POWERING HEALTH

OPTIONS FOR IMPROVING ENERGY SERVICES AT HEALTH FACILITIES IN HAITI

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EXECUTIVE SUMMARY

The acquisition of reliable and affordable power poses a challenge to many health facilities in developing countries. This is the case in Haiti where the PEPFAR (President's Emergency Plan for AIDS Relief) program requested USAID assistance in assessing options for improving energy services at health facilities.

With support from the USAID's Bureau for Economic Growth Agriculture and Trade, Office of Infrastructure and Engineering/Energy Team in Washington, DC, a team of energy specialists visited Haiti, interviewed stakeholders in the health and energy sectors, and visited a representative sample of twenty health facilities to assess their energy supply conditions. This report presents the results of this assessment along with recommendations for improving energy service at these facilities. The Team investigated options for improving the energy reliability and quality at grid-connected facilities and also examined options for off-grid facilities in the Central Plains. A technology neutral approach was taken for all analysis in the report although special consideration is given to the applicability of renewable energy because of local stakeholder interest.

The quality of grid power in Haiti is arguably some of the worst in the world. Many health facilities receive only a few hours of power per day with prolonged outages of up to a month not uncommon in some locations. Every health facility manager rated the lack of reliable power as one of their top challenges in delivering quality service. The effectiveness, sustainability and reach of several PEPFAR programs in Haiti have been directly compromised by the lack of a reliable power supply. The lack of reliable electricity in health facilities across the country complicates the storage of cold chain dependent blood, laboratory reagents and HIV rapid test kits. Power anomalies cause damage to laboratory equipment and jeopardize the accuracy of sensitive laboratory tests. In addition, a significant portion of many health facilities operating budget was used for the purchase of diesel fuel to power generators during frequent power outages. Reducing this expense would allow these facilities to use these funds for other priority needs.

The assessment highlights the following overall observations and recommendations:

- Nearly every facility visited during the assessment had a unique set of energy challenges indicating that facility specific solutions, designed and implemented by trained personnel, are required. The assessment found that, with a few notable exceptions, public health facilities in Haiti did not have the technical capacity, funding, and/or managerial discipline to effectively install, operate and maintain energy systems.

  Recommendation: PEPFAR should consider supporting national and perhaps regional level engineers/electricians to help improve the energy infrastructure at health facilities around the country. This engineer could be located at the national reference lab or join the civil engineer from the National Plan. To be effective, the engineer would have to be very hands on, and be willing to travel to health facilities frequently. PEPFAR support for training of on-site facility managers is also suggested.

- The ability of health facilities to mitigate the impact of unreliable power and manage on-site energy systems was directly related to a facility's management capacity. Even with national support structures in place implementing sustainable programs at some of the poorly managed public facilities in Haiti would be difficult. Based on its experience in the health sector, PEPFAR must decide if its funds would have greater impact at the facilities which faced the biggest energy challenges but were often poorly managed, or those that are better managed but had less dire energy needs.

  Recommendation: The assessment found a select group of facilities with motivated and competent management that did not have the funding or capacity to solve their energy challenges. These facilities should be considered as priority candidates for support. Facilities with incompetent management should generally be avoided until management is strengthened, and facilities which are in need of incremental investments to improve functioning energy systems could be considered a second priority.

- Many of the larger hospitals had a majority of the technology required to mitigate the effect of the unreliable and poor quality grid power. However, few hospitals had the technical ability, or financial resources, to integrate the various components into a well function system.

  Recommendation: With a reasonable investment, PEPFAR would be well positioned to "connect the dots" at these facilities and greatly improve their energy systems. At many of the larger facilities such support would likely involve training of the on-site electrician, re-wiring, integration of UPS systems, and installation of automatic transfer switches.

- PEPFAR has shown great foresight by providing point of use UPS systems and inverters and battery bank systems to improve the power supply at ARV labs in Haiti. The approach is technically sound and if implemented correctly will be an effective way to reduce laboratory equipment damage and improve testing results. Although the batteries and inverters are not complex technology, several steps must be followed to improve the success of this program. This assessment found that just 50% of the systems in the field were functioning properly.

  Recommendation: The success rate of the inverter program could be drastically improved with a few low cost steps:

  1) Load Analysis: Before a system is provided to a health facility a load analysis should be conducted. With the correct training, a load analysis could be completed by CDC personnel or by a nationally based (e.g. reference lab) electrical engineer. The load analysis will help inform PEPFAR about the proper size system to provide, and will identify appropriate loads which should be connected to the inverter. A proper load analysis can help maximize the loads supported by the inverter and minimize battery failure resulting from excessive discharge.

  2) Installation and Operation Support and Guidance: Few, if any, of the systems were installed for optimal performance. In addition, some of the supplied systems were not installed because the hospital claimed it had insufficient funds. Given these observations it is recommended that PEPFAR insure professional installation and

provide training to local users on proper operating procedures. An inverter and battery operations manual should also be produced in French/Creole.

3) Trained Support Network: The proper design, installation, and maintenance of these systems can be achieved by establishing a trained support network. A national level engineer should be responsible for the installation of all systems and for providing operational training to local users. PEPFAR should immediately support the establishment of such a network and a training program. The training program could be targeted at local users, CDC regional logistics officers, and an engineer employed by the national reference lab or National Plan

- The use of propane/electric hybrid refrigerators seem to be an effective approach to deal with the intermittent power supply found throughout Haiti. The assessment found refrigerators operating on both electric and propane supply. Operation of the refrigerator on propane was an effective way to keep contents cold during extended power outages, and electric operation was observed in many clinics because of the logistical challenge in obtaining propane.

  <u>Recommendation</u>: One of the observed weaknesses of the refrigerator currently being supplied by PEPFAR was that it closed with a magnetic strip rather than a more robust latching system. In addition, the propane component of several of the refrigerators was reported not to be working, the exact cause of failure was not identified. PEPFAR may consider investing in more robust hybrid refrigerators even if they are not locally available.

- The multitude of energy challenges facing health facilities in Haiti require a diversity of technological solutions. The assessment found no reason to preclude any specific technology from consideration when designing a solution to a given facility. Several solar systems were observed that had been operational for many years. Based on the experiences of the WHO EPI program, the location of the health facility appears to be one of the primary determinants in the sustainability of the solar systems. Solar systems in major population centers were often stolen, while systems in places like Port Salut and Jeremy have had no reported problem with theft.

  <u>Recommendation</u>: Grid power will almost always be the most economic option for charging back-up battery systems. In cases where no grid power is available, or extended grid outages require prolonged generator operation, solar installations should be considered on a case-by-case bases for battery charging. Several theft resistant measures can also be employed to help secure the solar panels. These strategies were not being utilized in the installations reviewed in this assessment.

- The ubiquitous use of battery based back-up systems in health facilities in Haiti requires that careful consideration be given to the energy demands of all donor provided equipment. The donor community, local stakeholders, and MOH should seriously consider the power demands of all new infrastructure projects in the health sector. Consideration of energy savings techniques, such as natural lighting and cooling and use of energy efficient appliances, should be a pre-requisite to facility construction.

ABBREVIATIONS AND ACRONYMS

AVR: Automatic Voltage Regulator: Equipment placed between the power supply to the facility and the voltage-sensitive loads to provide conditioned electricity to the loads, at the appropriate voltage. An AVR can only operate successfully within a given range of input voltage from the utility.

ARV: Antiretroviral

COE: Cost of Energy: Usually presented as a Net Present Cost (NPC) of energy factored over 20 years. This includes all of the equipment and on-going maintenance for the system that will be expected in this time frame, and assumes a given cost of financing.

EDH: Electricité d'Haiti: The national utility company in Haiti.

kVA: Kilovolt-Amps: Equipment capacity ratings, (in power terms) are rated in kVA.

IPP: Independent Power Producers: Can be either quasi-grid entrepreneurs selling un-metered power, or – more generally – formal power producers under a written agreement with the utility company to provide electricity of a given quality and a specified price.

MOH: Ministry of Health

PEPFAR: United States Government President's Emergency Plan for AIDS Relief

UPS: Uninterruptible Power Supply: Equipment inserted between the normal power supply and the load that has sufficient battery capacity to allow the load to operate for a specified amount of time after the normal power supply disconnects. This time is used to either power up a generator, or to shut down equipment if no generator is available.

W: Watts: A unit of power – either consumed or produced

Wh: Watt-Hour: 1 watt being consumed (or produced) for 1 hour.

kWh: Kilowatt-Hour: 1000 Watt-hours

Wp: Watts-peak: The nominal size of a solar array based on the laboratory optimal rating of the panel. An array of 100 – 100 watt panels, would constitute a 10,000 watts-peak solar array.

1 ASSESSMENT PURPOSE AND METHODOLOGY

This assessment was conducted at the request of the United States Government President's Emergency Plan for AIDS Relief (PEPFAR) program in Haiti and was supported by the USAID Office of Infrastructure and Engineering - Energy Team. The purpose of the assessment was to investigate options to improve energy services to critical health facilities in Haiti. Specifically, the team was asked to investigate the following key issues:

- Review the efficacy of PEPFAR Haiti's current approach to mitigate the impact of poor quality power on the operation of Antiretroviral (ARV) labs through the provision of battery banks and inverters;

- Assess options for improving the facility wide power supply at several different types of health facilities

The report is technology neutral and focuses on cost effective and practical solutions to health facilities energy challenges.

The evaluation was conducted over a two-week period by a team comprised of Jeffrey Haeni, Rural and Renewable Energy Specialist, USAID Office of Infrastructure and Engineering/Energy Team, Walt Ratterman, Chief Project Officer and Director, SunEnergy Power and consultant to Institute of International Education, and Boris Derenoncourt, logistics specialist, CDC Haiti. Mr. Edzier Orelus, a civil engineer with the National Plan, and Dr. ????, accompanied the team on the site visits in the West and South Departments. In addition, John Pitman, CDC-Atlanta blood safety team, and Rachanee Cheingsong and Clement Ndongmo, CDC-Haiti Laboratory infrastructure team, joined the assessment team for one day of consultations and site visits. During the course of the assessment, the team visited over twenty (20) health facilities in five different departments as detailed in Appendices 1 and 2.

The site visits were strategically chosen to provide an illustrative cross section of health facilities in terms of their ownership (public vs. private), the level and nature of services provided, and in terms of their current energy supply. The full gamut of facilities was visited– from small rural clinics with no grid supplied electricity to HUEH which has a priority line from EDH and has power requirements in excess of 1 MW.

The quality of grid power and specific energy challenges found at each facility varied greatly across the country. Even within the same city local variations in the quality of the energy distribution hardware often resulted in vastly different energy supplies at different facilities. Thus, although some generalizations can be made concerning the problems and solutions for different types of health facilities, each facility must be analyzed individually by a trained technician before any site-specific solutions are implemented. Thus, this report is intended to provide a general guide to the types of interventions which could improve the energy services at a variety of health facilities in Haiti.

2 HAITI PEPFAR PROGRAM OVERVIEW

The PEPFAR program in Haiti is working with over 45 clinics and laboratories across the country. Each of these facilities plays a unique role in supporting HIV/AIDS care and treatment and prevention activities, and each is equipped with specific medical technology. PEPFAR funds already support infrastructure improvements in many of these facilities. For example, the PEPFAR blood safety team has been working with the Haitian National Blood Transfusion Service and its sub-partner, the Haitian Red Cross, to retrofit a network of small blood banks. The Antiretroviral (ARV) team has been focused on retrofitting 13 ARV labs that use screening and treatment (CDT) instruments, hematology analyzers, and blood chemistry analyzers, as well as many other smaller ARV labs with more basic equipment. Finally, the PEPFAR team is working with the MOH and other local partners to improve service delivery through clinics, many of which are in rural areas. The lack of reliable and high-quality electricity has been identified by the PEPFAR staff, and the staff at each of these facilities, as a significant barrier to the successful operation of each of these facilities.

2.1 IMPACT OF POOR ENERGY SERVICES ON PEPFAR PROGRAM

Poor quality and unreliable power affect many aspects of a health facilities operation. The managers of each facility visited during the assessment rated poor energy supply as one of their top challenges. Poor quality power is defined by persistent power "spikes" and voltage anomalies which are damaging to a wide range of health facility equipment including air-conditioners, x-ray machines, lights, dental chairs and laboratory equipment. Power anomalies compromise the integrity of the results from some of the more complex electronic laboratory equipment. Low voltage power also increases the power consumption of some energy intensive devices such as refrigerators.[1] The lack of reliable power complicates nearly every aspect of hospital operations. Back-up diesel generators are an expensive way to generate electricity and a large portion of many hospital's operating budget is dedicated to the purchase of diesel fuel. Power disruptions also complicate the cold storage of blood, rapid test kits, reagents, etc. Many Haitian health facilities are utilizing electric/propane hybrid refrigerators to mitigate the effect of power outages on the cold chain. This approach works well but the acquisition of propane appeared to be a challenge for many rural facilities. Figure 1shows a blood bank refrigerator in Haiti whose contents were at room temperate because there was no electricity and the propone had run out.

Figure 1: The contents of this refrigerator were at room temperature because the propone had run out.

Power outages also seriously reduce the quality of service delivery at Haitian health facilities. Much donor supplied equipment, such as the computer and x-ray machine in figure 2, cannot be utilized because of insufficient power supplies. An interview with a doctor in the pre-natal ward of one hospital indicated that lack of power had been directly responsible for the death of three

[1] In a study by Carmeis, a 9% decrease in voltage caused a 16% increase in refrigerator power consumption

infants during the previous week as a result of inoperable pumps and incubators, and insufficient lighting (causing an IV to be adjusted incorrectly). Reliable power is a critical input to successful health facility operation.

Figure 2: Insufficient power supply has prevented health facilities in Haiti from utilizing some equipment provided by PEPFAR and other donors.

3 ENERGY SECTOR OVERVIEW

Solving the critical power problems of key health facilities in Haiti cannot be achieved in the absence of systematic improvements in, and reform of, the power sector. The quality of care that can be provided by the large grid-connected health facilities is directly related to the quality of power they receive from the grid. Thus, while power sector reform and investment lie beyond the manageable scope of the PEPFAR program, it is important to understand the fundamental problems facing the sector and the key players addressing the problems before deciding on site-specific investments.

3.1 ENERGY SECTOR CHALLENGES

Electricité d'Haiti (EDH) is the principal public supplier of electricity in Haiti. As a vertically integrated utility, EDH owns generation, transmission, and distribution assets. GPL's installed capacity is approximately 216.11 MW, out of which 154.36 MW in thermal generation and 61.75 MW is hydro power. Independent Power Producers (IPP) have been operating in the electricity sector in Haiti since 1996 and provide additional generation capacity. Nonetheless, the total available capacity is much less than the installed capacity due to serious problems with maintenance, which lead to frequent scheduled and unscheduled outages. It is estimated that total system losses are between 46 – 53 percent with technical losses accounting for about 18%.

The power quality and reliability of EDH supplied power are the result of a variety of problems –including poor distribution system design and system overloading. Power outages are also the combination of a variety of factors including planned "rolling black-outs" to account for system overloading and line specific failures such as blown transformers or line damage. As a result of these issues, nearly every health facility in Haiti has on-site generation capabilities to supplement the power provided by EDH.

Large portions of the interior of the country are not serviced by EDH's primary grid and facilities must generate their own power.

3.2 KEY PLAYERS

Many of the health facilities visited during the assessment had one or more generators or other energy technology provided by a donor organization. The World Health Organization/UNICEF were responsible for the majority of systems and have recently provided several generators to hospitals as part of a program to reduce maternal mortality. It was reported that the WHO was supporting a group of Brazilian and Haitian technicians to repair diesel generators and that they were also providing funding for the purchase of diesel fuel for a select group of health facilities. Despite repeated attempts, the assessment team was unable to get specific information on the details of any of these programs. UNICEF reported that it was up to the discretion of their partners to determine what type of equipment was required and procured. If PEPFAR/Haiti implements a program to address the energy challenges at key health facilities, it will be critical to coordinate activities with these other donors and among different PEPFAR implementing partners and program areas. There is no reason to establish separate regional/national technical support staff to oversee health facility energy technology and cold chain storage equipment for the immunization program, blood banks, and ARV labs.

The assessment team did not have the time to evaluate donor efforts to improve the operation of the overall energy sector but understands that the IDB is active in this area. However, given the long-term nature of this reform effort, and multitude of challenges that must be overcome, delaying on-site improvements in the power supply of grid-connected health facilities is not advisable.

3.3 RENEWABLE ENERGY OPPORTUNITIES

The extremely poor quality of grid power in Haiti and the expense of running diesel generators have generated a lot of interest among a variety of stakeholders into renewable energy options. Haiti has excellent solar resources and localized hydro and wind potential which can be used to generate on-site power that can augment, or replace, grid or diesel generator power. As a result of the stakeholder interest in such technology, and mixed track record concerning the success of previous renewable energy deployment programs in Haiti, the assessment team investigated whether renewable energy technologies should be considered for health facilities in Haiti. While Haiti does face many of the same challenges found in other developing countries with regards to renewable energy system theft and sustainability, the success rate of renewable energy systems reviewed on health facilities in Haiti was actually higher than most developing countries. Thus, although the assessment found that renewable energy was not a recommended "first tier" solution for a majority of the sites visited, there is no reason to exclude any of these technologies from consideration in Haiti. The critical question which should be considered is not *if* renewable energy should used but 1) when and where should renewable energy systems be utilized and 2) what strategies should be employed to maximize the sustainability of these systems.

The following sections explore these questions with regards to solar power – the most ubiquitous of Haiti's renewable energy resources applicable to health facility electrification. The assessment team did visit one health facility that was powered by micro-hydro, which was working well several years after installation. Micro-hydro should be considered as an option for the select group of health facilities located near an appropriate hydro resource.

3.3.1 HAITI'S SOLAR EXPERIENCE

Haiti has a long history of utilizing solar systems to power health facilities. The majority of these systems have been installed by the WHO as part of their expanded program on immunization. The assessment team visited several of these installations that were operational. The WHO systems are designed to exclusively power vaccine refrigerators. Several installations supported by other groups, including the HFH (???) Hospital in Jeremy with 14 separate solar systems dating back to 1993, were visited or reviewed and all were operational.

The success of the WHO installations is a result of professionally designed and installed systems and a well developed technical support program. The WHO has a national level technician responsible for installation of the systems and a regional technician in each of the departments who is responsible for refrigerator and solar system operation. The regional technicians attend regular trainings in Port au Prince. This program provides a good model for PEPFAR to use for improving the success of the battery/inverter program.

3.3.1.1 WHERE SHOULD SOLAR BE USED?

Currently, the majority of Health facilities in Haiti are utilizing battery banks and generators to provide power to critical loads during grid power outages. The batteries are charged by a combination of grid power and by the generator. In certain cases, it may be advantageous to add another generation source in the form of a solar panel. The decision on whether a solar array should be used can be primarily informed by economic analysis but several other important factors should also be considered.

A solar "system" typically consists of solar panels, an inverter, and a battery bank. The solar panel has a lifetime of over 25 years and requires very little maintenance. The batteries and inverters have lifetimes between 4-10 years and are the most challenging components to keep operational. Therefore, with the exception the initial capital cost and challenges associated with the theft of panels, there is very little difference between the requirements for successfully operating a battery/inverter system and a solar system (battery/inverter system + solar panel). If PEPFAR is able to successfully implement the recommendations in Section 4.1.2 to improve the sustainability of the battery/inverter systems, the addition of a solar array at a later date to facilities which require an extra source of generation will not be complicated.

Facilities that have no grid power are typically the best candidates for solar systems. Such facilities are also well suited to economic analysis, where computer models can determine which combination of generation and storage technologies will provide the cheapest power. In general, properly designed and well maintained solar systems provide the most economic form of power for small, off-grid, health clinics, while larger facilities require diesel/battery or diesel/PV/battery hybrid systems. Section 4.2.2 explores the economics of a variety of technology configurations for an off-grid blood bank.

Economic analysis of grid-connected facilities is more complicated because the grid provides an intermittent and random source of power for the facility. Nearly all of the facilities visited during this assessment had some form of grid power and a back-up generator. From an economic perspective the grid power should be used when available because it usually provides the cheapest form of electricity. ***The economic valuation of grid power in Haiti is difficult because none of the health facilities visited during the assessment were paying for their power*** and non-health facility customers reported wide ranges of EDH tariffs. From the perspective of the overall energy sector, the inability of EDH to collect revenue from customers is unsustainable and a direct cause of the poor quality services it delivers. From the perspective of the health facility, however, any power received from the grid currently is free of charge while diesel fuel charges come directly from the facility's operating budget. Health facility administrators reported that current budget levels are not sufficient to pay for electricity from EDH. Clearly, a paradigm shift is required whereby EDH improves its billing and collection practices and quality of service while public facilities receive increased budgets to cover the cost of electricity. Such reform is beyond the scope of the PEPFAR program and for the purpose of this assessment grid power is considered the least cost option. From an engineering perspective, complete self-generation of electricity would make sense for many of the health facilities in Haiti. Under the current paradigm, however, it is not economically feasible for the larger health facilities in Haiti to generate their own power without sustained operating and maintenance support from donors. For some of the smaller health facilities, however, an upfront donor investment in renewable technology such as solar is one option to provide an affordable, reliable, and high quality power supply to the facility with reduced operating costs.

When the grid power is not available, power for a facility is typically provided through a combination of battery banks and back-up generators. Under normal circumstances, the batteries are charged utilizing the grid power and generator. When the grid power experiences prolonged outages or is only available for a few hours per day, however, it may be economical to add an addition generation source such as a solar panel to reduce generator run time. Under such circumstances a first order calculation can be done knowing the average grid characteristics, generator run time, battery size, and load characteristics of the facility but longer system monitoring is required to determine the extent of prolonged grid outages and other deviations from the norm.

In certain circumstances the installation of a solar panel may be advantageous regardless of the outcomes of the economic analysis. The high capital and cheaper operating costs of solar systems make them a viable option for donors looking to offset future energy costs associated with new health facility construction. In addition, for critical loads, it may be advantageous to "over engineer" the system by adding a solar array for battery charging. For instance, because of the critical nature of the vaccine refrigerators the WHO often provides stand-alone power systems which are less vulnerable to the uncertainties associated with the overall clinic power supply. This option is discussed further in Section 4: Facilities Analysis. In addition, solar power provides compelling environmental dividends which are considered by many stakeholders to justify the price premium. Distributed energy systems are also an effective way to reduce the load on the overloaded national grid.

3.3.1.2 THEFT PREVENTION

Any investment in high value technology in developing countries is an automatic target for theft. Solar systems have historically been susceptible to pilfering and theft has been cited as a reason for failure of several past solar installations in Haiti. Proper installation of a solar system is one effective strategy to reduce theft. Tamper free mounting systems are often used which complicate removal of the system. Solengy, a solar company in Haiti, has designed a PV array mounting bracket which prevents the removal of individual panels, greatly complicating theft. (figure 3) The timely maintenance of solar systems is also an important deterrent to theft. Local stakeholders who benefit from the system's operation will be much more likely to protect the assets against removal. Perhaps the most effective strategy for reducing theft is to establish a sense of local ownership. Experience has demonstrated that if a local stakeholder feels personally responsible for the operation of the system – either because of a financial incentive or because of its perceived value to the community – the likelihood of theft decreases significantly. Many of the facility managers who had successful solar installations in Haiti claimed that theft was not an issue because everyone in the community realized the benefit of a functioning health facility and no one in the community would dare jeopardize the facility's operation by stealing the solar panel. Several stakeholders indicated that the location of the facility was also a critical factor in determining the likelihood of the solar panels to be stolen. It was reported that systems installed in larger cities, such as Les Cayes, Port au Prince, and Cap Haitien had experienced significant challenges with theft, while systems in smaller communities had not. The hiring of a full-time guard to protect the equipment has been another effective technique utilized in USAID-supported solar hospital electrification programs in sub-Saharan Africa.

Figure 3: Special solar array mounts prevent individual panels from being removed, greatly deterring theft.

3.3.1.3 PRIVATE SECTOR CAPACITY

Although there are several suppliers of solar panels and accessories in Haiti, the assessment team was particularly impressed with the capacity and services of a company called Solengy. Solengy has impressive technical capacity and offers systems that have been designed to work in the challenging environment found in Haiti. Solengy offers a lifetime (25 year) warranty on the solar panels including losses that result from theft. In addition, Solengy provides real-time monitoring of system operation so a technician can be immediately deployed if a failure occurs. Although their prices are not the cheapest available, the assessment team highly recommends using a company with comparable capacity and services as Solengy to implement any solar electrification programs at priority health facilities in Haiti. Implementation of solar projects without skilled technicians may result in short term savings, but will often result in systems that are designed and installed incorrectly quickly leading to failure.

4 FACILITIES ANALYSIS

The primary objective of this assessment was to develop site-specific solutions to the energy challenges at key health facilities. Site visits were made to over 20 facilities strategically chosen to provide an illustrative cross section in terms of their ownership (public vs. private), the level and nature of services provided, and in terms of their current energy supply.

The large majority of health facilities visited during the assessment had some form of grid power. In general, there are two strategies that can be employed to improve the power supply at grid connected facilities:

- Pursue solutions with EDH, such as dedicated feeder lines, that will improve the reliability and quality of power delivered to the facility

- Invest in site-specific technologies designed to improve the quality of the power received from the grid and provide continuous power during grid power outages.

These two strategies are not mutually exclusive and even with significant improvement in the national grid quality and reliability, site-specific investments will need to be made to ensure continuous and high-quality electricity for the critical power needs of health facilities. This section focuses on site-specific technologies and solutions with the understanding that negotiations with EDH for better quality grid power should be a top priority for all facilities.

The energy needs, challenges and solutions for each health facility was often unique. However, regardless of the quality of grid power reaching a facility, one aspect was universal: the quality of energy services at health facilities in Haiti is directly related to the quality of management of the facility. ***Without the correct people and support systems in place, no amount of investment in site-specific technologies will adequately address the health sector's energy crisis.*** As detailed in Appendix 2, the majority of health facilities visited in Haiti did not have the technical capacity, financial resources, and/or managerial discipline to successful manage on site energy systems. Therefore, a successful energy retrofit program will not only need to provide health facilities with the correct technology, but must also build the local capacity of staff and develop national/regional support networks to oversee the installation, operation, and maintenance of the energy systems.

Successfully mitigating the effect of poor grid power on health facility operations through the provision of on-site technologies requires *both*:

1) Proper system design and appropriate Technology Selection; and

2) Proper installation, operation, and maintenance through:

    a) Operation and maintenance funding

b) Trained personnel and support/oversight systems

All too often, one of these criteria is absent leading to sub-optimal performance and/or rapid failure of on-site energy systems. The site visits in Haiti revealed a substantial amount of technology which had been purchased by a given donor agency but was not operating because one or more of the criteria had not been considered.

This section profiles several different types of facilities, presenting a general discussion of the energy challenges and a specific analysis of the issues and options for the particular health facility profiled. A complete summary of the energy challenges and recommended solutions for each of the facilities visited during the assessment can be found in Appendix 2. This section discusses four different types of facilities which were representative of the sites visited during the assessment: 1) ARV labs, 2) blood banks, 3) large grid connected facilities, 4) small grid connected facilities and 4) off-grid facilities

Cost figures for different solutions are provided when possible but should only be considered rough estimates – primarily to illustrate the relative affordability of various solutions. Generally, they include primarily equipment capital costs and maintenance and operating expenses but do not include many of the other project related costs (e.g. overhead, training, etc) that are often part of these programs. These costs are discussed in Section 5.

4.1 ARV LABORATORIES

The PEPFAR program in Haiti is focused on improving the laboratory infrastructure at many health facilities around the country. With the exception of the National Reference Laboratory, all ARV Labs visited in Haiti were co-located with care facilities. Reliable energy supply is vital to the successful operation of ARV labs. Poor quality power will quickly destroy sensitive laboratory equipment and compromise the integrity of sensitive lab results. The PEPFAR program has been providing CD4 machines, Hematology Analyzers, Blood Chemistry Analyzers, and other critical equipment to a large number of labs in Haiti.

4.1.1 CURRENT APPROACH AND CHALLENGES

The PEPFAR program in Haiti has shown impressive foresight in addressing the energy challenges at ARV labs across the country. Point of use UPS systems and voltage regulators are supplied with each piece of electronic equipment and battery bank/inverter systems have been provided to mitigate the effect of power outages on lab operation. The approach is technically sound and if implemented correctly will be an effective way to reduce laboratory equipment damage, improve testing results, and provide continuous power needed for laboratory operation. Although the batteries and inverters are not complex technologies, several steps must be followed to improve the success of this program. This assessment found that just 50% of the systems in the field were functioning properly. Currently, PEPFAR has limited its role to procuring the systems and delivered them to the health facility. To be effective, PEPFAR must ensure procedures are in place to properly design, install, operate and maintain the systems.

4.1.2 STRATEGIES FOR IMPROVING BATTERY/INVERTER SYSTEM OPERATION AND SUSTAINABILITY

The sustainability of the recently installed battery/inverter systems at health facilities in Haiti indicates that health facilities can not be left to their own devices to insure the sustainability of these systems. The procurement of energy systems is only the first step in a sustained effort which must be undertaken to ensure the correct installation and long term operation of the system. This section highlights four key areas that should be a central component to any future efforts to improve the power supply at ARV labs in Haiti.

4.1.2.1 SYSTEM DESIGN

All battery based power systems must be carefully designed and managed to ensure that the batteries are not overdrawn and are fully recharged. Many of the battery bank/inverter systems reviewed in Haiti had failed because the system had not been correctly sized to power the connected loads for the desired time. Before a system is provided to a health facility, a load analysis must be conducted to determine the correct number of batteries for the desired time of operation. The load analysis will help inform PEPFAR about the proper size system to provide, and will identify appropriate loads which should be connected to the inverter. A proper load analysis can help maximize the utility of the inverter system and minimize battery failure resulting from excessive discharge. A load analysis is not complicated and with the correct training, a load analysis could be completed by CDC personnel or by a nationally based (e.g. reference lab) electrical engineer.

Table 1 shows a load summary for four different types of ARV labs visited in Haiti. The table considers basic and standard labs with and without air-conditioning and shows the number of hours that the load can be powered with different battery configurations. As is evidenced by the wide range of battery discharge rates, care must be taken to appropriately size the battery systems to match the expected duration of power outages. Appendix 3 has the supporting load calculation sheets for each of these labs.

Table 1: Summary of ARV lab loads and autonomy given different battery configurations.

Laboratory Type	Watt-hours			Total Conn Watts	Watt-hours/Hr		Hrs of use with x sets of batteries (8-T-105)		
	Day	Night	Total		Day	Night	1	2	3
Basic Lab with Efficient Refrigerator	8,140	840	8,980	1,855	814	60	4.91	9.83	14.74
Basic Lab with Efficient Refrigerator and Air Conditioning	18,140	840	18,980	2,855	1,814	60	2.21	4.41	6.62
Standard Lab without Air Conditioning	13,090	1,680	14,770	2,405	1,309	120	3.06	6.11	9.17
Standard Lab with Air Conditioning	23,090	1,680	24,770	3,405	2,309	120	1.73	3.46	5.20

4.1.2.2 INSTALLATION

Correctly installation and wiring of the battery/inverter systems is critical to ensure proper operation. Health facilities in Haiti have relied on local electricians or their on-staff electrician or facility manager to install the PEPFAR provided system and few, if any, were installed correctly for optimal performance. In addition, some of health facilities claimed they had insufficient funds to install the systems rendering them useless.

One of the most common problems observed was the use of insufficiently size wire to handle the charging current and to power the loads (figure 4). If the wiring from the grid (or generator) to the inverter is undersized, the inverter powers the loads first and takes the current that is left to charge the batteries. In addition, long runs of undersized wire produce a voltage drop, which, when combined with the low voltage power from the grid, often resulted in the inverter shutting off completely. Both of these issues result in undercharging of the batteries that decreases their lifespan and quickly leads to system failure.

Figure 4: Small gauge wire is both a fire hazard and prevents proper operation of the inverter.

In order to operate correctly, wire must be used which is large enough to carry both the charging and load current. In addition, the distance between the battery bank/inverter setup and loads should be minimized.

4.1.2.3 OPERATION

A majority of the battery/inverter system failures were a result of incorrect settings on the Xantrex SW Inverter. Many of inverters were preventing charging of the batteries because the input voltage was below the low-voltage cutoff set-point. A trained user can adjusting the low voltage set-point in less than a minute but if not adjusted it will result in system failure. Even if the set-points are adjusted at installation they will return to their factory default settings when DC power is lost so local user training is required.

A second critical requirement for correct system operation is training local users on proper energy management protocols. Users must be trained that unlike power from the grid, battery systems contain a finite quantity of power and care must be taken to manage the use of this power. Facility staff must also be encouraged not to connect additional loads to the system. Careful monitoring of battery charge is also required for proper system operation. The initial load calculations and system design are based on staff reports for equipment use patterns and grid reliability. Actual usage and grid reliability may deviate significantly and systems must be monitored to ensure that batteries remain charged.

4.1.2.4 THE SOLUTION: TRAINED SUPPORT NETWORK

The successful implementation and operation of a battery/inverter program will likely involve a multi-tiered support structure and training will be required at each level.

At the facility level, health care professionals or facility managers must be trained on basic system operation and maintenance. Experience has demonstrated that with minimal training local users are capable of performing the required routine maintenance checks, such as adding water and cleaning terminals, required for battery-based systems to operate successfully. Ideally, this local user training should be a required component of system installation protocols. The distribution of "user guides" is also recommended covering proper system operation and maintenance protocols.

When the local user encounters a problem that they are unable to solve, they must have a pre-determined contact at the regional or national level that is trained to diagnose and correct all potential system problems. At the national level this individual should be an energy professional with extensive training in the proper installation and operation of energy system. In Haiti, this technician could be employed by the National Reference Lab or National Plan, or a private sector firm could be used. This technician should do all of the system designs and installations and provide training to the local users at the time of installation. The number of installations, size of a country, and accessibility of the facilities in a given country will determine if this support must also be provided on the regional level. In Haiti, the regional CDC logistics officers may be able to offer a first line of defense given the correct training.

4.1.2.5 MAINTENANCE/REPLACEMENT FUNDS

Significant effort has been expended in the past to design effective financing models to cover the high initial capital costs of distributed energy systems in developing countries.[2] Given the grant funding available within the PEPFAR program, the initial capital cost of the battery/inverter system is not the primary barrier to the utilization of this technology for any of the recommended applications in this report. Rather, ensuring sufficient funds to cover the lifetime maintenance and replacement costs - which may be required after the donor community has left - present the most significant challenge.

Batteries and inverters are designed to last approximately 3 – 10 years, making periodic component replacement a necessity. Regardless of the level of training of local users and technicians, these systems will not be sustainable in the long term if funds are not available to purchase replacement parts. This issue is of particular importance to health facilities in Haiti, because they claimed to have little or no revenue stream that can be utilized to cover system maintenance.

A prudent approach to pursue in Haiti may be to set aside replacement funds in an account at the time of system installation. The optimal administration and structure of such a fund needs to be further studied, but it must be designed in a manner that prevents the money from being utilized to cover other hospital operating or maintenance costs. Co-mingling of energy system maintenance funds with overall facility operational budgets has not been successful for two reasons: 1) system failure can not be predicted and is therefore often not included in the facility's yearly operating budget request, 2) even if money is provided for this purpose, it is

[2] See, for instance, Cabraal, Cosgrove-Davies, and Schaeffer, "Best Practices for Photovoltaic Household Electrification Programs", World Bank Technical Paper #324.

often used for other perceived priorities if the system is operational at the time the funds are received.

Upfront payment for maintenance contracts is another option that has been used with mixed results. To be effective, both the structure and duration of the contract needs to be carefully considered. Typically, maintenance contracts are purchased from the installation company for an initial period of 1– 5 years. Trouble free performance of the systems during this "honeymoon" period can be an incentive to not renew the contracts with system failure following in short order. If maintenance contracts are used they also need to be structured in a way that provides a strong incentive for the contractor to optimize the performance and lifetime of the system – not just replace parts when they break.

The National Reference Lab may want to consider establishing an internal inventory of replacement components for the battery/inverter systems under its jurisdiction. Such an approach could benefit from bulk procurement discounts, would alleviate the financial burden from the budgets of the individual health clinics, and would allow technicians to quickly respond to the maintenance needs of any faulty systems.

Figure 5: Old batteries stored in the bathroom of a health facility. Battery recycling is economical and environmentally sound.

Finally, PEPFAR should ensure that a battery collection and recycling program are in place. Several of the health facilities visited had dead batteries lying around the facility causing an eye sore and environmental liability (figure 5). Deep-cycle batteries can be returned at the place of purchase in Haiti for a $15 refund. Thus, recycling old batteries makes both environmental and economic sense.

4.1.3 POWER CONDITIONING

The sensitive electronic equipment being provided to the ARV labs requires that the power supply is not only continuous, but of high quality as well. Power anomalies can damage equipment and jeopardize test results. Two options exist for improving the quality of grid power – point of use power conditioners or larger facility wide power conditioners or "double conversion" technology.

Although system wide power conditioning is preferable, there was no evidence that the cheaper point-of-use systems were not operating effectively. There have been some problems with the CD4 machines but there was no evidence that this was linked to power anomalies. Therefore, it is recommended that the current practice of providing point of use UPS/Power Conditioning units for all electronic laboratory test equipment continue.

For new construction and high priority facilities such as the National Reference lab, facility wide solutions are worth the investment. "Double Conversion" or on-line UPS technology is typically used when power quality is an issue, and when there is an emergency generator present for power outages. The expense of these systems also requires that the health facility be wired in a way that isolates the critical and non-critical loads which is currently not the case in most facilities in Haiti. During normal operation, the standard grid electricity is fed into the UPS system, which cleans up the power, and sends it out to the sensitive loads, via a battery system. When there is an outage on the grid power, the UPS/Battery system will power the sensitive loads for 10 to 20 minutes, which allows time for either (a) the generator to come on and take over the loads, or (b) an orderly shut-down of equipment to take place.

On-line UPS systems cost about $1.00 - $2.00 per VA, or around $15,000 and $20,000 for the largest ARV labs in Haiti.

4.1.4 RENEWABLE ENERGY OPTIONS FOR LABS

Several stakeholders involved in the laboratory program expressed interest in the use of solar panels to establish stand-alone energy systems for labs which would not be susceptible to the variability of the overall health facility energy supply. As discussed in section 3.3.1.1 stand-alone and/or parallel energy systems for high priority critical loads are often desirable. However, such an approach is also expensive and given the limited resources of the laboratory support program it is not recommended that this approach be adopted as standard practice. The need for solar panels should be examined on a case by case basis with facilities that have the worst grid power receiving top priority. (see, for example, section 4.4) Solar panels should not be a priority for labs associated with large facilities that have somewhat reliable grid power and/or large generators which are used during power outages.

4.2 BLOOD BANKS

The PEPFAR blood safety team is working with the Haitian Red-Cross to improve the services at several blood banks across the country. The assessment team visited a stand-alone blood bank in Les Cayes which will provide the basis for the discussion below.

The fundamental approach to providing reliable power to Blood Banks in Haiti is similar to the discussion above for the ARV labs. The only difference is that because the blood banks are typically stand alone facilities, with a medium size load, they are attractive candidates for on site renewable energy systems in cases where the grid power is particularly unreliable.

Like the ARV labs, Blood Banks should rely on battery bank/ inverter systems and if necessary back up generation in the form of a diesel generator or solar panel to provide power to the facility during grid power outages. The criteria for success for the batter/inverter systems are the same as the ARV labs including correct system design, installation, operation and maintenance. The battery/inverter system at Les Cayes blood bank was not function properly at the time of the visit and although the staff had called someone "two weeks ago" no one had been out to repair or replace the system.

4.2.1 LOAD CALCULATION AND REDUCTION

The calculated connected load of the Les Cayes blood bank, excluding the air conditioning system, was 25,000 Watt-hrs/day (Table 3 and Appendix 4). Over 66% of this load was from a large double section Jewett blood bank refrigerator. The battery bank at the facility was capable of providing 8,000 watt-hours of energy before needing a complete re-charge which corresponds to only 6 hours of back-up power with such a large load. Some simple measures could effectively reduce the load connected to the battery system to around 10,000 Watt-hrs and prolong the time the batteries can power the facility. There did not appear to be a need for such a large blood bank refrigerator at Les Cayes. The refrigerator was less than 25% filled at the time of the visit and the facility did not appear to have the kind of patient flow to require such a large storage capacity. Table 2 lists the power consumption of several different models of blood bank refrigerators.[3] Replacing the existing Jewett refrigerator with, for instance, the 319 Liter Dometic DR320 would help reduce the refrigerator load from 16,000 watt-hours/day to 3,600 watt-hours/day.

Table 2: Power requirements of common blood bank refrigerators

Manufacturer	Model	Internal Capacity (L)	Blood Bags	Energy Consumption (kWhr/day)	W-hrs /bag	W-hrs /liter
Dometic	BR320	319	240	3.60	15	11.29
Huurre	BB510	315	60	9.86	164	31.30
Huurre	BB710	455	90	10.20	113	22.42
Jewett	BBR25S1	702	360	16.68	46	23.76
Jewett	CT1-2A	153	60	4.53	76	29.61
Dulas[4]	VC65F	68	24	0.53	22	7.79
Dometic[5]	MB50DC	14	32	1.14	36	81.43
Queue	QBR404	133	48	5.00	104	37.59
Dometic	BR60	55	24	0.60	25	10.91

In addition to refrigerator replacement the three TV's in the blood bank must either be taken off the battery back-up system or the staff must be trained about energy management techniques and encouraged not to watch the TV's during power outages. These changes would help reduce the blood bank load to 10,000 watt-hours/day and more than double the time the batteries could support the facility during grid outages. (Table 3 and Appendix 4)

Table 3: Summary of Blood Bank Loads

Facility	Watt-hours			Total Conn Watts	Watt-hours/Hr		Hrs of use with x sets of batteries (8-T-105)		
	Day	Night	Total		Day	Night	1	2	3
Blood Lab - Les Cayes - Existing	13,710	11,018	24,728	3,707	2,371	787	1.69	3.37	5.06
Blood Lab - Les Cayes - Modified	6,600	3,080	9,680	1,860	660	220	6.06	12.12	18.18

These calculations do not include the air conditioner which is another large load found at the blood bank. The Les Cayes Blood Bank had a 20,000 BTU air conditioning unit consuming, on average, 10,000 watt-hours per day (assuming an on time of 10 hours per day). While air conditioners are not a problem for facilities with somewhat reliable grid power, their use should be minimized for battery powered energy systems. The blood bank in Les Cayes had correctly not connected the air conditioning unit to the battery back-up system.

[3] WHO Report "Blood Cold Chain"
[4] 12V DC
[5] 12V or 24V DC

4.2.2 RENEWABLE ENERGY OPTIONS FOR BLOOD BANKS

Several stakeholders in Haiti expressed interest in utilizing renewable energy sources, such as solar, to power blood banks in Haiti. Section 3.3.1.1, discusses the criteria for utilizing solar power in a generic sense. This section considers the topic with regards to blood banks. For the sake of discussion, a blood bank which has no grid power will be considered. The modest size of the electrical load and high price of diesel fuel in Haiti make renewable energy sources feasible and economic for such a scenario.

Table 4: Comparison of costs for different power generation options at a typical off-grid blood bank. a) including all costs and b) excluding initial capital costs.

A) HAITI – BLOOD BANK – OFF GRID

Scheme	PV Cost Multiplier = 1.0			PV Cost Multiplier = 1.7		
Limited to 10,000 Whrs/day	Initial Capital	D=$1.5/L $/kWh COE	D=$2.5/L $/kWh COE	Initial Capital	D=$1.5/L $/kWh COE	D=$2.5/L $/kWh COE
Solar Only	48,000	1.00	1.00	72,000	1.37	1.37
Solar / Diesel Hybrid	51,000	1.00	1.00	76,000	1.40	1.40
Generator / Battery	19,000	1.45	1.92	19,000	1.45	1.92
Generator Only	13,000	3.11	4.23	13,000	3.11	4.23

B) HAITI – BLOOD BANK – OFF GRID

Excluding initial capital costs

Scheme	PV Cost Multiplier = 1.0			PV Cost Multiplier = 1.7		
Limited to 10,000 Whrs/day	Initial Capital	D=$1.5/L $/kWh COE	D=$2.5/L $/kWh COE	Initial Capital	D=$1.5/L $/kWh COE	D=$2.5/L $/kWh COE
Solar / Diesel Hybrid	0	0.14	0.14	0	0.14	0.14
Solar Only	0	0.14	0.14	0	0.14	0.14
Generator / Battery	0	1.12	1.59	0	1.12	1.59
Generator Only	0	2.89	4.01	0	2.89	4.01

An estimated blood bank load of 10,000 watt-hours was calculated based on the discussion in section 4.2.1. A modeling program was utilized to compare the lifetime cost of electricity for the blood bank using four possible generating configurations: 1) a solar system, 2) a diesel generator, 3) a diesel generator and battery bank and 4) a combined generator/solar hybrid system. Costs are dependent on a variety of factors discussed in Appendix 5. The optimum solution to power these loads independently from the grid-power, calls for the installation of a 3.5 kWatt-peak solar array with appropriate batteries, and inverter in a hybrid situation with a small 3 kVA generator for battery charging during cloudy days.

The equipment costs of such a system (not project costs) are between $50,000 and $70,000. The resulting COE over a 20 year period, accounting in full for all initial capital costs and lifetime maintenance requirements, is about $1.00 per kWh. The COE for a solar only system is similar, but would not be recommended for this facility given the zero tolerance for electricity shortage for critical loads. If the hospital chose to install and operate an efficient, high-quality diesel generator to provide continuous power for this load the COE would be over $3.00 based on current diesel prices in Haiti. If diesel fuel increased to $2.50 per liter, these costs would increase to over $4.00 per kWh. Adding battery storage to a diesel generator greatly reduces the cost to $1.45 per kWh. Table 4 shows the Initial Capital costs of different generation configurations and compares the lifetime cost of energy or Net Present Cost (NPC) with and without consideration of the initial capital costs.

It is important to remember, however, that the economic benefits of utilizing renewable energy can only be realized, however, if the system lifetime is maximized with appropriate maintenance protocols.

4.3 LARGE GRID-CONNECTED FACILITIES

Donors have made significant investments in a variety of new buildings and energy intensive equipment at health facilities throughout Haiti. For instance, the Hopital Immaculee Conception reported that their electricity load had more than doubled in the past four years because of new equipment and construction. Unfortunately, there has not been a corresponding investment in the energy production or distribution systems at the same facilities. Investments that have been made have been piecemeal, and it was common to see solutions provided for particular wards (e.g. laboratories, pediatrics ward, etc) but little effort to provide facilities with holistic solutions to their energy challenges. For instance, Hopital Justinien had at least four different generators connected to different loads and a large generator whose use had to often be rationed during power outages because of insufficient operating funds. Hopital Immaculee Conception had a brand new generator whose life-span and utility was being jeopardized because of a lack of routine maintenance and sub-optimal installation. They had a power-conditioning unit donated by an NGO that had been sitting in storage for two years because of insufficient funds to install it. The internal distribution and wiring system of the hospital was designed for ¼ of the current load.

PEPFAR investment in retrofitting the energy systems at one or more of these large public hospitals could make a substantial impact on the quality of service at that facility.

SITE-SPECIFIC SOLUTIONS

In the absence of any near term solution to the grid power problems, investment in on-site solutions could make a substantial improvement in the power situation at hospitals in Haiti. The complexity of the electrical system at a large hospital such as HUEH, coupled with the uncertainty in the future quality, reliability, and cost of the grid power supply, require that a detailed engineering and cost analysis be performed before any site-specific investments are made. This is a multi-day effort and such a study is beyond the scope of this survey report. Nonetheless, a general approach for improving the energy supply at these facilities is outlined below:

Optimize Grid Power – Many of the health facilities in Haiti were missing key technologies – such as a full complement of transformers – needed to effectively utilize the grid power. Such deficiencies exacerbate the inherent poor quality of the grid power reaching the facility. In addition, the distribution system within each hospital compound was often outdated and inefficient.

Re-wire Facility and Optimize existing systems –Nearly every health facility visited in Haiti needed to be re-wired. Current wiring systems were outdated and overloaded, causing a variety of problems and preventing the implementation of a holistic solution to the energy challenges at the facility. The first priority should be to wire the facility in a way that separates the critical and non-critical loads. This will help drastically improve the economic feasibility of providing continuous and high quality power for facility operation in periods of grid power outages. Currently, many of the larger hospitals have all loads connected to a large back-up generator. Such generators are costly to run and their use was often rationed based on budgetary shortfalls creating crippling power outages for the facility. Separating the critical loads will allow them to be powered by more economic battery banks and/or small generators. This approach will also allow the power quality for the critical loads to be improved utilizing power conditioners. Rewiring of the facility will also help address incorrect and inefficient phase distribution from three-phase generators and voltage drops caused by undersized wires.

Add additional technology if needed – Once a plan has been developed to rewire the facility, additional technology such as an automatic transfer switch and power conditioning unit can be considered.

Train Hospital Facilities Manager and Establish Support Structure – Significant improvements in the power situation at most health facilities in Haiti could be achieved with rigorous training for the facilities management staff. These on-site staff must also be supported by a trained electrician at the national level within the Ministry of Health or through a contract with a private sector firm.

4.3.1 ENERGY EFFICIENCY CONSIDERATIONS

The energy challenges in Haiti should be an important consideration in the construction of all new health care facilities. Incorporating energy efficiency measures, such as, natural lighting and cooling and energy efficient equipment, into the hospital design will help to reduce future challenges associated with the unreliable grid power. Health facility design issues are complex – and a multitude of stakeholders need to be consulted in order to strike the correct balance between facilities that are modern, efficient, and functional. The use of air-conditioning, for instance, is an issue that deserves close examination. Air-conditioning units are notoriously sensitive to power anomalies and are difficult to keep operational in developing countries. They also draw a significant amount of power. On the other hand, climate controlled rooms can be essential for sensitive laboratory equipment and for sanitary purposes. Only an informed discussion between health professionals and facility engineers with a collective knowledge of the facility-specific function, power issues and climate can appropriately address this issue. The donor community should take a proactive approach to ensure that these critical discussions occur. Facilities that are built to Western standards without the corresponding reliability and quality of Western energy services can be problematic.

In addition to architectural designs, the type of equipment purchased is critical for reducing power consumption at health facilities. All loads connected to battery back-up should use energy efficient CF lighting. The PEPFAR program in Haiti is distributing standard desktop computer which are power intensive compared to laptops or solid-state desktop options.[6] Energy efficient refrigerators are discussed in section 4.2.1 and should be used when possible. If air-conditioning must be used, units with a high EER rating (ratio of BTU/watts) should be purchased.

4.4 SMALL GRID CONNECTED FACILITIES

Although the general approach to improving the energy supply is similar regardless of the size of the grid connected facility, there are some unique issues and approaches worth highlighting for small facilities. Several of the smaller health facilities visited in Haiti were in rural areas and as a result had even worse quality grid-power than the larger urban hospitals. St. Anne is a perfect example of a small grid-connected facility in Haiti. Typically, the clinic receives power from EDH from 11PM to 7 AM each day, although extended outages occur frequently. The total load of St. Anne is 13,000 watt-hours/day with 2,200 watt-hours needed during the night when EDH power is available. Because of this relatively small load, PEPFAR should consider utilizing the battery/inverter system to provide power to the entire facility, or to the lab and other critical loads such as computers and emergency lighting. Appendix 6 details load calculations for the entire facility and for the critical loads. The lab in St. Anne requires 4,500 watt-hrs/day so powering the additional clinic loads would require only a small additional investment in batteries.

4.4.1 BATTERY CHARGING

St Anne also provides an excellent case to further explore the issue of energy generation options for battery charging and facility operation. In order to power the entire facility, 12,000 watt-hrs of battery capacity would be required, or three strings of eight Trojan T-105 batteries. Each string of eight batteries would require a reliable AC connection for 2.25 to 2.5 hours to fully charge from a 50% discharged state, or 7.5 hours to charge the entire battery pack. The grid is typically on for 8 hours/day which should be sufficient to provide the majority of charge for the batteries. Another option to consider when there is only a limited duration of grid power is to use two battery inverter sets thereby reducing the charge time by ½.

Regardless of the configuration used, an additional source of generation will be required to account for prolonged periods of grid outage. Both a diesel generator and solar system would be feasible for this size facility. Given the availability of grid power, a 11kVA three phase

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[6] See, for instance: http://www.inveneo.org/

generator or 7 kVA two phase generator capable of producing 30 amps would be the most economic option. A solar system should also be considered as an option if long term monitoring of the facility finds frequent prolonged (days or weeks) power outages requiring the generator to be run exclusively to charge the batteries.

4.5 OFF-GRID FACILITIES

Haiti has a large number of health facilities in the central plains that are off-grid and either have no electricity or generate all electricity on site. Although these facilities represented a minority of the PEPFAR supported facilities, the lack of grid electricity makes operation of these facilities particularly expensive and challenging.

The assessment team visited a medium sized clinic in Thomonde supported by Partners in Health which provides an excellent case study for discussing the options for off-grid facilities. Thomonde spends an average of $5000 USD per month on diesel fuel to run a 40 KVA generator for thirteen hours per day (7A.M – 4 P.M. and 7P.M – 11P.M.). The load at Thomonde is approximately 16,000 watt-hours/day excluding short burst high loads of the x-ray machine and dental lab. (Appendix 7) Thomonde also has battery back-ups for some of the critical loads.

The first priority for Thomonde should be to purchase a smaller generator. Their current generator is greatly oversized and uneconomical. The cost of a properly sized generator could be quickly recovered through fuel savings. Further savings could be realized by increased battery storage capacity and with the addition of solar panels to reduce generator run time. A solar system for this size facility would cost approximately $100,000 USD.

4.5.1 HEALTH POSTS

Although no small off-grid health posts were visited during this assessment, several stakeholders claimed that they existed in Haiti and expressed interest in options for providing power to these basic health care facilities. The energy demands of rural health outposts are typically quite similar and can be classified in two categories depending on the need for refrigeration. These loads are detailed in Table 5.

Table 5: Typical load requirements of small health posts

Qty	Load	Watts	Hours/Day	Energy/Whrs/Day
Option 1:				
1	CB Radio-Transmitter	20	1	20
1	CB Radio-Receiver	10	6	60
1	CF Light	20	6	120
1	Security Light	20	6	120
1	LED Light	1	10	10
	Total			**330**
Option 2: all items above plus:				
1	Vaccine refrigerator			650
	Total			**980**

The best option for powering these loads is a properly designed, installed and maintained solar system.

The costs for the PV system to power Option 1 would be $1,500 while the larger system to power a clinic with a refrigerator (Option 2) would cost $4,500.

The lifetime cost of solar power produced from this system costs about half of diesel generator produced power over the 20 year lifetime of the system.

While provision of power to these facilities is straight forward from a technological point of view, the institutional support structure needed to make these systems sustainable requires considerable attention and development. Before launching an off-grid health clinic electrification program, the Ministry of Health should develop a strategy which takes a holistic view of the needs of all health posts in the country and prioritizes the facilities to receive power based on a pre-determined set of criteria.

The Ministry of Health should also institute design standards for these systems. Finally, a detailed training program and maintenance protocols should be established to ensure long-term system sustainability.

5 EXAMPLE ENERGY RETROFIT SUPPORT PROGRAMS

This report has detailed several options for improving the energy services at priority health facilities in Haiti. Although the prioritization of investments will need to be considered by the PEPFAR staff in the context of their overall programmatic objectives, notional activities that could be implemented within certain budget constraints are detailed below. (Table 6) Top priority should be given to interventions that could improve the sustainability or effectiveness of existing PEPFAR investments – such as the distribution of battery and inverters through the laboratory infrastructure program.

The base case outlines a program focused on establishing a trained network of engineers and health facility maintenance staff to improve the success of the current battery/inverter program. Such an effort could also include retrofitting the wiring and adding additional generation sources at up to five small health facilities. Such modifications would allow the facility to maximize the impact and sustainability of the battery/inverter systems while providing a hands on training ground for the newly hired engineers.

A more substantial PEPFAR investment would allow the energy systems at one or more of the large public health facilities to be improved. Accurate cost estimates for the type of project require a multi-day engineering assessment so a broad range of estimated costs have been used in Table 6. Hopital Justinien or Immaculee Conception would be excellent candidates for an investment in the $200-500,000 range, while HUEH may require a more substantial investment in excess of $1 million.

The budgets in Table 6 are based on estimates for the total cost for PEPFAR to implement the detailed activity. This contrasts to the cost estimates in the report which were primarily limited to equipment expenses. The costs below should be used only as rough estimates as actual program costs can vary significantly based on the implementing partner. For most of the recommendations in the report it is suggested that the expertise of the international consulting community be used to augment the local technical capacity in Haiti to ensure the implementation of a sustainable program. After initial projects are successfully implemented, local capacity should be built sufficiently to phase-out the need for international consultant oversight.

Implementation of the training program can be done very quickly utilizing a pre-existing energy team contract with an appropriate implementing partner. Several different implementation options for the health facility retrofit program should be considered based on the size of program and priority facilities chosen by the PEPFAR program. One option is for the Haiti PEPFAR program to utilize existing USAID/Washington Energy Team Task Orders.

Table 6: Notional budgets for energy retrofit programs.

Available Budget: $200,000

Program	Unit Cost	Cost
Training program for technicians – local, regional, national. (see Appendix 7)		$100,000
Retrofit up to 5 smaller health facilities (e.g. St. Anne, etc).	$20,000 - 40,000	$100,000
Total		**$200,000**

Available Budget: $800,000

Complete the work described above plus:

Program	Unit Cost	Cost
Retrofit large hospital(s) (Justinien and/or Immaculee Conception)	$200,000-$500,000	$500,000
Total		**$600,000**

Available Budget: $1,500,000[7]

Complete the work described above plus:

Program	Unit Cost	Cost
Retrofit additional large hospital(s)	$200,000 -$500,000	$500,000
Total		**$500,000**

[7] Alternatively, a budgetary expenditure of greater than $1 million USD would be sufficient to improve the internal wiring and distribution system at HUEH and implement a training program for the battery/inverter program.

6 CONCLUSIONS

Reliable electricity is a critical input to all levels of health care delivery in Haiti. The acquisition of reliable power poses a challenge to nearly every facility visited during this assessment. The grid in Haiti is limited in coverage and characterized by frequent and often prolonged power outages and power anomalies resulting in a wide-range of challenges that require a diverse set of solutions.

Improving the power supply of health facilities in Haiti could have a dramatic impact on the quality of health care delivery and should be seriously considered by the PEPFAR program. Donors have made significant investment in the construction of new health facility buildings and in upgrading medical equipment, but there has not been a corresponding investment in the energy sources needed to power these new loads. Investments that have been made are on a piecemeal basis. PEPFAR investment in holistic solutions to health facility energy challenges would help ensure the sustainability of a variety of current PEPFAR investments, improve the quality of health care at key health facilities, and free significant financial resources that are currently being spent on inefficient energy solutions.

Unfortunately, there is no “quick-fix” to the health sector’s energy crisis. Provision of the correct energy technology is only the fist step of a solution, and longer term efforts to build local capacity and establish oversight and monitoring systems are required to make these systems sustainable.

Significant financial resources are not required to implement a program with substantial impact. A PEPFAR program focused on retrofitting the energy systems at a few model facilities and establishing a trained support network of engineers would have a ripple effect across the entire network of health facilities by highlighting that cost effective solutions are viable and by providing the technical capacity to implement these solutions.

APPENDIX 1: FACILITIES VISITED

West Department : National Lab, Hopital de la Paix, Grace Children, Tabarre (IMIS Clinic), HUEH

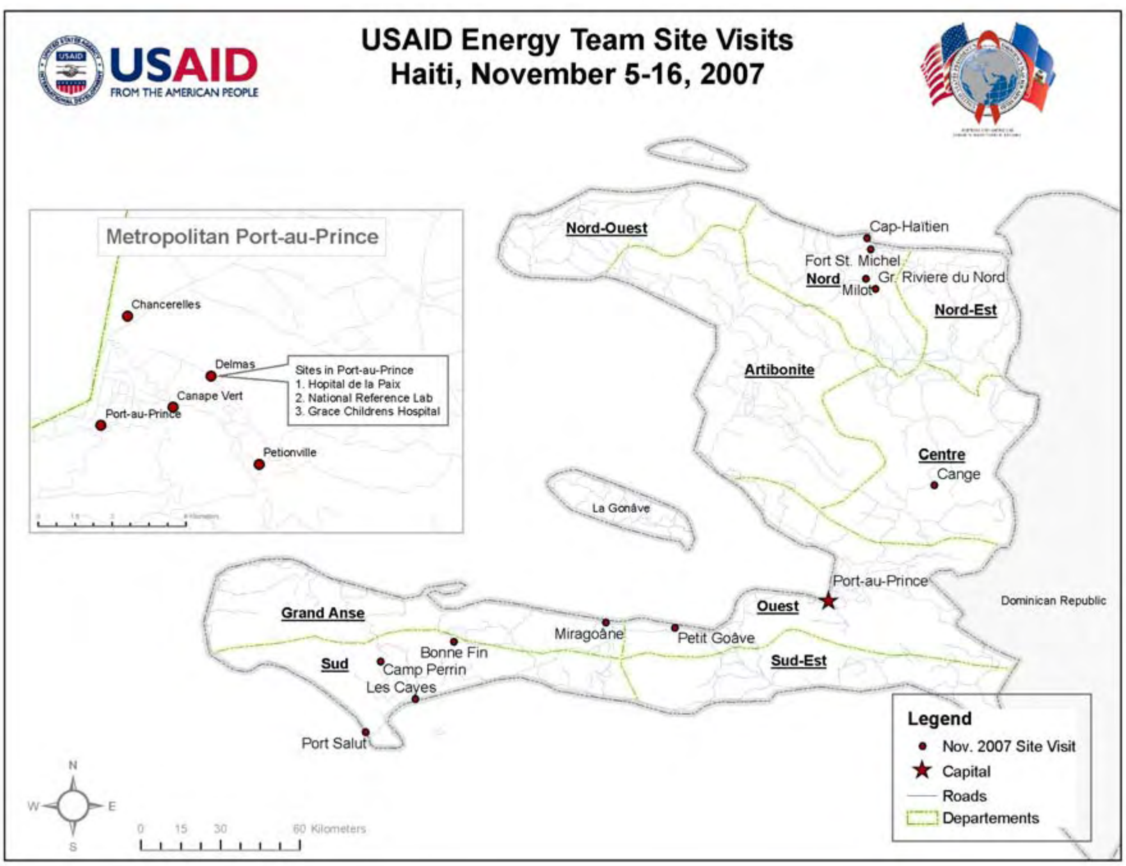
South Department: Petit Goave, Camp Perrin St Anne, Port Salut, Les Cayes Blood Bank, Hopital Immaculee Conception, 4-Chemin, Bonne Fin

Central Department: Cange, Thomonde

Nippes Department: Miragoane

North Department: La Fossette, Hopital Milot, Centre de Sante Fort Michel, Hopital Justinien, Hopital Rivier du Nord

Figure 1: Map of Haiti with locations of site visits indicated in red



APPENDIX 2: FACILITY SPECIFIC ANALYSIS

This appendix provides a one page summary of key issues and recommendations for each of the facilities visited during the assessment.

Petit Goave Hospital

Overall Power Analysis: The Petit Goave Hospital reportedly receives an average of 18 hours/day of grid power from EDH. Power outages generally occur during the day during which time the hospital runs a 60 KW generator. The hospital also has an 80 KW generator that appeared to be brand new and was yet to be connected. The hospitals primary transformer (three-phase) was not working and the transformer dedicated to the operating room was currently supplying power to the entire facility. (figure 1)

There are two EDH power lines in the town. A 13.2 KV line with reported 24 hour power is dedicated to an ice-making facility while a 4.2 KV line powers the hospital and the rest of the town. EDH has told the hospital that they will connect them to the 13.2 KV line if they provide the new transformers and cable. The hospital has recently received a quote for $9000 USD to complete this work but apparently does not have sufficient funds to implement the improvements.

Key Issues:

- Although CDC provided the hospital with an inverter and batteries in August 2007, they had yet to be installed. The hospital administrator claimed they had insufficient funds to install the system. A quote from a local electrician indicated the installation would cost $500.
- The hospital had a newly renovated X-Ray room although the equipment had not been assembled or connected. They planned to wait until 3-phase power was available from the ice-house line to install the x-ray machine.
- The blood bank contained two CDC provided refrigerators and one Red Cross provided refrigerator. The Red Cross refrigerator was not in use because of insufficient power. Neither of the CDC refrigerators were plugged in and neither had gas. The contents of the refrigerator were at room temperature. It was reported that the gas had run out the night before and someone was refilling the tank. One of the CDC refrigerators had a faulty gasket. (Figure 3)

Recommendations: Although the current power situation at Petit Goave is dire, the future looks brighter. The human capacity at Petit Goave appeared to be limited and it was one of the few facilities that did not have a full time electrician. Increasing the capacity of the staff should be a top priority. PEPFAR could also consider supporting an overall facility upgrade including:

- Transformer and line upgrade
- Inverter and generator installation

- Facility rewiring

Estimated Equipment Cost: 70K

Figure 1: Three-phase transformers inoperable

Figure 2: X-ray machine not installed because of insufficient power supply.

Figure 3: a) CDC provided blood lab refrigerator not connected to gas or electric power b) gasket on refrigerator faulty, c) contents of refrigerator at room temperature, d) temperature log out of date, and e) blood bank refrigerator not in use because of insufficient power.

Miragoane Hospital:

Overall Power Analysis: Miragoane is a well run facility with a skilled electrician. The power supply is pretty reliable with periodic outages during a typical day. The hospital has a 60 KW generator that is run on average five times per week during power outages and surgery. Average diesel fuel cost per month is $1200. The facility has a basic lab and several refrigerators (one from USAID and two from CDC) all of which are run on propone because of concern about the power supply. The hospital had three Xantrex inverters for critical loads and lighting– one of which appeared to be working.

Key Issues:

- The generator is rated at 50 Hz which is not ideal for running equipment rated at 60 Hz. They have adjusted the speed to 55 Hz but the generator is still not able to power the x-ray machine.
- The CDC provided inverter was not operating properly. Upon inspection, it appeared that the voltage window for the inverter (110 V) was set above the average input voltage from EDH (104 V) (figure 1). The inverter input voltage was lowered and the system appeared to work better. Further tests are required to insure there is not an additional problem with the inverter circuit board.

Recommendations: This hospital has all the components for a well functioning electric system: talented engineer, generator, inverters, and somewhat reliable grid power. The primary need is for some additional training for the engineer – particularly on the operation of the inverters. Upgrading the generator to a 60 Hz system could also be considered but is not critical.

Estimated Equipment Cost: < 10K

Figure 1: The inverter voltage window was set above the average line voltage preventing proper battery charging.

<u>Immaculee Conception Hospital</u>:

<u>Overall Power Analysis</u>: The hospital director identified power issues as one of her primary challenges. Although they have nominal 24 hour service from EDH, power outages and poor quality power are common, disrupting service and damaging equipment. The hospital has a one year old 175 KW generator with capacity to power the entire facility. The electrician estimated the generator runs for about 5 hours per week although the hour meter indicated it may be as little as two hours per week. The hospital has supported a study in 2004 and 2007 identifying key recommendations for improving the power supply. None of the actions have been implemented because of a lack of funding.

<u>Key Issues</u>:

- In the past several years the electrical load of the hospital has more than doubled. This increased demand has placed a significant stress on the internal wiring and the distribution wiring between the buildings that were not designed for such a load.
- The transformer (35kW) appeared to be undersized for the calculated maximum instantaneous load of the facility (100kW).
- The generator does not have an automatic transfer switch causing a disruptive delay during grid power outages.
- No preventative maintenance (e.g. oil and filter change) has been conducted on the generator since installation (2006). This was blamed on lack of funding although it was also likely a result of lack of capacity of the electrician and mechanic and a lack of understanding about the critical nature of such maintenance for the long-term operation of the generator.
- CRS purchased a power-conditioning unit for the hospital two years ago but the system has not been installed as a result of insufficient funds.
- CDC has provided batteries and an inerter for the lab and for the new infectious disease building. The laboratory inverter was not installed because they are waiting for the construction of a new lab. The infectious disease building inverter was not operational because the battery cables had been stolen.
- The generator produces three phase power and the distribution system at the hospital has a single phase / two wire configuration. One of the phases of the generator is completely unloaded which is inefficient and harmful to the generator.

<u>Recommendations</u>: Immaculee Conception would be an excellent candidate for a PEPFAR supported “facility wide” power system upgrade as part of an effort to establish a “model” large health care facility. Various donor (CRS, IADB, USG) have provided the hospital with the necessary technology required to produce a suitable power supply (new generator, power conditioner, UPS systems) but the hospital has insufficient funds and human capacity to tie all these systems together into a functioning whole. Because the hospital has most of the hardware it needs, such an effort would be relatively low cost

and would significantly improve the electrical supply at the hospital. The following specific activities could be supported:

- Provide technical assistance to the hospital in its bid to get improved power from EPH.
- Upgrade internal wiring and distribution system including equal distribution of the generators 3-phases.
- Install centralized powering conditioning and UPS systems
- Train technician and mechanic on proper maintenance protocol for the generator and wiring techniques.
- Install finer mesh bars on the battery cages to prevent theft of cables.

Estimated Equipment Cost: 100K – 300K

Figure 1: Funding issues have prevented the hospital from replacing the open transformer slot on this pole. Transformer is likely undersized for facility.

Figure 2: Although operational since 2006, no preventative maintenance has been performed on the hospital's generator.

Figure 3: New buildings and equipment, such as the PEPFAR supported infectious disease building, have more than doubled the hospital's electrical load in the past four years with no associated upgrade of the internal wiring and circuitry.

Figure 4: The PEPFAR provided inverter was not functioning because the battery cables had been stolen. Smaller mesh on the battery cage would deter future theft.

4 Chemin:

Overall Power Analysis: 4 Chemin is a small clinic in downtown Les Cayes currently being retrofitted to provide palliative care services. Currently, 4 Chemin has very limited electrical equipment. The current power situation at the clinic is very poor because the transformer that feeds the area failed three month ago and has not been replaced. EDH claims the failure is a result of illegal connections and therefore replacement is not a priority. The clinic was without power for several weeks until they ran a wire to a nearby distribution line powered by a different transformer. During extended power outages the hospital rents a 1000 watt generator.

Key Issues:

- Clinic has no legal supply of power.
- Generator rental and fuel are expensive.
- New construction of palliative care facilities will require more reliable energy sources (figure 1)

Recommendations: The limited electric load of 4 Chemin makes it a perfect candidate for an inverter and battery system to provide continuous electricity during power outages. If EDH does not replace the transformer the hospital will have to upgrade its generation system – either with a generator or a solar system. Training of the local medic and access to a technician will be required to keep any system operational because the clinic has no on-site electrician.

Estimated Equipment Cost: < 10K

Figure 1: New construction of palliative care facilities at 4 Chemin will require a more reliable power supply

<u>Les Cayes Red Cross Blood Bank</u>:

<u>Overall Power Analysis</u>: The grid power at the blood bank was reported to be some of the most reliable of any facility visited although it is likely that it was not significantly different than other facilities in Les Cayes. The blood bank had a large blood bank specific refrigerator and a propane/electric refrigerator. In the case of power outages the blood could stay within the required temperature range for about ½ hr in the electric refrigerator. If the power outage persisted, the blood would be switched to the propane refrigerator. For lengthy outages the blood would be switched back to the electric unit and the generator would be started because the staff was not confident of the temperature control in the propane unit. The blood bank had recently (one year ago) received a battery and inverter system which was connected to all loads except the air-conditioning.

<u>Key Issues</u>:

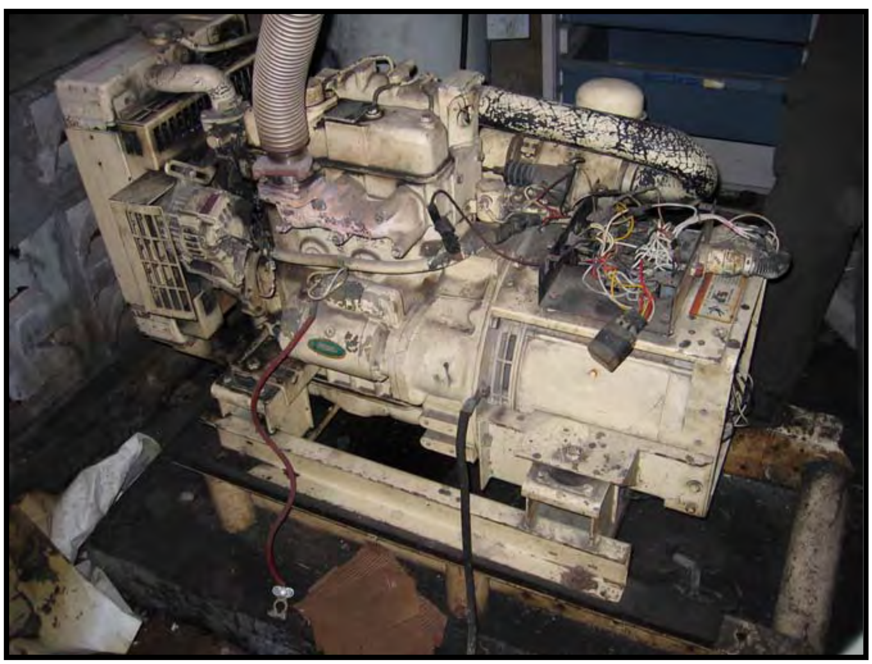
- The double-wide blood refrigerator located at the facility uses a significant amount of power and seemed to be oversized for the needs of this blood bank.
- The generator needs a starting battery.
- The UPS system was not operating properly. The staff believed the batteries were dead. It is possible that the large refrigerator was too big of a load for the battery bank capacity.

<u>Recommendations</u>: A load analysis of this facility must be performed before replacement batteries are provided. It is possible that the load on the batteries was too large and they were left in a persistent discharged state. In addition, a maintenance network must be established for the blood bank battery and inverter systems. The staff reported that although they had informed the Red Cross about the failed system several weeks ago no one had come to repair it. A battery also needs to be provided for the generator. A training program for the local staff on the use of the Xantrex inverter and basic battery maintenance is required since most blood blanks will likely not have an on-site electrician.

<u>Estimated Equipment Cost</u>: < 10 K

Figure 1: The batteries on the blood bank's UPS system have failed.

Figure 2: Although antiquated, the blood-bank's generator still runs.   A starting battery must be found each time they want to use the generator.



<u>Port Salut</u>:

<u>Overall Power Analysis</u>: Port Solut is a very well run facility with a medical director who is proactive with regards to the energy systems. The grid power at Port Solut is very poor – often only on for a few hours per day. The power was out for an entire month in Sept-Oct 2007. The hospital has a well-maintained 60 KW generator for use during power outages. PEPFAR has supported the purchase of fuel for the generator which the director said has had a significant impact on the quality of care at the facility. During extended power outages, the generator is typically run from 8 am – noon to power the hospital and charge the batteries. For the rest of the day, limited loads in the hospital are run by the inverter and battery bank. Diesel fuel is expensive in Port Salut ($5 gallon) and the hospital typically uses 200 gallons per month.

Port Salut has two functioning solar systems. WHO provided one system for the vaccine refrigerator which has been operational for two years. The system failed one time and WHO immediately dispatched a technician to fix the problem. The second system has been operational for 6 years and is used to power the communications equipment. The hospital director said they have had no problem with theft of the systems.

PEPFAR has provided Port Solut with a inverter system which was operational at the time of the visit. The inverter initial did not work properly because of a faulty installation so the hospital called a technician in Les Cayes to install the system properly.

<u>Key Issues</u>:

- Limited grid power and expensive diesel fuel.
- Inverter replaced much smaller system but was connected to same loads.

<u>Recommendations</u>: The objective at Port Solut should be to minimize the run time of the generator and maximize the loads that can be run off the inverter. A load analysis should be completed for the facility (will be done for final report) to determine the optimal size of the inverter/battery bank and the loads which should be connected to the system. The hospital should then be re-wired to achieve this load distribution. It is likely that more batteries will need to be provided for the hospital. The grid power and generator appear to provide sufficient charge for the batteries so it is likely not necessary to increase the size of the solar system at the facility.

Figure 1: WHO installed solar powered vaccine refrigerator has worked well for two years. A smaller solar system has worked for 6 years powering the radio.

Saint Anne:

Overall Power Analysis: St. Anne is a small facility with a very poor power supply. The staff has an impressive understanding of the energy challenges but does not have the technical capacity to address them. EDH power is typically on between 11PM – 7 AM during which time it has very low voltage (90 VAC). PEPFAR has provided support for the clinic to purchase a new transformer which will improve the voltage characteristics of the line power. The project has been delayed because of logistical issues but should be completed soon. The clinic has a 2300 Watt Honda generator and a 6 KW generator which does not work.

The hospital has an inverter system provided by CDC which was not functioning at the time of the visit.

Key Issues:

- The CDC provided refrigerator was also not working properly (electric worked but propane did not.) Another propane refrigerator was operational but the hospital must rent a car and drive to Les Cayes every time they need to refill the propane tanks.
- The voltage window on the Xantrex (110 V) was set above the line voltage (90V) preventing the inverter from operating correctly. As a result, the batteries had been discharged and at least half were no longer useable.
- The wiring of the clinic needs to be redone. The AC OUT wire from the inverter goes all the way to the other end of the building, just to intercept the circuits from the lab at the main electrical panel, and then back. This is confusing and will likely result in unintended load being added to the system. The overcurrent protection is being bypassed by removing the lab load wiring at the panel and wire nutting the circuits into the inverter output wires.

Recommendations: A small investment could go a long way in improving the power supply at St. Anne. The first step is to conduct a load study of what should be on the inverters, determine how many batteries are needed and then re-wire the whole installation. Training of local users will also be required since the facility does not have an on-site electrician. If the grid power proves insufficient to charge the battery bank a solar installation may be appropriate for St. Anne.

Estimated Equipment Cost: 15 K

Figure 1: a) The majority of the batteries for the inverter system have failed because of insufficient charging b) computer equipment sits unused because of a lack of electricity.

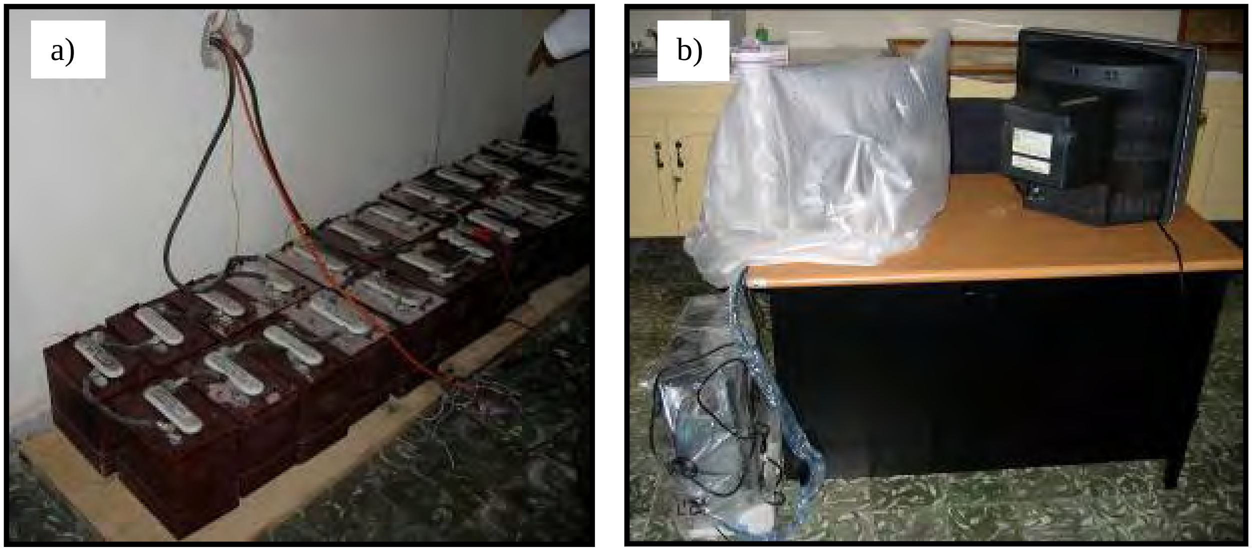
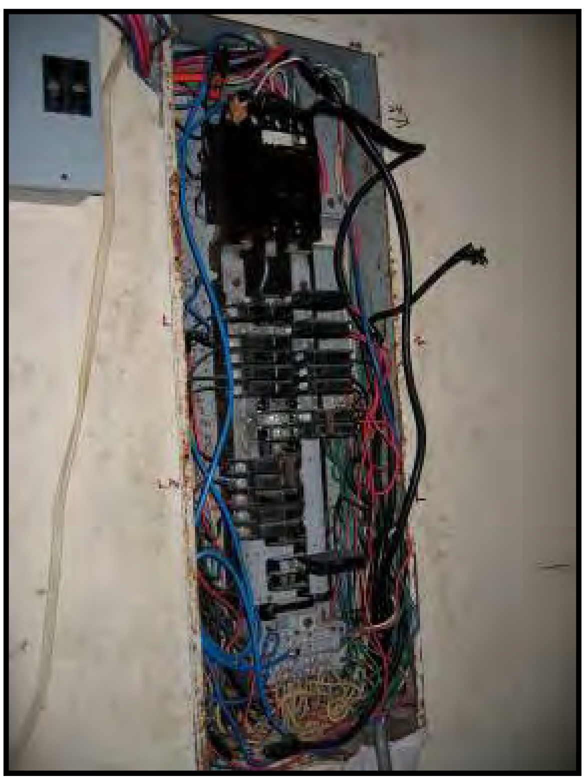


Figure 2: Poor wiring which is typical of many clinics in Haiti.



<u>Hospital Bonne Fin:</u>

<u>Overall Power Analysis</u>: Bonne Fin was one of the most impressive facilities visited during the assessment. Although not connected to the EDH grid, Bonne Fin had a very reliable power supply as a result of a micro-hydro plant installed by American engineers. The hydro facility has a 50 and 75 kVA turbine and provides power to the hospital and to some of the houses in the town. The hospital had a well maintained 45 kW generator which was run if the hydro facility was not working. The wiring at the facility was professionally done and they had a full time electrician.

<u>Key Issues</u>:

- In general, the hospital does not seem to have sufficient funds to properly maintain the hydro system. The system required $6000 USD of repairs in 2004 and only ½ has been paid off.

- The 50 kVA turbine was not operational and the hospital did not have funds to fix it. Estimated cost for the replacement part was $2,500.
- The combined load of the hospital and town was often too large for the hydro facility. As a result the electrician would often cut power to the town. Because of the system design, the hydro turbines could not be run simultaneously.

Recommendations: The power situation at Bon Finne is quite simple: if the hydro plant is operational they have no problems, if it fails they have no power. PEPFAR may want to support repair of the broken hydro system and train the on-site engineer on system maintenance. In addition, an investment in paralleling hardware would allow both turbines to be run simultaneously and the output of the system would be doubled. This would allow more power to be provided to both the hospital and town and would be a good investment from a community development perspective. It would also be beneficial to work with the hospital to establish a sustainable maintenance fund for the system. One source of revenue could be from the sale of excess electricity to the town. Currently they only charge a nominal amount for the power they provide.

Estimated Equipment Cost: 20 K

Note: Information sheets on facilities in the North and Central Department are still in development.

APPENDIX 3: ARV LABORATORY LOAD CALCULATIONS

BASIC LAB WITH EFFICIENT REFRIGERATOR

Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts	Days Per Week	Weekly Calc
				Day	Night	Day	Night	Total			
Lighting											
Laboratory	4	Fluorescent Lamps	40	8		1,280	0	1,280	160		-
Total Lighting						1,280	-	1,280	160		-
Equipment											
Laboratory	1	CD4 Machine	200	4		800	0	800	200		-
	1	Hematology Analyzer	230	4		920	0	920	230		-
	1	Blood Chem. Analyzer	45	4		180	0	180	45		-
	2	Microscope	30	6		360	0	360	60		-
	2	Centrifuge	400	2		1,600	0	1,600	800		-
	1	Fan	150	8		1,200	0	1,200	150		-
	1	Efficient Refrigerator	60	10	14	600	840	1,440	60		-
Total Equipment						5,660	840	6,500	1,545		-
Other											
Office	1	Desk Top Computer	150	8		1,200	0	1,200	150		-
Total Other						1,200	-	1,200	150		-
Grand Totals						**8,140**	**840**	**8,980**	**1,855**		**-**

BASIC LAB WITH EFFICIENT REFRIGERATOR AND AIR CONDITIONING

Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts
				Day	Night	Day	Night	Total	
Lighting									
Laboratory	4	Fluorescent Lamps	40	8		1,280	0	1,280	160
Total Lighting						1,280	-	1,280	160
Equipment									
Laboratory	1	CD4 Machine	200	4		800	0	800	200
	1	Hematology Analyzer	230	4		920	0	920	230
	1	Blood Chem. Analyzer	45	4		180	0	180	45
	2	Microscope	30	6		360	0	360	60
	2	Centrifuge	400	2		1,600	0	1,600	800
	1	Fan	150	8		1,200	0	1,200	150
Total Equipment						5,060	-	5,060	1,485
Refrigeration									
Laboratory	1	Efficient Refrigerator	60	10	14	600	840	1,440	60
	1	Air Conditioning Unit	1,000	10		10,000	0	10,000	1,000
Total Refrigeration						10,600	840	11,440	1,060
Other									
Office	1	Desk Top Computer	150	8		1,200	0	1,200	150
Total Other						1,200	0	1,200	150
Grand Totals						**18,140**	**840**	**18,980**	**2,855**

STANDARD SIZED LAB WITHOUT AIR CONDITIONING

Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts
				Day	Night	Day	Night	Total	
Lighting									
Laboratory	6	Fluorescent Lamps	40	8		1,920	0	1,920	240
Total Lighting						1,920	-	1,920	240
Equipment									
Laboratory	2	CD4 Machine	200	6		2,400	0	2,400	400
	1	Hematology Analyzer	230	6		1,380	0	1,380	230
	1	Blood Chem. Analyzer	45	6		270	0	270	45
	4	Microscope	30	6		720	0	720	120
	2	Centrifuge	400	2		1,600	0	1,600	800
	1	Fan	150	8		1,200	0	1,200	150
Total Equipment						7,570	-	7,570	1,745
Refrigeration									
Laboratory	2	Efficient Refrigerator	60	10	14	1,200	1,680	2,880	120
Total Refrigeration						1,200	1,680	2,880	120
Other									
Office	2	Desk Top Computer	150	8		2,400	0	2,400	300
Total Other						2,400	-	2,400	300
Grand Totals						**13,090**	**1,680**	**14,770**	**2,405**

STANDARD SIZED LAB WITH AIR CONDITIONING

Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts
				Day	Night	Day	Night	Total	
Lighting									
Laboratory	6	Fluorescent Lamps	40	8		1,920	0	1,920	240
Total Lighting						1,920	-	1,920	240
Equipment									
Laboratory	2	CD4 Machine	200	6		2,400	0	2,400	400
	1	Hematology Analyzer	230	6		1,380	0	1,380	230
	1	Blood Chem. Analyzer	45	6		270	0	270	45
	4	Microscope	30	6		720	0	720	120
	2	Centrifuge	400	2		1,600	0	1,600	800
	1	Fan	150	8		1,200	0	1,200	150
Total Equipment						7,570	-	7,570	1,745
Refrigeration									
Laboratory	2	Efficient Refrigerator	60	10	14	1,200	1,680	2,880	120
	1	Air Conditioner	1,000	10		10,000	0	10,000	1,000
Total Refrigeration						11,200	1,680	12,880	1,120
Other									
Office	2	Desk Top Computer	150	8		2,400	0	2,400	300
Total Other						2,400	-	2,400	300
Grand Totals						**23,090**	**1,680**	**24,770**	**3,405**

APPENDIX 4: BLOOD BANK LOAD CALCULATIONS

BLOOD BANK IN LES CAYES

Existing Condition (excluding air conditioning)

Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts
				Day	Night	Day	Night	Total	
Lighting									
Laboratory	4	Fluorescent Lamps	40	8		1,280	0	1,280	160
Total Lighting						1,280	-	1,280	160
Equipment									
Laboratory	0	CD4 Machine	200	-		-	0	-	-
	2	Heaters	100	4		800	0	800	200
	1	Precision Scientific	500	2		1,000	0	1,000	500
	2	Microscope	30	6		360	0	360	60
	2	Centrifuge	400	2		1,600	0	1,600	800
	1	TV	200	4		800	0	800	200
Total Equipment						4,560	-	4,560	1,760
Refrigeration									
Laboratory	1	Refrigerator for Drinks	50	10	14	500	700	1,200	50
	0	Air Conditioner	1,000	10		-	0	-	-
	1	Back-Up Refrigerator	70	10	14	700	980	1,680	70
	1	Blood Bank Refrigerator	667	10	14	6,670	9,338	16,008	667
Total Refrigeration						7,870	11,018	18,888	787
Other									
Office	0	Desk Top Computer	150			-	0	-	-
Total Other						-	-	-	-
Grand Totals						**13,710**	**11,018**	**24,728**	**2,707**

BLOOD BANK IN LES CAYES

Modified

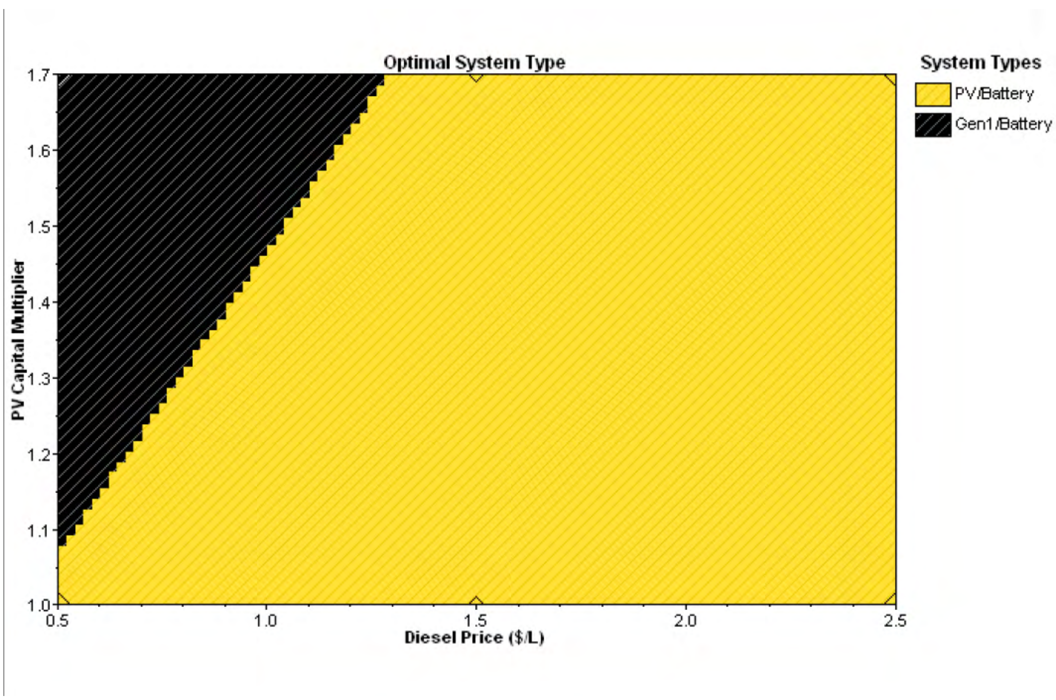
Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts
				Day	Night	Day	Night	Total	
Lighting									
Laboratory	2	Fluorescent Lamps	40	8		640	0	640	80
Total Lighting						640	-	640	80
Equipment									
Laboratory	0	CD4 Machine	200	-		-	0	-	-
	2	Heaters	100	4		800	0	800	200
	1	Precision Scientific	500	2		1,000	0	1,000	500
	2	Microscope	30	6		360	0	360	60
	2	Centrifuge	400	2		1,600	0	1,600	800
	0	TV	200	4		-	0	-	-
Total Equipment						3,760	-	3,760	1,560
Refrigeration									
Laboratory	0	Refrigerator for Drinks	50	10	14	-	0	-	-
	0	Air Conditioner	1,000	10		-	0	-	-
	1	Back-Up Refrigerator	70	10	14	700	980	1,680	70
	1	Blood Bank Refrigerator	150	10	14	1,500	2,100	3,600	150
Total Refrigeration						2,200	3,080	5,280	220
Other									
Office	0	Desk Top Computer	150			-	0	-	-
Total Other						-	-	-	-
Grand Totals						**6,600**	**3,080**	**9,680**	**1,860**

APPENDIX 5: PV PRICING DISCUSSION

Several factors have a strong influence on the price of energy calculated by HOMER in table 4. These are discussed below:

- Interest rate: Because of the large upfront investment for solar panels the interest rate used has a huge impact on the lifetime cost of solar power. The difference between 0% and 6% interest rate results in a 50% price increase for solar power. Assuming the solar systems for health facilities in Haiti are going to be purchased by donor funds, and not an investor with other interest producing investment opportunities, a low interest rate is justified. 2% is used for these calculations.
- Diesel Costs: Obviously the cost of diesel fuel strongly influences the cost of all diesel generator produced power. Interviews with health facilities in Haiti revealed a diesel cost of $1.30/liter. For the sake of calculation, $1.50/liter was used to account for fuel transport costs. Diesel prices of $2.50 were used for comparison.
- Solar equipment costs vary drastically depending on the supplier, installer, and specific country tariffs, etc. For the sake of this calculation, PV system costs between $13.50/watt and $20/watt were used. The price of $13.50 per watt is represented by the multiplier "1" and represents estimates based on experience from other developing countries. The $20 per watt price is represented by the "1.7" multiplier and represents the cost per watt provided by a private sector firm in Haiti. The actual costs of a project will depend on project specifics.

The figure below shows a sensitivity graph comparing a pure solar system with a generator/battery system for different diesel and PV costs. The shading represents the least cost option for that combination of prices.



APPENDIX 6: SAINT ANNES LOAD CALCULATIONS

ST. ANNE

Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts	Days Per Week	Weekly Calc
				Day	Night	Day	Night	Total			
Lighting											
Laboratory	2	CF Lamps	22	8		704	0	704	88	5	503
Security Lighting	15	CF Lamps	11	4	7	660	1,155	1,815	165	7	1,815
Wards and Offices	20	CF Lamps	22	4		1,760	0	1,760	440	7	1,760
Hallway Lighting	15	CF Lamps	11	4	2	640	330	990	165	7	990
Operating Suite	4	Tube Fluorescents	40	2	2	320	320	640	160	3	274
Total Lighting						4,104	1,805	5,909	1,018		5,342
Equipment											
Laboratory	1	CD4 Machine	200	4		800	0	800	200	5	571
	1	Hematology Analyzer	230	4		920	0	920	230	5	657
	1	Blood Chem. Analyzer	45	4		180	0	180	45	5	129
	2	Microscope	30	6		360	0	360	60	5	257
	1	Centrifuge	400	2		800	0	800	400	5	571
	0	Other Loads	400	2		-	0	-	-		-
	0	A/C	1,000	6		-	0	-	-	5	-
	1	Refrigerator Efficient	60	16	8	960	480	1,440	60	7	1,440
Total Equipment						4,020	480	4,500	995		3,626
Other											
Office	2	Desk Top Computer	150	8		2,400	0	2,400	300	5	1,714
	1	Internet Equipment	20	12		240	0	240	20	7	240
Total Other						2,640	-	2,640	320		1,954
Grand Totals						**10,764**	**2,285**	**10,049**	**2,333**		**10,992**

ST. ANNE : CRITICAL LOADS

Area	Qty	Load	Watts Each	Hrs/Day		Watt-hours			Total Conn Watts	Days Per Week	Weekly Calc
				Day	Night	Day	Night	Total			
Lighting											
Laboratory	2	CF Lamps	22	8		352	0	352	44	5	251
Security Lighting	15	CF Lamps	11	4	7	660	1,155	1,815	165	7	1,815
Wards and Offices	10	CF Lamps	22	4		880	0	880	220	7	880
Hallway Lighting	8	CF Lamps	11	4	2	352	176	528	88	7	528
Operating Suite	4	Tube Fluorescents	40	2	2	320	320	640	160	3	274
Total Lighting						2,564	1,651	4,215	677		3,749
Equipment											
Laboratory	1	CD4 Machine	200	4		800	0	800	200	5	571
	1	Hematology Analyzer	230	4		920	0	920	230	5	657
	1	Blood Chem. Analyzer	45	4		180	0	180	45	5	129
	2	Microscope	30	6		360	0	360	60	5	257
	1	Centrifuge	400	2		800	0	800	400	5	571
	0	Other Loads	400	2		-	0	-	-		-
	0	A/C	1,000	6		-	0	-	-	5	-
	1	Refrigerator Efficient	60	16	8	960	480	1,440	60	7	1,440
Total Equipment						4,020	480	4,500	995		3,626
Other											
Office	1	Desk Top Computer	150	8		1,200	0	1,200	150	5	857
	1	Internet Equipment	20	12		240	0	240	20	7	240
Total Other						1,440	-	1,440	170		1,097
Grand Totals						**8,024**	**2,131**	**10,155**	**1,842**		**8,472**

APPENDIX 7: THOMONDE LOAD CALCULATIONS

THOMONDE

Area	Qty	Load	Watts Each	Hrs/Day Day	Hrs/Day Night	Watt-hours Day	Watt-hours Night	Watt-hours Total	Total Conn Watts	Days Per Week	Weekly Calc
Lighting											
Laboratory	4	CF Lamps	22	8		704	0	704	88		-
Security Lighting	15	CF Lamps	11		11	-	1,815	1,815	165		-
Wards and Offices	20	CF Lamps	22		4	-	1,760	1,760	440		-
Total Lighting						704	3,575	4,279	693		-
Equipment											
Laboratory	0	CD4 Machine	200	4		-	0	-	-		-
	0	Hematology Analyzer	230	4		-	0	-	-		-
	0	Blood Chem. Analyzer	45	4		-	0	-	-		-
	3	Microscope	30	6		540	0	540	90		-
	2	Centrifuge	400	2		1,600	0	1,600	800		-
	1	Other Loads	400	2		800	0	800	400		-
	1	A/C	1,000	6		6,000	0	6,000	1,000		-
	1	Refrigerator Efficient	60	10	14	600	840	1,440	60		-
Total Equipment						9,540	840	10,380	2,350		-
Other											
Office	1	Desk Top Computer	150	8		1,200	0	1,200	150		-
	1	Internet Equipment	20	8	4	160	80	240	20		-
Total Other						1,360	80	1,440	170		-
Grand Totals						**11,604**	**4,495**	**16,099**	**3,213**		**-**

APPENDIX 8: NOTIONAL TRAINING PROGRAM

One of the first priorities for the PEPFAR program should be to support the hiring and training of the appropriate support staff needed to improve the success of the ARV laboratory inverter/battery program. The table below outlines a notional agenda for a two week training class. The ideal class size would be between 10-20 people and could include national level technician, regional CDC personnel, and facility managers from select hospitals and clinics. The class would be a combination of classroom lecture and field work including the retrofit of a small health facility's Energy systems.

HAITI COURSE OUTLINE

Day	Time	Class Material	Discussion	Notes
Day 1		**Energy Systems Overview**		
		Introduction	Overview of key course objectives.	
		Criteria for Success	Review importance of good design, good installation, assured maintenance..	
		Basic Electrical Principles	Discuss Basic Electrical Formulae needed for understanding the design of the systems.	Optional depending on the level of the class.
		Watt hour Concept	Review principles of load calculation.	
		Loads versus Sources	Review typical loads, energy generation and storage options, and other available technology and engineering methods..	
		Energy Efficiency	Compare loads of standard and energy efficient equipment. Discuss similar considerations in energy generation and storage devices.	
		Overview of Different System Configurations	Grid only, grid / inverter / battery; grid / generator; grid / generator / inverter / batter; introduction of solar for off grid (or nearly non-existent grid applications).	
		Overview of Scope	Review Pros and Cons of localized and facility wide approaches.	
Day 2		**Equipment and Inverter / Battery Design**		
		Load Equipment	Review equipment types, inputs for actual equipment loads, and daily equipment use (in hours).	Provide access to real loads and operational labs, including refrigerators and air conditioning equipment. Install Kill-a-Watt meters to study real loads over > 24 hour period.
				Provide Internet access for class to enable searches on actual equipment loads.
			Review and evaluate pros and cons of locally available equipment currently in use vs. future purchase of energy efficient equipment.	
		Daily Watt hour Calculations	Develop spread sheet for common use to summarize daily loads or expected outage.	Discuss diversification factors.

HAITI COURSE OUTLINE

Day	Time	Class Material	Discussion	Notes
		Inverter / Battery System Design	Basic design parameters: discuss sizing of inverter and battery bank; inefficiencies, DOD, and autonomy issues related to design of battery bank. Summarize data in spreadsheet that will input watt hours and provide on output number of batteries.	Use locally available batteries. Have students determine availability, watt (Amp) hours), Review cost of higher watt-hours vs. locally available equipment.
Day 3		**Equipment and Inverter / Battery Design (continued)** **Introduce Generators to the System**		
		Installation of Battery / Inverter systems	Base discussion primarily on the locally available and commonly used Xantrex SW system. Cover the AC IN, AC OUT inputs, wiring and connections. Discuss need, (or lack thereof) and requirements for transfer switches and disconnects,	
		When do we need a Generator?	Almost always.	
		The role of the generator in a system	Discuss different applications of generator, besides providing energy only= to an inverter/ battery system..	
		Sizing of the Generator		
		Three phase versus Single Phase		
		Review Locally Available Generators	Use locally available generators, with output KW and Amps. Student groups collect data from generator distributors and suppliers (Valerio, Haytien Tractor, etc.)	Students gather data from manufacturers' representatives, on fuel consumption of various generators at different loading. .
		System Installation Considerations when a generator is included.	Examine changes in AC In and AC OUT considerations based on generator use.	Provide block diagrams of typical installations with inverter / batteries / generator.
Day 4		**When should we Consider Solar? And How…**		
		Solar Feasibility	Discuss parameters for including solar in off grid or poor grid situations. Examine options for locations where entire facility is run on solar and on generator, even with a grid present (Ie.g. St. Anne's).	Potential cost issues associated with use of Homer depending on class' needs.
		Solar Design	Understanding sizing of the solar system and the operation of the sun.	
		Basic Principles of Photovoltaics		
		Basic System Concepts and Introduction to Components.	Discuss how solar panels can impact/change overall system design.	
		Producing energy with Solar - Design Concepts	Discuss matching up whr load with whr production, and sizing solar panels to produce the needed watt hours.	
		The Solar Resource - Hands On	Make voltage and current calculations to demonstrate the use of solar energy, by using meters and a solar panel, and a lab sheet, and make a variety of	Need voltmeters with DC Amps (at least 10 amps, or clamp-on). One meter for every four people
		Proper Aiming of Panels	Assign class to measure Voltage and Current measurements with variety of angles - both azimuth and altitude.	

Day	Time	Class Material	Discussion	Notes
		Shading and Cleanliness Issues		
		The Solar Resource	Determine the amount of available solar resources.	Detailed review of how to use the solar pathfinder to come up with a percentage.
		Concept of PSH	Review development of PSH, using data from the installation meter.	Have people use the Day-Star results, at least up to this point, and continue using the Day Star for results for the next several days.
		PSH Resources	Show how PSH Information can be determined for different areas. Samples of solar installation maps and NASA data for PSH.	Internet access would be great here as well.
Day 5		**Solar Design (cont'd)**		
		When is a 100W panel producing 100W?	Introduce STC - and show that a 100W panel NEVER produces 100W.	
		Inefficiencies & Production Losses Solar Panel Inefficiencies	Discuss the temperature losses dealing with solar panel production.	
			Summarize Solar Panel daily production with the use of a multiplier.	
		System Design with Solar Panels	Show overall system design, and how it changes with the introduction of solar panels.	
		Review of equipment	Provide samples of panels, charge controllers of different types, connectors, and installation materials.	Equipment available at the site.
		Solar Panels		
		Overview on Solar Panels		
		Amorphous vs. crystalline - pros and cons	Familiarization with different types, since both are used in Haiti.	
		Discussion of IV Curves	How temperature and sun affect solar panel outputs.	
		Rules of Thumb for Isc and Voc	Discuss how Isc and Voc for given ranges of modules are similar - look at index of library.	
		How to determine rough wattage rating of an unmarked panel using Voc and Isc	Discuss ways to determine Wp rating (without getting out a variable resistor bank) of unmarked panels.	
		30 Cell, 33 cell, 36 cell differences	Feasibility of working with 36 (or multiples of) cell modules, unless working with MPPT.	
		Examine Various Manufacturers of Panels		
		Costs of Solar Panels	Compare cost of local purchase vs. import and customs. Determine available pricing in Haiti.	
		Charge Controllers		
		Multiple Purposes of a Charge Controller	Review three purposes of charge controller.	
		Qualities to Look for in a Charge Controller		

HAITI COURSE OUTLINE

Day	Time	Class Material	Discussion	Notes
		Compare various brands of controllers		
		Discussion of MPPT Controllers like MX60	Discuss appropriate use of MPPT, voltage and panel selection. Provide Ecuador example.	
		Look at Functions versus cost		
		Batteries		
		Functions of the Battery - heart of the system		
		Deep Cycle versus truck batteries	Examine pros and cons of deep cycle batteries.	
		Gel vs. Flooded Batteries	Examine advantages and disadvantages of gel batteries vs. flooded.	
		Battery Safety	Review chemical, electrical, and explosive hazards.	
		Life Cycle - with varying discharge depths	Highlight role of charge controller in extending battery life (ranging from 6 months to 6 years).	
		Costs of Batteries	Solicit input from class participants on battery costs in Central Asia.	
		Inverters		
		Function of the Inverter	Discuss DC to AC Conversion.	
		Pros and Cons of using them on smaller systems	Discuss potential inverter related problems. Give examples (Thailand, Burma, Ecuador, etc.)	
		Costs	Some of this information is on library summary sheet. Go over just general costs.	
		Series / Parallel Connections		
		Series and Parallel Connections for both the Solar Panels and the Batteries.	Review series parallel; give handouts for class exercises and homework.	
Day 6		**Installation Work**		
		Wire Sizing General Wiring Discussion - about current, voltage drop, types of wire, etc.		
		Voltage Drop - Review what it is, and how it is calculated.	Review real calculations, and derivation of numbers in tables.	
		Work out real examples of proper wire sizing for panel circuits, battery, and load wires.		
		Look at big differences between 12V and 24V and between low voltage DC and 120 or 240 VAC.	Work detailed examples out on the board.	

HAITI COURSE OUTLINE

Day	Time	Class Material	Discussion	Notes
		Use of Tables	Review pre-made voltage drop tables, and interactive voltage drop excel sheet.	
	1:30	Overcurrent Protection		
		Discussion on Fusing, and Overcurrent Protection	Focus on critical need for Overcurrent Protection.	
	2:30	Mounting and Racks		
		Need for strong supports.		
	3:00	Grounding		
	3:30	Other Installation Topics for Discussions		
		Need for Solid Terminations		
		Need for Protection Boxes		
		Battery Boxes - why bother?		
		Polarity Issues and How to try to make it work.		
		Color Coding - Different thoughts.		
Day 7		**Installation Project (cont'd)**		
		Installation Introduction	Work on a project that requires installation of inverter and battery system, and generator.	Field trip to collect data on site, including loads and wiring. Site and class proximity will is useful.
		Class Design of Real Installation	Class will work together on system design, wiring, and disconnecting switches.	
		Purchase of Equipment	Scope site ahead of installation.	
Day 8		**Installation Project (cont'd)**		
		Hands On Installation Work	Install system at site.	
Day 9		**Installation Project (cont'd)**		
		Hands On Installation Work	Complete installation at site.	
Day 10		**System Programming and Maintenance**		
		Programming	Review menu screens of Xantrex inverter, recommend changes, and monitor parameters.	Consider a review of Outback inverter.
		Load Management	Setting up and enforcing a load management system that the facility is respons ble for.	
		Maintenance Issues.	Battery maintenance and other issues.	
Day 11		**Wrap Up**		
		Questions and Answers	Open.	
		Examination	Conduct an examination and award diplomas to students with a passing grade.	
		DIPLOMAS	State course content.	

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