POWERING HEALTH
OPTIONS FOR IMPROVING ENERGY SERVICES AT HEALTH FACILITIES IN ETHIOPIA

AUGUST 2008

This publication was produced for review by the United States Agency for International Development. It was prepared by Pamela Baldinger of the Office of Infrastructure and Engineering's Energy Team and Walt Ratterman of SunEnergy Power.

POWERING HEALTH

OPTIONS FOR IMPROVING ENERGY SERVICES AT HEALTH FACILITIES IN ETHIOPIA

CONTENTS

ACRONYMS AND DEFINITIONS

watt	A unit of electrical power, used to measure energy production and consumption
KW	Kilowatt (1,000 watts)
MW	Megawatt (1 million watts)
Watt-hour (wh)	Power utilization for 1 hour measured in watts. Watt-hours are commonly used to rate how long it takes for a battery to discharge
PV	Photovoltaic (used to describe solar electric systems)

EXECUTIVE SUMMARY

At the request of PEPFAR/Ethiopia, the USAID Office of Infrastructure and Engineering's Energy Team conducted a two-week assessment of Ethiopian health facilities in April 2008. The purpose of the assessment was threefold:

1. Gain a better understanding of the energy situation in Ethiopian health facilities, particularly as it affects the PEPFAR program;
2. Gain a better understanding of how energy needs will be met in new facilities to be constructed under the government's program to provide universal primary health care by 2010; and
3. Provide practical recommendations to PEPFAR on measures it can adopt to ameliorate the impact of energy problems on the delivery of HIV/AIDS programming.

To accomplish these tasks, a member of the Energy Team and a consultant visited 18 health facilities (health centers, hospitals, health posts, and regional labs) and met with government officials, PEPFAR implementing partners, other donors, and members of the Ethiopian private sector and civil society.

The assessment team discovered that a) problems with electricity supply and quality significantly limit the ability of Ethiopian health centers and hospitals to deliver health services, and b) the implications of additional electrical system needs imposed by PEPFAR-related programs are not adequately recognized or accounted for by the PEPFAR partners. As a result, many PEPFAR investments (particularly expensive, sensitive medical equipment) are at risk, and the ability of Ethiopia's health system to develop reliable networks to diagnose and treat HIV/AIDS is undermined.

However, there are practical, cost-effective solutions that PEPFAR can employ to solve or ameliorate many of the energy problems confronting Ethiopia's health facilities and strengthen the impact of PEPFAR programming. These recommendations are referred to in this executive summary, and elaborated upon more fully in the attached report.

KEY FINDINGS

Virtually all of the sites visited on the mission, like the majority of facilities in which PEPFAR works, currently are connected to the electric grid. The government is planning to build several thousand additional facilities over the next few years, at least 50% of which are expected to be off-grid. In most countries, the national grid provides the cheapest, most reliable source of electricity; off-grid sites are more complicated and pose special challenges. In Ethiopia, the following problems characterize health facilities connected to the grid:

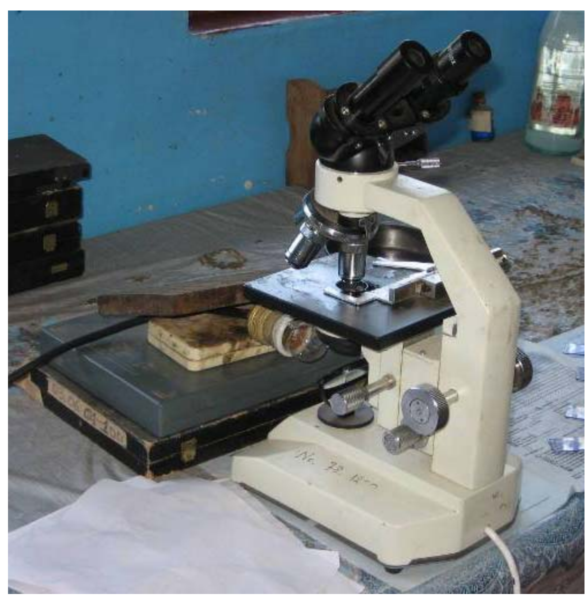
Intermittent power supply: Brownouts are common (especially during the dry season), as the national utility is not able to meet demand throughout the system. However, electrical loads are not shed on a predictable basis, posing a serious challenge for facilities possessing expensive electrical equipment and running sensitive medical tests. The intermittent power supply necessitates the use of a back-up power source or special equipment (i.e., UPS systems) designed to safely power down equipment when the main power supply cuts off. Few facilities had this equipment in place.

Poor quality power: The national utility has problems delivering electricity at the expected voltage, especially during times of drought. Voltage that is too low may prevent equipment from functioning; voltage spikes can damage equipment and make it unusable.

Non-functioning equipment: Ethiopian health facilities are equipment graveyards, often containing rooms full of equipment that is broken or not useable. We suspect much of the problem originates with the fluctuating voltage and intermittent power problems cited above. Some equipment may function, but cannot be used because the health facility lacks the adequate power source to use it (i.e., the equipment uses too much power or requires circuitry not available in the facility's current electrical configuration). *At some health centers, up to 80% of the electrical equipment was not functioning/useable.*

ABOVE: A closet full of non-functioning equipment at a health center in Amhara.

BELOW: The lab in the same health center had to jury rig an exterior light bulb in order to use its one partially functioning microscope.



Inadequate wiring/electrical configuration: The internal wiring in most of the health facilities visited was substandard, causing a number of problems, including decrease in voltage and overheating (and in one regional lab, visible signs of an electrical fire). In addition, as health facilities expand, wire (often incorrectly sized) is simply strung from one building to the next rather than connected to a main service panel, further reducing voltage and available electricity supply.

Little/no in-house ability to deal with technical problems: None of the health centers or regional labs visited had staff able to provide basic electrical maintenance or repairs, and all seemed unclear how to obtain such services (hospitals tended to have just one electrical technician or engineer for the entire facility). Repairs of medical equipment are also a major problem.

Electricity needs not integrated into planning: At all levels, from PEPFAR partners to health facility managers to government planners, electricity needs have not been integrated into health program planning. As a result, resources are not being maximized and malfunctioning equipment is negatively impacting health delivery. The impact could be particularly strong in new facilities being planned for construction outside the grid. Options for providing electricity to these facilities should be assessed before they are built so construction designs can accommodate the selected electrical system and bulk procurements of energy generating equipment can be conducted. However, interviews indicate that few of the regional planners have the ability to conduct this kind of analysis.

RECOMMENDATIONS

Many of the problems cited in the key findings above are beyond PEPFAR's ability to solve. However, PEPFAR partners can take a number of steps to lessen the impact of Ethiopia's power problems on HIV/AIDS delivery. Suggested measures include:

- Install voltage regulators and UPS systems on key pieces of electrical/medical equipment.
- Upgrade internal health facility wiring, at least to PEPFAR-critical sites (i.e., laboratories, data analysis/info systems, blood banks, etc.).
- Ensure that PEPFAR-provided equipment is appropriate for the electrical configuration and staff capacity of the facility. Provide training to staff on how to use equipment and ensure that manuals are provided.
- Put in place a maintenance/training/referral process, particularly for critical equipment/systems.
- Consider providing back-up energy systems (generators or battery/inverter systems) in key facilities with significant PEPFAR investment (i.e., large hospitals and regional labs).
- Consider upgrading the utility electrical connection to the health facility where needed (i.e., in critical facilities such as large hospitals or regional laboratories).
- Assist the government to better match electrical/medical equipment with health facilities and to better understand the energy needs/costs of off-grid health facilities.

I. INTRODUCTION

At the request of PEPFAR/Ethiopia, the Energy Team in USAID's Bureau of Economic Growth, Agriculture and Trade (EGAT) conducted a two-week assessment of Ethiopian health facilities in April 2008. The purpose of the assessment was threefold:

1. Gain a better understanding of the energy situation in Ethiopian health facilities, particularly as it affects the PEPFAR program;
2. Gain a better understanding of how energy needs will be met in new facilities to be constructed under the government's program to provide universal primary health care by 2010; and
3. Provide practical recommendations to PEPFAR on measures it can adopt to ameliorate the impact of energy problems on the delivery of HIV/AIDS programming.

To accomplish these tasks, a member of the Energy Team and a consultant visited 18 health facilities (health centers, hospitals, health posts, and regional labs) and met with US Government PEPFAR partners, Ethiopian Government officials, PEPFAR implementing partners, other donors, and members of the Ethiopian private sector and civil society. With the exception of the health posts, all of the facilities were connected to the electric grid.

The findings of the assessment team are presented in this report, which aims to highlight common problems and suggest possible solutions. Due to the limited amount of time the team spent in each facility, the report does not provide a detailed analysis of the conditions at each site. Rather, the report identifies and makes general recommendations based on type of facility (i.e., health center, hospital, regional laboratory), so that the PEPFAR partners can begin thinking about how to address energy problems in a holistic manner, and integrate energy needs into their planning. Site-specific recommendations would require follow-up visits that provided more time at each facility.

II. CURRENT SITUATION IN THE ENERGY AND HEALTH SECTORS

Ethiopia has one of the lowest per capita electricity consumption rates in the world, at about 28kw/year/person.[1] Availability of electricity is almost entirely concentrated in urban areas, even though 80-85% of the population is rural. The Government of Ethiopia has embraced an electrification strategy to increase electricity access from the national grid from 13% in 2002 to about 20% by 2012.[2] To meet this increase, power generation capacity is expected to double to about 1570 MW over the same period. The additional capacity will be provided mainly through large-scale hydro (94%) and some fossil fuel-based systems augmented on a relatively small scale by alternative energy options.[3]

Until this new generation capacity comes online, Ethiopia's power distribution system will remain taxed, particularly during the dry season (when water reserves in the hydropower system are low). During the assessment team's April visit, all regions were subjected to official, rolling brownouts. The norm seemed to be for an area to be without power all day, two days per week. (The local English-language newspaper reported that EEPCO, the Ethiopian Electric Power Company, could only meet 60% of total electricity demand).

The energy situation has a great impact on Ethiopia's health care system, which essentially consists of a referral-based, three-tier system:

- Health Posts: provide grass-roots outreach and counseling, preventive services and some maternity care.
- Health Stations: health stations are being phased out; they will be upgraded to health centers.
- Health Centers: provide preventive, curative and rehabilitative services to the surrounding communities. Health centers currently have catchment areas of up to 100,000 people.
- Hospitals: provide comprehensive health services to patients referred by the health centers.


A typical health post.

In addition, each region maintains at least one reference laboratory; these facilities participate in the PEPFAR program and therefore are included in this report.

FUTURE PLANS

Ethiopia's government is now striving to reach a goal set by the Prime Minister to provide universal access to primary health care. This strategy calls for the catchment area of health centers to shrink to 25,000 people. Health posts are to serve around 5,000 people, meaning there should be five health posts referring patients to each health center.

---

[1] Ethiopia Electric Power Corporation (EEPCO), 2002.

[2] Ethiopia Energy Access Project Renewable Energy Component Final Report, October 2004.

[3] Ethiopia Energy Access Project Renewable Energy Component Final Report, October 2004.

Much of the planning and budgeting for Ethiopia's health facilities has been decentralized to the regions. Regions in turn provide funds to districts (woredas), which disperse funds to individual facilities. This system makes it difficult to get a comprehensive view of plans for upgrading and expansion, as different regions may have different strategies. To gain a better understanding of the current and planned situation with the health facilities we participated in meetings with the following groups:

- Ministry of Health - Program and Planning Division;
- Oromia (East) Regional Health Bureau;
- Amhara Regional Health Bureau;
- A select group of private industry concerns conducting business in the energy sector;
- Crown Agents;
- Management Sciences for Health (MSH); and
- GTZ.

In order to meet its universal access goal, Ethiopia will need to construct a huge number of health facilities throughout the country in a very short period of time (around 2,500 health centers alone by 2010). Since the idea is to expand access to health care in areas currently unserved, it is likely that at least 50% of the new facilities will be in areas with no access to electricity (or water service). Both regional and national planners suffer from extreme shortages of professional engineering personnel qualified to execute the expansion mandate, but they are proceeding with whatever expertise they have. USAID has provided some assistance to the central government through its contract with Crown Agents, but that contract will expire at the end of the fiscal year. Neither the Ethiopian planners nor Crown staffs have experience planning for or designing off-grid energy systems.

III. SITE VISITS

The assessment team visited around 18 facilities, as listed in the following table:

TYPE OF FACILITY	REGION	NAME
Health Posts	Oromia	Mojo
		Zeway
Health Centers	Addis	Shiromeda
		Kazanchis
	Oromia	Shashemene
		Godina
		Bishoftu
		Zeway
	Amhara	Njibara
		Dangla
		Kolla Diba
		Gondar
Hospitals	Addis	Zewditu
		Black Lion
	Amhara	Felege Hiwot
		Gondar University
Regional Labs	Oromia	Adama (Nazareth)
	Amhara	Bahir Dar

With the exception of the health posts, all of these sites are in densely populated urban or peri-urban areas, and are connected to the electricity grid. The Addis region is the metropolitan area immediately surrounding Addis Ababa. The Oromia and Amhara regions are two of the most populated regions in the country, south (Oromia) and north (Amhara) of Addis.

IV. HEALTH FACILITY ENERGY USE

Based upon our limited observations and discussions with others, health posts typically are not connected to the electricity grid and do not possess energy intensive equipment. They serve as outposts to interface with the community on prevention programs, vaccinations, and maternity issues. To support the vaccination programs, they often have refrigerators, provided by UNICEF and powered by kerosene. (Most of the refrigerators are actually dual energy supply machines and can be run by electricity, if available.) To support maternity services, the health posts are equipped with kerosene-fired sterilizers. Due to the lack of energy intensive equipment in the health posts, and the large number of issues surrounding the provision of electricity in PEPFAR-supported health centers and hospitals, this report will focus on the latter group of facilities, particularly the laboratories, since this is where most PEPFAR equipment is being placed.

Health Centers vary in size from three to ten "blocks." A block is typically a one-story building that will have three to five individual rooms. Aside from the great variation in size of facility, there is also great variation in the amount and type of medical/electrical equipment the health centers possess.

New equipment at the Oromia regional lab.

In other PEPFAR countries, the government (or sometimes the program) has devised a standard equipment list for various PEPFAR labs, which makes it easier to estimate and provide for the facility's energy needs (since the lab is usually the most energy-intensive area of the health center). In Ethiopia, equipment distribution appears to be more random (i.e., we saw sterilization units range in size from 500 watts to 7,000 watts). Generally speaking, we estimate that the energy load of a health center lab is in the neighborhood of 2,000-6,000 watts; actual energy use would range from 10,000 to 20,000 watt-hours per day (this would not include electrical devices in the maternity areas).

Laboratories in hospitals and regional laboratories will generally require more power, perhaps 6,000-12,000 watts, though the figure could be much higher for the regional labs. For example, the regional lab built for the National Laboratory in Haiti had multiple labs within the same building and each laboratory probably required 10,000 watts of power.

V. KEY FINDINGS AND OBSERVATIONS

The assessment team found a number of problems common to most of the facilities. These problems may be grouped into the following general categories:

- Lack of capacity to deal with electrical/mechanical problems;
- Unreliable or insufficient power supply; and
- Inadequate power quality.

All of these factors combine to inhibit the ability of the health facilities to conduct critical procedures and ensure quality health care delivery. The most conspicuous impact of these problems is on medical and electrical equipment. Virtually every facility visited by the team contained a large amount of equipment not being used. In most facilities such equipment (often still in the shipping box) was taking up valuable space (sometimes an entire room or more) in cramped facilities. In some cases health facility staff claimed the equipment was broken or malfunctioning; in others, the equipment had never even been connected due to lack of installation and operation instructions or lack of appropriate electrical supply, or both. Further explanation is provided below.

A. LACK OF CAPACITY

Much of Ethiopia's health facility infrastructure is old and/or poorly maintained. Though USAID has funded Crown Agents to partially renovate 45 health centers, to date improvements have focused primarily on water and hygiene. But virtually every facility visited suffered significant (and sometimes potentially dangerous) problems with its electrical infrastructure as well (these are explained in detail in the next section). However, none of the health centers had in-house ability to deal with even minor electrical problems. This lack of knowledge regarding basic wiring, etc is complicated by the fact that many pieces of equipment arrive at the facility with no operating, maintenance, or installation instructions (or the instructions are lost or in a non-understandable language). Health centers stated that they report malfunctioning equipment to the woreda level, which maintains a small number of staff (supposedly) trained to repair medical equipment. The wait for assistance can take months, if not longer. Any upgrades/maintenance of the electrical infrastructure itself must be paid for by the health facility from its own budget.

Hospitals did have some in-house ability to cope with electrical problems, usually one electrician or technician or engineer. Many of these people seemed very competent, but were overwhelmed by the scale of the problems, and lacked the time/budget necessary to tackle them. While PEPFAR has obtained maintenance contracts for some of the most expensive equipment it supplies, many of the partners appear to have overlooked the need to order and store spare parts and build local capacity to service the most common equipment necessary for the program (or if such efforts have been made, the system is not functioning well).

B. TECHNICAL REASONS FOR EQUIPMENT FAILURE

It is very likely that many equipment malfunctions are due not to mechanical problems, but stem from inadequate electricity supply and quality at the health facilities. These include:

- Low voltage from the power company;
- Insufficient capacity in the power company connection at the health facility;

- Deficient electrical distribution at the site;
- Substandard interior electrical wiring; and
- Lack of planning for proper electrical connections for equipment.

A brief explanation and possible solutions to these problems are provided below:

1. Low Voltage from the Power Company

The team received repeated complaints of low voltage at the service connection points, meaning that the voltage coming to the health facility from the electrical utility is below the normal 230VAC (we did not have time to verify these claims). Low voltages can exist on the utility company lines for a number of reasons, including:

- Long distances between the utility company substation and the health facility.
- Lower output voltages at the generating station (this can occur when water levels are low at the hydropower plants, the main source of grid power in Ethiopia).
- Higher loads on the power lines than originally anticipated by the utility company.

In Ethiopia, it is likely that several or all of these situations are occurring simultaneously at many health facilities. Low voltage often can be corrected by the utility with a proper transformer that bolsters the voltage at the facility to account for any voltage drops in the transmission lines.

2. Insufficient Capacity in the Power Company Connection to the Health Facility

When a health center or hospital is constructed, electrical loads should be calculated and a corresponding capacity electrical connection should be provided by the electric utility. The size of the load is usually reflected in the size of the transformer and wiring that connect the health facility to the high voltage wiring owned by the utility company.

If this connection point is not upgraded as electrical requirements grow, the capacity of the power supply equipment may be inadequate to meet the needs of the health facility. This condition results in low voltages, service disruptions, and power equipment failures.

Growth in electric demand is caused by two factors, both of which exist at most of the facilities we visited:

- Increase in number of power consuming devices in the health facility; and
- Physical growth in the number buildings and services offered.

Many of the health centers visited by the assessment team were built 30 or 40 years ago. At that time, they likely contained few electricity consuming devices and electricity was, most likely, an afterthought.

However, as these facilities obtain more electrical equipment, the originally planned electrical capacity becomes quickly outdated. For example, the power requirement of one medium-sized autoclave today might be greater than the power requirement of an entire health center when it was originally built.

Moreover, virtually every facility we visited had been expanded several times, and many are undergoing further expansion. This is placing a huge demand on the existing electricity supply infrastructure.

Some of the facilities we visited were aware of the need to increase the capacity of the electrical supply, and had already started discussions with the power company to increase the size of their connection. However, they did not have sufficient funds for the payment requested by the power company.

3. Deficient Electrical Distribution at the Health Facility
As the health facilities continue to expand by adding new buildings, it has been the common practice simply to run a small cable from the new building to the nearest existing building. In most cases the wiring extensions utilize severely undersized wire, with no grounding conductor. The connection points often consist of nothing more than tape. The wire is then run overhead, either in the rafters or trees, to get to the next building. (This situation would not pass for even temporary wiring in many countries.) Besides being unsafe, this inadequate wiring can significantly impact the quality of the power it transmits.

When electric current has to run over long lines that are too small, voltage is lost. So, even if the voltage was adequate at the starting point, by the time the electricity reaches the remote building, the amount of voltage being provided will have dropped. Different pieces of equipment have different tolerances for voltages that are out of spec. For example, some equipment that is rated as 230V will operate well at +/-10%. On the low side, this would allow the equipment to function at 200 or 210 volts. However, the assessment team was told that voltages often drop to 170V (a figure reportedly confirmed by the electrician at Felege Hiwot Hospital). At that level, many types of equipment simply won't function.

Inadequately sized and hung wire connecting buildings at a health center.

Moreover, when more current is carried along a wire than it is designed for, the wire overheats. This lowers the voltage even more, and puts a high temperature on everything the wire touches, i.e., the building structure, and the terminals of the piece of equipment. This high heat at the equipment terminals can damage the equipment.

In addition, undersized wiring often results in blown fuses and tripped circuit breakers, which results in intermittent power supply to the equipment or complete power loss.

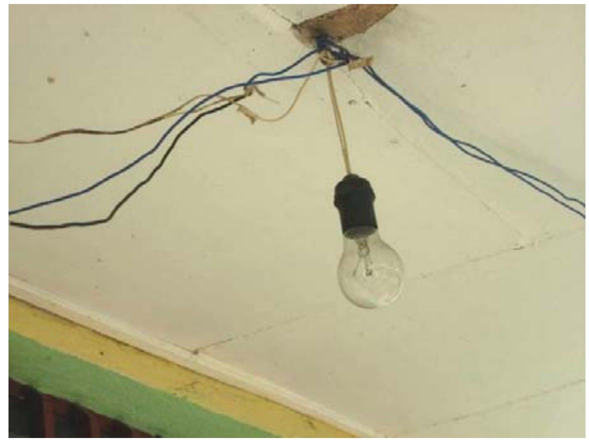
Deficient site wiring distribution is a problem at almost every site we visited.

4. Substandard Interior Electrical Wiring
Aside from inadequate wiring between buildings, the wiring inside most of the buildings visited also is problematic. In many buildings the original wiring was installed for a few lights and small devices. As

equipment has been added, or buildings have been added, the wiring has been installed at improper sizes, and without concern for adequate fuses, circuit breakers, or grounding.

The result is inadequate electrical supply to the equipment. Again, this is manifested by low voltage, high conductor temperatures, and intermittent power supply.

At sites where PEPFAR partners had added or upgraded structures, the wiring generally appeared to be installed in a professional manner, concealed in the wall to flush switches and receptacles. (However, since we did not have the schematics or a chance to speak with the electrical contractors involved, we cannot verify that the proper size wire was used).



Exposed wires in an Ethiopian health center.

5. Lack of Planning for the Required Electrical Loads
Lack of planning for the electrical equipment that is to be used in a given room or building can lead to many problems. Each piece of medical or electrical equipment has specific electrical requirements, which must be taken into account if the equipment is to operate safely and properly. In Ethiopia, we witnessed mismatches in voltage, frequency, phase, and other specifications that resulted in expensive equipment gathering dust.

A new sterilizer unable to be used because the health center lacks the proper wiring.

Moreover, many facility directors seem to re-organize their facilities without recognizing the need to take electrical requirements into account. Therefore, a room designed as a document storage area (i.e., low electricity demand) may be turned into a lab (i.e., high electricity demand) even though it lacks the requisite wiring to serve this purpose. Staff may then try to augment the wiring or electrical devices in inappropriate ways.

Assume, for example, that a room designed to be a lab is installed with 10 amp outlets, but the facility receives a piece of equipment that requires a 30 amp outlet. Even though the equipment will have a plug that doesn’t fit the outlet, the users likely will figure out a way to connect that piece of equipment, at least temporarily. The result may be a destroyed outlet, burned up wiring, and quite possibly, a damaged piece of medical equipment. We saw numerous examples of

The pins on this autoclave plug have been taped so staff can try to use it in an inappropriate outlet.

equipment plugs boot-legged onto improperly sized outlets and wired with tape in order to be able to turn on the equipment. This practice is unsafe both for people and equipment.

C. DEALING WITH POWER QUALITY ISSUES

Most of the problems noted above can be resolved by improving the wiring at health facilities. There are other factors that affect power quality, however, which cannot be resolved simply through re-wiring. These include voltage sags and spikes in the power lines from the utility, variances in line frequencies, and intermittent power supply issues (i.e., blackouts and brownouts).

These situations require the addition of power conditioning equipment that can "clean up" the power before it goes to the equipment, and/or back-up systems that provide continuous power during power failures. It is important to recognize that power quality problems exist all over the world, and whenever there is expensive equipment that can be susceptible to power quality issues, some form of protective equipment is the rule. The appropriate equipment will be selected based on:

- The condition of the incoming power supply;
- The sensitivity of the medical equipment; and
- The cost of the medical equipment.

In Ethiopia, the following systems would be appropriate for consideration:

1. Point-of-Use UPS (uninterrupted power supply) Systems

UPS systems protect equipment and guard against data loss during power failures by providing battery back-up power for a limited amount of time (typically 5 to 15 minutes). This enables the end-user to safely shut down the equipment, or work through short, intermittent power failures (which occurred frequently during our visit) until the grid power comes back or a generator kicks in. It takes a minimal amount of training to learn how to use and maintain point-of-use UPS systems. Batteries must be replaced every year or two, but are relatively inexpensive.

2. Voltage Regulation

Where small power sags and spikes are common, and/or can damage the equipment, an appropriately sized voltage regulator can be provided with the piece of equipment. This will adjust the voltage coming in from the source to a voltage that is suitable for the equipment. Options range from a simple voltage regulator that modifies slight under- or over-voltages, to more sophisticated equipment that can handle wider ranges. Small voltage regulators have no training or maintenance requirements; larger units designed to handle a heavier load would require some periodic servicing.

3. Inverter / Battery System

If the problem is primarily extended periods of time with no grid electricity, or highly fluctuating connection times, one solution might be an inverter/battery system. When the grid power is disconnected, the power is supplied to the equipment from the batteries through an inverter. The inverter creates high quality AC electricity with no voltage or frequency fluctuation. The grid power, when on, is used to charge the batteries and to power the loads.

This solution is not one that applies to an individual piece of equipment, but generally is applied to a given group of equipment such as a lab, or often an entire area such as a health center. The batteries and inverter must be selected based upon the quality of the incoming power source, the size of the load, and the amount of time the loads must be powered. This requires the input of a specialist to help select, design, and install the system. If the incoming power source is not reliable enough to charge the batteries daily (or nightly) back to full, then this solution will not work unless a generator is added to the mix.


Inverters at a health center in Rwanda.

One drawback of battery/inverter systems is that when they are matched with grid power, they generally pass through whatever power they receive, and therefore do not "clean" the power when connected. Inverter/battery systems also require considerable training to maintain; there should be an on-site person trained to perform daily maintenance tasks, with periodic (more specialized) maintenance performed by a specialist. If the latter does not exist, local capacity will need to be built to ensure sustainability of the systems.

4. System-Sized UPS Systems

In larger labs, and with more expensive and power-sensitive equipment, larger UPS systems can be employed. There are many types and sizes, and they can get expensive (in the same range as the battery/inverter system noted above). The least sophisticated are similar to the inverter / battery systems mentioned above, but with generally short battery time periods (in the minutes instead of hours). They are always used in conjunction with a generator with automatic start.

Like the inverter / battery systems described above, the least sophisticated models do not provide power conditioning, or conduct limited power conditioning, when the AC power is on. The more sophisticated units will "clean" the power. Again, these units are used in conjunction with an automatic back-up generator to provide continuous power when the primary power source is lost.

VI. RECOMMENDATIONS

In order to ensure that PEPFAR and other US Government-funded health programs meet their objectives, it is important to ensure that vital medical equipment is connected to a power supply that will enable it to (a) be available for productive use when needed, and (b) not be damaged. This can be accomplished through a variety of interventions, depending on the existing electrical situation, and the sensitivity and cost of the equipment being protected.

The following section provides recommendations to PEPFAR on possible strategies for improving electricity supply at Ethiopian health facilities. The most basic, and universal, needs are addressed first, advancing to more specialized solutions, organized by type of facility. All cost estimates are in US dollars.

A. RECOMMENDED ACTIONS FOR ALL FACILITIES

1. Put in Place Training Protocols

PEPFAR, either centrally or through implementing partners, should ensure that any equipment provided by the program (energy/electrical-related or medical) is accompanied by instruction manuals, which should be retained and stored for future use. Relevant staff should be trained (by the vendor or relevant expert) how to use the equipment safely and effectively, and how to provide day-to-day upkeep/maintenance. Periodic refreshers should be held to accommodate staff turnover. Management should be held accountable for ensuring that records and training are kept up-to-date.

2. Establish/ Strengthen Service and Maintenance Systems

Provisions for more specialized service and maintenance should also be incorporated into the program. This can be accomplished through capacity building/funding at the central and/or regional levels; training/hiring staff specifically for this purpose to serve key PEPFAR facilities; or another method. The key point is to bolster local capacity to the extent possible to maintain key investments, and ensure that service contracts are in place for external assistance for more sophisticated or complicated pieces of equipment. Roles and responsibilities of the various parties, from those at site level to the region and national levels, must be clearly laid out for the system to be effective, and appropriate communications channels must be established. Each site/agency should designate staff that will be held accountable for implementing the system. A tracking and follow-up database should be established in order to document all service requests and ensure a timely response. An up-to-date contact list of all vendors and service contracts should be available to relevant parties at all times.

3. Improve Wiring

Upgrading the wiring at PEPFAR facilities would improve safety and delivery of health services. Adequate wiring should consist of:

- Dedicated electrical sub-panel for the laboratory (and any other critical) circuits;
- Wiring installed in separate, dedicated raceways, with appropriate grounding systems and conduit;
- Proper connection to the existing power distribution panels on site; and
- Specially identified outlets for specific types of equipment, so that the outlets are not used inappropriately.

Certain pieces of equipment, either due to power consumption or need for extra reliability, need to be installed on dedicated electrical circuits, protected by a separate circuit breaker, with appropriately sized and grounded cables feeding it. The outlet for the equipment should match the requirements of the specific piece of equipment.

An electrical plan should be made for each area that is going to receive electrical equipment. If the lab equipment is going to be installed all in one room, then this may necessitate a detailed room design. This design should include all of the wiring from the point where the power distribution system enters the building, and should detail the number and size of circuit breakers required for each outlet.

Items that should be included in the building / lab design and on the drawings include:

- General purpose outlets for small, low power-draw instruments.
- Defined maximum number of outlets on a given circuit (for example, two or three outlets on any given circuit).
- Minimum cable size for general purpose outlets.
- Provision for grounding in all feeders, branch circuits, and outlets.
- Special purpose outlets for all equipment consuming larger blocks of power, or determined to need extra reliability (i.e., autoclaves, steam baths, CD4 machines, blood chemistry analyzers, hematology machines). All special purpose outlets should be so labeled.

For small health centers, the cost of performing wiring upgrades could be under $2,000, if the existing power distribution system (i.e., the main service panel and connection to the utility) is adequate to connect to.

If the existing power distribution system is not adequate, then the costs would depend on the existing conditions, and could be in the range of $1,000 to $10,000 (for small to medium health centers or labs within hospitals).

Once a power delivery system is installed that can properly and safely provide electricity to medical and electrical equipment, PEPFAR should take steps to ensure that the power being delivered is acceptable for that equipment. Recommendations for achieving this goal appear below, organized according to the type/size of the facility.

B. RECOMMENDATIONS FOR SPECIFIC FACILITY TYPES

1. Health Centers

Install point-of-use UPS systems and voltage regulators on each piece of important/expensive electrical equipment (i.e., computers, large centrifuges, etc.).

Point-of-use UPS systems will cost from about $300 per unit (for a small 500 watt UPS device) up to $2,000 for the larger, higher-wattage devices. In most cases, the smaller device would be adequate. Voltage regulators (500-1000 watts) should cost under $1,000 each.

In many of the small and medium-sized health centers, if (a) the wiring is re-installed in a professional and safe manner, and (b) appropriate UPS and voltage regulation equipment is installed, then the facility should be able to perform critical tasks more reliably and with much less damaged equipment.

2. Hospitals

At hospitals or larger health centers with more (and more sophisticated) equipment (such as CD4 and blood hematology equipment), PEPFAR will have to decide whether to take a “holistic” approach that addresses the entire facility, or whether to treat the laboratory (or other PEPFAR-critical sites) as an “island,” and focus resources on the island rather than the entire hospital. While the latter approach will not address the electrical problems throughout the hospital, it will help the electrical lab equipment survive and keep the cost of renovation down.

In order to supply continuous, good quality power to these facilities, PEPFAR may wish to consider introducing an alternative or back-up energy source for the grid. Several options are described below:

Generator

Generators can provide good quality power, but require regular fuel and maintenance. Capital costs of generators are fairly modest; a 7-10 KW generator (sufficient for a small to medium lab) can be purchased for about $7,000 to $12,000. If a site requires a generator as large as 30KW, this unit could cost in the neighborhood of $20,000. However, the cost of fuel and maintenance can overtake the initial purchase cost in a short amount of time, especially given current trends. Generators require someone on-site to provide routine maintenance.

Gondar University Medical Center’s new generator.

Inverter / Battery Systems

When properly designed, an inverter / battery system can be installed that, when coupled with the first step of proper laboratory wiring systems, can provide high quality, reliable power to the laboratory equipment, with lower operational costs than generators, since no fuel is required.

As these systems depend on a regular charging mechanism for the batteries, they must be coupled with a fairly reliable electrical grid, a generator or solar panels. For the grid to work as a reasonable charging system, it must be able to be relied upon for 6 or 8 hours/day within an acceptable voltage range. This does not have to be the time when the lab is operating. So, in areas where the grid is unreliable during the day, but is almost always on and of good quality at night, the grid could be a viable charging source for the batteries.

For a moderately sized lab that would include a standard assortment of lab equipment including an efficient refrigerator, the inverter / battery system equipment costs would be between approximately $15,000 and $20,000. If a generator is required, the cost of the generator would need to be added to these costs.

It is important that these types of systems be properly designed and installed by qualified individuals /companies. As we have learned in other PEPFAR countries, inadequate design will result in the batteries failing in a very short period of time, and the equipment will no longer be protected. Equally as important as the proper design and installation is the commitment to maintenance and continued training, without which the systems will surely fail. PEPFAR Haiti, for example, has already installed 30 battery/inverter systems, and will probably install another 30. With USAID Energy Team technical assistance, PEPFAR is training local technicians (to be based at the national and regional levels) to maintain the systems. In the meantime, such service is being provided through a short-term maintenance contract with a local company.

3. Large Hospital Considerations

If PEPFAR wants to address electrical problems in hospitals more holistically, it will need to help the facilities upgrade their entire electrical wiring systems. (Of the hospitals visited by the assessment team, Gondar University Hospital in Amhara, which had recently upgraded its energy infrastructure, was the only one with acceptable wiring).

The first step in fixing the wiring distribution system in a large hospital facility is a detailed engineering study, which will assess the current situation and recommend improvements. These will likely include:

- Upgraded connection to the electric company
- New electrical distribution system (i.e., proper main service panel and inter-building wiring)
- New main electrical equipment (i.e., central distribution point with proper breakers)
- New emergency generator
- Rewiring of emergency power distribution
- Rewiring of individual buildings to accommodate the electrical loads

A professional engineering study to review these issues and prepare a scope of work could cost up to $100,000 for a large hospital. The installation costs will vary widely, but, using Gondar University Hospital as a guide, should be in the neighborhood of $1 million.

Part of the engineering study will need to include an honest assessment of the present and near future power company electricity supply. If the power supply is unreliable now, and is not likely to improve, system designs would be significantly different than if the electrical power supply is reliable and of good quality.

4. Regional Laboratories

Regional labs are often installed within or adjacent to existing hospital complexes, and utilize the hospital's power distribution system. Where regional labs are installed within existing hospital systems, the guidelines above for hospitals would be applied.

In cases where PEPFAR is contracting (or can influence the contracting of) new facilities, special attention needs to be paid to the electrical wiring systems to assure that they are installed to meet the needs of the laboratory equipment. To summarize, the issues that must be taken into account include:

Wiring at the Amhara Regional lab, with evidence of an electrical fire.

- In the design, separate the critical from the non-critical loads, which will make the conditioned powering of the critical loads much more feasible and economical.

- Use energy efficient equipment wherever possible (especially computers, refrigerators and lighting).
- Assure that all of the wiring systems are designed for the specific loads that will be utilized in the building (i.e. – don't just let the builder install standard wiring to the labs).
- Consider individual point-of-use UPS and power stabilization equipment for the sensitive lab loads.
- Depending on the quality and reliability of the existing grid power, provide an appropriate back-up power system that will include at least a generator for the critical loads, and likely an inverter / battery system.

A table to summarize these prioritized solutions is presented below.

ESTIMATED COSTS OF POTENTIAL PEPFAR ENERGY INVESTMENTS
Approximate Initial Costs (US$)

Action	Small Facility	Medium Facility
Rewire the laboratory	$1,000 to $2,000	$2,000 to $5,000
Provide Point-of-Use UPS and Voltage Regulators	$2,500 to $5,000	$5,000 to $20,000 (Depending upon size/amount of electrical equipment to be protected.)
Provide Generator (for lab only)	$7,000	$10,000 to $30,000
Provide Inverter / Battery System (connect to existing grid and/or generator)	$10,000	$15,000 to $25,000
Provide Solar Power System for battery charging in addition to battery and inverter	$20,000-50,000	$60,000-120,000 (Depending upon the size of the electric load; the figures at the lower end of the range would be unlikely to meet the entire load.)

The above table reflects capital costs only. The actual long-term Cost of Energy (COE in $/kwhr) including maintenance, fuel, replacement equipment, etc. can reflect a very different picture. Energy supply options listed in ascending order of COE with very approximate costs to show orders of magnitude only are as follows:

LONG-TERM COST OF ENERGY FOR VARIOUS POWER SUPPLY OPTIONS (US$)

Power Supply Option	Approximate COE $/kwhr	Remarks
Grid Electricity Only	$0.10 to $0.20	Ethiopia is in the low range of grid electricity costs.
Generator Only	$0.25 to over $3.00 (assuming fuel price of $1 to $1.50 per liter)	Lower cost is for large primary power generators (e.g. 250kw). Higher cost is for small health center units (e.g., 15 kw to 30 kw).
Grid with Generator Back-up	Varies, but less than generator only	The cost will vary depending how often/long the generator is expected to run.
Inverter / Battery / Grid System	Slightly more than grid electricity alone	Depends upon reliable and good quality grid power.
Inverter / Battery / Generator System	$2.00 to $3.00	Assuming little support from the grid.
Inverter / Battery / Generator System with Solar PV	$1.00 to $2.00	

The costs in the table are indicative, and reflect a range of prices across a wide host of countries. Actual costs in Ethiopia could differ. Typically, however, the cost of one option relative to another will not change; grid power is virtually always the least expensive, while generators will be amongst the most expensive over the lifespan of the equipment (i.e. 15-20 years).

C. RECOMMENDED ACTIONS IN SUPPORT OF GOVERNMENT DEPARTMENTS

As noted in section II (p.5), the government plans to expand dramatically the number of Ethiopia's health facilities over the next few years. All of the planners we met with at the national and regional levels expressed a desire for assistance with virtually all phases of the expansion efforts (planning and design, construction management, etc).

There does not seem to be any universal approach regarding how to deal with the electrical needs of the large number of new health facilities that will be off-grid. Planners in Oromia, for example, were in the process of soliciting bids for diesel generators for such facilities in their region, but acknowledged that neither they nor the health centers have any budget to purchase fuel. Amhara Regional Health Bureau had not made any plans to provide electricity to the new, off-grid health centers.

The government clearly would benefit from technical assistance in the provision of electricity to off-grid health facilities. Typically, the choice is between a generator (with or without batter/inverter back-up) and a solar photovoltaic (PV) system (with battery/inverter), though micro-hydro may be an option for some areas of Ethiopia. The most economical choice over the long term may be a hybrid system, combining a generator and solar PV (see the table on the previous page). In a hybrid system, the generator would operate for far fewer hours, and far more efficiently, than if it was the sole source of power. However, capital costs of PV systems are higher than for systems relying only on a generator.

A small- to medium-sized health facility likely would require a solar system to include a 3,000 to 6,000 watt array for all electrical needs. The cost of this equipment, with the batteries and inverters, would be $60,000 to $120,000. GTZ plans to equip 50-100 health centers with solar systems in the neighborhood of 1,000 watts, but this size system is unlikely to be able to address the full energy needs of the laboratory loads. The Energy Access Program supported by the World Bank and Global Environment Facility (GEF) will supply 200 health posts with 360 watt PV systems, but these will not power much more than lights. The program has already conducted international bidding and the finalist should be declared soon.

Solar panels at a health center in Rwanda.

Designing and installing off-grid energy systems requires specialized skill. Significant resources also will need to be committed to build capacity for service and maintenance to ensure the sustainability of the systems. Should PEPFAR decide to provide planning support for the new health facilities to the government, it should ensure that someone with the requisite energy background is selected.

The government agency responsible for distributing medical equipment also clearly could use some assistance in understanding the relationship between electricity and equipment function, and how to incorporate energy concerns into its equipment distribution strategy. Technical assistance that might provide them with a template for selecting and standardizing appropriate equipment (from an energy standpoint) might result in more strategic decisions and also would benefit health bureau planners and health facility managers.