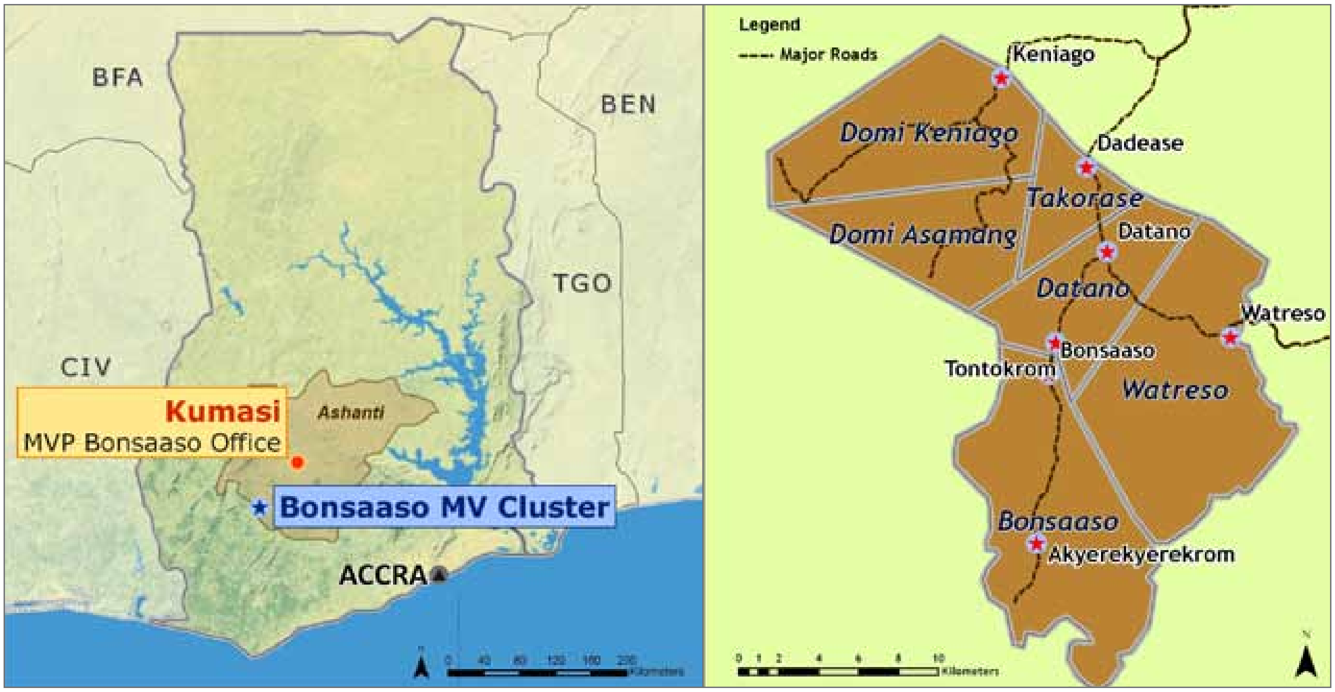
CHAPTER 6

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.

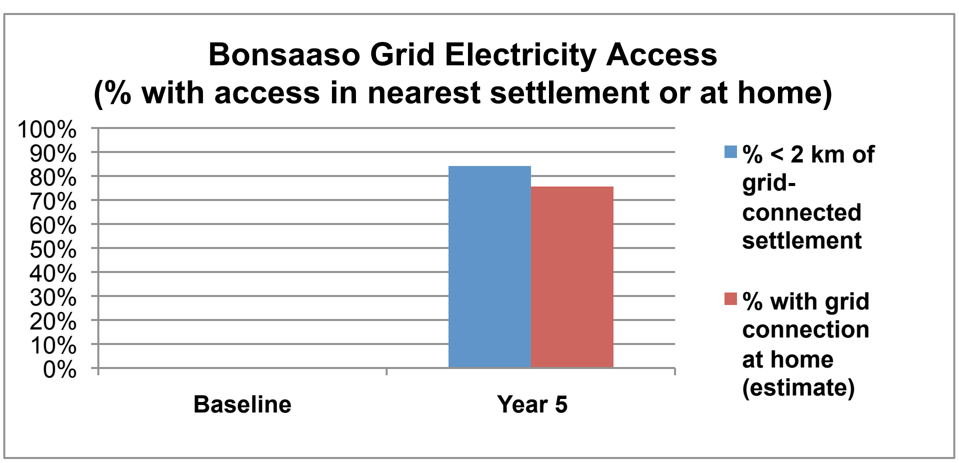
Grid Extension to Markets and Households

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

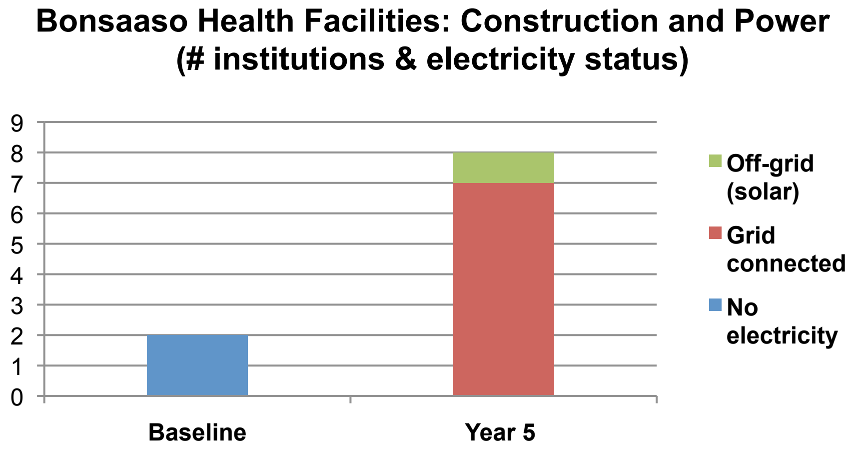


Table 6.2: Recurring costs for grid power in Bonsaaso cluster health facilities.

	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 Bsonsaaso 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, Akyer-ekyerekrom, 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.

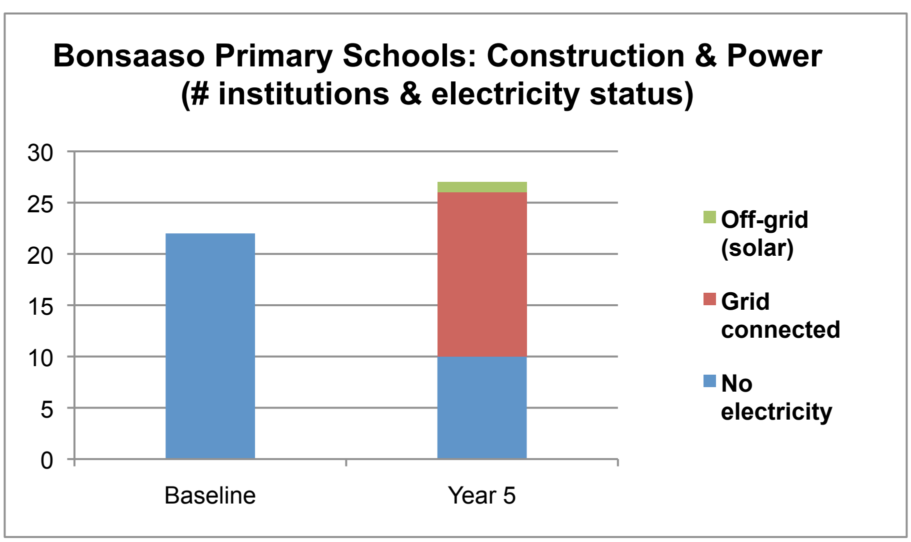
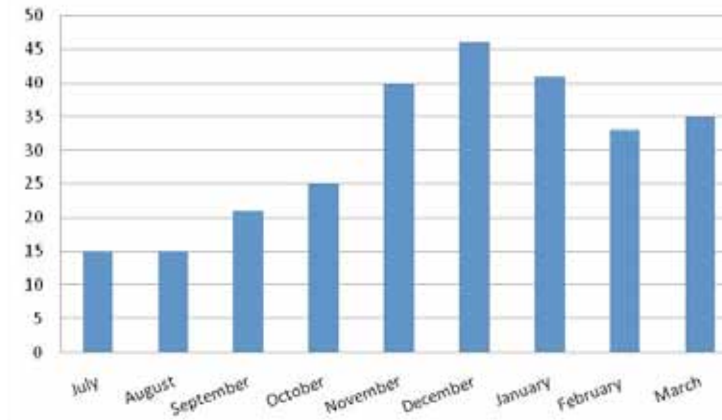


Figure 6.9: A solar lantern vendors in Bonsaaso (left); lantern sales statistics for the cluster, 2010-11 (right).



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

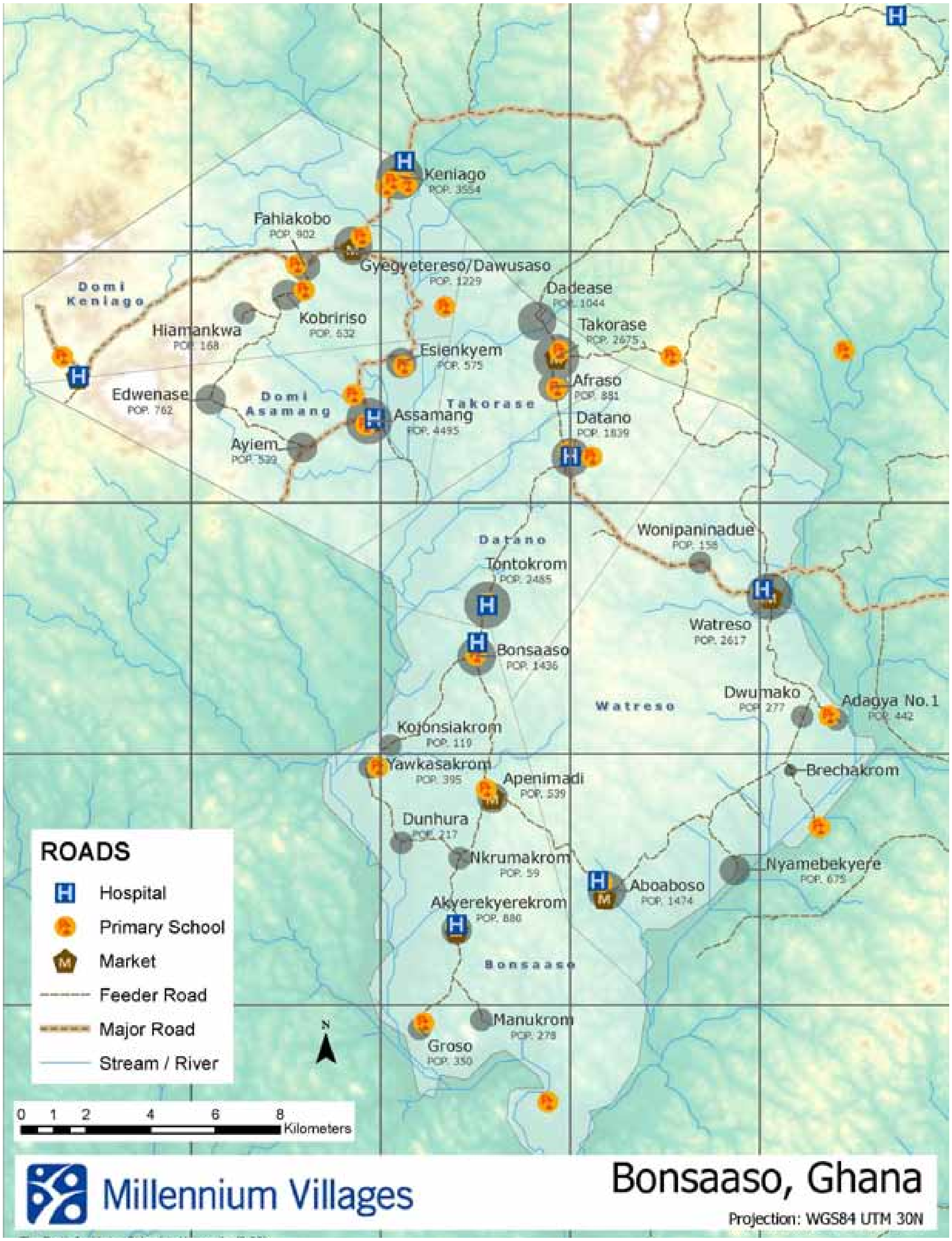
To meet low-wattage household electricity needs (lighting, phone charging) in areas with no expectation of grid within 5 kilometers in the near future, MVP introduced portable, rechargeable, solar-powered lanterns for purchase by villagers, following the approach detailed in Chapter 4: EI researchers 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)

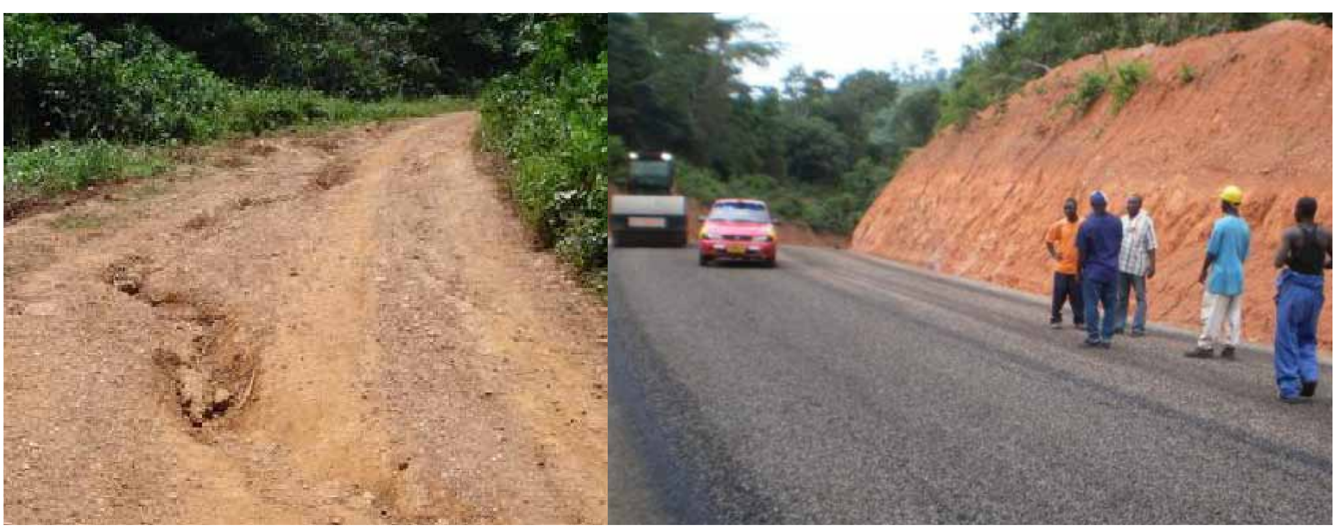


Table 6.6: Cost summary of Bonsaaso cluster water piping projects

	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.