figure 6.6 (left to right): a battery and inverter at Watreso Clinic; the newly built, grid-connected Assamang Clinic; a low-wattage computer used by a community health worker.

- **Electricity in public buildings:** Nearly 20 community institutions will soon be grid connected including computer learning centers, police stations, village-level financial institutions (microfinance outfits, loan services), chief's residences and a community radio station.

Electricity and Construction in the Health Sector

In 2006, there were only two clinics in the cluster (Tontokrom and Watreso), and both lacked electricity. In response, MVP provided support for the construction, renovation and opening of six clinics and one medical store. The cluster now has seven functioning clinics and one medical store in Bonsaaso. Construction of new health facilities costs, on average, $241 per square meter.

All health facilities have grid, off-grid (solar) electricity, or both (since solar was installed early in the project in anticipation of grid extension delays). Grid connections to each health facility (clinic plus staff quarters) cost about $12,000, almost all of which was for wiring since connection fees are insignificant. Monthly electricity bills vary from $10–$60. Currently, MVP pays these bills, but there are plans for the National Health Service to take over payment. The grid electricity system is managed and maintained by the local utility—the Electricity Company of Ghana (ECG). The reliability of grid power varies by clinic, which is particularly relevant to vaccine refrigeration. Recent efforts by MVP to spur the utility to improve reliability (replace transformers, improve

MVP Target:	Electrify health facilities as required by MVP health sector
Status at Project Launch: 0%	2 clinics in cluster, none electrified
Outcome at 5th Year: 100% electrification of health facilities	All 8 heath centers have electricity (grid for 6 centers and 1 medical store & laboratory, solar for 1 center on solar).
MVP expenditures: $40,057	$40,057 (primarily for solar photovoltaic systems at a cost of ~$10 per peak Watt)
Government contribution: $59,519	(included within support $1.2 million for total grid extension)

Figure 6.7: Construction and electrification in Bonsaaso cluster health facilities

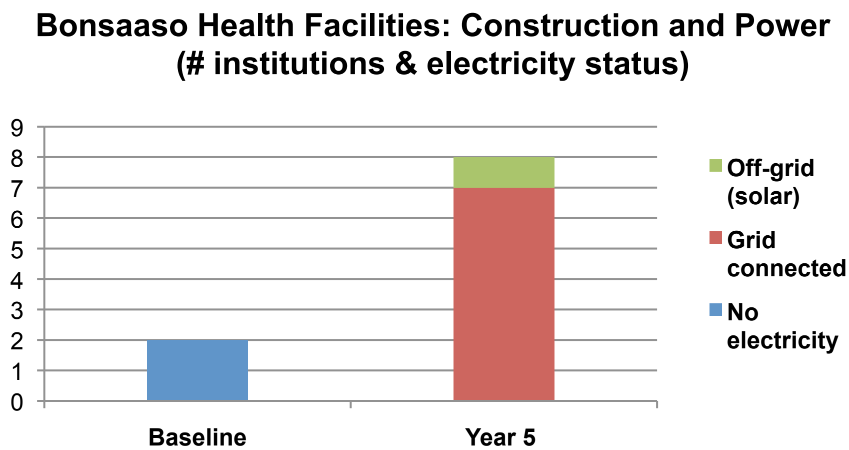


Table 6.2: Recurring costs for grid power in Bonsaaso cluster health facilities.

	MVP expenditures for connection (nearly all wiring)	
Health facility grid connections	**Costs**	**Detail**
6 clinics (Keniago, Watreso, Tontokrom, Datano, Assamang, Aboaboso)	~$72,000	6 X ~$12,000 per clinic (~$7,000/clinic + $5,000/staff quarters)
Medical laboratory (Tontokrom)	~0.12 - 0.17 / kWh (estimate from bills)	$2,643.22 (~65% genset, ~25% wiring, ~10% labor)
Total for 7 facilities	**~$75,000**	

Table 6.3: Technical and cost details for purchase of solar PV systems in Bonsaaso health facilities

		Total System Costs (equip. + install)	
Solar PV Systems & Locations	**System size**	**Total costs**	**Cost per Wp**
2 large clinic systems ($11,882 ea.) (Watreso, Tontokrom)	1275Wp	$23,764 (for 2)	$9.30 / Wp
2 small clinic systems ($4,028 ea.) (Aboaboso, Akyerekyerek-rom)	425Wp	$8,056 (for 2)	$9.50 / Wp
3 med staff quarters systems ($1,684 ea.) (Wat., Aboaboso, Akyere'krom)	170Wp	$5,052 (for 3)	$9.90 / Wp
1 medical store system ($3,185 ea.) (Bonsaaso)	340 Wp	$3,185 (for 1)	$9.40 / Wp
		Total: $40,057	**Average: $9.60 / Wp**

service in forested areas) are progressing, but not fully resolved. Clinics now on solar power do not have vaccine refrigerators, but will be grid-connected within a few months, enabling this key service.

Total solar system cost (equipment plus installation) averaged $9.60 per peak watt (Wp), which is much lower than similar installations at other MVP sites. So far, MVP staff has performed routine solar maintenance (checking connections, batteries, cleaning panels, etc.) and trained villagers in these tasks. However, over the longer term the Ghana Health Service will assume the cost of maintenance and repairs for clinic systems. Meanwhile, provisions to limit power demand include use of low-wattage equipment (65W computers, CFL lighting and phone charging) and discouraging personal use.

Electricity and Construction in the Education Sector

In 2006, the cluster had 22 primary schools, none with electricity. Now there are 27 primary schools in the cluster (out of 32 schools in all). New school classroom blocks cost, on average, around $138 per square meter to build.

MVP did not prioritize MV grid extensions to schools since classes are conducted during the day and the payment of tariffs can be a challenge for schools and rural communities. However, recognizing the broad benefits of school electrification (enabling ICT services, improving teacher retention), MVP supported LV connections to schools in communities where MV line existed. Sixteen schools will be grid-connected. One, Akyerekyerekrom, has a solar PV system (do-

Table 6.4: Cost for internal building wiring in preparation for grid connection in Bonsaaso education facilities.

Educational Facilities	MVP expenditures for wiring (estimates)		
	Total	per structure	Wiring Detail
16 (9 done,7 pending)	~$13,000	$800	classroom blocks: lighting, one socket
2 teachers' quarters	$ 8,600	$4300	residential: multiple rooms, sockets, lighting
5 learning centers	$ 8,750	$1750	
Total	**$32,000**		

MVP Target:	Electricity service to schools as required by education sector.
Status at project launch: 0%	22 primary and secondary schools existed in the cluster; none had electricity
Outcome at 5th year: 63% of schools electrified	17 of 27 (63%) primary schools are electrified: 16 grid, 1solar. All schools (primary and secondary) are connected in communities with grid.
MVP expenditures ~US$50,000 (est.)	Est.: ~$31,000 for wiring for grid connections at schools, learning centers and staff quarters; ~$19,000 for solar systems in learning centers
Government contribution N/A	(included in estimate of total government grid extension contribution of $1.2 -1.3 million)

nated by JICA). As with health facilities, the costs of grid connections to schools consist mostly of wiring.

The reliability of service and ability of schools and communities to pay tariffs or maintenance (for solar) remain issues. One school (Keniago) could not pay its electricity bills and ECG cut the supply in 2011. At another (Datano) teachers enjoyed power in staff quarters, but were disappointed with the frequency of power cuts. At the one solar-powered school, Akyerekyerekrom, there are questions as to whether the school can afford maintenance from a private provider in the future. Similarly, for small systems at computer learning centers, Internet connectivity and ICT training are provided free to school children and for a small fee to community members (50 pesewas / ~$0.35 per hour for Internet use), but it remains to be seen if this income will be sufficient for all recurring costs.

Figure 6.8: Bonsaaso cluster school construction and electrification.

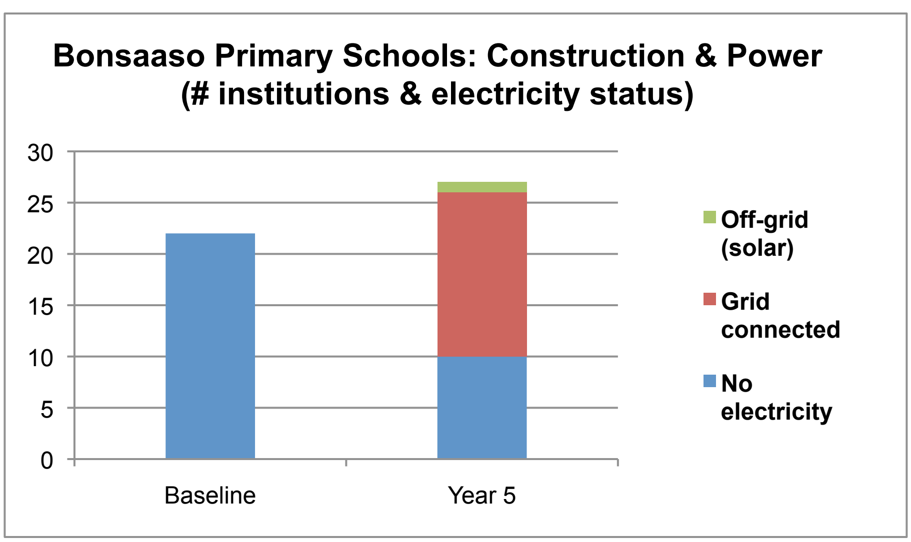
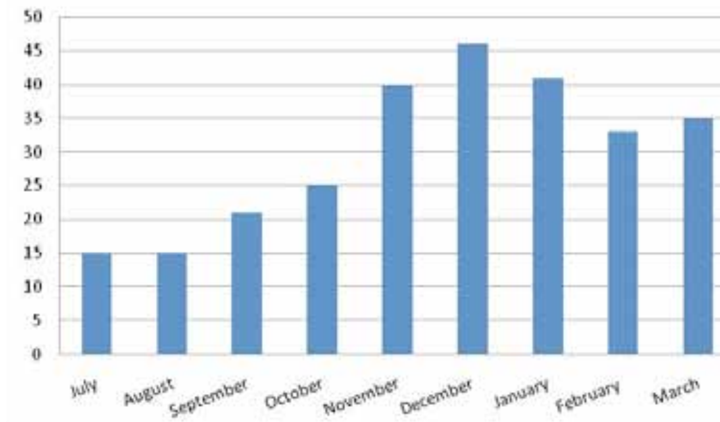


Figure 6.9: A solar lantern vendors in Bonsaaso (left); lantern sales statistics for the cluster, 2010-11 (right).



Household Energy: Portable, Rechargeable, Solar-powered LED lanterns

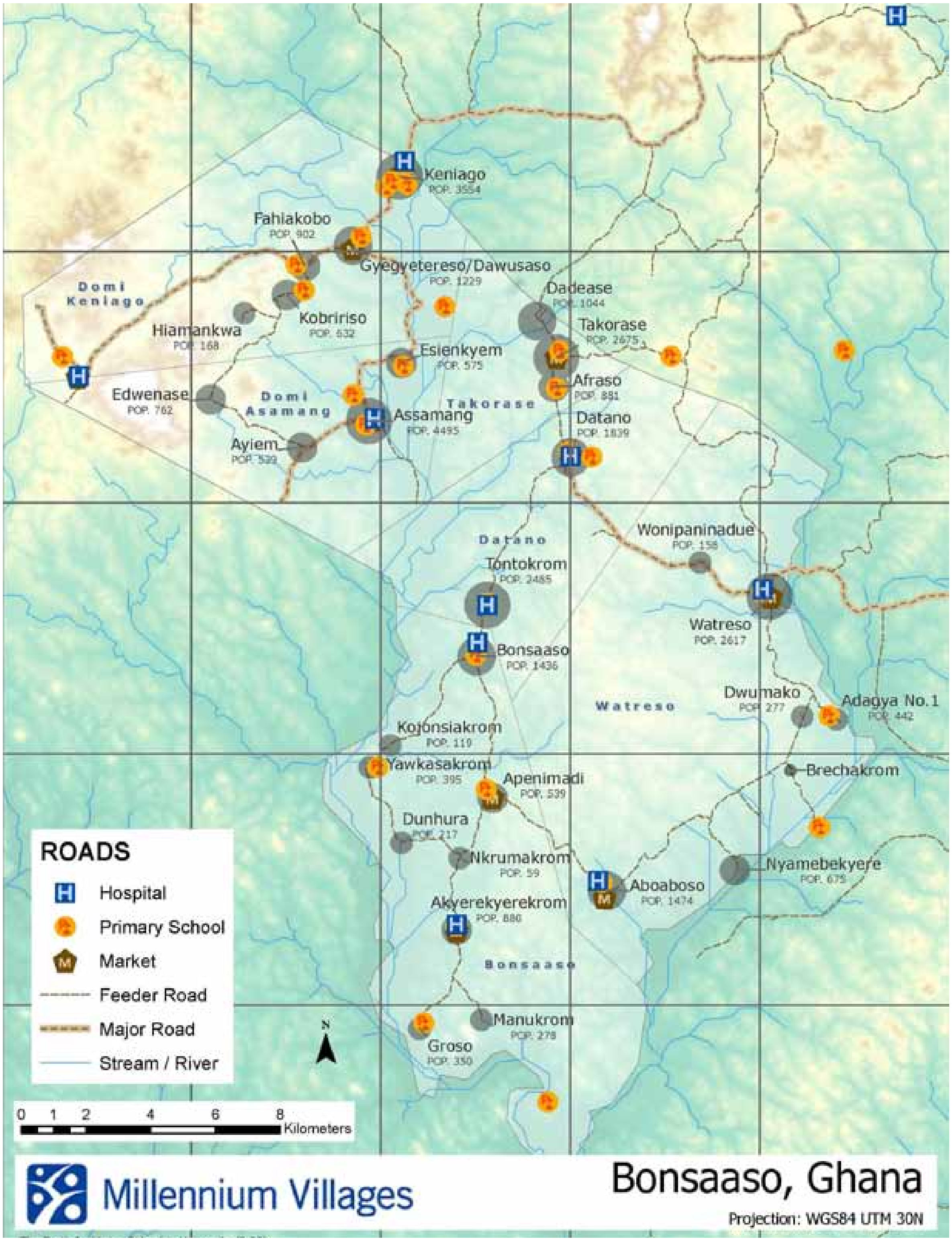
To meet low-wattage household electricity needs (lighting, phone charging) in areas with no expectation of grid within 5 kilometers in the near future, MVP introduced portable, rechargeable, solar-powered lanterns for purchase by villagers, following the approach detailed in Chapter 4: EI researchers identified four lantern models, from which communities selected two preferred models (both with phone charging capabilities). A total of 500 lanterns were ordered and shipped to the site by MVP: 250 Sun Transfer 2 lanterns, which retailed for GH¢85/$55-60 and 250 d.light Nova lanterns, which retailed at GH¢55/$35-40. Ten lantern vendors were selected from non-grid connected areas and trained in lantern operations, price build-up and distribution model. To establish a supply chain, MVP partnered with a Kumasi-based solar vendor, Aeko Solar Enterprise, which agreed to act as a storage facility and wholesaler. Each vendor was issued a voucher redeemable from the wholesaler, creating a few hundred dollars of "working capital." Lanterns were sold to villagers, netting the vendors a profit of about 5 percent of each lantern's purchase price (about GH¢4.20 / $3). Vendors repaid the balance into a revolving fund and in return received additional vouchers, thus creating a cycle of sales and restocking. Nearly 200 of the initial order of 500 lanterns have been sold. Sales have varied with the seasonal patterns of villagers' cash availability. The greater challenge is establishing a supply chain from international manufacturers to a local wholesaler. In the future, Adinkra, a solar vendor in Accra, will import lanterns from international manufacturers and sell to Aeko, in nearby Kumasi.

MVP Target:	Initiate private sector led sales of solar-powered LED lanterns within the cluster providing access to 50% of the population.
Status at Project Launch: 0%	No improved solar LED lanterns available
Outcome at 5th Year: 84% coverage	10 village vendors, located within 2 km of 84% of the cluster's off-grid population, have sold ~200 lanterns
Cost summary: $53,000	The program costs include ~50% for lanterns and 50% for "soft costs" (mostly personnel)

Roads and Transport in the Bonsaaso Cluster

At the beginning of the project in 2006, the road network was identified as perhaps the main challenge to the development of the Bonsaaso cluster. Located in a rainforest, the area's frequent, heavy rains and hilly topography made virtually every road intermittently

Figure 6.10: Major roads projects: (1 & 3) two steel bridges (Ghanaian government), 2) paving of steep slope (MVP)



MVP Target:	Fifty percent coverage of population with 2km of an all-weather road
Status at Project Launch: 10-20% (estimate)	Most roads in the cluster were heavily damaged by rains and impassable during at least some part of the rainy season.
Outcome at 5th Year: 52%	52% of population is within 2 kms of an all-weather road
MVP Expenditure $520,000:	Includes ~10 total projects (roads and culverts); plus paving of a 1.1 km road on steep slope for ~US$136,000 (26% of total MVP costs)
Government Contribution: $5,360,492	Over 100 km of gravel and earthen roads, two steel bridges, and 124 culverts.

impassable. The Ghanaian government made a large investment in rehabilitating the cluster's core road network. This included: building two steel bridges across major rivers (map points 1 and 3), adding more than 120 concrete culverts to replace dangerous wooden structures over seasonal streams, and funding the majority of roads projects overall (137 of 156 kilometers). The MVP complemented this effort with spot improvements, including replacing about 15 culverts and rehabilitating (widening, paving, and installing side drainage) a key stretch of the main route, fulfilling a longstanding request of local residents.

A total of 16 roads projects were implemented throughout the cluster, and are summarized in the table with major projects linking the cluster with important external towns (Manso Nkwanta) in red; improvements to main roads serving large communities and markets within the cluster in blue; and local roads projects in black. No cost data is available for government projects; MVP contract data shows an average cost of ~$18,500 per kilometer of road repaired.

One major project undertaken by the MVP is not listed on this table, a 1.1 kilometer stretch on a steep slope frequently damaged by rains that was rehabilitated and paved at a cost of ~$136,000 (map point 2). Other MVP records list 13 projects in which a total of 138 culverts were installed or repaired, most of which (124, ~90% of the total) were funded by the government and the remainder by MVP.

Figure 6.11: A wooden culvert that was replaced by concrete ring (left); a steel bridge installed by the government (right).

Table 6.5: Roads rehabilitated by the Ghanaian government and the MVP in the Bonsaaso cluster

Locations Connected by Rehabilitated Road	LENGTH	Surface		Project Detail	
	(km)	Gravel	Earth	Institution	Year
Manso Nkwanta—Dadease	28.00	28	0	GoG	2007
Manso Nkwanta—Keniago	29.50	29.5	0	GoG	2010
Dadease—Bonsaaso—Apenemadi—Groso	18.00	7	11	GoG	2008
Datano—Watreso	7.80	7.8	0	GoG	2009
Watreso—Aboaboso	14.20	9.2	5	GoG	2008
Aboaboso—Apenemadi	5.40	0	5.4	GoG	2007
Keniago—Dawusao\Gyegyetreso	3.50	0	3.5	GoG	2010
Bonsaaso—Yawkasakrom	10.40	10.4	0	GoG	2008
Dawusaso— Assamang—Edwenase	14.00	10	4	GoG	2010
Dawusao—Kobriso—Edwenase	9.00	1.5	6.5	MVP	2008
Yawkasakrom—Nkrumakrom	6.00	0	6	GoG	2008
5 more projects	9.60	0	9.60	All MVP	2008-11
TOTAL	**155.4**	**103.4**	**51**		

Figure 6.12: A steep slope on a central road (2 on map): degraded, 2006 (left image); repaired by MVP, 2010 (right image)

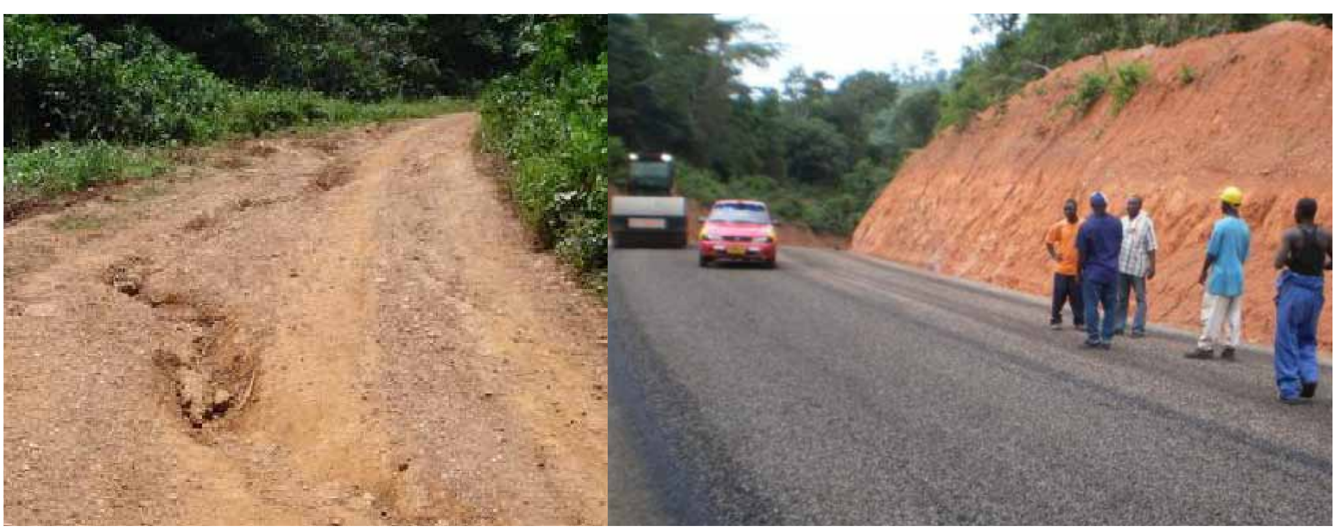


Table 6.6: Cost summary of Bonsaaso cluster water piping projects

	Tontokrom	Datano	Watreso	Takorase & Afraso	Total
Technical and cost breakdown:					
Total number of new water points	6	13	8	9	**36**
Total new pipeline length	3.86 km	4.0 km	4.10 km	4.0 km	**15.96 km**
Total project costs	$216,150	$230,797	$194,516	$213,477	**$854,940**
MVP contribution	$172,974	$172,797	$150,253	$156,977	**$653,001**
Cost breakdown by categories:					
Large Infrastructure	$71,000	$78,000	$73,000	$74,000	**$296,000**
Pumps	$8,000	$16,000	$8,000	$14,000	**$46,000**
Generators	$15,000	NA	$15,000	NA	**$30,000**
Installation costs	$78,974	$69,050	$54,253	$59,230	**$261,507**
Transport costs	$4,333	$4,333	$4,333	$4,333	**$17,333**
Other costs (community, etc.)	$15,440	$20,000	$16,360	$20,000	**$71,800**
Surveys, training, etc.	$2,969	$5,413	$2,969	$5,413	**$16,764**
Donations of pipe	$20,434	$38,000	$20,609	$36,500	**$115,543**
Impact and Sustainability:					
Total population living within 1 km of the new water points (2010):	2,750	4,290	2,900	3,939	**13,879**

Water, Sanitation, Piping in the Bonsaaso Cluster

MVP Target:	100% coverage: proportion of population using an improved drinking water source, year-round (wet and dry seasons)
Status at Project Launch: 41%	41.2% of population using an improved drinking water source, year-round:
Outcome at 5th Year: 89%	89.3% of population using an improved drinking water source, year-round:
MVP Expenditure: $900,547	$854,547 (95%) on water and piping $46,000 (5%) on community latrines
Government Contribution: $0	$0

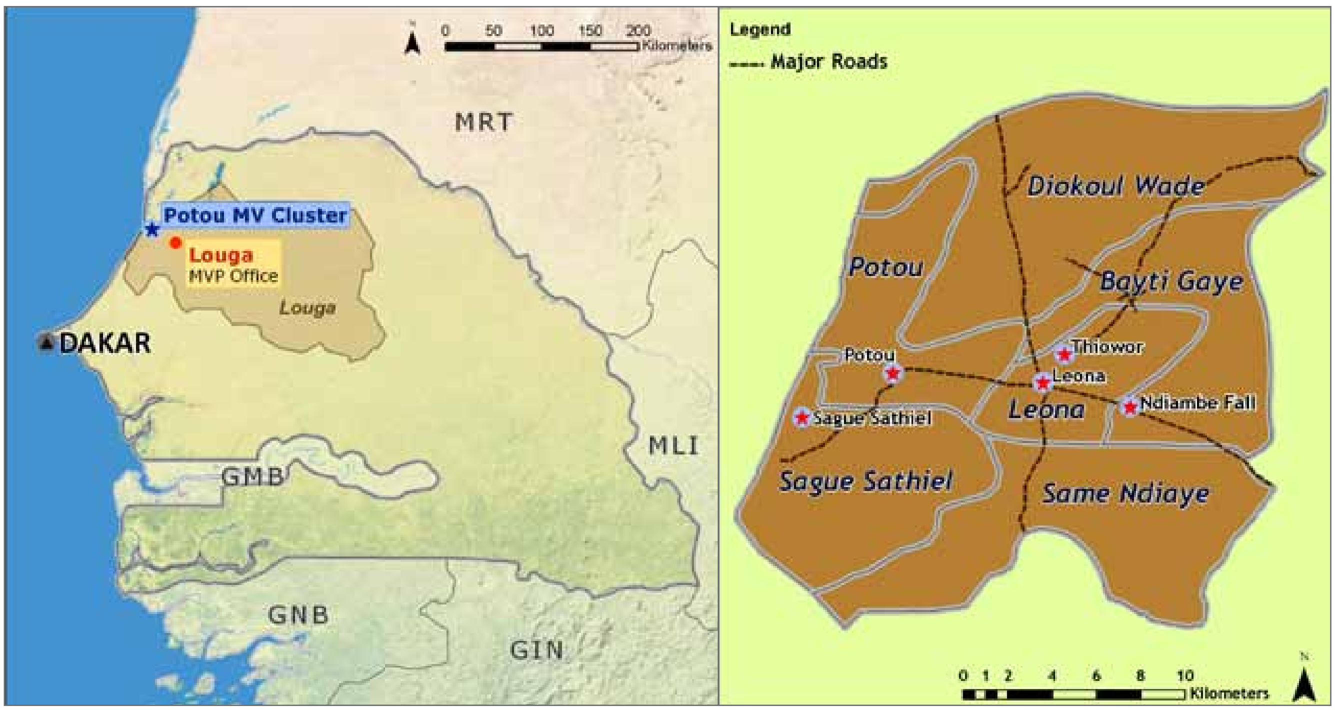
At baseline, around 41% of the population in Bonsaaso was using an improved drinking water source during the wet and dry seasons. The existing water distribution infrastructure consisted of a single borehole. To increase access to improved water sources, MVP targeted six villages for new water systems, consisting of 62 miles of piping, plus water towers, pumping infrastructure and public taps to be installed in each village, reaching 16,633 people, with projected per capita daily usage of 20-40 liters. This project was supported by a generous donation of pipe from U.S. pipe manufacturer JM Eagle. The JM Eagle pipes arrived in April 2011 and construction is to be completed by August. Upon project completion, the percentage of people improved drinking water access will increase to 89.3%. A representative examples of a village-level project (Tontokrom) is described below; technical and cost information for all projects is summarized in the following table.

Women washing dishes in Bonsaaso. Photo: Kyu Lee

Tontokrom: The system is comprised of a borehole, diesel pump filling a concrete reservoir, 3.86 kilometers of piping and six public standpipes (with three backup boreholes in case of system failure or maintenance needs). The system now serves 2,750 (8 percent of the cluster population), but the design allows for expansion, and is expected to serve a population of 3,465, or about 667 households, by 2020. The community Water and Sanitation Development Board (WSDB) will set tariffs (with community approval), and operate and maintain the new systems, with the District Water and Sanitation Team (DWST) providing overall supervision. Annual operations and maintenances costs are estimated at $24,882, versus an estimated income of $28,875 when water is sold at GHC 1.93 ($1.33) per cubic meter. Once the system is grid connected, operations costs are expected to fall considerably. ■

CHAPTER 7

Site Profile: Potou, Senegal



The Potou Millennium Village cluster is 415 square kilometers in size, with an estimated population of over 31,000 living in 106 mostly small and dispersed villages, many with fewer than 10 households. Prior to the MVP, modern energy was virtually nonexistent in the cluster Many villages also lacked access to transportation and water infrastructure.

Summary of Infrastructure Outcomes and Lessons Learned

1. Plans for comprehensive grid extension based on cost-sharing agreements between the MVP and the Senegalese government experienced major delays. Projects moved forward when funded separately, first by the government (three central villages) and later by MVP (six outlying villages).

2. In the short term, solar systems met the energy demands of off-grid institutions as clinics, health posts, schools and a fisheries post.

3. A solar lantern program provided basic electricity services to around five percent of off-grid households; supply chains must be strengthened for scalability.

4. Eighteen kilometers of all-weather roads were constructed to link the cluster to the region of Saint Louis, and connect Leona, headquarters of the rural community, with new local clinics.

5. The MVP provided five community vehicles to the rural council for public transport.

6. MVP collaborated with the government and private sector donors to create piped water systems with public taps that brought improved water sources closer to households than previous systems and open wells.

7. Two MVP-supported irrigation programs have helped to reduce farmers' labor costs, eliminate dependence on rainfall and boost agricultural production: a program of motor pumps sold in installments, and community gardens with irrigation.

Energy in the Potou Cluster

GRID EXTENSION

In 2006, no households in Potou were connected to the national grid. Instead, the population relied on dry cell batteries, kerosene and candles for lighting, and lead acid vehicle batteries for higher electric loads, such as television. Occasionally, residents had solar systems at home, though these were often ineffective due to low quality equipment and installation. Mobile phone recharging was provided via pay-per-charge services in towns, powered by diesel generators.

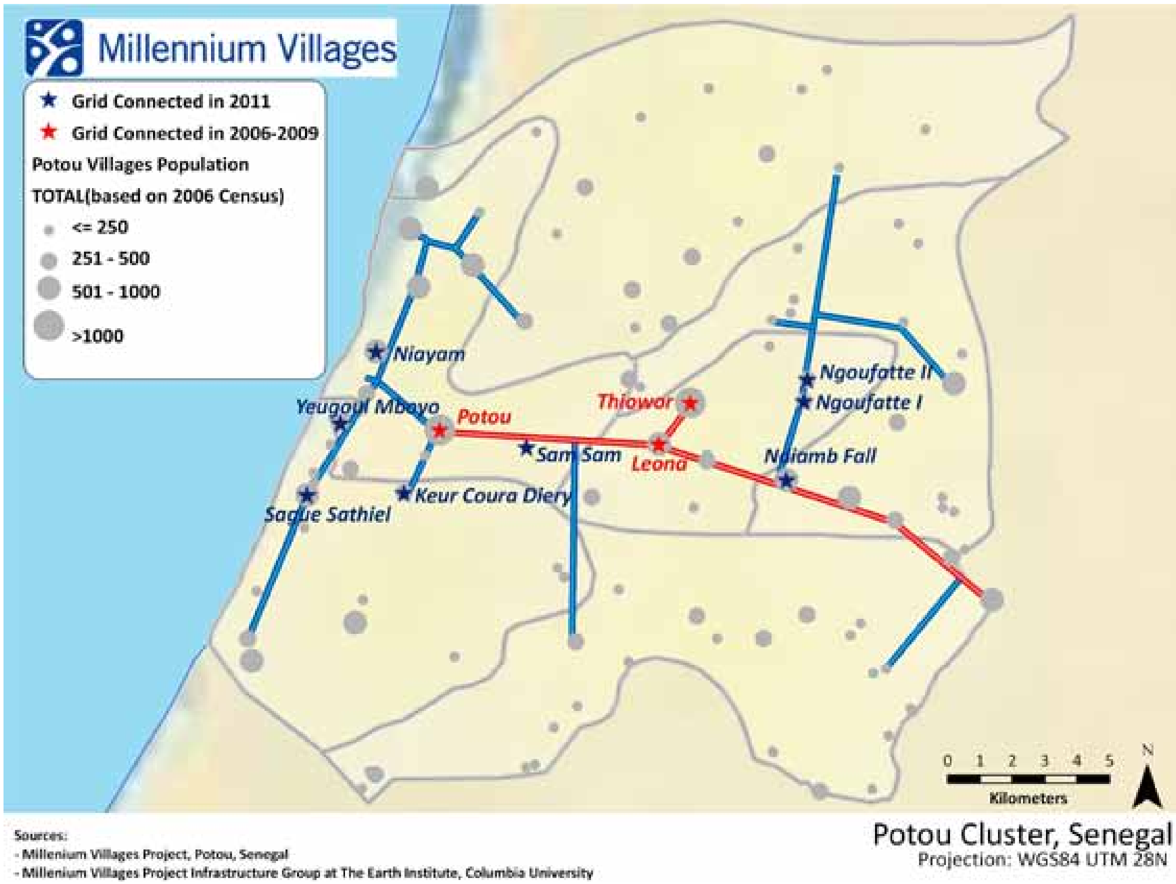
MVP Target:	Community-level electricity service to all markets and 50% of cluster population
Status at Project Launch: 0%	Grid had been extended to Potou and Leona, were not yet providing electricity
Outcome at 5th Year: 15% Grid Electrification	9 villages connected (3 by ASER; 6 by MVP) To date 475 household connections (15%)
MVP expenditures $334,000	75% of $445,143 allocated for connection of 7 villages
Partner / Government contribution: Information not available	The government contribution for initial electrification. The contribution for outlying villages is $1,030,000 (pending)

Early in the project's timeline (2006-09), three large and central villages—Potou, Leona, and Thiowor (map lines in red)—were connected with funding from the Senegalese Agency for Rural Electrification (ASER). This provided access for 30-40 percent of the cluster population and allowed for the electrification of institutions including health facilities, schools, and other government and community buildings in these towns. Rates of connection for households and businesses reached over 80 percent within two years. Alongside this electrification work, a comprehensive plan with cost-sharing provisions for 70 percent contribution by ASER and 30 percent by MVP to electrify around 20 additional villages was agreed upon with the government (map lines in blue). However, government funding for these outlying villages was substantially delayed, and in 2010, MVP agreed to independently fund the electrification of six of the original 20 outlying villages—Sague Sathiel, Ngoufatt 1&2, Keur Koura Diéri, Ndieumb Fall, Niayam and Yeuggoul Mboyo (map points in blue)—that were connected in 2011. ASER plans to connect the remaining villages in the future.

The approach to grid electrification in Senegal is generally as follows. The Senegalese Agency for Rural Electrification (ASER) was created to achieve a rural electrification rate of 60 percent by 2022. To this end, villages near medium of low voltage grid networks are entitled to extensions, which are requested from the Director General of ASER. In response to a request, the agency does the following.

1. **Identification of potential beneficiary communities:** ASER locates the village and conducts a feasibility study, including all demands (residential, business, schools, clinics, etc.)

Figure 7.1: Potou Cluster Grid Extension (Grid lines in blue are estimated)



2. **Mobilization of funds:** Funds are mobilized through international partners (such as the World Bank, Millennium Promise, etc.), and the national government.

3. **Validation and call for tenders:** ASER calls for tenders, examines bids and makes its selection, which must be validated by the Directorate of Monitoring (DCM).

4. **Contracting:** ASER identifies potential electricity subscribers in the village (homes, businesses and public structures) and employs a contractor to make the connections.

5. **Operation of New Power line:** ASER instructs the local electricity provider to operate the new line. If the dealer does not exist, ASER convenes a Transient Delegate Manager (GTD) for this work. The operator applies a four-tiered ASER tariff structure—which includes three tiers of monthly flat-rate pricing, plus an additional fourth option for per kilowatt-hour pricing.

As of December 2010, more than 80 percent of households and businesses were connected in the first three villages to see grid extension (Potou, Leona, and Thiowor).

Interviews conducted in 2009 provide details on electricity use. Household demand varies by size, but the primary uses are typically evening lighting, cell phone charging, radio and television. Businesses report purchasing new appliances, expanding hours and services to customers and increased customer traffic leading to increased revenue following grid connection. Businesses previously relied on fuel-based energy, such as kerosene for lighting and LPG refrigerators for cold drinks. Following connection to the grid, the main

Table 7.1: Costs for grid power of monthly pricing structure (SENELEC, 2010)

Cost category	Businesses	Households
Connection Fee	22544 F CFA / $51.94	18320 F CFA / $42.21
Tier 1 (up to 50kWh)	1512 F CFA / $3.48	1512 F CFA / $3.48
Tier 2 (up to 500kWh)	1524 F CFA / $3.51	1524 F CFA / $3.51
Tier 3 (above 500kwh)	1534 F CFA / $3.53	1534 F CFA / $3.53

Table 7.2: Number of households and businesses connected by year 5 (2010 data)

	Households	Businesses	Total
Potou	196	123	319
Leona	76	30	106
Thiowor	172	13	185
Total	**444**	**166**	**610**

business use of electricity was nighttime lighting, which business owners say helps boost revenues. One sewing business reported staying open all night around major holidays thanks to increased demand.

Many shop owners in these grid-connected villages have purchased electric refrigerators and now sell cold yoghurt, soda and other local beverages, such as the popular hibiscus juice, in part to increase customer traffic. While some cell phone charging businesses existed before grid extension, competition has since increased, with businesses with new grid connections offering free phone charging in an effort to keep and attract customers. Some businesses offer charging of car batteries, which are carried home and used for electricity in off-grid households. A welding business may heavily rely on grid energy throughout the day. Seasonally, the demand for energy tends to rise during the hottest season of the year (May to September) and around major holidays. Prolonged power failure is rare in the cluster, but villagers report that short blackouts (10 minutes) are becoming increasingly frequent. The greater a business's reliance on grid energy, the greater the negative impact of electricity failures. For example, prolonged blackouts severely affect welding businesses.

At baseline, there were no public facilities with grid access. Today, five public buildings are electrified. Four are grid connected: the new Rural Council building in

Figure 7.2: Grid in Leona Market (left); Energy in use by a community tailor (right)

Figure 7.3: The grid electrified Rural Council Building (left); solar installation at Fishery Post (right)

Leona (completed in 2010), two community media centers and the Maison Familiale (community support center) in Potou. One office, the fisheries post in Niayam, had a 150 Wp system installed in 2008, which is used for lighting and one computer. Apart from the efforts of MVP and ASER, the international company Infraco is undertaking a study in the cluster for construction of a 50MW wind power generation project which will supply power to the national grid system under the auspices of the national power utility, Société Nationale d'Electricité du Sénégal (SENELEC).

Energy and Construction for Health

The Potou health facilities offer a variety of services requiring power, including refrigeration for vaccines, a laboratory for conducting diagnostic tests for TB and malaria and lighting and fans for primary care and infant deliveries. At baseline, there were 19 health structures (one post and 18 dispensaries) in the cluster. Four of them received power via solar PV systems prior to MVP by Agence Française de Développement du Sénégal (AFDS).

Today, there are five health posts. Two of these (Léona and Potou) are connected to the grid. Three other health posts have solar installations provided by MVP, and each solar system includes three independent systems (with separate inverters and charge controllers) at a per system cost of F CFA 8,053,015 ($16,632). The three isolated systems prevent disruptions of basic clinic needs (lighting, computers, etc.), vaccine refrigeration and power to the staff quarters for lighting, charging cell phones as well basic entertainment options like television. These grid connections and solar systems provide 100 percent coverage of the infrastructure deemed necessary by the MVP health sector. In addition, seven out of 18 dispensaries have PV solar systems. The average cost of these systems, nearly $18 per peak watt, is higher than typical international market prices, and possibly slightly higher than prices in other countries in SSA.

MVP Target:	Electrify health facilities (selected by MVP health sector)
Status at Project Launch: 21%	Some health facilities by an outside organization (AFDS)
Outcome at 5th Year: 67%	12 facilities had power: 5 health posts (2 grid; 3 solar) & 7 dispensaries (3 solar by MVP; 4 solar by AFDS)
MVP expenditures: $58,000	Solar systems at 3 clinics and 3 dispensaries
Government contribution: $ 0	To date no funds have been provided by the government

Table 7.3: Health centers, electricity types and system capacity (figures in kW are for grid; figures in Wp are for solar)

Location	Health Facility Type	Energy Type (provider)	Maximum Power subscribed (Watts or peak Watts)	Cost per system	Unit Cost (US$/Wp)
Leona	Post	Grid	5.742kW	N/A	N/A
Potou	Post	Grid	5.742kW + 0.957kW	N/A	N/A
Sague Sathiel & Syer Peulh (2)	Post	solar (MVP)	225Wp + 300Wp + 300Wp	$16,632 each	$20.16
Samb	Post	Solar (MVP)	225Wp + 375Wp + 300Wp	$16,632	$20.16
Batlamine & Ndemba (2)	Case	solar (MVP)	225Wp	$3,000 each	$13.33
Wassoum Massal	Case	solar (MVP)	150Wp	$3,000	$20.00
Gabar, Keur Koura Dieri, Maka Tare, Santhiou Djadji (4)	Case	AFDS solar system	50Wp	Unknown, outside organization	Unknown
			Total:	**$58,896**	
			Average:	**$9,806**	**$17.85/Wp**

Figure 7.4: Construction and electrification for Potou cluster health facilities.

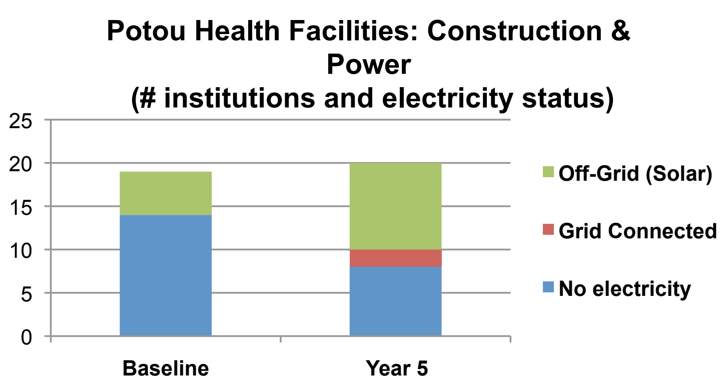


Figure 7.5: Solar Panels at a community clinic

In the long term, the site team is concerned that the bills for grid electricity at health posts in Potou and Leona may be too high and therefore unsustainable. For example, the health post in Leona reported having spent FCFA 362,760 ($725.52) for the two month period from February to March 2010. A more general estimate of yearly grid power costs for health posts is provided below.

Table 7.4: Estimated recurring costs for grid electricity at Potou cluster health facilities.

Average Price per KWh ($ includes taxes and service fees)	Average monthly energy use (kWh/month)	Projected Cost per Year ($)
$0.365	**626.215**	**$2,738**

Energy and Construction for Education

MVP Target:	Electricity service to education facilities as required by education sector.
Status at Project Launch: 0%	42 schools total, none with electricity
Outcome at 5th Year: 12%	50 schools total, 6 electrified: (2 grid; 3 solar PV; 1 both grid and solar)
MVP expenditures: $ 6,400	A small percentage of the overall grid extension costs, plus $6,400 for four solar systems
Government contribution: $0	No contribution

Schools in the Potou cluster are comprised of one or more brick structures with concrete floors and aluminum roofs, one or multiple classrooms and an office for staff and the headmaster. It is not uncommon for educational staff to use a classroom as living quarters after school hours. At baseline, there were 42 primary schools in the cluster, none of which had electricity. At year five, there are 50 in the cluster, six of which have been electrified: two are grid-connected, three have solar PV systems only, and one has both a grid and solar power. MVP installed 75 watt peak solar photovoltaic systems in four schools, at a cost of $1,600 per system, where they are used for classroom lighting and phone charging.

Since grid electricity has been recently extended to five other villages—Keur Koura Diery, Sague Sathiel, Niayam, Ngoufatt 1 & 2 and Ndieumb Fall—the opportunity exists to connect schools in these villages in the near future. Furthermore, if the Senegalese government's plans to electrify a further 14 villages is realized, grid electrification of the vast majority of schools will be possible. The MVP has also organized and trained a team of solar technicians affiliated with an energy cooperative (La Luminere Solaire) that can be called upon by the local rural council to perform maintenance, without the need for a contract with an external organization or MVP's technical expertise, as the current warrantees expire. Initially twelve, and later six more, volunteers received tools and training from MVP, as well as in Dakar and Louga, in matters including basic maintenance and trouble shooting.

Figure 7.6: Construction and electrification of Potou cluster schools

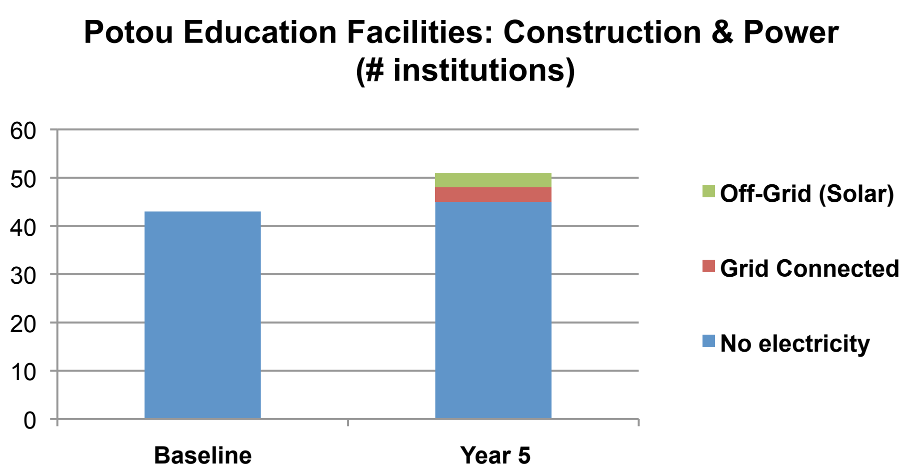


Table 7.5: Technical and cost details for electrification of Potou cluster schools

Location	Energy system Type	Electrified Classrooms (# of total or %)	Maximum Power subscribed (peak Watts)	Cost ($)	Unit Cost ($/Wp)
Leona	Grid	1 of 8	0.957	N/A	N/A
Potou	Grid	1 of 7	Unknown*	N/A	N/A
Batlamine, Gabar, Sague Sathiel	PV solar system	varies (50-100%)	75 Wp each	$ 1600 each	$ 21.33
Thiowor	Grid / PV	4 of 6	0.957/75Wp	$ 1600	$ 21.33
		Average	**75 Wp**	**$ 1600**	**$ 21.33**

Household Energy: Portable, Rechargeable, Solar-powered LED lanterns

MVP Target:	Initiate private-sector led sales of solar-powered LED lanterns within the cluster providing access to 50% of the cluster's off-grid population.
Status at Project Launch: 0% availability	No improved solar LED lanterns available in the cluster
Outcome at 5th Year: 5% coverage	168 lanterns sold since fall 2010, covering 5% of off-grid population
Cost summary: $ 56,500	$56,500 covered procurement of lanterns and a technical consultant to launch program

In late 2010, MVP initiated a program, assisted by solar lantern technical consultants, to sell improved LED solar lanterns in off-grid communities. This program follows a market-based model that relies on a local energy cooperative, La Lumière Solaire, for promotion and sales. To date, there have been 168 lanterns sold in the Potou cluster, covering five percent of the total off-grid households. However, the supply-chain for lantern products must be strengthened before the Potou lantern program will be sustainable or scalable. The team endeavored to simulate a full price build-up, though some important stages in the supply chain, such as the costs of overland transport and warehousing, are still unknown and will likely be important factors in affordability of lanterns sold in the villages. Similarly, preserving tax-free import into Senegal and sale at the local level will be important in keeping lanterns affordable to villagers. Supply chains must also flow in the other direction: Replacement parts and warranties have been an ongoing issue. Since warranties offered by lantern manufacturers cannot easily be fulfilled by distant suppliers, the site teams have been responsible for replacements of broken or faulty lantern products.

Figure 7.7: solar lanterns for sale in Potou Market

Table 7.6: Potou lantern price build-up (in US$), with percentage of retail price added at each stage in the supply chain

	Nova S-201		Kiran		Notes
	Cost added	% of retail price	Cost added	% of retail price	
1. Price From Distributor	$34	87%	10.5	70%	
2. International Shipping	$1.58	4%	1.58	10.5%	Air shipping was relatively inexpensive due to the short distance (Gambia-Dakar).
3. Import Duties	$0	0%	$0	0%	Initial shipments were tax free; this will continue once the solar association is registered.
4. Warehousing / Distribution	$0	0%	$0	0%	Association members take this responsibility including financial obligation for any losses.
5. Overland Transport	$0	0%	$0	0%	Initially provided by MVP; needs to be determined for future shipments.
6. Retailer Margin	$3.42	9%	2.92	19.5%	$3: includes ~$1 for association fund & ~$2 for vendor (rounded to match local denominations)
7. Sales Tax	$0	0%	$0	0%	Sales will be tax free once association is registered with the local authorities.
Total	**$39**	**100%**	**$15**	**100%**	

Roads and Transport

MVP Target:	Fifty percent coverage of population with 2km of an all-weather road
Baseline Coverage: 30%	30% of the cluster population living within 2km of an all-weather road
Coverage After five Years 50%	MVP's construction of 18.4 km in targeted areas means that 49% of the population now live within 2km of an all-weather road
Cost summary: Total: $323,663	Total includes all three sections of roads at a unit cost of $17,590/km

Working with the Potou Cluster's governing body, the Rural Council, the MVP identified the need for improved transport routes to increase the mobility of people, facilitate timely access to rural health clinics and enable transport of agricultural products and finished goods to and from the community hub of Leona to markets throughout the greater St. Louis region. Using a community participatory approach, 18.4 kilometer of track was identified for construction. STTP (Societé de Transport et de Travaux Publics) was

Table 7.7: Cost and length of Potou cluster road projects

Road	Length (km)
Leona—Syer Fulani	8.6
Diokoul—Wade Ndialakhar	2.1
Mboltim—Diokoul Wade	7.7
Total Length	**18.4 km**
Total cost	**$323,663**
Cost per km	**$17,590**

Figure 7.8: Road construction in the Potou cluster

awarded $299,619 for road construction, and engineers with the Cabinet Polyconsult were awarded $24,045 to oversee the construction. The work commenced in October of 2009 and completed in March of 2011.

Field staff members report numerous beneficial impacts of the new transport routes. The roads allow for expedited travel via ambulance to all cluster health facilities and reduce the travel distance to the larger medical facilities of St. Louis by 70 kilometers. Businesses and producers may benefit from decreased time and costs of shipping to and from markets, reducing ice purchases by the fishing community and increasing prices received for fresher fish. In order to ensure that the transport routes remain passable, the Autonome des Travaux Routiers (AATR, or Autonomous Agency for Road Works) was approached and agreed to maintain the roads in the future. The government agency's mandate will ensure periodic reshaping, pothole elimination and the clearing of ditches and trenches. The Rural Council in the region has taken over the responsibility of applying for the maintenance to AATR on an annual basis.

Water and Sanitation

PIPED WATER

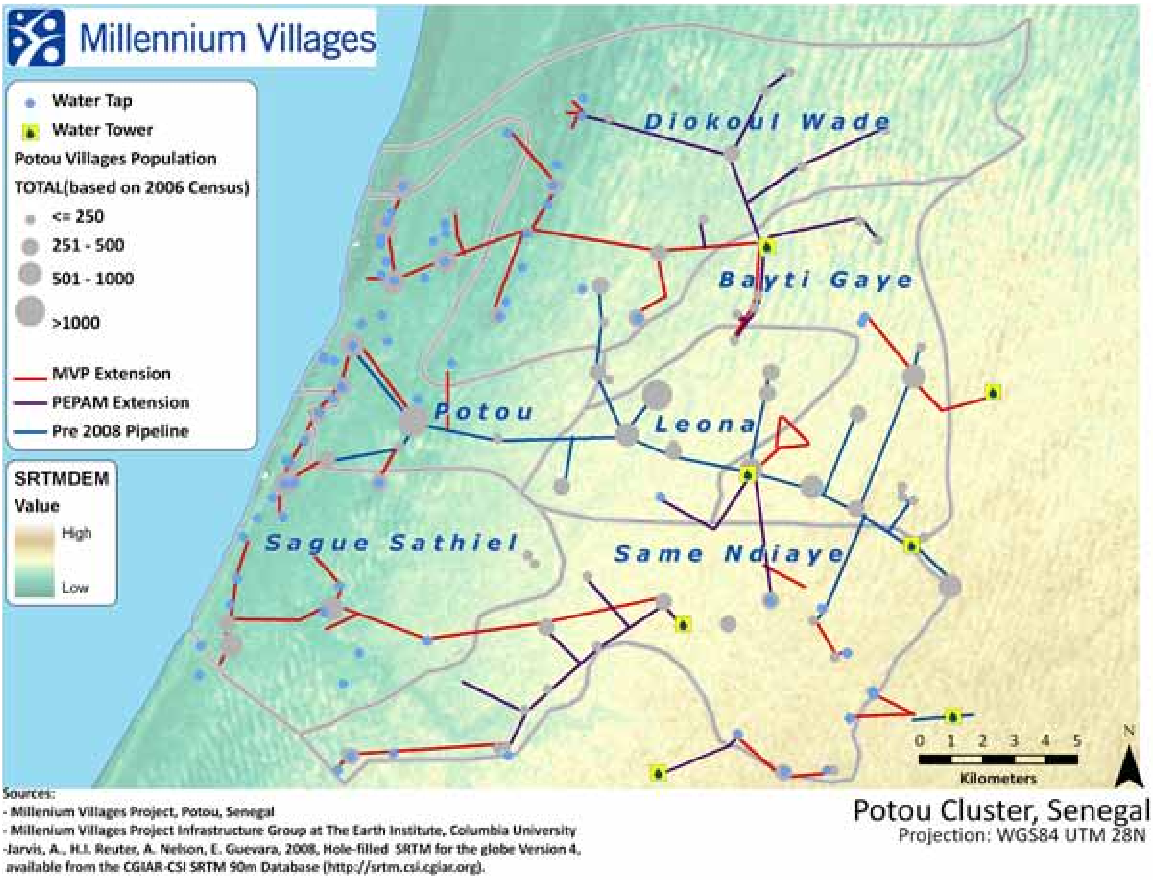
MVP Target:	100% population using an improved drinking water source, year-round: during both wet and dry seasons
Status at Project Launch: 20% coverage	20% of population had access to improved drinking water source at baseline
Outcome at 5th Year: 78% coverage	70km piped water extensions (MVP) and 30km (government) provided an additional 58% with access to improved drinking water
Cost summary: Total: $ 340,000	Total represents MVP costs for installation only of 70 km pipe ($4857/km); this excludes value of pipe donated by JM Eagle ($498,780)

At baseline, only 20 percent of the population of Potou was using improved drinking water sources year-round. However, the Senegal site is unique among MVP sites in that much of the required water supply infrastructure and management capacity needed for comprehensive coverage was already in place before the MVP. At baseline, Senegalese government agencies such as Direction de l'Hydraulique Rurale (DHR), and programs such as PEPAM, (Programme Eau Potable et Assainissement du Millénaire / Water and Sanitation Program for the Millennium) had already installed an extensive piped water distribution system (>70 kilometers, with more than 40 public taps), six mechanized boreholes equipped with diesel generators and submersible electric pumps (>40 cubic meters / hour) and seven elevated reinforced concrete water towers (100-200 cubic meters). Notably, one of the previously equipped boreholes in the project zone had never been put to use because the previous World Bank project had run out of funds before installing the complementary distribution network. Borehole users associations (ASUFORs) were already formed, trained and functioning for the six boreholes in the project zone, and the DHR was actively engaged in the oversight of these committees.

Building upon these resources, MVP undertook improved piping interventions to bring cleaner drinking water to 100 percent of the Potou cluster population by establishing public taps closer to households than previous systems and existing open wells. A collaborative approach between MVP, government (PEPAM) and outside donors (JM Eagle) ensured cost-effectiveness by building upon unfinished projects in the cluster and utilizing established capacities at the community and government levels to reduce the costs of technical design and implementation and ensure sustained local management.

To date, MVP has installed 70 kilometers of pipeline and PEPAM has installed approximately 30 kilometers. The pipeline provides 13,500 people with improved water sources with 85 public taps in 63 villages at an average of 220 meters from the household, increasing improved drinking water coverage from 56 percent to 99.5 percent in those villages, and to 78 percent for the cluster overall. When broken down by cost component, unit costs for water delivery are overwhelmingly spent on diesel fuel for pumps.

Figure 7.9: Map of Potou cluster piped water projects



Installation proceeded under the supervision of PEPAM, the MVP and The Earth Institute, in close collaboration with the village chiefs and councils. Efforts were made to minimize the travel distance for water users and the average distance from household to public taps. For 997 households, this was found to be a significantly shorter distance than that to previous piped installations and existing open wells. Along the new network, 80 percent of the households were within 400 meters of a public tap.

In addition to the public taps, 11 communal animal troughs, each designed to serve several villages, were also constructed. Site selection was coordinated with the Livestock Association of the CR-Léona and a contractor who chose sites that were within 100 meters of the main pipeline and near access corridors to minimize costs and allow animals without negatively impacting adjacent fields.

Table 7.8: Unit cost breakdown for piped water in two Potou cluster projects

Cost Component	Cost per Unit of Water Delivered (Average, $/m3)	Percent of Total Costs (%)
Diesel Fuel	0.28	71
Management	0.06	15
Maintenance	0.03	7
Other	0.16	6
TOTAL	**$ 0.54**	**100%**

Irrigation

Agriculture is the most important economic sector in the Potou cluster, and farmers are highly dependent on inconsistent rainfall during a three-month season, allowing only one crop per year. Farmers typically hired a seasonal manual laborer who drew water from a well and carried it in buckets, in exchange for food and lodging for the season. After harvest, the farmer sold his proceeds, subtracted costs (such as fertilizer) and split the income evenly with his seasonal worker. Two irrigation projects were undertaken in the cluster with the broad objectives of increasing farmers' incomes by reducing seasonal labor costs, eliminating dependence on rainfall and boosting agricultural production and diversifying crops.

MVP Target:	Support irrigation and water pumping for agriculture according to site-specific needs and opportunities
Status at Project Launch: N/A	Unknown, no survey data compiled concerning pumps at baseline
Potou MVP objective:	Provide 500 individual farmers with pumps
Outcome at 5th Year:	45 farmers in 16 villages have received pumps.
Cost summary:	$21,222

One MVP irrigation intervention is to provide motor-pumps on credit in Niayes, the traditional horticultural zone of the Potou cluster. To date, 45 farmers in 16 villages have received motor pumps courtesy of a revolving fund, originally with 35 pumps, established with an initial investment from MVP and now managed by a local financial institution (FI). The farmers, organized in a cooperative, obtain the motor pumps from the local FI; they are to be repaid in three years with a seven percent annual interest rate. The interest earned is split evenly between the lender and the cooperative. This repayment schedule was designed with the seasonal nature of farmers' revenue in mind, and to ensure that they are not financially burdened. Payment is made directly to the FI, which returns the money to the revolving fund, which is then used to purchase additional motor-pumps, which will be loaned to other farmers in the cluster.

Figure 7.10: Irrigation pump, provided through revolving fund initiated by MVP

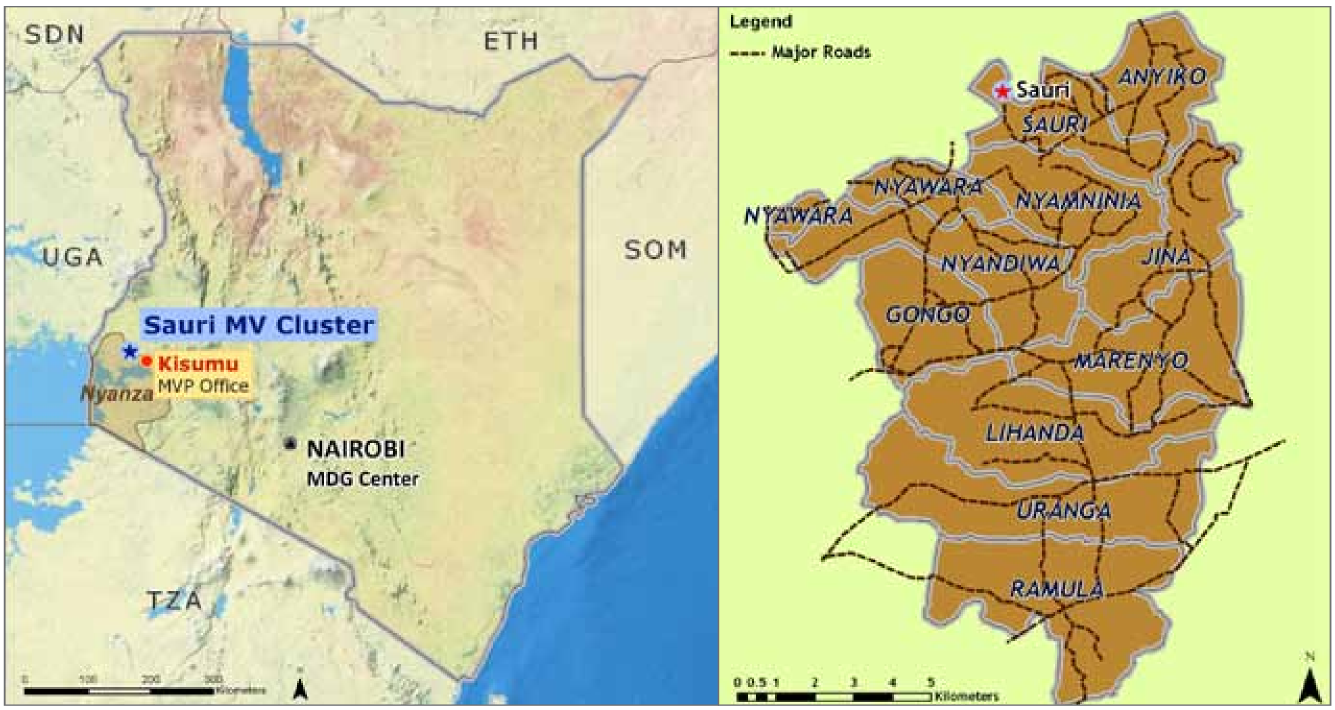
The motor-pumps (Yamaha YP20 or YP10) are diesel-powered and both cost approximately 268,000 CFA ($617). These models were chosen by the MVP site team because of their performance and fuel consumption. A single pump can irrigate an average rate of 0.22 ha/hr while consuming 11.47 mm/day of water and consuming fuel at a rate of 1.69 l/h. For manual labor, the average rate of irrigation is only five percent of this (0.011 ha/hr), while it consumes a comparable amount of water (11.72 mm/day). Also as part of the motor pump program, a farmer can buy an irrigation kit.

The pumps have had an immediate impact on the agricultural practice, making it faster, cheaper and less risky. Farmers no longer depend on rain or the availability of seasonal workers and can have four farming campaigns per year, doubling farmers' incomes. Many farmers reported that they have increased their land plots because the motor-pumps allow them to irrigate more land with less effort and time. To date, the systems have low maintenance costs and the users are generally very satisfied.

In a second intervention, irrigation is being promoted in Dieri, the drier part of the Potou cluster and specialized in rain fed agriculture, to diversify crop production and reduce climate related risks. Six village or community gardens measuring between 0.5 ha and four ha are already functional, and there are plans to establish over a dozen more. Three of these gardens are connected to the piped water network and pay fees to the ASUFORs. The three others use water from a hand-dug well -- two with windmill pumps (repaired by MVP) and the third with a solar pump (installed by MVP). ■

CHAPTER 8

Site Profile: Sauri, Kenya



The Millennium Villages Project began with Bar Sauri, a rural area of roughly 5,000 people located in the Siaya District in the highlands of western Kenya, near the city of Kisumu. As the project expanded, the Sauri MVP cluster came to comprise approximately 65,000 people spread over 132 square kilometers.

When the MVP began, the population density in Sauri was already high (500–600 people per square kilometer), and poverty and hunger were widespread, with almost 80 percent of the population earning less than $1 per day. Education and health facilities were generally in poor condition. Most schools lacked grid electricity, supplies and improved latrines, and few had sufficient teachers. With just five government health facilities and one referral hospital in the area, the average distance from villagers' households to a clinic was more than five kilometers. Although a major, paved road passes through the cluster, local roads were in poor condition. Most markets were served by the central electricity grid, but high fees prevented connections for most households. Despite the abundance of water from rivers and streams, only seven percent of the population had access to an improved drinking water source, with the majority using unimproved springs that showed high levels of contamination.

Summary of Infrastructure Outcomes and Lessons Learned

- Clear division of roles and expenditures in partnerships with local utilities were essential to the rapid implementation of grid electrification projects.
- A trial subsidy and loan program to reduce the costs of household connection fees has shown some potential to increase penetration rates.
- Improved "rocket" stoves have been installed in all primary schools (saving an estimated 200 tons of fuelwood annually).
- In implementing roads projects, MVP prioritized funds according to economic feasibility and population density, capitalized on community participation and addressed land rights issues prior to construction.
- Thorough investigation was important to ensure that water sources followed population density, project costs were kept low and delays were avoided with p artners.

Energy in the Sauri Cluster

ELECTRICITY

At baseline, the Sauri cluster already had an extensive electricity grid, with 38 kilometers of medium voltage line reaching all but one of its 14 trading centers. However, most primary schools and health facilities were not connected, and few households were connected, even in areas near transformers, due to high connection fees ($500 or more) charged by the national power utility, KPLC. With good pre-existing grid access in markets, the MVP prioritized grid extensions to clinics and schools as well as household connections. These projects targeted about 36 institutions, including 25 schools, eight health facilities, and three institutions of different types, at a total cost of nearly $680,000, a mix of MVP funding (~72 percent or $559,000) and Kenyan government support (the remaining 28 percent or $121,000). Details of institutional electrification are provided in the sections describing education and health facility interventions. This section focuses on general costs and implementation steps for grid projects.

A sustained, high-level of engagement with the Kenyan national utility and government was critical to the success of grid extension projects. The public Rural Electrification Program (REP), later Authority (REA), prioritized the extension of the electricity grid to health facilities, secondary schools and community water pumping stations. Agreements with the local utility, Kenya Power and Lighting Company (KPLC), defined specific projects for which KPLC carried out technical work and MVP paid extension costs. Following this agreement, applications for extensions to institutions were submitted to KPLC, which sent engineers to conduct detailed site surveys, including generating designs and costs. For most projects, particularly schools, MVP paid grid extension costs, and KPLC extended power lines to the institutions. For other projects, primarily health centers, the utility undertook extensions with government funding. Contractors were engaged to do the internal wiring.

These projects provide detailed grid electricity cost information. They are of two basic types: low voltage (LV) connections and medium voltage (MV) line extensions. The average cost of MV line extension, $25,000/kilometer, is within the usual range for sub-Saharan Africa. Around $12,000 of this went to MV line equipment, while the balance was for other equipment (LV line, transformers, labor, permits, etc.)

To help overcome KPLC's high household connection costs ($432), MVP initiated a pilot program to support connections for households located within a 600-meter radius of a transformer. The project paid $185 per household (more than 40 percent of the full connection fee), and the household contributed the remainder. To date, just 91 households have been connected under this arrangement, suggesting that the balance of connection costs ($247) is still too high for most households.

Figure 8.1: Map of Sauri cluster medium voltage grid extension projects

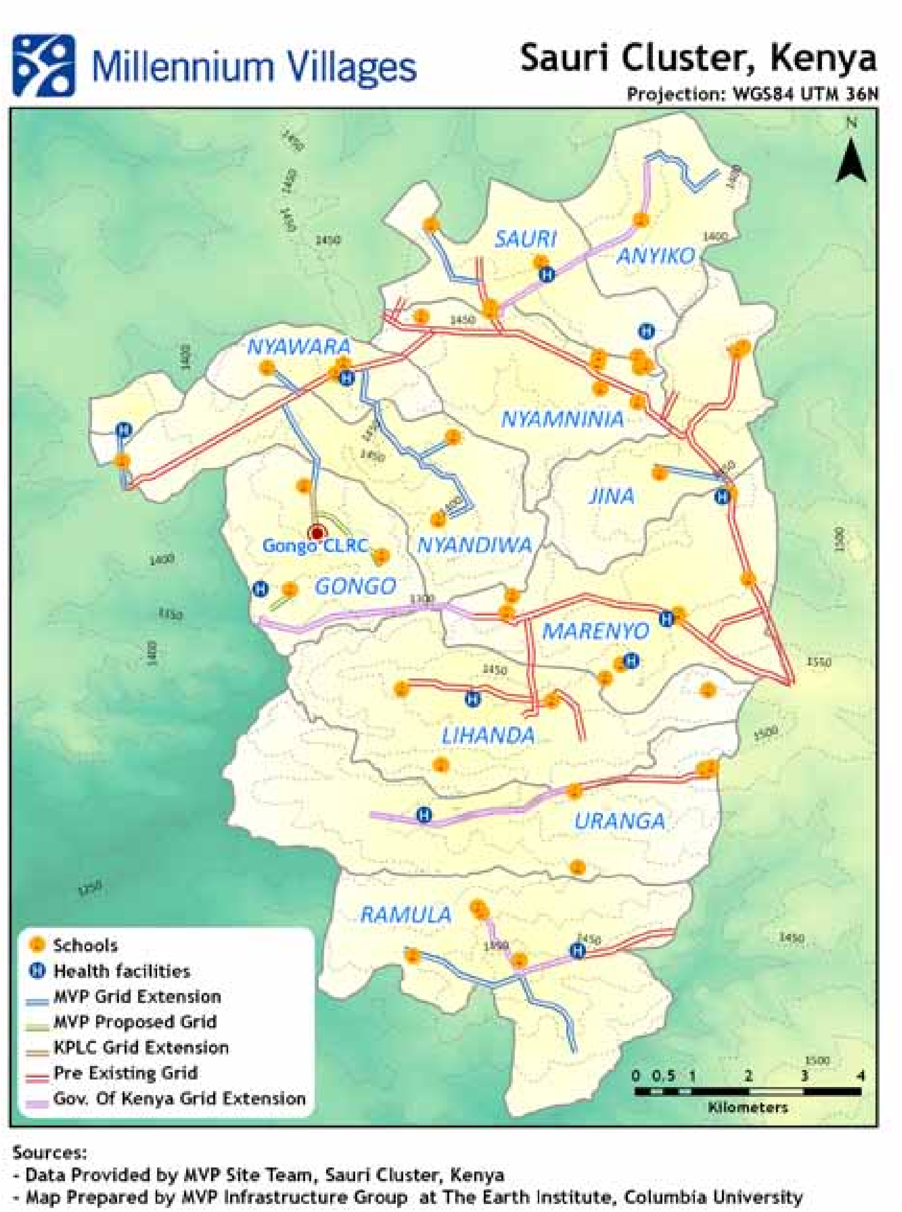


Table 8.1: Approximate cost breakdown of grid extension projects, Sauri, Kenya

Full project costs (MV & LV equipment, and all other)		Equipment costs		Other Costs, (Ave. per project)	
$ per kilometer of MV line	Ave: ~$25,600 $/km	MV ($/km)	$12,000	Labor	$4,000
	High: ~$49,600 $/km	LV ($/km)	$8,500	Materials Transport	$1,800
	Low: ~$16,500 $/km	Transformer (each)	$4,000	Permits & Supervision	$13,200

Table 8.2: Approximate cost breakdown of grid connection projects, Sauri, Kenya

Connection Costs (per project)	"drop down" (with 1-2 LV poles)	Connection with transformer
Household:	$432	Not applicable
Institutions (Schools, Clinics & Community Centers, etc.)	$400-500	~$6,000—6,500 per connection

To help fill the gaps in electricity services for institutions lacking both a grid connection and a solar photovoltaic system, MVP introduced 134 LED lanterns to health facilities and primary schools for lighting and installed solar photovoltaic systems in four health facilities, which eventually got grid connections as well.

Health (Construction and Energy)

MVP Target:	Electrify health facilities as selected by MVP health sector
Status at Project Launch: 40% Electrification of Clinics	5 clinics existed in cluster (2 with grid, zero with solar PV)
Outcome at 5th Year: 100% Electrification of Clinics	All 10 health clinics in the cluster are electrified (10 with grid, 4 of which also have solar PV backup)
MVP expenditures: Estimate: $4,700	Estimated grid costs (connection only) for 4 clinics undertaken by the MVP
Government contribution: Estimate: $ 120,00	Kenya's REP/REA funded grid MV extensions to four clinics at an average cost of ~US$30,000 per project.

At project launch, Sauri had five health facilities with a catchment area of 96,000 people. Three of the health facilities did not have grid power, and all five relied on rainwater harvesting and surface water collected from nearby streams. The project's strategy regarding infrastructure for the health sector is an integrated approach: improved health facilities (i.e. clinics, dispensaries, posts, etc.), improved housing conditions for health facility staff, better access to

Figure 8.2: Electricity status of health facilities

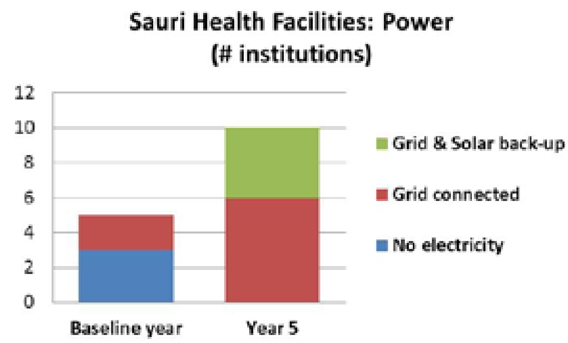


Figure 8.3: Health sector related construction

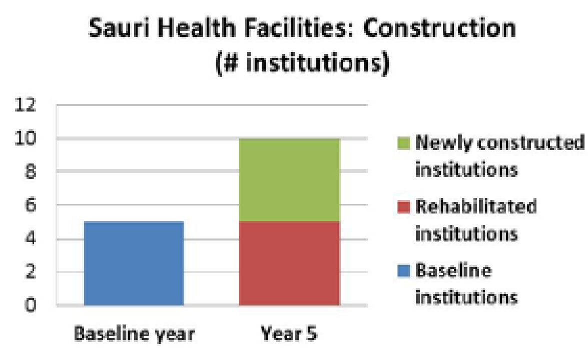


Figure 8.4: Availability of health services

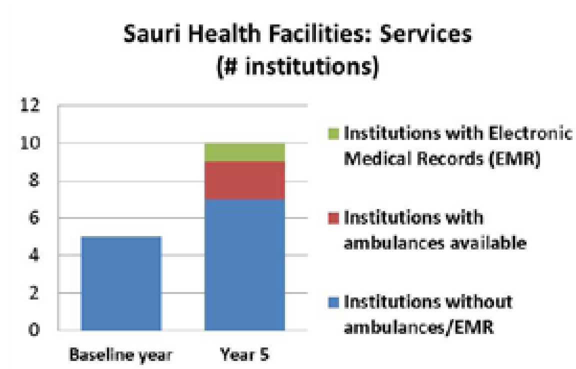


Table 8.3: Cost breakdown of health facility building projects: rehabilitation and new construction

	Rehabilitation			New Construction		
	Existing facilities (Area, in m^2)	Total costs (US$)	**Unit cost (US$/$m^2$)**	New facilities (Area, in m^2)	Total costs (US$)	**Unit cost (in US$/$m^2$)**
By Year 5	2,501	$296,455	**$118/$m^2$**	1,204	$218,107	**$181/$m^2$**

facilities (i.e. roads and ambulances) and enhanced telecommunications (i.e. mobile telephony) between health facilities and the community for both community health worker visits and emergencies. These objectives were to be achieved by upgrading the level of services in existing facilities, rehabilitating and constructing new centers and staff quarters and connecting these to clean water and power. Transport and ICT interventions related to health will be discussed in the transportation and telecommunication sections, respectively.

Clinic construction was the first building activity in the Sauri cluster. The community provided land, labor, and local materials, and MVP worked with local governments to determine the type and architectural plan for the structures. The Yala Sub-district Hospital (SDH), a referral hospital located near Sauri village, has undergone major changes, including the construction of two wards and the renovation of the hospital's operating theatre to ensure continuous availability of medical services for expectant mothers and other patients. MVP also installed a voltage stabilizer to safeguard sensitive medical equipment against power fluctuations and a compact water treatment plant, donated by General Electric, to filter water pumped to the facility from a nearby borehole. Other interventions, some of which were undertaken in partnership with the Constituency Development Fund (CDF): construction of new facilities and maternity units at six locations (Bar Sauri, Lihanda, Gongo, Onding, Masogo and Mindhine) and building rehabilitation, including main facility structures, staff houses, and outpatient and maternity units at four facilities (Ramula, Marenyo, Nyawara, Mindhine).

To ensure the maintenance of facilities and sustainability of services, the health facilities were registered by the government and listed on its Master Facility List (MFL), permitting them to receive supplies from the Kenya Medical Supplies Agent (KEMSA).

In order to provide for services while awaiting grid extension, the project provided solar photovoltaic systems for four health facilities. The Kenyan government took the lead in grid electrification of health facilities. REP/REA provided ~$120,000, or 96% of all funding for MV line extensions to four health facilities (Bar Sauri, Gongo, Lihanda, and Onding), at an average of ~$30,000 per facility, and roughly 1.5 kilometers of MV line per institution. The remaining four percent, paid by MVP, was for grid connections at four other facilities (Masogo, Ramula and Marenyo and Mindhine Dispensary), typically at a cost of $400-$500 each.

MVP Target:	New construction and electricity service for educational facilities as required by MVP education sector
Status at project launch: 16% electrification of schools	5 of 35 primary and secondary schools were electrified at baseline
Outcome at 5th year: 89% electrification of schools	5 new schools and 51 new classrooms built All 41 of 46 schools electrified
MVP expenditures: $460,000	Electrification of ~22 schools (13 LV connections, 9 MV extensions) at an average cost of $21,000 per school
Government contribution: estimate: $45,000	Three MV extensions at an average cost of $15,000 per school

Prior to the Project, the cluster had 35 primary schools, five that were connected to the grid and the others with no power. Most schools were in a deplorable

Figure 8.5: Uyonga Primary School (before (left) and after construction (right)

state, with classrooms that were temporary mud structures with earthen floors and teachers frequently conducting lessons under trees. The education sector goal of increased access to a full course of quality primary education for all children was supported through:

- Construction and rehabilitation of schools to improve access for underserved areas of the cluster
- Construction of improved kitchens and installation of improved stoves to strengthen the school meals program
- Provision of electricity and ICT services to primary schools and administration blocks
- Construction of more gender-separate latrines to improve retention for girls (described further in Water and Sanitation)

A total of 51 new primary school classrooms were constructed. Clean water was also supplied to all schools through improved rainwater harvesting systems. These interventions helped improve learning environments, encourage better attendance and advance the performance of existing students. To ensure sustainability, MVP conducted interactive sessions with school administrators and management committees on best practices to maintain the newly constructed structures.

The number of schools with electricity increased from five (of 35 total) at baseline to 41 (of 46 total) at year five, at an approximate cost of $21,000 per school. The cost breakdown for each project was determined largely according to the required equipment: the 11 schools that required only LV line connections cost between $400–500 each, while the two schools that required transformers, but no MV extensions, cost ~$6,300 each. The 10 schools that required full

Figure 8.6: Construction for Sauri cluster education sector

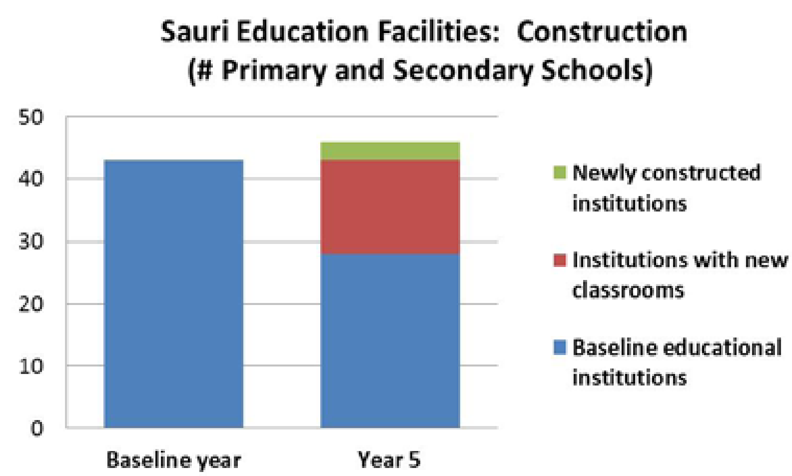


Table 8.4: Approximate cost breakdown of construction of new classrooms

New Classrooms:	Number	Area (m^2)	Total cost (US$)	**Unit Costs (US$/$m^2$)**
By Year 5	51	3,970 m^2	$327,704	**$82.5/m2**

Figure 8.7: Electricity status of Sauri cluster primary schools

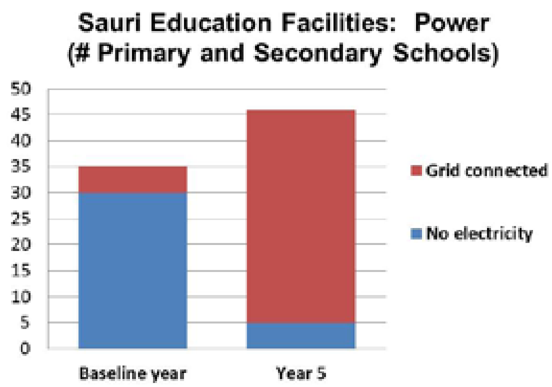


Figure 8.8: Sauri cluster educational institutions with improved stoves.

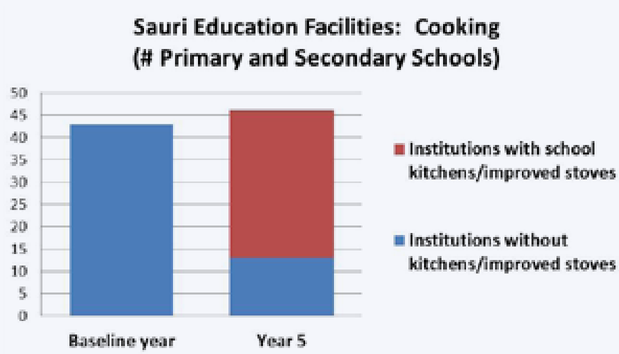


Figure 8.9: Cooking at Nyamninia Primary School using a three stone stove (left) and a fixed institutional Rocket stove (right)

MV extensions and transformers, plus LV line, cost an average of $48,000 each, at an average MV extension length of 1.8 kilometers. The MVP paid the majority of these costs, contributing around $500,000 total for the connection of roughly 23 schools, accounting for 97% of all expenditures for school electrification. The Kenyan government contributed only three percent of the total school electrification expenditures: about $45,000 for MV extensions serving three schools.

Prior to the project, all schools and nearly all households in Sauri cooked with collected fuelwood over traditional three stone fires. To address this, MVP implemented two improved cooking interventions. First, MPV constructed school kitchens in all 31 primary schools. It installed 88 rocket stoves, which use large pots (about 100 liters), and reduce fuel consumption for the schools' free mid-day meals programs by around 35 percent, amounting to total fuel wood savings of roughly 250 tons per year across all participating primary schools.

The household cookstove model chosen for Sauri was the Lorena Rocket, a mud and clay design built in each household kitchen costing less than $5. To date, 6,894 improved cookstoves have been constructed in the cluster, reaching 51 percent of the total households in Sauri.

Roads and Transportation in the Sauri Cluster

MVP Target: 50% within 2km of all-weather road	At least fifty percent of the population with 2km of an all-weather road
Status at Project Launch: less than 30% access	Less than one third of the population lived within 2km of an all-weather road
Outcome at 5th Year: Greater than 50% access	Over 90 kilometers of road improvements , over 1,200 meters of culverts installed
MVP expenditures: $1,221,348	Includes road repair and construction, with some preliminary maintenance
Government Contribution: $361,227	Includes road repair and construction, with some preliminary maintenance

Although Sauri is served by a major paved road, at baseline, about 75 percent of the cluster's more than 300 kilometers of local roads were in poor condition, and less than one third of the population lived within two kilometers of an all-weather road. MVP's transportation strategy focused on upgrading existing roads to all-weather standards and constructing new roads to bring at least 50 percent of Sauri's villagers within two kilometers of an all-weather road.

The Kenyan Ministry of Roads & Public Works categorizes roads as either classified (maintained by the government) or unclassified (not government maintained). The MVP focused on the rehabilitation of unclassified village roads to improve access to roads leading to major trading centers, schools, health fa-

Figure 8.10: (left to right) Rehabilitated Saola Road in Jina Village, Rawalo-Madangala Road construction, Culverts at Muhanda-Arude Road

cilities and community centers. After mapping the existing road networks, the Sauri MVP worked with village roads committees to prioritize roads for rehabilitation and collaborated with the government to identify spots for improvement and the costing of road works. The community contributed labor for bush clearing and land where road widths were inadequate.

Over 90 kilometers of roads were improved (dozed, graded, graveled, compacted, or spot-patched) to upgrade their classifications to all-weather roads. In addition, over 1,200 meters of ring concrete culverts were installed to improve drainage and to allow the passage of small streams during rainy seasons, improving access for villagers to markets, health facilities, schools and other institutions.

In view of this significant MVP contribution to the community, the MVP engaged the district roads engineer to upgrade rehabilitated roads to classified status to ensure the availability of national funds for maintenance and rehabilitation. The local road authority inspected the rehabilitated roads as a preliminary step. Meanwhile, at the local level, over 400 road committee members were trained in basic road maintenance techniques such as culvert cleaning, weed removal and limited spot-gravel.

Water and Sanitation in the Sauri Cluster

MVP Target:	100% access to an improved drinking water source, year-round: during both wet and dry seasons
Status at Project Launch: 6.9% coverage	6.9% of population at baseline with access to improved drinking water source at baseline
Outcome at 5th Year: 93% coverage	93% of population at year 5 with access to improved drinking water source
MVP expenditure: $426,000	Includes spring construction ($104,000), rainwater harvesting ($165,000) borehole drilling and equipping and pipeline construction ($157,000)
Government Contribution: $83,000	Including spring construction ($41,000), borehole drilling and equipping and pipeline construction ($42,000).

The water and sanitation sector's primary goal is to halve the proportion of people without access to safe drinking water and basic sanitation services by expanding the coverage of improved water sources (e.g., piped water, boreholes, spring protection, rainwater harvesting etc.) and sanitation structures (VIP latrines in households and institutions). At baseline, access was low to both improved water (6.9 percent of households) and improved sanitation (14.4 percent). The average distance to a water source was 370 and 429 meters during the wet and dry seasons, respectively, and most villagers used unprotected springs complemented by informal, dirty household rainwater harvesting systems. A piped water system, Sidindi-Malanga, was present in Nyamninia Village, but due to the deterioration of pipes and the breakdown of pumps at the Yala River intake, some household taps had service just two days of the week while others had not produced water for years. Sauri made great progress in increasing access to improved water sources through a diverse range of strategies, principally boreholes, piped water, rainwater harvesting, improved springs and ventilated improved pit (VIP) latrines. By the end of year five, 93.6 percent of households had access to improved water sources and almost 20.5 percent of households had access to proper sanitation.

MVP constructed four piped water networks, extending over 17 kilometers in length and serving more than 11,000 villagers. The MVP worked with the Lake Victoria South Water Services Board to rehabilitate the intake of the Sidindi-Malanga Water Supply from the Yala River, which fed a water treatment plant and 3,300 cubic meter reservoir. The system served a total population of 15,000 people, 4,160 within the Sauri Cluster. Works involved the repair of two turbines and the installation of two new pumps, plus an extension of the pipe network by 13 kilometers. This project cost around $51,000, roughly half borne by MVP, and served around 15,000 people, resulting in an investment of roughly $3.40 per beneficiary, considering populations both inside and outside the cluster.

Figure 8.11: Impact of water interventions

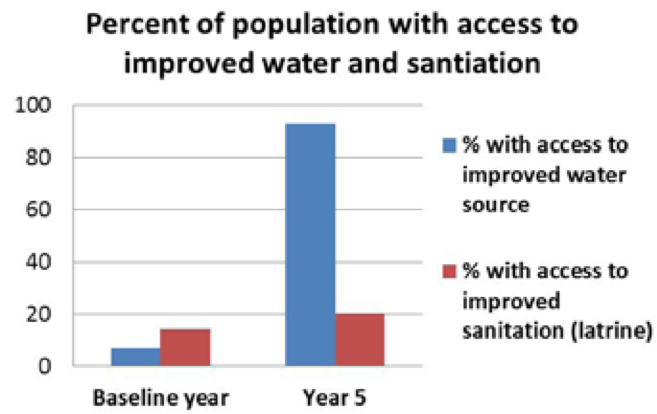


Figure 8.12: Number of piped water networks

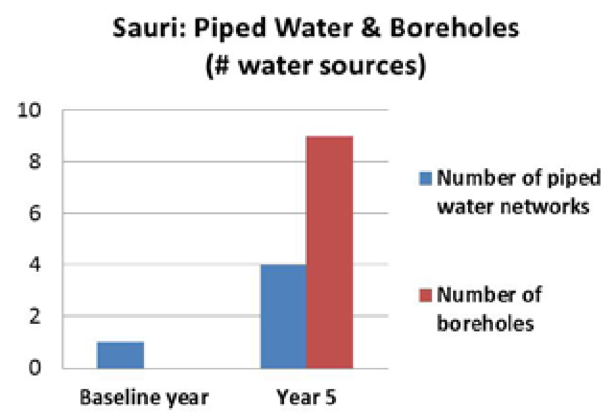


Figure 8.13: The Sidindi-Malanga project: turbine to be rehabilitated at Yala River intake (left); water treatment plant in Nyamninia Village (right).

Table 8.5: Sauri piped water interventions

	No. of newly constructed Piped water networks	Total length of new pipes (km)	No. of rehabilitated Piped water networks	Total length of rehabilitated pipes (km)	No. of drilled boreholes
Year 5	3	17	1	8.60	9

Other piped water projects implemented in collaboration with the community include:

- The extension of 3.8 kilometers of pipes to supply water from Rabuor tank to Marenyo Health Centre, in partnership with Ahono Singa Community Water Project, Marenyo Village.
- The extension of Ramula piped water supply from the borehole to Ramula Health Centre and market.
- The extension of two kilometers of pipes to supply 47 households in in the Sauri Village.

A total of 10 borehole projects were undertaken by the project: eight boreholes equipped with pumps at a total cost of $34,500 (around $4,300 each) serving 5,200 villagers, yielding a cost of $6.65 per person served. The other two boreholes were equipped with electric submersible pumps. The project also drilled a borehole at the Yala Sub-District Hospital; this project included a generous donation for pumping and water treatment by General Electric.

Rainwater harvesting (RWH) was a major part of the water strategy. The Project installed 52 plastic and concrete RWH tanks in 40 institutions, at a cost of about $3,200 per water point, serving an estimated 18,000 users and almost doubling the cluster's storage capacity from 642,000 to 1,279,000 liters. The RWH systems at schools facilitated the school meals programs, because students no longer had to fetch water from nearby sources. At health facilities, RWH systems capture water, which is pumped into overhead tanks with treadle pumps and then gravity-distributed to points within the facility.

Working closely, and through cost-sharing, with the community's help, MVP protected 270 water springs at a cost of around $550 per spring. The total cost was $145,000, 72 percent of which was borne by the MVP. These springs are estimated to serve a population of 35,000, yielding a cost of around $4.10 per person. Spring management committees, made up of users, were trained on catchment conservation and contamination reduction techniques such as surface water diversion and buffer zone tree planting.

MVP Target:	Reduce by half the population without access to basic sanitation services
Status at Project Launch: 14.4% of households 20% of institutions	14.4% of households and less than 20% of health centers and other institutions have access
Outcome at 5th Year: 20.5% of households 100% of institutions	20.5% of households and all schools, health centers and other institutions have access
MVP expenditure: $220,501	More than 400 VIP latrines constructed (approximately $550 each)
Government Contribution: $5,598	Septic tanks for schools ($5,598)

At baseline, sanitation in the cluster's primary schools was insufficient, consisting of mud-wall latrines with neither roofs nor doors, and some schools had no gender-separate facilities. Kenyan Ministry of Education guidelines required that a total of 1,296 gender segregated toilet stalls be installed, at a ratio of one to each 25 girls and 30 boys. The key sanitation intervention was the construction of over 400 gender-separate Ventilation Improved Pit (VIP) latrine cubicles in health facilities, primary schools, households, and public facilities at a unit cost of approximately $550 each. This project included more than 280 gender-separate VIP latrine cubicles in primary schools, with the objectives of improving sanitation while targeting

Figure 8.14: Map of Sauri cluster water piping projects

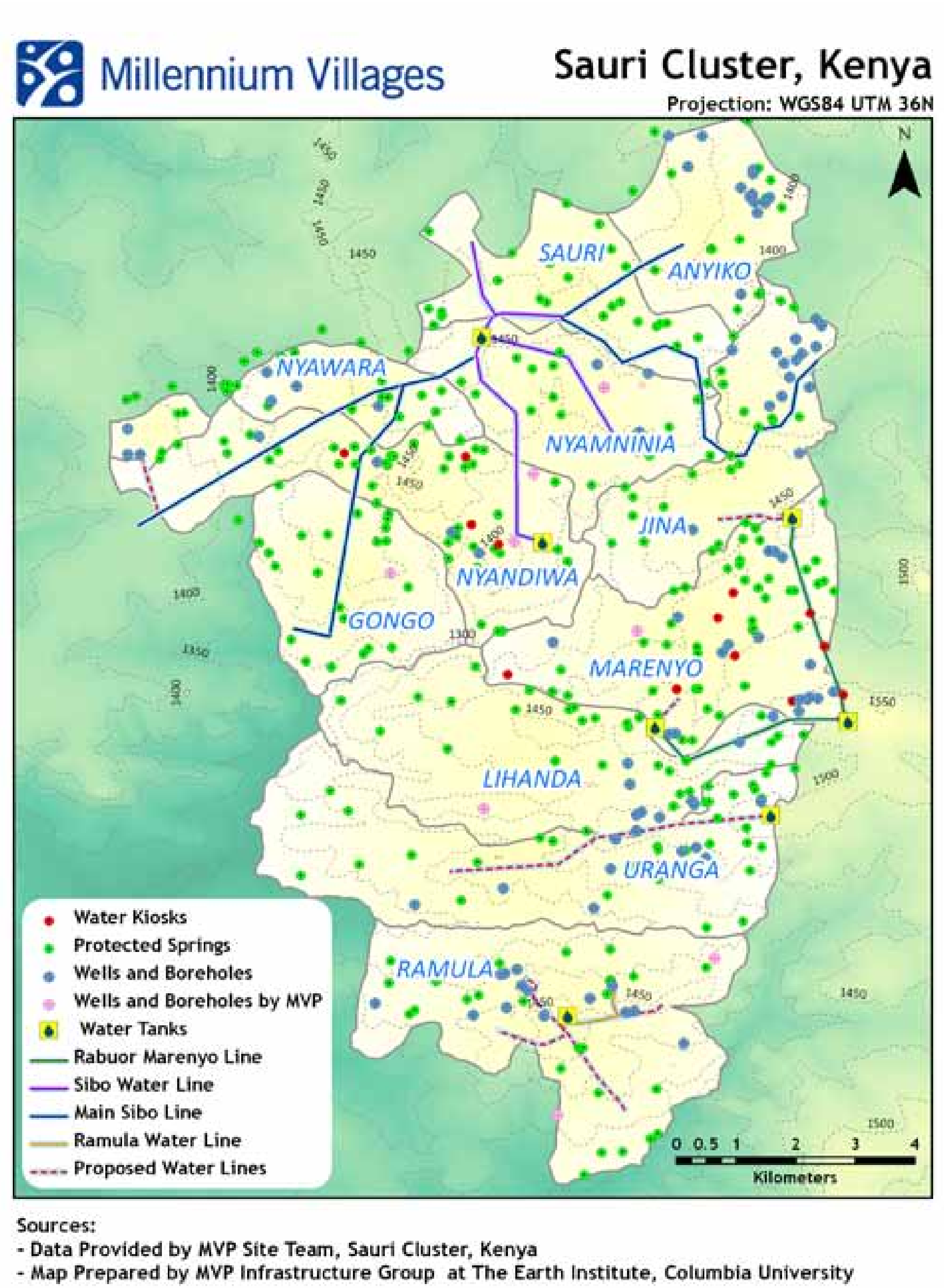


Table 8.6: Summary of rainwater harvesting projects in the Sauri cluster

	RWH Capacity (1,000 liters)	No. of schools with improved RWH	No. of health facilities with improved RWH
Baseline Year	642	—	—
Year 5	1,279	31	9

Figure 8.15: (left to right) Tatro Primary School latrine before, then after construction; training for construction of VIP latrines

improvements in the attendance of girl students, who may not attend school to avoid sharing toilets with boys. In order to build local capacity, some 33 villagers were trained on the construction of VIP latrines. Other sanitation interventions included participatory sanitation trainings for communities and schools, as well as the construction of incinerators and placenta pits for disposing of biomedical waste at health facilities. Sewage systems with septic tanks were also constructed at three health facilities.

Information and Communication Technologies (ICT)

MVP Target:	Mobile phone network access within 2kms of 80% of all households
Status at Project Launch: N/A	Limited access
Outcome at 5th Year: 80% coverage	Over 80% of households have mobile network coverage.

Prior to the MVP, telecommunications in the Sauri cluster were limited but more varied and extensive than at other MVP sites. Some villagers possessed cell phones, which were often left uncharged due to power limitations. Seven of the cluster's 14 markets had community pay phones, and five of the trading centers had photocopying, word processing, or printing services. The Project's objectives were to achieve mobile phone network coverage within two kilometers of 80 percent of all households; to improve villagers' access to educational materials, agricultural prices and related information and to introduce mobile phone-based health services.

Partnerships with Ericsson and regional GSM operators expanded and strengthened GSM network coverage. Ericsson worked with CelTel (later AirTel) to provide both voice and data GSM network coverage through the installation of five strategically located GSM service masts in the cluster--at Barkalare (Uranga), Muhanda, Rabour, Nyamninia, and Yala Centers. By 2010, the number of households using a telephone (primarily mobile) had risen to 80 percent.

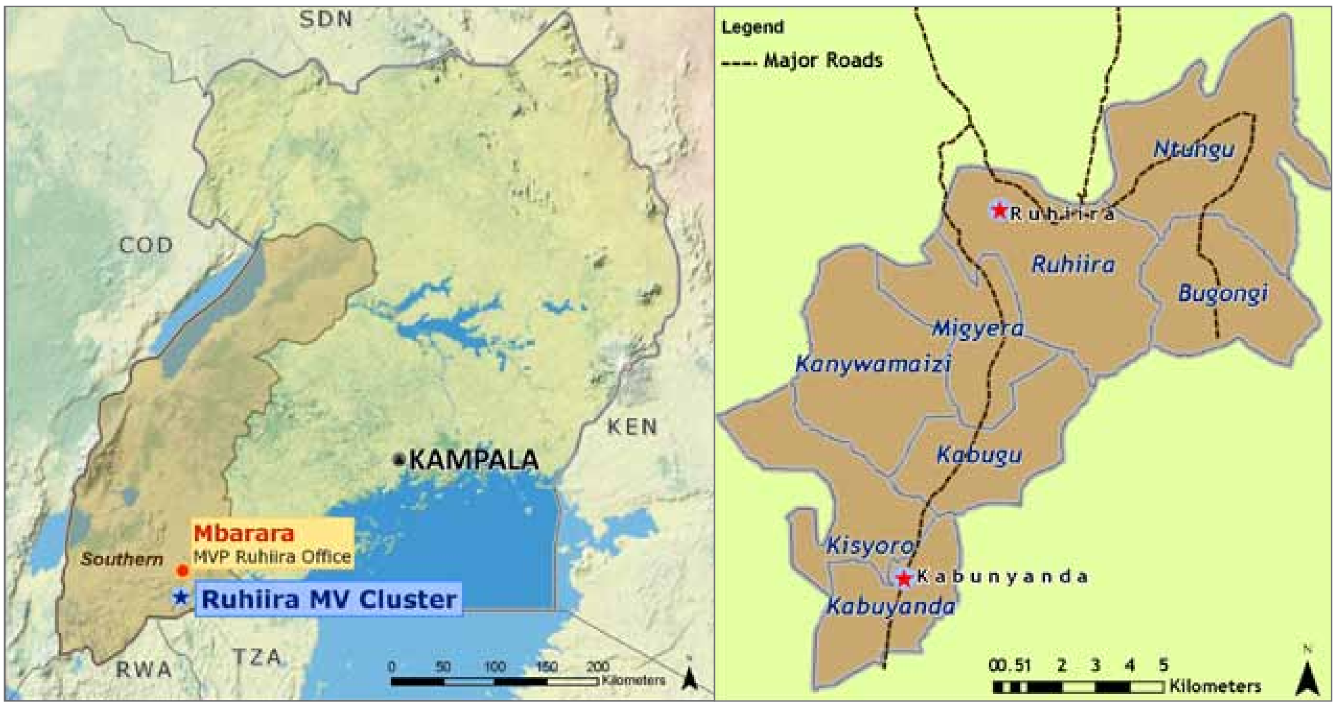
Wireless networks were created for clinics, schools, and other institutions. MVP installed computers at nine health facilities, equipping them with wireless Internet terminals. The Project also installed VSAT at Siaya District Hospital, which was funded by General Electric. Good network coverage allowed for the introduction of mobile phone-based health services (mHealth), improved data collection and transmission for health workers, as well as the installation of an electronic medical record system (Open MRS) at

Yala Sub-district Hospital as well as the introduction of two on-call ambulances. For the education sector, MVP provided 265 computers, allowing Sauri to affordably create a computer lab in each of the 26 primary schools and offer computer training for teachers and students. The Project constructed Community Resource Centers (CRC) in four villages (Marenyo, Gongo, Nyawara, and Bar Sauri) that house community banks, adult education centers, computer rooms, meeting halls, and one community radio station that will endeavor to provide news, weather and agriculture-related education programs and pricing information. ■

Figure 8.16: Computer room at Nyamninia Primary School (left); computer training for teachers (right)

CHAPTER 9

Site Profile: Ruhiira, Uganda



Ruhiira is a cluster villages located in the Isingiro District of southwestern Uganda, near the town and commercial center of Mbarara. The cluster has a total population of about 50,000 people, 95 percent of whom practice agriculture as their primary occupation, with plantains as the primary staple food and cash crop. The area covers about 140 square kilometers, with elevations ranging between 1,350 and 1,850 meters, and rainfall between 900 to 1200 millimeters annually. The undulating hills are characterized by steep slopes, which drain into the valley bottoms, creating a stream system that finally drains into the Kagera River, which flows into Lake Victoria.

Ruhiira is a relatively recent settlement that was created after sub-tropical forest was cleared in the early 1950s. Clearing indigenous forest for farming is estimated to have left only about five percent of the land under tree cover. There are serious signs of deforestation, environmental degradation and a shortage of available wood (for firewood, construction, etc.). High population density, continued growth rates and commercial over-cropping have contributed to land shortages and degradation. Ruhiira is among the poorest of areas of southwestern Uganda, with close to half the people (40-50 percent) earning less than one dollar a day.

Summary of Infrastructure Outcomes and Lessons Learned

- MVP increased the proportion of residents using improved drinking water from seven percent at baseline to 56 percent by year five with a combination of piped water and improved springs. Topography was decisive for piped water schemes, leading to a factor of three to four times difference in costs for serving villagers in upland areas (served by pumps) versus lowlands (served by gravity-flow systems).

- Plans for comprehensive grid electrification with the cost sharing between the government and MVP experienced multi-year delays. SharedSolar micro-grids were undertaken to fill the resulting gap in household electricity access.

- Improved institutional cookstoves in schools can dramatically decrease the fuel consumption of school meals programs. Households have shown a willingness to pay (~$10) for improved, manufactured household stoves that are sold with ~50 percent subsidy.

- MVP road works consisted of substantial widening and grading (>50 kilometers), new road construction (40 kilometers), and installation of drains and culverts (~30 kilometers).

Energy in the Ruhiira Cluster

MVP Target: 50% Grid Electrification	Community-level electricity service to 50% of cluster population
Status at Project Launch: 0%	No grid connection in Ruhiira
Outcome at 5th Year: k13% Grid Electrification + SharedSolar for off-grid	13% of the population lives within 2km of the grid
MVP expenditures: $150,000 (estimate)	$45,678 for grid-related costs. Estimated $100,000 spent so far on SharedSolar
Partner / Government contribution: N/A	Costs for grid extension to Kabuyanda are not available.

Before the MVP, the nearest electricity gridline was 15 to 20 kilometers outside the Ruhiira cluster. Most clinics had inadequate power or none at all, and households relied on kerosene, candles or dry cell batteries for lighting and other non-cooking energy tasks. Several households and some market centers had diesel generators for lighting, cell phone charging and small appliances. MVP Ruhiira aimed to halve the number of institutions and households lacking access to modern energy. Plans were developed to extend the electricity grid via collaborations with the local energy utility and national Rural Electrification Agency. However, government cost-sharing contributions were delayed, and MVP undertook SharedSolar (standalone mini-grid systems serving 10 to 20 households) where grid extension activities were not feasible.

After an early MVP appeal, the Rural Electrification Agency (REA) offered over $1 million in cost sharing (>50 percent of total project costs) for comprehensive grid extension throughout the Ruhiira cluster, serving social infrastructure and water points. While the government did support MV grid extension to one important location—Kabuyanda, which has a population of greater than 5,500, a major market, a hospital and two schools—full cost-sharing support from REA was not forthcoming for the rest of the electrification plan within the project's timeframe. In response, the MVP initiated installations of SharedSolar, a standalone micro-grid solar system (see Chapter 5), as an alternative strategy to meet project electrification targets. In the Ruhiira cluster, eight SharedSolar systems were planned across three to four communities. One system installed in Ruhiira is now serving 20 customers (mostly households), with others planned for Nyankitunda and other locations not yet identified.

SharedSolar sites were selected based on a combination of technical and social criteria: no electric grid now or planned in the near future, a high density of potential customers (10-20 within a 100 meter radius) with willingness and ability to pay, strong and consistent mobile phone network coverage and year-round vehicle accessibility. Community sensitization involves three steps: i) community meetings to describe SharedSolar, noting how it differs from both grid electricity and solar home systems and identify possible sites for the central generation equipment; ii) targeted small group conversations to plan the pathways of wires to homes, with a goal of reducing total line length and helping move targeted consumers to the next step; iii) registration, which details initial and recurring costs (i.e. scratch cards) plus a survey of household characteristics, energy use and related expenditures. Registration concludes with customers paying connection fees.

The first SharedSolar system carried a capital and installation cost of about $27,000: $5,000 for the meter, $10,000 for the PV system and about $12,000 for the civil and electrical works, including a shed, trenches, labor, wire etc. Each household contributed ~$55 as a connection fee for the first system installation in Ruhiira (estimated at $70 for future customers). At $25,000, the cost is nearly $18/Wp installed, and the cost per household connection is $1,250. The cost of future installations is expected to fall—by 20 percent in the short term and 60 percent in the long term (i.e. down to $500 per connection)—as experience is gained in civil and electrical works, management and economies of scale.

HOUSEHOLD COOKSTOVES

Fuelwood scarcity, due primarily to cleared forests for farming, caused many cluster villagers to rely on farm waste (maize stokes and banana rhizomes) as their major energy source for cooking, and some reported limiting the number of meals cooked per day due to lack of fuel. The MVP improved cookstove program was introduced to ameliorate these problems by introducing improved, fuel saving stoves. The Project conducted Controlled Cooking Tests (see Chapter 4) to compare fuel use of the locally-produced Ugastove, the imported StoveTec and the three-stone fire combined with a survey to evaluate which stove users preferred. Results indicated statistically significant fuel savings for both the StoveTec and the Ugastove (around 35-40 percent for each), but cooks showed a greater preference for the StoveTec.

Based on these results, the MVP introduced StoveTec stoves through a program in which stoves were sold via an energy cooperative and village vendors at a subsidy of ~50 percent: 20,000 USh each ($9) purchased individually, or 100,000 USh ($45) for six stoves ($7.5 each) purchased in bulk. The majority of customers opted to buy as a group, through one of 14 village vendors, who received a 500 USh commission (~$0.50) per stove. Over 1,000 stoves were sold, indicating villagers' willingness and ability to pay. Delays

Figure 9.1, SharedSolar, (left to right): a shed housing the batteries and electronics; solar panel installation; home with electric lights powered by SharedSolar next to a home using kerosene lighting


Figure 9.2: Three-stone fire (left); household Rocket-style cookstove (right)

in the arrival of the second order of cookstoves complicated marketing and program operations and caused some vendors to lose motivation. In response, raising vendors' per-stove commissions from 500 USh to 1,500 USh incentivized them to stock stoves and to provide better post-sales service.

Energy and Infrastructure for Health

MVP Target:	Electrify health facilities as required by MVP health sector
Status at Project Launch: 33% of health centers electrified	6 clinics existed in cluster, 2 electrified with solar at baseline
Outcome at 5th Year: 100% of health centers electrified	One facility (Kabuyanda) has grid power and solar All others have solar power
MVP expenditures: US$11,568	Includes small solar systems, diesel generators
Government contribution: N/A	Costs for electricity grid extension to Kabuyanda are not known

At baseline, the Ruhiira cluster had six health facilities, only two of which had consistent power (solar systems), and one used a generator intermittently. Due to the inadequacy of local facilities and services, the Ruhiira population often traveled 58 kilometers to the regional referral hospital in Mbarara for major medical services such as surgeries. By year five, one of the health facilities had been connected to the grid, which the Ugandan government extended to Kabuyanda, and the remaining four had standalone solar systems.

The introduction of the Ruhiira water scheme also provided the Ruhiira health center with access to clean tap water with three fully installed rainwater harvesting tanks, plumbing, a pump and an elevated water tank (500 liters). The other five clinics all had one to two new rainwater harvesting tanks installed. The project assisted in the construction of gender-separate, brick VIP latrines in order to improve the sanitary conditions at the health facility.

Figure 9.3: Health Facility Electrification in the Ruhiira cluster

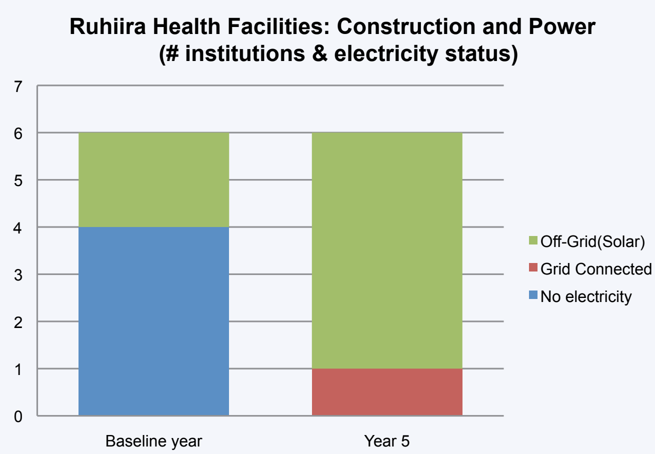


Figure 9.4: Rainwater harvesting with PVC tanks (left); VIP at Ruhiira District health center (right)

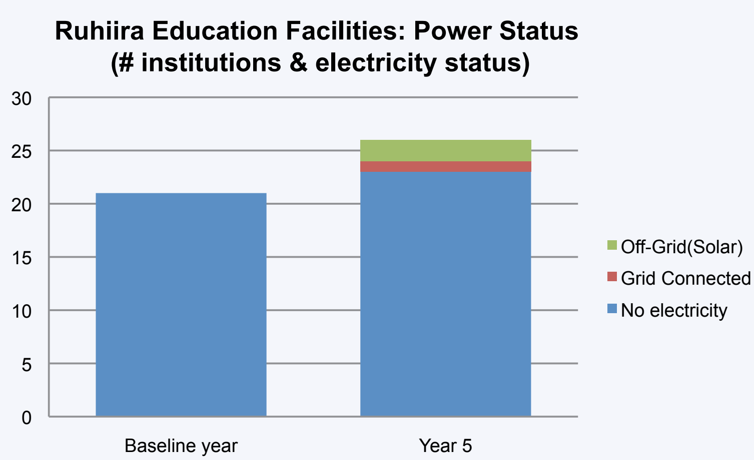
Energy and Infrastructure for Education

MVP Target:	Electricity service to education facilities as required by education sector
Status at Project Launch: 21 schools, 0% electrified	None of the cluster's 21 schools had electricity
Outcome at 5th Year: 26 schools, 12% electrified	5 new schools were built. 3 schools have electricity (12%): 2 have solar power, 1 is connected to the grid.
MVP expenditures: $3,000	Two solar systems at $1,500 each.
Government contribution: $0	$0

At the start of the MVP, there were 21 schools in the cluster, 18 primary schools and three secondary schools, and none of them had access to grid electricity. At year five, the project had constructed an additional five schools, bringing the total number of schools to 26 (19 primary schools, four secondary schools and three nursery schools). The project also electrified two schools using solar systems and connected one school to the grid near the Kabuyanda extension.

In school kitchens, MVP installed more than 40 Rocket cookstoves in more than 20 schools. These improved stoves reduced the burden of fuel collection as well as fuel costs of the meal programs. Each of the institutional stoves cost roughly $1,800, which was covered by MVP.

Figure 9.5: Construction and electrification of educational facilities in the Ruhiira cluster



The Project also upgraded rainwater harvesting activities by introducing PVC and ferro cement rainwater tanks in schools to reduce contamination. This provided students with washing stations for use after leaving the latrines, improving sanitary conditions. Between baseline and year five, the project installed an additional 34 rainwater harvesting tanks in cluster schools. Also, in accordance with Ministry of Education guidelines, 324 VIP latrines were constructed (25 to 30 students per stall), in order to improve the attendance of girls who might avoid school if required to share latrines with boys. The five stance VIP latrine blocks were constructed by MVP at a cost of $3,896 each, including a small community contribution to the project.

Standalone solar systems were installed in two schools for lighting and powering donated computers. Each system cost approximately $1,500 and was funded through the project's education budget in conjunction with the ICT program to bring connectivity to schools (see ITC section below).

Transportation

MVP Target:	Fifty percent coverage of population within 2km of an all-weather road
Status at Project Launch: 20% of the population	20% of the Population within 2km of an all-weather road (Roughly 20km of existing road)
Outcome at 5th Year: 75% of population	75% of population within 2km of an all-weather road (Representing 70km of opened, graded and maintained.)
MVP expenditures: $176,370	Including assessments, road related salaries and road work
Government Contribution: $19,330	Including assessments, road related salaries and road work

The Ruhiira cluster is located in a hilly setting with heavy rainfall and steep elevation changes causing rainwater to rapidly damage road surfaces. At baseline, there were only two all-weather roads: one connecting Ruhiira to Kabuyanda, and another connecting Ruhiira and Nyakitunda. The MVP's roads and transportation strategy focused on improving roads and providing access to timely, motorized ambulance service for medical emergencies.

At baseline, MVP assessed all roads within the cluster and created a plan for road improvement in the cluster. This meant working with local authorities to compile a list of roads with lengths, locations and current status; community meetings to prioritize road construction and rehabilitation; consultations with district engineers to avoid overlap with government roads works; and creation of a final list of priority

Figure 9.6: Rehabilitation of the Kaaro-Karungi-Kisyoro road, before (left) and after (right).

roads for MVP rehabilitation and construction.

At year five, over 50 kilometers of community roads have been widened and graded, and 40 kilometers have been newly constructed. Around 30 kilometers of local roads were outfitted with side drains and line culverts to reduce water damage during the rainy season. The Project maintained all-weather specifications for all newly-constructed, graded, and spot-graveled roads to ensure they would be passable during heavy rains. These roads have improved access to the nearby Kabuyanda market and have increased the community's access to cluster markets in general, health facilities, schools, water sources and other institutions.

For future maintenance, the project organized beneficiaries into road committees and trained them in simple road maintenance tasks such as culvert cleaning, weed removal, spot-graveling, etc. Also, each year, the district classifies and takes over the roads that have been constructed or rehabilitated by MVP, making them eligible for annual road maintenance programs supported by district funding.

Water and Sanitation

MVP Target:	100% Coverage: Proportion of population using an improved drinking water source, year-round during wet and dry seasons
Status at Project Launch: 7%	Most underground water sources contaminated by salts; protected springs were far from homes
Outcome at 5th Year: 57%	Combination of piped water and protected springs
MVP expenditure: $157,148	Including borehole rehabilitation, shallow wells, springs protection and piped water design, planning and construction
Government contribution: $82,645	Including piped water design, planning and construction

The provision of cleaner drinking water was perhaps the primary challenge for the Ruhiira MVP. Despite an estimated annual rainfall of between 900 to 1,200 millimeters and two rainy seasons annually, only seven percent of the cluster's population had reliable access to clean water at the Project's start. Most underground water sources contained concentrations of iron and salts at levels that made them unsuitable for human consumption. A limited number of protected springs were available; however, a 400-500 meter elevation differential between hilltops where most villagers live, and valley bottoms where springs are located, made access a daily challenge. Villagers typically lined up at springs as early as 5 a.m. to access clean water, and these long morning queues contributed to school absenteeism and tardiness.

These difficulties led residents to obtain water for drinking and cooking elsewhere. Some collected pooled rainwater from road drainage ditches, ponds or puddles. Others employed informal rainwater harvesting (RWH) methods, gathering rain from rooftops, using simple gutters made from strips of corrugated metal or split plastic pipes to guide water into bucket containers or tarpaulin-lined underground tanks. Both methods risked contamination. Most institutions in the cluster, particularly health and educational facilities, did not have access to clean water. In schools, the majority of the buildings used less than 50 percent of their major roofs for rainwater harvesting.

The site's primary water and sanitation sector goals are: i) to halve the proportion of people without access to safe drinking water within 1 kilometer from the household; ii) to provide basic sanitation services. Toward these ends, MVP performed an extensive assessment of Ruhiira's water and sanitation resources and needs: the demands of households and institutions; the quality of water sources and the specifications of the local water authority. This included information gained through local government agencies, community members and other development partners. Feasibility studies were performed to determine the technical, social, cultural, institutional, financial, and environmental viabilities of the intervention. Existing water sources and communities were identified and viable interventions are prioritized for improvement.

The result was work-plan for constructing four piped-

Figure 9.7: Collecting water from a ditch (left); rainwater harvesting from roof to underground tank (right)

water schemes (in Ruhiira, Kyeyare, Kyenyanga and Kabuyanda) using a total of 11 water springs at an estimated cost of $1.75 million. Due to limited funds, two water schemes were prioritized through a collaborative effort between MVP, the local water authority and villagers: 1) a pumped water system in Ruhiira costing $480,000 and serving an estimated 5,073 villagers ($24 per capita); and 2) a gravity-fed water system for Kabuyanda, costing $180,000 and serving 7,637 villagers ($95 per capita).

The reason for the difference in construction costs was topography: The source for the Kabuyanda system was 150 meters away and allowed for gravity distribution. However, the source for the Ruhiira scheme was almost 300 meters below the village and required the addition of four pumps (two duty and two standby), two diesel generators to operate the pumps, over 1,400 meters of ductile iron transmission pipe to withstand the pressure of the pumped water and two 150 cubic meter water storage tanks (one made of reinforced concrete to capture the water from the springs before it is pumped into an elevated pressed steel reservoir at the highest point).

Supplementary interventions were required to provide remaining villagers with access to safer water. These interventions included i) upgrading rainwater harvesting activities through the use of PVC tanks at schools and health centers to reduce contamination in 52 facilities, ii) expanding the number of water points from 86 to 163 and iii) increasing the number of protected water sources from three to 16.

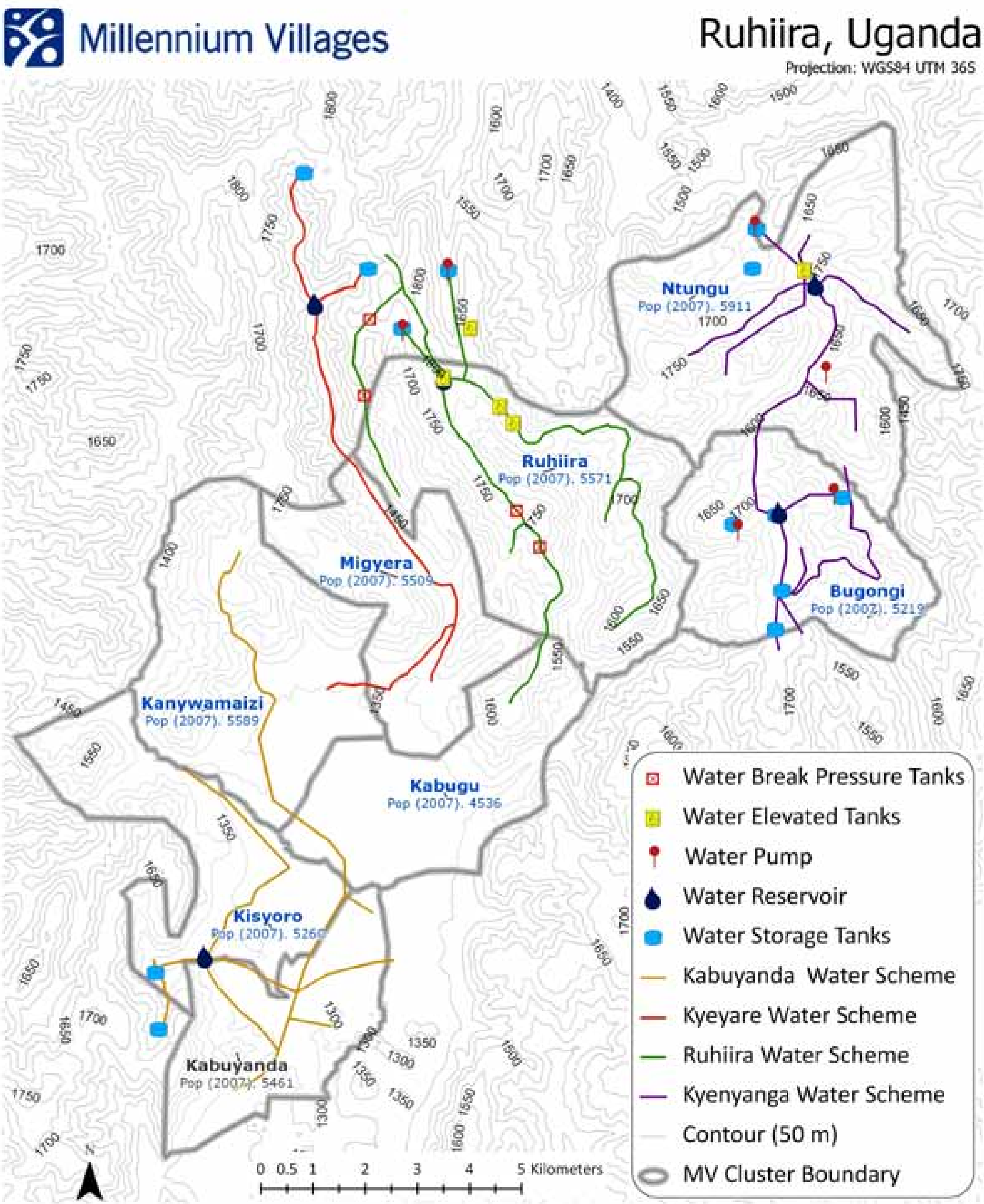
MVP Target:	Reduce by half the percentage of population without access to basic sanitation
Status at Project Launch: N/A	Baseline information not available.
Outcome at 5th Year: 100% institutions	MVP programs to construct VIP latrines resulted in 500 latrines in households, 84 in institutions.
MVP expenditure: $60,000	MVP contributed around $90 for each household latrine ($44,973 total); estimate of $15,000 for 84 institutional latrines.
Community contribution: $45,800	Each household contributed ~$91 (materials and labor).

As assessment of primary school latrines revealed that none achieved the minimum standard for providing access (no more than 40 students per stance), and many latrines were made of earthen materials with doors of woven dried banana leaves and contained no hand washing stations. In response, MVP constructed institutional and household latrines. MVP supported the construction of Ventilated Improved Pit

Table 9.1: Breakdown of the two constructed water schemes

Water Scheme	Population Served (2010)	Cost		Pipes		Transmission		Distribution & Connection
		Construction (total)	per captia	Total (m)	Ave cost per km	Ductile iron (m)	HDPE (m)	PVC (m)
Kabuyanda	7,637	$180 K	$23.50	35,890	$5,000	—	11,500	24,390
Ruhiira	5,073	$480 K	$94.70	44,255	11,000	1,430	3,337	39,488

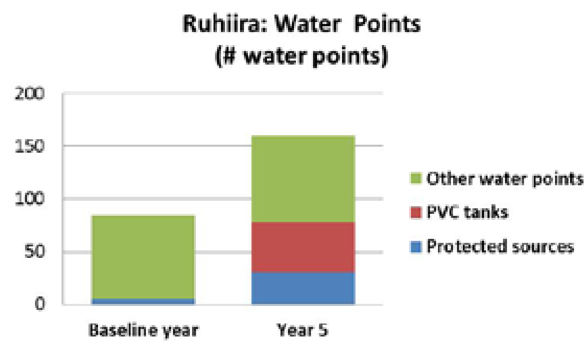
Figure 9.8: Piped water projects in the Ruhiira cluster



Sources:
- Millenium Villages Project, Ruhiira, Uganda
- Millenium Villages Project Infrastructure Group at The Earth Institute, Columbia University

Figure 9.9: Protection of Ruhiira's water source

Figure 9.10: summary of cluster water point interventions



(VIP) latrines (50 stances) in schools, six at health facilities (26 stances), and three at other institutions (12 stances). At the household level, a total of 500 homes have benefitted from latrines and the project aims to construct an additional 1,500 household latrines in the coming years. The project costs are divided between MVP, which contributed approximately $90.40 for each latrine (iron sheets, PVC pipe, treated poles, concrete, and skilled labor, transport, and oversight), and households, which provided in-kind contributions of approximately $91.40 (pit evacuation, poles, water, mud and labor). Beneficiary households are selected by Community Health Workers and are given sensitization trainings on latrine use and handwashing at village-level meetings.

Information and Communication Technologies (ICT)

MVP Target:	Achieve mobile phone network access within 2 km of 80% of all households
Status at Project Launch: N/A	Very limited basic telecommunication
Outcome at 5th Year: 80% of households	Over 80% of HH are within access to mobile phone networks
MVP expenditure: $80,000 (estimate)	Approximately $50,000 for computer installations; around $30,000 on towers, and $20,000 for community radio.
Government contribution: N/A	N/A

At baseline, only Kabuyanda, with less than 20 percent of the population, had mobile phone reception. There was no wireless data service in the area, and health facilities and schools had no computers. The MVP's primary strategies were to increase cell phone coverage, install computers in clinics and schools and establish a community ICT Center in Ruhiira as well as a community radio station to facilitate low cost communication throughout the community.

MVP constructed and furnished a community ICT Center that was equipped with a computer laboratory providing Internet access and word processing. To enable Internet connectivity and basic VOIP (voice over Internet) services, the MVP installed a 65 kilometer WiFi network connecting the ICT Center in Ruhiira with the MVP office in Mbarara, as well as six clinics, four primary schools, two community learning centers, a community radio station, two community ICT kiosks and two MVP field offices. Each of the community ICT kiosks was set up to improve Internet and connectivity access to people throughout the cluster. The communities ran them as businesses and are responsible for maintenance and any expansion. MVP also supported the purchase of 28 computers in total: two computers in four clinics, allowing OpenMRS and ChildCount; and four computers each in five schools, which allowed students and teachers of Nyakamuri Primary School to access the Internet and discuss world matters with students from other parts of the world via the School to School program. E-learning programs have been launched at Omwichwamba Primary School and Kabuyanda Central School.

Later, Ericsson, working with local mobile phone network operators, added cell phone towers that provided cell phone coverage for 70 percent of the area and population. These networks were upgraded with data service (EDGE/3G), which is available in most areas that have cell phone coverage.

To establish the community radio station, MVP supported the procurement of a transmitter/mast, a frequency license, acoustic preparations for a radio room and the training of two operators. The station, the Millennium Voice at 102.2 FM, is a tool for villagers to learn about such things as price and market information on local commodities, agricultural best practices (e.g., seed selection, watering, fertilizing, etc.) and local news bulletins (weather conditions, emergencies, etc.).

CHAPTER 10

Maintenance and Sustainability

Since its inception, the MVP has made substantial progress in addressing the infrastructure and energy indicators outlined in the Millennium Development Goals. Looking ahead at the next five years, MVP is committed to addressing issues of sustainability and maintenance, ensuring that energy and infrastructure projects in the Millennium Villages endure beyond the duration of the project. While each energy and infrastructure intervention raises unique issues and challenges, several overall themes and lessons emerge from the Millennium Villages. This last chapter briefly examines the issues and provisions that seek to ensure sustainability.

Each of the MVP technical solutions requires specific maintenance that must be addressed with attention to the local context. Size, scale and the cost of infrastructure, both in terms of the initial investment and ongoing maintenance, must be considered. As was discussed in Chapter 3 (Operations), the physical and demographic scale of the MVP sites—clusters of villages, with geographic areas typically in the hundreds of square kilometers and populations of generally 30,000 to 60,000—is much smaller than the administrative unit for which infrastructure planning and budgetary allocations are typically made. In MVP countries, examples of these larger administrative units include districts, counties, woredas (in the case of Ethiopia) and other local jurisdictions with populations ranging from 100,000 to 500,000. In cases in which the local government is expected to adopt, scale-up or maintain MVP projects or similar interventions, this issue of relative scale plays an important role.

At the local level, the strategy for funding the maintenance of infrastructure—such as community level piped water systems and solar photovoltaic micro-grids (SharedSolar)—has been a fee-for-service approach. At the regional level, the responsibility for upgrading and maintaining roads often falls to district offices, which request and receive funding from national or sub-national government taxes. At the national level, power utilities provide electricity service and maintain grid infrastructure, which is paid for primarily through the collection of tariffs.

However, efforts to maintain and sustainably manage infrastructure are beset by economic and technical challenges that come with the task of serving the poorest. Although funds are collected at each management level, they are frequently insufficient. The need to measure and collect payments for numerous, small service deliveries often increases recurring costs to the point that traditional billing and payment methods are no longer cost-effective, and novel management systems and technologies are required. At least a minimal amount of water and electricity services are necessary—or nearly so—for people's very survival, and the poorest may have virtually no ability to pay during cash-poor seasons, necessitating special provisions such as "lifeline tariffs" or minimum daily allocations for these users. Commercial providers tend to locate in cities and large towns, making technical expertise for system maintenance scarce and costly in poor, remote areas. If systems are not properly sized for the poorest at the outset, according to these users' needs and ability to pay, the imbalance adds to the difficulty of recovering costs.

MVP projects have faced these and other challenges. Some of the approaches used to address them are described below:

Drinking water

The effective maintenance of drinking water systems is demonstrated by projects targeting areas of comparable scale to MVP sites. This can work well when villagers obtain water from a distribution system fed by either a borehole or surface-water, when a system is in place for collecting small user fees for maintaining the water supply and paying for fuel for pumps. But in areas served by other types of systems—such as standalone hand pumps, which often make sense from a technical perspective—both the mechanism and the resources for maintaining the pumps are not always in place. Issues beyond drinking water supply can also be challenging: Establishing a mechanism to carry out regular water quality checks is very difficult to institutionalize. In the MVP, it has also been difficult to institutionalize sanitation and hygiene education and practice.

Schools and health facilities

For infrastructure in social institutions such as schools and health facilities, even in cases where the initial investment in buildings and equipment is satisfactory, there is often an unmet need for a range of services and goods that would pose additional recurring costs—including routine maintenance, major repairs and, in some cases, fuel—for water, sanitation and electricity systems as well as ambulances.

Some of the technical issues that contribute to poor maintenance are: a) poor initial sizing of the systems, b) failure to upgrade systems to match changing demand growth, c) poor initial technology choice, resulting in systems that are not robust and d) lack of routine maintenance protocols. Attempts by individual facility managers to work directly with private sector providers to specify, install and maintain individual systems can, without higher level technical and budgetary guidance, lead to fragmented and ad hoc implementation across many similar facilities, leading to inconsistent system specification and maintenance. There are also often administrative challenges: Health and education facility staff members rarely have the skills and time to attend to maintenance of infrastructure systems that operate at the facility level. Where training takes place or maintenance skills already exist, a facility often lacks the funds for crucial repairs, and skilled individuals may move on to other locations, taking their capacity with them. Transport difficulties and weak supply chains in remote areas make it difficult and costly to carry out routine maintenance that requires both periodic (monthly) service visits and a consistent supply of parts to keep pumps, generators and solar systems well maintained. While service contracts are one approach to addressing many of these maintenance issues, such contracts should be arranged to include not only traditional "maintenance" tasks and parts, such as the periodic servicing of an ambulance engine, but also "major repair" and "reinvestment" needs and costs, such as re-purchasing a battery for a solar system.

Roads

Road and transport improvements are a quintessential public good, and can generate adequate enhanced economic activity and internal taxes to provide for their maintenance. A project at MVP's scale can demonstrate the building and rehabilitation of needed road infrastructure, but it is much more difficult for a project of this scale to ensure the maintenance of such roads works. This is primarily due to the political and administrative difficulty of ensuring the allocation of significantly more government resources, for a period of five to ten years, for maintenance only in the specific project area.

There are two primary reasons for this. First, the project area's administrative unit does not generally have internal mechanisms for levying taxes or generating revenues specifically for road maintenance. In most cases, maintenance budgets come from federal funds—which are likely to be partly raised from transport-related levies or taxes, for example, fuel taxes or vehicle registration/licensing fees or custom duties on the import of vehicles. Some countries have programs or civic traditions by which locales (jurisdictions that are smaller than districts) mobilize support for labor-based repairs by community members (Uganda, Rwanda), or apply for funds to allocated for specific roads projects (Kenya's CDF - Constituency Development Fund). Such programs can typically cover only a portion of the maintenance fund shortfall.

Second, the funds that are disbursed by the federal government for maintenance and repair are often inadequate overall, and specific road works may be delayed until a crisis situation leads to additional political pressures for repair. Nearly all metrics of development used by administrations and politicians see value whether in statistics or in media opportunities of reporting new infrastructure built. Moreover, the typical MVP project area is only part of the larger administrative area and its economic success cannot translate directly into a local maintenance budget. It may be better able to articulate an additional need for roads if, for example, there is a significant increase in surplus produce moving to market. Some ideas on how a project of this nature can provide added value by a) making current resources go further, and b) articulating the need to budget a greater allocation for maintenance, are presented later in this chapter.

Water systems in Potou: Nearly three-fourths (71 percent) of the delivery cost of piped water in Potou is due to fuel expenses for pumping. Steps being taken to manage and reduce service delivery costs include:

- Switching from diesel pumps to electric pumps with grid power should reduce recurring costs by 20 to 30 percent.
- The investment required to replace pre-existing but oversized generators with new, properly sized systems can quickly be recovered in reduced operating costs.
- Properly clarifying responsibilities and reducing redundancy in water supply management can lead to more effective maintenance.

Equally critical to the sustainable management of this new water infrastructure is the community's continued involvement and willingness to pay for services. An MVP study of household water collection patterns at the Potou, Senegal, site found that approximately 20 percent of the population that had access to a tap within one kilometer nonetheless continued using open wells. Distance was the most commonly stated reason for not taking advantage of pay-per-use taps, which in some cases required villagers to travel an additional 500 meters each way. ■

The problem of financing for maintenance of systemic, network infrastructure is such still a deep unsolved challenge that most site-specific development projects shy away from building it. What would be desirable for long-term maintenance is to focus on ensuring that communities and/or local governments address maintenance as part of their ongoing work plans. In Sauri, Kenya, this involved re-classifying roads, sometimes to a higher designation, thus justifying more frequent maintenance by the district. The long-term question remains whether governments and communities will be able to sustain this commitment to maintain improved roads. ■

Electricity and mechanical power

For grid electricity, a utility is responsible for maintaining systems. If maintenance falls short, remedies may consist of improving overall utility management and cost-recovery and increasing penetration rates in areas with grid "backbone" but few connections. These are two types of improvements that tend to work together: Without sound management and efficient cost-recovery, additional customers may decrease overall reliability. But with both elements in place, increasing the number of rate payers for a given electricity line can increases revenue for the utility's system maintenance with relatively low additional capital expenses. The former issue is beyond the scope of this project, but for the latter, the primary lesson of MVP experience has been that penetration rates are higher in countries where grid connection costs for homes and businesses are already low (Ghana) or where additional subsidy programs are enacted (such as MVP's trial program in Kenya).

Systems that mainly provide mechanical power, such as grinding mills and irrigation pumps, are generally owned by a private entity—an individual, cooperative or private business—and pumps are often provided for rental. In both cases, service is on a "pay-per-use" basis, providing an income stream to pay for maintenance by the owner.

The way forward

Greater understanding and innovation are needed for improved maintenance and sustainability. Currently, the project does not have an overarching successful protocol or strategy to provide lessons for scale-up. There are, however, some ideas worth considering:

1. **Greater use of information systems for reporting operations and maintenance status.** Such information can be valuable in identifying the location of broken infrastructure, and what infrastructure is failing frequently and why. Particularly when such data is

aggregated over time and across a broad scale it becomes possible to identify patterns and reasons for failures and to address them in a systemic fashion. Information systems may be beneficial in managing parts inventories and procurement requirements, allowing for bulk purchasing and the efficient planning of repair visits. Both are significant operational benefits, especially when the cost of transport vehicles can dominate the small discretionary budgets of district and field offices, and when supply chains are weak in rural areas.

2. **Greater community Involvement.** Local health and school facility directors/heads/principals are not always empowered to spend discretionary budgets on repairs in order to prevent the misuse of funds. Moreover, while skilled labor (e.g. construction, trenching, piping, electrical and mechanical repair) exists in many small towns, such rural personnel may not be familiar with the bidding, procurement, licensing and payment requirements of state administrative structures or large NGOs. It is worth investigating what combination of community, civil and local governance structures can provide the necessary oversight to utilize local skills in a flexible manner that ensures that such systems are efficiently maintained.

3. **Greater role of private sector through service, performance and output-based contracting.** As many developing nations have grown rapidly in the last decade, their private sectors have matured. A parallel strengthening of legal, contractual and banking infrastructures is also taking place, at least in large urban centers. Thanks to ubiquitous monitoring and measurement systems that can leverage mobile phone and data connectivity, the cost of verifying service delivery is shrinking significantly. This opens a space for simpler contracts tied to measured performance and service delivery that in turn allows for larger private participation. For example, the electricity needs of an off-grid, rural health clinic may now be feasibly fulfilled by measured, monitored power delivered to the clinic using a model like that of **SharedSolar**.

4. In some sectors, help from higher management with modular system specifications can help in many areas, particularly in reducing problems with system design. Sectoral leadership (such as health and education ministries at the district or national level) can aggregate knowledge and experience across many facilities and longer timeframes to specify or recommend a standard set of infrastructure services required at specific facility types, then work with infrastructure specialists to determine standard system designs to cost-effectively meet those needs. Such a program could plan for maintenance in a systematic fashion, aggregating service needs across many facilities and taking advantage of economies of scale for service calls and replacement parts, thereby reducing the degree of ad hoc, high cost maintenance.

Sustainability

The larger issue of sustainability is closely tied to the question of whether the infrastructure deficit of Sub-Saharan Africa is addressed at scale. For road/rail transportation, all the various networks—port facilities, rail (in dense corridors), pipes for fuel and efficient border crossings—must be addressed. The same holds true for power infrastructure: There are large gaps in generation and transmission that call for regional collaboration and coordinated action. For such investments to pay off, they must be made in concert (spatially and temporally) with the economic engines underpinning growth. Experience from the MVs shows, however, that there is an ability and willingness among the rural poor to pay for the small but crucial first few units of service (whether it is for connectivity, electricity or water) if that service is reliable and measurable. This "bottom-up" experience may create space for cheaper, leaner infrastructure to be deployed in rural settings, which can then be incrementally upgraded if and when demand grows. ■

Appendices

Appendix I: Basic Information for 10 Millennium Villages

Site (MRV Name, Country)	Agro-ecological Zone*	Elevation (m)	Precipitation (mm/annum)**	Population Density (persons / km2)***	Persons per Household	Population
Bonsaaso, Ghana (GHA)	Tree crop	147	1359	76	5.2	**35,000**
Dertu, Kenya (KEN)	Pastoral	0	495	4	6.0	**6,150**
Ikaram, Nigeria (NGA)	Root crop (Guinea savanna)	386	1605	N/A	4.5	**20,000**
Mayange, Rwanda (RWA)	Highland perennial	1432	1195	298	4.8	**22,900**
Mbola, Tanzania (TZA)	Maize-mixed (unimodal)	1168	960	44	5.6	**38,740**
Mwandama, Malawi (MWI)	Cereal root-crops mixed (Southern Miombo)	1035	986	496	4.0	**34,260**
Pampaida, Nigeria (NGA)	Cereal root-crops mixed (Sudan savanna)	603	987	178	6.0	**26,600**
Potou, Senegal (SEN)	Coastal-artisanal fishing	10	406	64	9.7	**31,690**
Ruhiira, Uganda (UGA)	Highland perennial	1495	1245	325	5.3	**51,710**
Tiby, Mali (MLI)	Agrosilvo-pastoral	283	677	80	13.8	**74,350**

*Adapted from FAO, 2001.

** Unpublished data: International Research Institute for Climate and Society, The Earth Institute at Columbia University. 2006. Monthly satellite estimated rainfall averaged over the period from 1979-2005. Data compiled by Eric Holthaus, using methodology by Janowiak, J. E. and P. Xie, 1999: CAMS_OPI: A Global Satellite-Rain Gauge Merged Product for Real-Time Precipitation Monitoring Applications. J. Climate, vol. 12, 3335-3342.

***MVP Demographic Survey, 2007.

Appendix II: GPS Data Collection Check List

Questions for Point Locations and Access Attributes:

This document has 3 parts:

A) A chart listing types of locations for which your team should acquire location information (such as GPS latitude & longitude points)

B) A list of general Access Attribute questions, which can be applied across many location types

C) A list of specific questions to be applied only to a given type of facility.

Section A) Chart of which questions to ask at what type of facility

Types of facilities or locations	Attributes for each – refer to Access Attribute Questions below	
Health Facilities	Location Power Access Water Access	Road/Transport Access Computer/Internet Access Mobile Phone Coverage
Educational Facilities (Primary and Secondary)	Location Power Access Water Access	Road/Transport Access Computer/Internet Access Mobile Phone Coverage
Other Gov't / Community building	Location Power Access Water Access Road/Transport Access	Computer/Internet Access Mobile Phone Coverage Plus: Additional questions for this location type (see list below)
Markets / Trading Centers	Location Power Access Water Access Road/Transport Access	Computer/Internet Access Mobile Phone Coverage Plus: Additional questions for this location type (see list below)
Mobile Phone Towers	Location Power Access	Road/Transport Access
Churches / Mosques / religious institution	Location Power Access Water Access Road/Transport Access	Computer/Internet Access Mobile Phone Coverage Plus: Additional questions for this location type (see list below)
Warehouses / Cereal Banks	Location Power Access Water Access Road/Transport Access	Computer/Internet Access Mobile Phone Coverage Plus: Additional questions for this location type (see list below)
Transportation Points (Bridges and Culverts)	Location	Plus: Additional questions for this location type (see list below)

Section B) Access Attribute questions:

These are questions to be applied to for specific locations according to the chart above. Note that other surveys exist for specifc types of facilities (schools, clinics, water points) that are more detailed.

POWER ACCESS:

"What types of power sources are available at this facility?"

Choices:

- None/no power source
- Generator
- Solar system
- Grid connection/power/PHNC/NEPA
- Other: Please specify:

WATER ACCESS:

"What types of water source are available less than 100 meters away from the school or within the premises?"

Choices:

- No water source within 100 meters of the facility or within the premise/compound
- Borehole/tube well
- Protected dug well
- Unprotected dug well
- Protected spring
- Unprotected spring
- Other: please specify:

ROAD / TRANSPORT:

"What types of road access is available less than 100 meters away from this location?"

Choices:

- paved, year-round access;
- paved, seasonal access;
- gravel / murram; all-weather;
- gravel / murram, seasonal;
- dirt (or lower level road with vehicle access) seasonal OR all-weahter;
- footpath or other, non-vehicle access.
- Other, please specify:

COMPUTER / INTERNET SERVICE AT A LOCATION:

Does this location have one or more working computers:

- **Choices:** Y/N (then, if Yes, continue to…)

Do any computers have internet connectivity:

- **Choices:** Y/N

Does this location have mobile phone coverage?

- **Choices:** Y/N

Section C) Additional questions for specific types of institutions

LOCATION TYPE: OTHER PUBLIC / GOVERNMENT BUILDINGS: (DEFINITION/EXAMPLES: LOCAL GOVERNMENT OFFICES, CHIEF'S HOME/RESIDENCE, MINISTRY OR DEPARTMENT OFFICE SUCH AS AGRICULTURE/AG EXTENSION, WATER, ETC.)

"Is this government building related to one or more of the following….":

"ANY level of government (Village / community / district / provincial / regional, national government)":

- **Choices:** Y/N

"Ministry or Department office?"

- **Choices:** Y/N
  If Y, then choose between:
- agriculture,
- water,
- public works,
- [add any others to list that are needed]
- Other, specify:

LOCATION TYPE: MARKETS / TRADING CENTERS: (DEFINITION: A MARKET MUST HAVE MORE FOUR OR MORE VENDORS OF ANY KIND (SHACKS, STALLS, ETC.)

"Is this market open every day?"

- **Choices:** Y/N (if Y, continue to):

Is there anyone at the market with a generator (petrol/diesel), or grinding mill (fuel or electric)?

- **Choices:** Y/N

"Is there anyone at the market with an electric grid connection?"

- **Choices:** Y/N

Do any of the vendors sell ANY of the following: kerosene or batteries? Y/N

CHURCHES / MOSQUES/RELIGIOUS INSTITUTION:

"What is the name of this church/mosque/religious institution?"

- Text name

WAREHOUSES / CEREAL BANKS

"What is the name of this warehouse / cereal bank?"

- Text name

TRANSPORTATION POINTS: THERE ARE TWO SETS OF KEY TRANSPORTATION POINTS: BRIDGES AND CULVERTS:

For Bridges:
"Choose the largest of the following types of transport that can pass this bridge"

Choices:

- Pedestrian / footbridge,
- motorcycle,
- car, pickup
- truck, lorry
- train

FOR CULVERTS:

"Choose the largest of the following types of transport that can pass this culvert"

Choices:

- Pedestrian / footbridge,
- motorcycle,
- car, pickup
- truck, lorry
- train

Design: Stislow Design, NYC