POWERING HEALTH:
OPTIONS FOR IMPROVING ENERGY SERVICES AT HEALTH FACILITIES IN GUYANA

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EXECUTIVE SUMMARY

The acquisition of reliable and affordable power poses a challenge to many health facilities in developing countries, especially those in remote rural areas. This is the case in Guyana where the PEPFAR (President's Emergency Plan for AIDS Relief) program and the Ministry of Health (MOH) requested USAID assistance in assessing options for improving energy services in health facilities. Currently, full service district hospitals located on the coast suffer from expensive, unreliable, and poor quality power. District hospitals located in the interior face similar problems compounded by the fact that the power is intermittent, of worse quality, and from a variety of expensive sources. Hinterland health centers often have no energy at all, limiting the reach of cold chain dependent immunization programs and prevention of mother to child transmission (PMTCT) services.

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 Guyana, interviewed stakeholders in the health and energy sectors, and visited a representative sample of eight 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 and others currently in design or under construction. The Team focused on investigating those options that would improve the energy reliability and quality at grid-connected facilities, expand the reach and quality of health services in the unelectrified/quasi-electrified interior regions of the country, and reduce the energy costs of power intensive health facility infrastructure under construction across the country. While the report focuses on cost effective applications for renewable energy technologies, a technology neutral approach was taken for all analysis and many non-renewable energy investments are highlighted throughout the report.

The Team found that the effectiveness, sustainability and reach of several PEPFAR programs in Guyana have been compromised by the lack of a reliable power supply. The lack of electricity in many interior regions of the country limits the distribution of certain cold chain dependent ARV drugs and HIV rapid test kits. Power anomalies cause damage to laboratory equipment and jeopardize the accuracy of sensitive laboratory tests. Finally, the expensive cost of electricity in Guyana makes the long-term operating costs of power intensive health care facilities currently under construction significant.

The assessment highlights the following overall observations and recommendations:

<u>Improving energy reliability and quality at grid-connected facilities:</u> Many non-solar based investments, such as back-up generators, power conditioning units, and un-interruptible power supplies would likely take top priority when considering cost-effective options for improving the power supply at grid-connected health facilities such as New Amsterdam and Georgetown public hospital. In addition, self-generation of power is a cost effective approach that should be considered by nearly all health facilities in Guyana. The poor quality and reliability of grid power should be a major consideration in the design of all new facilities – such as the blood bank at New Amsterdam, and the reference lab in Georgetown. Inadequate attention to this problem could seriously jeopardize the sustainability and operation of the facility.

Expanding the reach and quality of health services in the unelectrified/quasi-electrified interior regions of the country: Investment in a power supply which could provide refrigeration for off-grid health facilities could help expand the provision of vaccination programs and HIV/AIDS testing services throughout Guyana. Solar power is an economic option to be seriously considered for any health facilities that are not connected to the GPL grid (or reliable grid such as Linden Electric). Hospitals located in Regions I, VII, VIII, and IX, provide the greatest overlap between PEPFAR programmatic priorities and solar suitable facilities. An investment in solar/diesel hybrid systems for these hospitals likely represents the most cost effective solution to meet the energy needs of these critical facilities which serve as the focal point of regional health care delivery. The similar energy needs of small health posts lend themselves to "off-the-shelf" solar systems with design standards determined by the Ministry of Health.

PEPFAR investment in the solar electrification of an interior regional hospital, coupled with the establishment of a PV training program, design standards, and maintenance protocols, would build the overall solar technical capacity in Guyana and translate into improved sustainability of all PV systems currently being installed at hinterland health facilities in Guyana.

Reducing the energy costs of power intensive health facility infrastructure: The donor community, local stakeholders, and Ministry of Health (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, should be a pre-requisite to facility construction. Facilities that are built to Western standards without the corresponding reliability and quality of Western energy services have proven to be problematic. Upfront investment in renewable technologies is a viable option for donors to offset the long-term energy costs of health facilities. The current cost of power from GPL makes "grid-tied" solar systems economic with a 50% subsidy of capital costs.

Ensuring the sustainability of solar electrification: Guyana has a poor track record concerning the sustainability of past health facility solar electrification efforts resulting from poor system design, improper maintenance protocols and lack of dedicated maintenance funds. Investment in solar solutions for any facility is only advisable if a corresponding training and maintenance program is initiated. Proper solar system design is essential and components need consistent maintenance from appropriately trained personnel. Since the health care facilities do not collect fees, maintenance funds must be established upfront and be dedicated only to solar system repair. Mixing maintenance funds with general operating budgets has proven to be an ineffective model.

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.

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.

GPL: Guyana Power and Light: The national utility company in Guyana.

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

PMTCT: Prevention of Mother to Child Transmission

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 Guyana and the Guyana Ministry of Health 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 Guyana. Specifically, the team was asked to investigate the potential for investment in renewable energy technologies to achieve the following objectives:

- reduce the energy costs of power intensive health facility infrastructure under construction across the country;
- improve the energy reliability and quality at grid-connected facilities; and
- expand the reach and quality of health services in the unelectrified/quasi-electrified interior regions of the country through improved access to reliable power supplies.

While the report focuses on cost effective applications for renewable energy technologies, a technology neutral approach was taken for all analysis and many non-renewable energy investments are highlighted throughout this report. Although consideration was given to both solar and wind renewable technologies, conversations with several entrepreneurs who operated wind turbines along the coast indicated that the wind resources were generally not sufficient to make wind turbines economically feasible. Off-shore wind development in Guyana has significant potential but lies beyond the scope of this assessment.

The evaluation was conducted over a two-week period by a team comprised of Jeffrey Haeni, Rural Energy Specialist, USAID Office of Infrastructure and Engineering/Energy Team, and Walt Ratterman, Chief Project Officer and Director, SunEnergy Power and consultant to Winrock International/Institute of International Education. Approximately half of the time in Guyana was spent in Georgetown meeting with key stakeholders and the other half was spent making site visits to various health facilities. During the course of the assessment, the team conducted over 30 interviews and visited eight (8) health facilities as detailed in Appendices 1 and 6.

The site visits were strategically chosen to provide an illustrative cross section of health facilities both in terms of the level and nature of services provided and in terms of their current energy supply. The full gamut of facilities was visited– from small hinterland health outposts with no electricity supply to Georgetown Public Hospital which is connected to the primary grid and has power requirements in excess of 1 MW.

Although some generalization can be made across different categories of health facilities, separate electricity grids and quasi-grids around the country, as well as large areas of the country that are currently unelectrified, require that each facility be analyzed individually before any site-specific solutions are developed.

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 Guyana. Before any site specific investments are made a comprehensive energy supply/demand review and cost-benefit analysis for different technologies should be completed.

2 GUYANA PEPFAR PROGRAM OVERVIEW

The PEPFAR program in Guyana is working with over 42 health facilities across the country. Each of these facilities plays a unique role in supporting HIV/AIDS care, treatment, and prevention activities, and each is equipped with specific energy intensive medical technology. The PEPFAR blood safety team has been working with the Ministry of Health (MOH)/National Blood Transfusion Service (NBTS) on a variety of regional blood collection centers and blood banks including construction of a new blood bank on the grounds of the New Amsterdam Regional Hospital. The blood banks have critical refrigeration needs as well as air-conditioning requirements. The PEPFAR team is also working with the MOH and other local partners to improve service delivery at the Georgetown Public Hospital, regional clinics, and other prevention of mother to child transmission (PMTCT) sites throughout Guyana. These facilities require high-quality power for the operation of sensitive laboratory equipment, climate control for the storage of HIV rapid test kits, and refrigeration for pediatric anti-retroviral drugs (ARV's) and a variety of testing reagents. PEPFAR is also supporting the construction of several major infrastructure projects, including a reference laboratory that will be located on the grounds of the Georgetown Public Hospital and a supply chain management warehouse in Georgetown. The lack of reliable and high-quality electricity has been identified by the PEPFAR staff as a potential barrier to the successful operation of each of these facilities.

3 ENERGY SECTOR OVERVIEW

Solving the critical power problems of key health facilities in Guyana 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 on the coast 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. The policy environment for renewable energy can also have a significant impact on the economic feasibility and sustainability of these technologies and is reviewed below.

3.1 ENERGY SECTOR CHALLENGES

Guyana Power and Light (GPL) is the principal public supplier of electricity in Guyana. As a vertically integrated utility, GPL owns generation, transmission, and distribution assets. GPL's installed capacity is approximately 113 MW, serving 126,000 residential, commercial, and industrial customers. GPL operates several isolated and connected systems along the coast including Demerara Interconnected System (DIS), Berbice Interconnected System (BIS) and isolated systems along the Essequibo Coast.[1]

The power supplied by GPL is characterized by three major issues: high cost, poor quality, and poor reliability. The high cost of power in Guyana (about 3 times what is typically paid in the United States) is a result of high generation costs and an inability of GPL to collect payment for service. The poor quality of 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. Low voltage power also increases the power consumption of some energy intensive devices such as refrigerators.[2] Such anomalies 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, many commercial customers in Guyana have chosen to generate all of their power on-site. None of the coastal hospitals have chosen complete self-generation and therefore must struggle with the expensive, poor quality power from GPL.

Large portions of the interior of the country are not serviced by GPL's primary grid and either has no electricity or is serviced by a small "quasi-grid" operated by a local entrepreneur. One exception is the area around Linden which is served by Linden Electric from power produced by the Omai bauxite facility. This region has some of the most reliable and affordable power in the country.

3.2 KEY PLAYERS

In comparison to the health sector there is minimal engagement from the donor community in the power sector in Guyana. The Inter-American Development Bank (IDB) has by far the largest program - a $34.4 million loan supporting the Unserved Areas Electrification Program. This initiative has three major components – a $20 million loss reduction and grid expansion program being implemented by Guyana Power and Light (GPL), a $4 million hinterland electrification program being implemented by the Office of the Prime Minister (OPM), and an institutional strengthening and capacity building program. Over the near to medium term the loss reduction program should greatly improve the financial situation of GPL and theoretically translate into service improvements. The grid expansion program is primarily focused on regions in close vicinity to the existing national grid and is unlikely to impact the energy supply situation at the interior regional hospitals highlighted in this report as prime candidates for PEPFAR investment. The hinterland electrification program has recently been put on hold after the initial strategy was rejected by the parliament. Once reformulated, the hinterland electrification program could synergize with any PEPFAR investments in on-site renewable energy systems.

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[1] Power Sector Assessment and Development Strategy, Inter-American Development Bank

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

Other minor players in the renewable energy sector include the United Nations Development Programme (UNDP) and Caribbean Community (CARICOM). The UNDP has traditionally invested approximately $100,000 USD per year in an off-grid renewable energy project. This money is transferred to the Office of the Prime Minister who implements the program. Recently, UNDP has supported the solar electrification of the Kato health clinic in Region 8. Lessons learned from this project are highlighted in Section 5.3.

CARICOM manages the Global Environment Fund's (GEF) Caribbean Renewable Energy Development Programme (CREDP), which is headquartered in Georgetown. This program has had difficulty getting of the ground and only has minimal funds available for project implementation in Guyana. They provide an annual $15,000 grant to OPM to address renewable energy issues and have a $100,000 loan available for public or private sector renewable energy projects in Guyana. It is possible that a PEPFAR supported health clinic retrofit program could leverage this loan program.

In terms of Government of Guyana (GOG) institutions, the Office of the Prime Minister and Guyana Energy Agency have little, if any, internal funding for programs. The Office of the Prime Minister does, however, have some technical capacity on staff that could be utilized to implement a program if so desired.

3.3 RENEWABLE ENERGY OPPORTUNITIES

The extremely high cost of energy in Guyana, combined with abundant renewable energy resources such as hydro, wind, solar, and biomass create a strong incentive for alternative energy development. Until recently, however, these efforts have been characterized by an abundance of planning and very little action. Three large projects are in the pipeline including a 10 MW bagasse plant, 4 MW off-shore wind farm, and 100 MW hydropower project. Each of the project developers are engaged in power purchase agreement (PPA) negotiations with GPL and thus much progress must be made before full financing can be secured and project construction begins. Clearly, doubling the generation capacity of Guyana with a domestic and economical source of hydropower could dramatically improve the reliability and reduce the price of power in the country. However, given the long-term nature of this project, and multitude of uncertainties which could disrupt its development, delaying on-site improvements in the power supply of grid-connected health facilities is not advisable.

Overall, the policy environment in Guyana can be characterized as neutral for the type of on-site renewable energy development projects that would be suitable for health facilities. Renewable technology such as solar is exempt from import tariffs but, as of January 1, 2007, is subject to the 16% VAT tax. Adding solar technologies to the list of VAT exempt products is a 60short-term policy intervention that would help to improve the economic viability of solar projects throughout the country. Guyana Energy Agency officials suggested this was a top priority but it is impossible to predict when, or if, this may come to fruition. Other types of renewable energy incentives, such as subsidies or net metering do not currently exist and do not appear to be under consideration at this time.

3.3.1 GUYANA'S SOLAR EXPERIENCE

Guyana has significant experience utilizing solar systems to power hinterland health facilities. Since the 1980's, the MOH and regional democratic councils, with support from the Pan American Health Organization (PAHO) and other donors, have installed solar systems in over 20 hinterland health facilities. While many of these systems were designed to power refrigerators to expand the reach of the cold-chain dependent immunization program, a full range of solar systems have been installed – from single cell systems which provide power to a communication radio to a 22 kW system at the District Hospital in Region I consisting of over 500 panels and capable of meeting the energy needs of the entire facility.

As a result of Guyana's past experience with solar, there is some local technical capacity in Georgetown which could be strengthened with any proposed solar electrification program. At least two stores in Georgetown sell and install solar systems, and, interviews with sales representative's revealed knowledgeable staff. Technical expertise also can be found at the Office of the Prime Minister and among individual consultants in Georgetown. Limited technical capacity was observed outside of Georgetown. Unfortunately, this local capacity has not translated into a track record of sustainable solar systems installed at public health facilities.

In fact, the sustainability of these systems has been poor. A cold chain assessment report completed in 2004 found that 13 of 21 systems installed between 1982 and 2004 were inoperable including the 22 kW installations in Region 1. Similar assessments were completed in 2000 and 2002, and all studies highlighted similar reasons for the failure of the systems, including theft, improper training of local staff, poor system design, and lack of maintenance. A visit to a hinterland health clinic with a solar system on the verge of failure that was installed only a year ago identified similar problems and indicated that these challenges have yet to be fully addressed. (See section 4.3.1.1)

Despite these setbacks, nearly every stakeholder interviewed remained enthusiastic about the potential of solar technology to deliver energy to off-grid health facilities. Many stakeholders were also able to articulate one or many reasons for the failure of previous installations. Section 5 addresses key recommendations which could be implemented to improve the success of future solar installations in Guyana.

4 FACILITIES ANALYSIS

The primary objective of this assessment was to develop site-specific solutions to the energy challenges at key health facilities. As a result, site visits were made to eight health facilities that were strategically chosen to provide an illustrative cross section of health facilities both in terms of the level and nature of services provided and in terms of their current energy supply.

For the purpose of this assessment, health facilities in Guyana were divided into three major categories based on their current electricity supply as detailed in Table 1. Category I facilities are connected to the primary electricity grid, Category II facilities receive a portion of their power from a "quasi-grid", and Category III facilities have no grid electricity supply. Although these categories are not meant to reflect the size or level of service provided by the facility, in general the Category I facilities visited were large regional hospitals, the Category II facilities were smaller, interior regional or district hospitals, and the Category III facilities were small health outposts.

The energy needs, challenges and solutions for each of these categories are quite different. Even within a single category there is significant variation in the energy challenges for a given facility based on the multitude of isolated grids and quasi-grids around the country.

This section profiles one facility in each category, presenting a general discussion of the energy challenges for that category of facility and a specific analysis of the issues and options for the particular health facility profiled.

Table 1: Categorization of Health Facilities based on current energy supply

Category	Description	Examples	Typical Loads	Challenges
I. Grid-connected	Connected to the National Grid (or similar large grid.) Usually a large load.	GPHC, New Amsterdam, Linden, Blood Bank, Reference Lab, Warehouse.	- air conditioning - full service laboratory - refrigerators - x-ray machine	- Expensive ($0.25- $0.30 per kWh - Power quality issues - Reliability problems
II. Quasi-Grid	Connected to IPP, or locally operated grid. Medium loads.	Mahdia and other similar interior district and regional hospitals.	- small laboratory - lighting - radio, computer - refrigerators	- Expensive (over $3.00 per kWh) - Very poor Power Quality - Not available 24 hours
III. No-Grid	No grid electricity available. Remote facilities. Small loads.	Hinterland health clinics and NGO offices.	- lighting - radio - vaccine refrigerator	- Generators are expensive - PV systems have not been sustainable

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. training) that are often part of these programs. These costs are discussed in Section 6. Several supporting facility specific calculations are presented in the appendices as noted in the text.

4.1 CATEGORY I: GRID-CONNECTED FACILITIES

The PEPFAR program in Guyana is somewhat unique in comparison to many other sub-Saharan Africa PEPFAR focus countries in that the majority of priority facilities are connected to the primary power grid. While a large portion of the interior of the country remains unelectrified, most of these areas have a low population density and to date have not been a primary focus of the PEPFAR program. All of the new infrastructure currently under construction with PEPFAR support, including the New Amsterdam blood bank, supply chain warehouse, and reference lab are in grid-connected areas along the coast. Nonetheless, these facilities face daily energy challenges based on the quality, reliability and cost of the power received from GPL. In general, there are two strategies that can be employed to address these problems:

- Pursue solutions with GPL 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 the health facility.

The assessment team visited a total of four Category I facilities, including New Amsterdam Public Hospital, Georgetown Public Hospital, Williamsburg Health Center and Linden Hospital. New Amsterdam Public Hospital faced the most significant energy challenges out of all Category I facilities and therefore is analyzed below. Information on other Category I facilities can be found in Appendix 4.

4.1.1 NEW AMSTERDAM PUBLIC HOSPITAL

The New Amsterdam public hospital was built with support from the Japanese Government and was commissioned in November 2004. The hospital is a full service facility providing care to an average of 60,000 people per year. It is located on the coast, on the border between regions V and VI (See appendix 1). New Amsterdam is separated from Georgetown by the Berbice River and is therefore part of the Berbice power transmission area.

4.1.1.1 CURRENT POWER SITUATION AND CHALLENGES

New Amsterdam Hospital's power supply is expensive ($0.25 per kWh), unreliable, and of poor quality. Based on interviews with the hospital staff, power outages occurred daily and severe voltage fluctuations are the norm. While it is difficult to quantify these problems in a short visit, the assessment team witnessed one 10 minute power outage during their two hour visit and was told that the hospital had just come out of a blackout situation prior to their arrival. The emergency generator has run for a total of 350 hrs in 24 months indicating an average of about 30 minutes of blackout per day.

These two issues – lack of power continuity, and poor quality power – take their toll on both the hospital staff and the equipment. The hospital has hired a full-time electrician to repair the air-conditioning compressors which consistently burn out because of the unstable voltage supply. In addition, the x-ray system and dental equipment were inoperable because of the poor quality power.

It was also reported by hospital staff that some of the lab equipment has been damaged due to the unstable power conditions. However, a tour of the lab revealed that the laboratory personnel has installed many "work-around" solutions to mitigate against power outages and poor power quality and such damage was not immediately evident. Numerous automatic voltage regulators (AVR) (500 watt and 1000 watt) were installed to shield the sensitive laboratory equipment from power anomalies.

The unreliable power supply also had an adverse effect on the hospital working environment and quality of care. In particular, the air-conditioning system in the operating theater is not connected to back-up power, quickly leading to unworkable and unsanitary conditions in the case of a power outage.

4.1.1.2 CURRENT HOSPITAL DESIGN

Although the architects of the New Amsterdam Hospital were clearly aware of the power issues at the site, the equipment installed to mitigate its effect on hospital operations is insufficient for the task.

Emergency power is distributed throughout the hospital to pre-determined critical loads. These critical loads include the three operating theaters, the labor and delivery area, fans in the wards, and a variety of receptacles throughout the hospital.

The emergency back-up power at New Amsterdam is provided by a 75 kVA generator.[3] The 75 kVA generator is undersized for the loads on the critical circuit and hospital staff reported the need to turn off some equipment, such as the sterilizers in the operating theater, before the back-up generator can be started. None of the air-conditioning units are connected to the emergency power distribution system.

There is no uninterruptible power system (UPS) to provide power between the times that the utility power goes out and the generator comes on line. Although generator transfer is automatic with a one to five minutes delay, loads such as computers and certain test equipment in the lab require continuous power. In many cases this situation is dealt with by local, point of use, UPS systems connected to each critical piece of equipment. While this is an effective work-around solution, it is not a substitute for a system-wide continuous and high-quality power source.

There is a 75 kVA automatic voltage regulator (AVR) installed in the main switchgear room. According to the power single line diagram, the AVR is connected directly to the emergency power system, and is coordinated in size with the emergency generator. The power issues encountered on equipment connected to the emergency circuit (e.g. blown fuses) indicate that this AVR is either not operating or the voltage fluctuations are outside the correctable range.

[3] By comparison, the new hospital being designed for Linden will have a 450 kVA backup generator.

4.1.1.3 OPTIONS FOR IMPROVING ENERGY SUPPLY

IMPROVE QUALITY OF POWER FROM THE GRID

Before significant investment is made for on-site power generation and conditioning equipment at New Amsterdam, a thorough investigation of options for improving the power delivered from GPL should be conducted. For instance, one option which may improve both the reliability and quality of power delivered to the facility is to install a dedicated line from GPL's generating station to the hospital. A dedicated line would help reduce power quality and reliability issues resulting from line-specific problems (e.g. harmonics, shutdowns for repair work). It would not, however, solve problems arising from overall system overloading. These problems would need to be addressed with expansion of GPL's generation capacity. While it is likely that such options were reviewed before construction of the hospital, the assessment team was not told of any ongoing dialogue between the hospital facilities management team and GPL personnel.

SITE-SPECIFIC SOLUTIONS

In the absence of any near term solution to the grid power problems, investment in on-site technologies could make a substantial improvement in the power situation at the hospital.

The complexity of the electrical system at a large hospital such as New Amsterdam, coupled with the uncertainty in the future quality, reliability, and cost of the grid power supply, require that a detailed cost analysis be performed before any site-specific investments are made. Such a study is beyond the scope of this report. Nonetheless, several potential options for improving the energy supply are presented below with rough cost estimates for each.

- *Optimize existing systems* – The first priority should be to examine the existing systems and make no or low-cost corrections to improve its performance. For instance, now that the hospital has been operational for over two years, the "critical loads" connected to the back-up generator should be re-examined. Removing some of the loads from the emergency circuit (e.g. the sterilizers in the operating theater) would help eliminate the need to turn off loads before switching to emergency power. The existing 75 kVA AVR should also be evaluated to determine why it is not performing its intended purpose.

- *Increase back-up generating capacity* – If it is determined that the critical loads exceed the capacity of the existing 75 kVA generator, then increasing the emergency generating capacity should be considered. Increasing the size of the generator would be a fairly significant project since it would require replacing the automatic transfer switch, cabling, portions of the main switchgear, and upgrading the emergency distributing cabling in the building. An alternative solution which may be more cost effective would be to install an additional generator and synchronize it with the existing 75 kVA unit, or to operate it separately to power an independent set of emergency loads (e.g. the air-conditioners in the operating theater).

- *Install site-specific technologies to improve quality of power* – The installation of a "double conversion" or on-line UPS technology at Category I facilities such as New Amsterdam Hospital could improve both the quality and reliability of power from the grid. Typically, these systems are used when power quality is an issue, and when there is an emergency generator present for power outages. During normal operation, the standard grid electricity is fed into the UPS system, which normalizes the power, and sends it out to the sensitive loads, via a battery system. When there is a grid-power outage, 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. Such a system would cost in the range of $1.00 - $2.00 per VA or $200,000 - $400,000 for the entire facility. Installing an on-line UPS system for just the laboratory at New Amsterdam would likely require a 10 kVA system, which would cost between $15,000 and $20,000 as detailed in Appendix 2.

- *Total self-generation* – The high cost and poor quality of electricity in Guyana has motivated many businesses to self-generate all of their power on-site. In fact, self-generation caused GPL power sales to decrease from 288 GWh in 2002 to 268 GWh in 2003. The cost of self-generation varies significantly with the size of the generating plant but several businesses with power demands similar in size to Category I health facilities claimed significant cost savings after making the switch to self-generated power. Self-generated power is not only cost competitive, it is also of high-quality and reliability. Self-generation is an option that should be seriously considered for many of the Category I health facilities in Guyana. In order to self-generate electricity New Amsterdam would need to purchase generators designed to run continuously. As one barometer of costs, the facilities manager at one health facility indicated that they could purchase a 450 kVA CAT engine/generator set for approximately $100,000. This pricing does not include the larger fuel tanks and delivery systems, or full-time plant operations personnel, maintenance and fuel costs which would be required for a power generating station.

- *Training of Hospital Facilities Manager* – Significant improvements in the power situation at New Amsterdam Public Hospital could be achieved with rigorous training for the facilities management staff.

4.1.2 CATEGORY I RENEWABLE OPTIONS

The extremely high cost of power has generated significant interest in the utilization of renewable power sources in Guyana. There is concern within the Ministry of Health that the proliferation of donor supported energy intensive infrastructure projects will result in soaring electricity bills that will be difficult to sustain in the long-term. As a result, the assessment team was asked to investigate the potential for renewable energy to reduce electricity costs at Category I facilities.

The large loads of facilities such as New Amsterdam Public Hospital make a self-contained solar system with battery storage economically impractical. Therefore, the typical design for such a system involves utilizing power from both the grid and the solar array to meet the total power demands of the facility. This configuration is typically referred to as a "grid-tied" solar system.

In general, the benefits of installing renewable technology at grid-connected facilities are two fold: 1) an upfront subsidy to cover capital intensive equipment can result in long-term savings in energy costs, and 2) renewable technologies offset hydrocarbon generation needs resulting in environmental and energy security dividends.

Although the power produced by a grid-tied solar array is of high-quality – it is not a complete solution for the grid power quality issues detailed above. Therefore, for power intensive facilities and investment in solar technology, it is not a substitute for the on-site power improvement technologies detailed in section 4.1.1.3. Solar power displaces electricity that would be required from the grid or from the on-site diesel generator if the self-generation option is pursued.

Grid-tied solar systems without batteries can produce power at a lifetime cost (25 years) of $0.50 - $0.60 per kWh. Therefore, from a strictly economic perspective, solar power is not cost competitive even when compared to the expensive grid power in Guyana ($0.25 per kWh). If all costs are considered, the payback period for a grid-tied system would be approximately 40 years for equipment with an average life expectancy of 25 years.

If, however, the initial capital cost of the solar equipment is subsidized (e.g. by the donor community), the economics change significantly. Unlike stand alone systems with batteries, charge controllers, and inverters which need regular replacement, maintenance costs of grid tied systems are minimal. Therefore, the percentage of subsidization for upfront capital costs closely correlates with the overall reduction in the lifetime net present cost of energy (COE). For example, a 50% capital subsidy would result in power that was cost competitive with the current rate charged by GPL ($0.25 – $0.30 per kWh).

Grid-tied solar systems could be designed to meet all or part of a facility's load.[4] A solar system that would provide all of the electricity that New Amsterdam consumes would be in the neighborhood of 0.3- 0.4 MW-peak (400,000 Watts or 4,000 100 Watt panels). Such a system would require almost an acre of land and cost between $4-6 million. The requirements to power a load representative of the laboratory at New Amsterdam is considered in Appendix 2.

The economics of grid-tied systems do not change significantly with system size. The primary difference is that for grid-tied facilities with smaller loads (or when considering partial loads of larger facilities) self-generation utilizing a stand alone PV or PV-hybrid system with batteries becomes feasible. From an economic viewpoint, however, the cost comparison with grid power is still valid in such cases because even poor quality, intermittent grid power can be acceptable for battery charging. In the extreme case where the intermittency of the grid is such that the

[4] A grid-tied system that provided "all" of the power needed for a facility would still use power from the grid at night unless battery storage was installed. Typically, grid-tied systems would offset this grid power use by selling excess electricity produced during the day back to the grid. Although no laws are currently in place in Guyana to facilitate such a transaction it is a feasible option.

power is insufficient to maintain the charge of the battery bank the economics of solar power become more favorable.

In sum, solar power is a viable option to reduce the long-term costs of grid-connected power intensive health sector infrastructure. At current power prices in Guyana, solar power becomes cost competitive with a 50% or greater subsidy of initial capital costs. Grid-tied solar systems can be designed to offset all, or part, of a facilities power load but do not fully correct for poor quality power from the grid.

4.1.3 CATEGORY I - ENERGY EFFICIENCY CONSIDERATIONS

Some of the challenges currently facing the New Amsterdam hospital could have been mitigated had the architects made a concerted effort to focus on energy efficiency measures, such as, natural lighting and cooling and energy efficient equipment, in the hospital design. One of the top priorities of the donor community, local stakeholders, and the MOH should be to ensure that this same mistake is not repeated at any of the multitude of new health facilities currently in design or under construction (e.g. Georgetown Hospital expansion, Linden Hospital, reference laboratory, New Amsterdam blood bank, etc). 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.

4.1.4 BLOOD BANK BUILDING

There is a CDC-funded Blood Bank building that is being constructed adjacent to the New Amsterdam Hospital. Although the blood bank will not be tied into the hospital circuit, it is likely that the poor quality power supply from GPL could be a serious issue for this building and serious consideration should be given to self-generation or power conditioning options.

It was assumed, but not verified, by the staff at New Amsterdam that a separate emergency power generator would also be installed for the Blood Bank.

4.2 CATEGORY II: QUASI-GRID FACILITIES

Outside of the primary population centers on the coast, Guyana is characterized by large interior regions with low population densities. The majority of these areas are not connected to a primary power grid and the rough terrain and low population density make grid extension unlikely in the near future. In several of the larger population centers in the interior, local entrepreneurs have established "quasi-grids" where electricity is generated at a central point in town and delivered to consumers via a local distribution system.

Several district hospitals, including those in Region I, VII, VIII, and IX, reportedly receive some, or all, of their power from such quasi-grid arrangements. Power received from quasi-grids can be economic and of good quality, but is more often poor quality, intermittent, and expensive. This is due to the quasi-grids' reliance on expensive and scarce fuel, poor quality distribution line construction, and "meter-less" pricing schemes.

The assessment team visited one "quasi-grid" facility – Mahdia district hospital in Region VIII. Mahdia presented an excellent example of the daily power challenges faced by many Category II facilities.

4.2.1 MAHDIA DISTRICT HOSPITAL

Mahdia district hospital in Region VIII serves a resident population of 1000 which swells to 4000 with the addition of workers from local mining operations. It is a priority area for the PEPFAR program based on the high-risk behavior of the mining community. Mahdia can be reached by a six hour drive from Georgetown on dirt roads. Mahdia district hospital is thought to be representative of district hospitals in Region I, IX, and VII which are connected to quasi-grids which provide intermittent and low quality power. The Regional Health Officer (RHO) in Mahdia identified power as his number one challenge.

4.2.1.1 CURRENT POWER SITUATION AND CHALLENGES

Mahdia health workers have done an impressive job of piecing together an assortment of available electricity sources to allow them to provide necessary services. These various sources include:

- Quasi-grid power from an Independent Power Producer (IPP) in the area. This power is only available from 6 p.m. to 6 a.m., has very low voltage,[5] and costs the hospital $75,000 GD/month.
- Quasi-grid power provided free of charge from another IPP to provide continuous power to one of the hospital's three vaccine refrigerators.
- An on-site 11 kW diesel generator which provides power from 10 a.m. – 2 p.m. Power supplied from this source is also reported to be low voltage.[6] High fuel costs prevent the continuous operation of this generator.
- Two solar systems for dedicated loads (radio and vaccine refrigerator).

[5] Small gauge wire combined with long distances from the point of generation to the facility result in inherent low voltage for distribution systems that do not utilize transformers.
[6] A quick evaluation could not determine the reason that the generator was delivering low voltage power. If the on-site generator were operating and wired correctly, it should produce high-quality power.

The hospital has no power (with the exception of the vaccine refrigerators and radio) from 6-10 a.m. and from 2-6 p.m. It is estimated the hospital pays an average cost of more than $3.50 per kWh for this electricity, more than 10 times the price paid in Georgetown. Please see Appendix 3 for more detail on the cost of Mahdia's current energy sources.

Based on the poor quality of these power systems, the following problems were observed:

- An extremely high failure rate on fluorescent lights and ballasts.

- Damaged dental chair and equipment seriously limiting the provision of dental services.

- Damaged blood lab equipment.

- Lack of 24 hour electricity for any load other than the vaccine refrigerator and the emergency radio.

- Lack of adequate power source for an x-ray building currently under construction.

4.2.1.2 OPTIONS FOR IMPROVING ENERGY SUPPLY

PURSUE A BETTER POWER SITUATION WITH THE LOCAL IPPS

Currently, two IPPs own distribution systems and sell power in Mahdia. Both IPPs currently only offer power for a limited time during the evening hours.

The hospital should examine whether it is feasible to obtain continuous, high-quality and affordable power from one of the IPPs. This would involve renegotiation of the current power contract and physical infrastructure improvements including larger gauge wire from the point of generation to the hospital and possibly the addition of generation capacity. Although one IPP does produce continuous power for his own facilities (and the hospital vaccine refrigerator), it is not clear if he has sufficient generating capacity to provide continuous power to the hospital. If this option is pursued the addition of a low-cost power meter at the hospital would help to ensure transparent pricing.

If continuous power is not an option, the power from the quasi-grid could be used to charge a battery bank that could provide the facility with continuous and high-quality power as described below. The economic viability of this solution would depend primarily on the negotiated price of the power from the IPP. The cost of power from alternative generation sources, as detailed below, would serve as the benchmark for evaluating the economics of any IPP contract.

SELF-GENERATION

Assuming the status quo in terms of the cost, quality, and intermittency of the IPP power supply at Mahdia, self-generation of all power at the hospital should be seriously considered. The modest size electrical load and high price of traditional power sources at Mahdia make renewable energy solutions feasible and economic.

An estimated hospital load of 16,000 watt-hours was calculated based on a review of the equipment in the hospital and interviews with the operators concerning frequency of use (Appendix 3).[7] This load does not include the current solar powered vaccine refrigerator, which would likely stay on its own dedicated power system, and it does not include any energy consumption for the X-Ray building. If the X-Ray building is completed, the best solution would likely be to buy power for its intermittent use from one of the IPPs. X-ray machines can be powered by battery based systems, but special equipment, including oversized batteries and high capacity inverters are required to cover the surge power required by the X-ray equipment.

A modeling program was utilized to compare the lifetime cost of electricity for the hospital using three possible generating configurations: 1) a solar system, 2) a diesel generator, and 3) a combined generator/solar hybrid system. The optimum solution to power these loads independently from the quasi-grid, calls for the installation of a 5,000 Watt peak solar array with appropriate batteries, and inverter in a hybrid situation with a small generator for battery charging during cloudy days.

The equipment costs of such a system (not project costs) are approximately $60,000. The resulting COE over a 20 year period, accounting in full for all initial capital costs and lifetime maintenance requirements, is just under $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 between $2.40 and $4.60 per kWh based on current diesel prices in Mahdia.[8] If diesel fuel increased to $1.80 per liter, these costs would increase to $3.45 - $6.80 per kWh. Table 2 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.

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[7] This analysis assumes the installation of energy efficient lighting and other cost-effective energy efficiency improvements.

[8] The wide range of the calculated cost of diesel power results from calculations using different generator sizes. The smaller value assumes an optimally sized generator, the larger value assumes the use of the facility's current generator.

Table 2: Comparison of costs for different power generation options at Mahdia District Hospital

Scheme	Initial Capital ($)	With Initial Capital		Without Initial Capital	
		NPC $/kWh D = $0.86/L	NPC $/kWh D = $1.80/L	NPC $/kWh D = $0.86/L	NPC $/kWh D = $1.80/L
16,000 Whrs per day					
Solar Only	55,000	1.00	1.00	0.14	0.14
Solar/Diesel Hybrid (3 kW)	47,000	1.00	1.00	0.14	0.15
Generator Only (5 kW)	7,000	2.40	3.45	2.25	3.35
Generator only (10 kW)	12,000	4.60	6.80	4.50	6.65

Clearly, $1.00 per kWh for 20 years of high-quality electricity is a bargain compared to the $3.58 per kWh the hospital currently pays for poor quality and intermittent power. The economic benefits of utilizing renewable energy can only be realized, however, if the system lifetime is maximized with appropriate maintenance protocols.

PROVIDE A SEPARATE POWER SUPPLY SYSTEM FOR THE CRITICAL LOADS:

A final option at Mahdia is to provide a high-quality battery based power system for only the critical loads and allow all other loads to be powered from the IPP. This option would be feasible if negotiations with an IPP resulted in improved power quality at a reasonable price. The battery supply for the critical loads could either be charged with solar power or with power from the IPP. The economic viability of this solution would depend primarily on the negotiated price, reliability, and quality of the power from the IPP.

4.3 CATEGORY III: OFF-GRID FACILITIES

Guyana has a large number of rural health posts that provide health services to communities of several hundred people. These facilities are a critical component to the health system as the alternative is often a several day walk to the nearest district hospital. Typical services provided at these clinics include delivery, diagnoses and treatment of malaria, and other illnesses, and vaccination.

The majority of these health posts is off-grid and has no electricity. Some have been the recipients of past solar electrification efforts as discussed in Section 3.3.1. Electrification of these facilities provides an opportunity to expand the reach of vaccination and PMTCT services and improve the overall quality of health care in rural communities in Guyana.

Solar power (including solar/diesel hybrid where appropriate) represents the most economical solution for providing electricity to these off-grid locations. However, the remoteness of these facilities increases the challenge of sustaining such technology and magnifies the importance of vigorous training programs and maintenance protocols.

Without such plans in place, any efforts expended towards the provision of electricity to these remote sites will be for naught.

4.3.1 MICOBEE AND TUMATUMARI

Micobee and Tumatumari are small health clinics in Region XIII separated by about five miles. These facilities serve a resident population of 360 as well as 300 miners from small villages along the river. Both facilities are attended by a part time local health worker. These facilities are typical of the large number of health posts scattered throughout the interior of Guyana and most other developing countries.

4.3.1.1 CURRENT POWER SITUATION AND CHALLENGES

The health facility at Tumatumari has been built recently and has no power supply. There is a small solar system which has recently been installed at Micobee and was on the verge of failure. The solar system was being used to power a communication radio, a light inside the building, and a security light outside the building. An examination of this solar system highlights several of the key reasons for the poor track record of solar system sustainability in Guyana as detailed in Section 3.3.1. These issues are addressed below:

1) *Lack of training for local user* – The local health worker had received no training in the maintenance of the system and was instructed not to touch the batteries. In case of system failure the health worker calls the RHO who sends technicians from Georgetown. The technicians were out to fix the system six months ago. The water was critically low in many, if not most, of the cells. Since the plates of the batteries were exposed to air, it is likely that they will no longer be able to be brought back to optimum performance. No distilled water was at the facility or in the community to refill the batteries.

2) *Improper system design* - The batteries were too large for the system. Once the batteries are taken to their 50% charge level (which is normal design) it would take several weeks of continuous charging to fully recharge them with the small panel. It is likely that at best, the batteries would exist in a persistent discharged state, which will shorten their life.

The solar panel is mounted on the metal roof, with no air circulation under it. This produces excessive heating of the panel which likely reduces its efficiency to 60% or 70% of its rated value.

The 300 watt inverter utilized for this project has no protective coating on the circuit board and experience in other countries indicates that it does not perform well in humid environments.

There appears to be no real need for the inverter, since it is only running small lighting load, which could also be taken care of with DC lights.

The charge controller used (C35), is a 35 amp charge controller, and does not have low voltage disconnect capabilities included with it. Normally, with a single panel system, a charge controller that is rated 10 amps, with built in low voltage disconnecting means would be utilized here.

The fact that the charge controller and batteries are oversized for the panel indicate that either (a) the designers of the system were not fully informed on proper system design, or (b) the system originally had more panels – that would support the larger charge controller and batteries – and they have been removed.

4.3.1.2 OPTIONS FOR IMPROVING ENERGY SUPPLY

The energy demands of 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 3.

Table 3: 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 economics of solar power for this size system are similar to the larger system described for Mahdia, with solar power costing 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. To date it appears facility selection has been done in an ad-hoc manner.

The Ministry of Health should also institute design standards for this system. Finally, a detailed training program and maintenance protocols should be established to ensure long-term system sustainability. More details on these recommendations are presented in Section 5.

5 STRATEGIES FOR IMPROVING SOLAR SYSTEM SUSTAINABILITY

The sustainability of past solar installations at health facilities in Guyana is a strong indication that current practices are not sufficient to insure the sustainability of these systems. While solar system operation and maintenance is not difficult, the technology has several unique characteristics that are unfamiliar to many developing country personnel, and that, will often lead to failure if the proper safeguards are not in place. The procurement and installation of a solar system is only the first step in a sustained effort which must be undertaken to ensure the long-term sustainability of the system. This section will review four key areas that should be a central component to any future solar electrification efforts in Guyana.

5.1 SYSTEM DESIGN STANDARDS

The procurement and installation of solar systems is the first important step to ensure optimal performance and reliability. The size, model and make, and physical installation of system components are all crucial elements to proper system operation. As a standard setting body for the health care sector, the Ministry of Health in Guyana should seriously consider adding solar system design standards to its regulations. It is important, however, to not confuse design standards with a "one size fits all approach." Properly drafted standards can allow each system to be tailored to meet the needs of the facility while still ensuring best practice design and installation protocols are followed.

5.1.1 TRAINING PROGRAM

Increasing the capacity of local stakeholders to install and maintain solar systems is often the first step to ensure system sustainability in developing countries. The successful implementation and operation of a solar electrification 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 another local stakeholder must be trained to perform basic system operation and care. This is particularly important for remote locations where service personnel from Georgetown are not likely to make regular visits. Experience has demonstrated that with minimal training system owners are capable of performing the required routine maintenance checks required for solar system 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 in case of staff turnover.

When the local user encounters a problem that they are unable to repair, they must have a pre-determined contact at the regional or national level that is trained to diagnose and correct all potential system problems. These individuals should be energy professionals with extensive training in the proper installation and operation of solar system. In Guyana, these solar technicians could be employed by the Ministry of Health or other government agency, or they could be hired from the private sector. The number of installations, size of a country, and accessibility of the facilities in a given country will determine if this support can be provided at the national level or if regional representatives are required.

5.2 MAINTENANCE FUNDS

Significant effort has been expended in the past to design effective financing models to cover the high initial capital costs of solar systems in developing countries.[9] Given the grant funding available to the Guyana Ministry of Health and within the PEPFAR program, the initial capital cost of the systems 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 costs - which may be required long after the donor community has left - present the most significant challenge.

Over the lifetime of a solar panel (25 years), a sustained investment in solar systems components is required to keep the system operational. Charge controllers, batteries, and inverters are all designed to last approximately 5 – 7 years, making periodic component replacement a necessity. Regardless of the level of training of local users and technicians, solar systems will not be sustainable if funds are not available to purchase replacement parts. This issue is of particular importance to health facilities in Guyana, because they provide free services and therefore have no revenue stream that can be utilized to cover system maintenance.

The estimated annualized maintenance/replacement costs of the solar/diesel hybrid systems outlined for the Mahdia district hospital are detailed in Table 4. These costs represent a "best case" scenario where preventative maintenance is performed on schedule and maximum component lifetime is realized. While the overall magnitude of maintenance funds required for solar installations is not significantly different than for a typical diesel system, some factors inherent to solar technology make a dedicated plan for maintenance financing particularly important. Solar systems components typically operate well for the first several years after installation and require little, if any, investment to maintain operation. Following this initial grace period (3-7 years), electronic and chemical system components begin to fail which are not well

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

suited to repair or "jury rig" solutions. Thus, a "lump-sum" payment must be made to procure a replacement component. This uneven distribution of maintenance fund requirements over the lifetime of the system has proven to be challenging in many developing country settings where capital is in short supply and the concept of savings is not well developed.

Table 4: Breakdown of total annualized costs (excluding initial capital) for Solar/Diesel hybrid system

Component	Initial Capital ($)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
PV Array	40,000	0	50	0	2496
Generator	2,400	68	71	222	372
Battery	4000	201	160	0	605
Converter	3000	54	100	0	337
Other	2000	0	200	0	322
Totals	**51,400**	**323**	**581**	**222**	**4132**

One financial model which is often promoted is the use of excess power generated from the panels to provide a community service that can generate a stream of revenue to pay for maintenance of the solar system. The UNDP-supported solar electrification of the Kato health facility in Guyana attempted such a scheme where excess electricity was used to power a cell phone charging station and a grain milling machine. A recent review of this program found that neither of these applications had produced any revenue for the clinic. Another strategy recently utilized in a hospital electrification project supported by the USAID Energy Team in Uganda was to couple a PV-powered clean water pumping system with the hospital electrification project. Clean water is currently being sold to community members to generate revenue to cover the operational and maintenance costs of both systems. It is too early to determine if this model will be effective over the long-term.

Given the mixed track record of previous "self-financed" maintenance fund schemes, a prudent approach to pursue in Guyana is to set aside maintenance funds in an escrow 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 solar 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 often used for other perceived priorities if the solar 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 solar system examined at Micobee is a perfect example of an installation that was being serviced by a private sector entity that has no incentive to train the local user on the routine maintenance steps necessary to maximize the lifespan of the system.

Finally, once design standards are developed, the Ministry of Health may want to consider establishing an internal inventory of replacement components for the solar 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.

5.3 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 Guyana. 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. 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. 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.

6 EXAMPLE ENERGY RETROFIT SUPPORT PROGRAMS

This report has detailed several options for improving the energy services at priority health facilities in Guyana. 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. Top priority should be given to interventions that could improve the sustainability or effectiveness of existing PEPFAR or MOH investments – such as the New Amsterdam blood bank, reference lab at Georgetown Public Hospital, or existing solar electrification efforts. Since both of the PEPFAR supported facilities are in the design/build stage, it is likely that the existing architectural firm should have the capacity to design solutions to meet the site-specific energy challenges detailed above.

The budgets below are based on estimates for the total cost for PEPFAR (USAID or CDC) 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 any of the recommendations involving the use of solar systems it is suggested that the expertise of the international consulting community be used to augment the local technical capacity in Guyana to ensure the implementation of a sustainable program. Budget estimates broken down by facility category can be found in Appendix 5.

Table 5: Notional budgets for energy retrofit programs.

Available Budget: $500,000

Program	Unit Cost	Cost
Establish Basic Design Standards and Prototypes for the MOH – focus on small and medium systems.		$75,000
Training program for technicians – local, regional, national. Initial program only.		$50,000
Retrofit / Install up to 5 small remote health post systems.	$20,000	$100,000
Design / Install a solar system for Mahdia or equivalent district hospital		$125,000
Address power quality problem for new blood bank at New Amsterdam. (solution needs more study)		$150,000
Total		**$500,000**

Available Budget: $750,000
Complete the work described above plus:

Program	Unit Cost	Cost
Complete one more Regional/District Hospital solar/ hybrid system of approximately 16,000 Whr/day size		$125,000
Augment the training and maintenance program.		$25,000
Retrofit/Install 5 additional remote health post systems.	$20,000	$100,000
Total		**$250,000**

Available Budget: $1,500,000
Complete the work described above plus:

Program	Unit Cost	Cost
Address power issues at New Amsterdam Hospital		$750,000
Total		**$750,000**

7 CONCLUSIONS

Reliable electricity is critical to all levels of health care delivery in Guyana. The acquisition of reliable power poses a challenge to nearly every facility visited during this assessment. Separate electricity grids and quasi-grids around the country, as well as large areas of the country that are currently unelectrified, present a wide-range of challenges that require a diverse set of solutions.

Improving the power supply of health facilities in Guyana could have a dramatic impact on the quality of health care delivery and should be seriously considered by the PEPFAR program. An upfront investment in a reliable energy supply can help ensure the sustainability of a variety of current PEPFAR investments and help to expand the provision of key health services to all regions of Guyana.

The key recommendations of this assessment are summarized below according to the three categories of facilities reviewed.

CATEGORY I: GRID-CONNECTED FACILITIES

- Many non-solar based investments would likely take top priority when considering cost-effective options for improving the power supply at grid-connected health facilities such as New Amsterdam and Georgetown public hospital.

- 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.

- The poor quality of grid power should be a major consideration in the design of all new facilities – such as the blood bank at New Amsterdam, and the reference lab in Georgetown. Appropriate back-up systems, power conditioning units, and/or complete self-generation using a combination of generators, battery banks, and PV arrays should seriously be considered.

CATEGORY II: QUASI-GRID FACILITIES

- Hospitals located in Region I, VII, VIII, IX appear to provide the greatest overlap between PEPFAR programmatic objectives and solar suitable facilities. An investment in solar/diesel hybrid systems for these hospitals likely represents the most cost-effective solution to meet the energy needs of these critical facilities which serve as the focal point of regional health care delivery.

- Investment in solar solutions for any facility is only advisable if a corresponding training and maintenance program is initiated. Proper solar system design is essential and components need consistent maintenance from appropriately trained personnel. Since the health care facilities do not collect fees, maintenance funds must be established upfront and be dedicated only to solar system repair. Mixing maintenance funds with general operating budgets has proven to be an ineffective model.

- PEPFAR investment in the solar electrification of an interior regional hospital, coupled with the establishment of a PV training program, design standards, and maintenance protocols, could have an important ripple effect on the sustainability of all PV systems currently being installed at hinterland health facilities in Guyana.

CATEGORY III: OFF-GRID FACILITIES

- Solar power is the most economic option to meet the energy needs of small off-grid health posts.

- The similar energy needs of these posts lend themselves to "off-the-shelf" systems with design standards determined by the Ministry of Health.

- Investment in a power supply which could provide refrigeration for these facilities could help expand the provision of vaccination programs and PMTCT services throughout Guyana.

- The remote setting of these facilities requires extra attention to training programs and maintenance protocols.

APPENDIX 1: FACILITIES VISITED

CATEGORY I:

Linden Public Hospital
New Amsterdam Public Hospital
Georgetown Public Hospital
Williamsburg Health Center

CATEGORY II:

Mahdia District Hospital

CATEGORY III:

Ribbons of Life – NGO office
Micobee Health Post
Tumatumari Health Post

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

APPENDIX 2: LABORATORY EQUIPMENT SUSTAINABILITY

The PEPFAR program is investing a considerable amount of money to improve the laboratory infrastructure in each focus country. In Guyana, laboratory equipment has been provided to improve the capacity of a variety of health care facilities and currently a reference laboratory is being constructed on the grounds of the Georgetown Public Hospital. The sustainability of this investment requires that the power supply for these laboratories is reliable and stable. Poor quality power will quickly destroy sensitive laboratory equipment and compromise the integrity of sensitive lab results. Many of the laboratories in Guyana were utilizing point of use power conditioning/UPS devices to shield the equipment from the poor quality grid power. While this is a viable option for the short-term, it is not a substitute for a system wide reliable power supply. The table below details the power requirements of a standard lab that might be found at one of the larger health care facilities in Guyana.

If investing in hospital wide power improvement systems is beyond the scope of the PEPFAR program, systems that provide continuous and high-quality power to a dedicated load such as the laboratory should be considered. One option, which would be appropriate at the Category I facilities visited in Guyana would be to install a "double conversion" or on-line UPS technology that is designed to take poor quality power, and process it into clean power to feed the loads.

Typically, these systems are used when power quality is an issue, and when there is an emergency generator present for power outages. 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.

This laboratory example would likely require a UPS system rated at 10 kVA, which would cost between $15,000 and $20,000.

If there was a desire to make the laboratory "energy neutral", or if the laboratory was located in an area with no grid power, a 10 kWp solar system could provide all the power for this lab. The initial cost of a stand-alone system with batteries would be between $120,000 and $150,000.

It is the important to note that these calculations do not include provisions for an air-conditioning system. Air-conditioning systems require significant power. For example, the power requirements for an air-conditioning system for a stand-alone laboratory of equivalent size to the laboratory at New Amsterdam Hospital would be equal or greater than the combined power needs of the equipment.

Table 1: Load analysis of typical hospital laboratory in Guyana

Qty	Load	Watts	Hours/day	Energy Whrs/Day
8	Fluorescent Light	40	12	3,840
4	Fluorescent Light	40	12	1,920
6	Microscope	30	10	1800
1	Radio (comm.)	30	8	240
3	Rotator	60	2	360
3	Refrigerator			3,000
4	Centrifuge	600	2	4,800
2	Water Bath	400	2	1,600
2	Spectrophotometer	63	4	504
2	Autoclave	630	1	1,260
2	Sterilizer	1400	2	5,600
5	Computer	150	8	6,000
	Total			**33,924**

APPENDIX 3: MAHDIA DISTRICT HOSPITAL - SUPPORTING CALCULATIONS

Table 1 breaks down the estimated current costs of energy at the Mahdia district hospital. The daily Watt-hour loads are taken from a site survey and do not include the blood lab refrigerator, temporarily being powered for free from an off-site IPP benefactor, or the DULAS solar powered vaccine refrigerator.

Table 1: Estimated current cost for energy at Mahdia District Hospital

Mahdia Loads	Daily Whrs	Cost USD	$per kWh	Notes
6 p.m. to 6 am: Basic facility operations. Includes area lighting, one refrigerator, and intermittent malaria microscope use.	4360	12.50	2.87	
10 a.m. to 2 p.m: Generator is run for refrigerator, computers, and other loads.	2880	17.00	5.90	10
Buffer	1000			
Total Energy Use	**8240**	**29.50**	**3.58**	

Table 2 breaks down the total current estimated load at Mahdia district hospital. Because of the large number of instruments that were not currently in use, the estimated daily load for the Mahdia hospital operating at optimal levels of service is about twice as large as the actual daily load presented in the figure above.

[10] The plant manager said that he uses 4 to 5 gallons of fuel per day. Diesel in Mahdia could be purchased bulk at 30,000 GD / 45 Gallons, (or $0.88/Liter), or at the pump at 220 GD/Liter ($1.10/L). This example, and others in this report uses $1.00/liter. 4.5 Gallons x 3.785 liters = $17.00.

Table 2: Total estimated load needed for optimal operations of Mahdia District Hospital

Area	Quantity	Load	Watts Each	Hrs per Day		Watt-hrs Day	Watt-hrs Night	Watt-hrs Total	Total Conn Watts	Days Per Wk	Total per Week
				Day	Night						
Lighting and Fans											
Entry and Corridors	10	Fluorescent Light	22	0	12		2,640	2,640	220	7	2,640
PMTCT Lab Partial	2	Fluorescent Light	22	2	4	88	176	264	44	3	113
PMTCT Lab Partial	2	Fluorescent Light	22	0	2		88	88	44	3	38
Blood Lab	1	Fluorescent Light	22	2	4	44	88	132	22	5	94
Male Ward	3	Fan	22	0	4		264	264	66	7	264
Male Ward	1	Fluorescent Light	80	4	4	320	320	640	80	7	640
Exam Room	1	Fluorescent Light	22	1	4	22	88	110	22	5	79
Post Natal	2	Fluorescent Light	22	0	4		176	176	44	5	126
Post Natal	1	Fan	80	4	4	320	320	640	80	5	457
Maternity Dorm	5	Fluorescent Light	22	0	4		440	440	110	5	314
Maternity Dorm	2	Fan	80	4	4	640	640	1,280	160	5	914
Delivery Room	4	Fluorescent Light	22	0	4		352	352	88	2	101
Kitchen	2	Fluorescent Light	22	0	2		88	88	44	5	63
Offices (5)	5	Fluorescent Light	22	4	4	440	440	880	110	5	629
Other Lights	4	Fluorescent Light	22	0	4		352	352	88	5	251
Security Lighting	4	Fluorescent Light	22	0	8		704	704	88	7	704
Total Lighting						1,874	7,176	9,050	1,310		7,427
Lab Equipment											
Blood Lab	3	Microscopes	30	2	2	180	180	360	90	5	257
	1	Radio	30	4	4	120	120	240	30	5	171
PMTCT Lab	1	Rotator	60	1		60	0	60	60	3	26
	1	Refrigerator-Maytag	500	1	1	500	500	1,000	500	7	1,000
	1	Centrifuge	600	1		600	0	600	600	3	257
	1	Water Bath	400	1		400	0	400	400	3	171
	1	Spectrophotometer	63	1		63	0	63	3	3	27
	1	Autoclave	630	1		630	0	630	630	3	270
						740					
Dental Suite	1	Chair	710	0.5		355	0	355	710	3	152
	1	Compressor	370	2		740	0	740	370	3	317
	1	Jet Sonic Cleaner	45	2		90	0	90	45	3	39
	1	Amalgam Filling Mach.	80	1		80	0	80	80	3	34
	1	X-Ray	200	0.5		100	0	100	200	3	43
Total Lab Equipment						3,918	800	4,718	3,778		2,765
Other Equipment											
RHO Office	1	Refrigerator	500	1	1	500	500	1,000	500	7	1,000
Admin Office	2	Computers	150	4		1,200	0	1,200	300	5	857
Separate Solar System	1	Dulas Solar Vaccine Refrigerator									
Separate Solar System	1	CB Radio									
Total Other Equipment						1,700	500	2,200	800		1,857
Grand Totals						**7,492**	**8,476**	**15,968**	**5,888**		**12,049**

APPENDIX 4: ADDITIONAL FACILITIES

GEORGETOWN PUBLIC HOSPITAL:

GPHC is the largest health facility in Guyana and is the focal point and last point of referral for the health system.

The electrical service at GPHC is presently just under 1 MW. (This is about five times larger than the electrical service at New Amsterdam. The new Linden Hospital will also be approximately 1 MW.)

The Facilities Manager has made some near term future predictions that this load will increase to nearly 2 MW when the new facility is built, and when the current visions for more technical equipment (such as CT scanning equipment) is procured and commissioned.

The emergency back-up system is already split into critical and essential systems, with a total emergency generator capacity of 750 kVA. They feel that the emergency power system is currently marginal and have asked for funds to upgrade back-up equipment. This situation is particularly aggravated by the addition of new loads, such as the Blood Bank, to their electrical distribution system. GPHC is hoping that the Blood Bank will soon purchase their own emergency generator for back-up purposes. (Estimated requirement of 100 kVA generator.)

Like all other facilities on the GPL grid system, GPHC faces poor power conditions in terms of both availability (blackouts) and power quality (low voltage, harmonics, and reactive power). They feel that even though it has improved somewhat in the past year, it is still a serious problem, resulting in lost time and lost equipment, and decreased ability to provide quality emergency health care. The power situation is significantly better than at New Amsterdam.

Over the past several years, the CEO and Facilities Manager have put in place several programs to improve the quality of the electrical distribution system within the plant, but they are unable to make any headway in the improvement of the power coming into the facility which is the largest problem.

The problem has magnified in recent years due to the new equipment and new facilities that are being given to Guyana from donor agencies. Although the facilities come as gifts, their high demand for good quality power puts a tremendous burden on the facility's ability to sustain their continued use.

SOLUTIONS:

The CEO and Facilities Manager have already worked towards solutions to the electricity supply problem. These are similar to the solutions suggested for the New Amsterdam Public Hospital.

1. DEDICATED GPL FEEDER:

A dedicated feeder from GPL has been discussed and should be high on the list of priorities. By putting the facility on their own feeder, disturbances on the grid line that are caused by the other customers on the same line will be smoothed out. This will not improve problems that result in brownouts or blackouts as these are more related to the overall capacity of the generating station.

2. USE OF A POWER CONDITIONING UPS SYSTEM:

A power conditioning UPS system (which may be similar to the one designed into Linden), would help with the loads that are most affected by the low voltages and transients in the line. The Facilities Manager is in the process of studying the appropriate loads that should be put onto such a system in hopes of making this a near term procurement item.

3. INCREASE THE CAPACITY OF THE EMERGENCY BACK-UP SYSTEM:

GPHC would like to increase the capacity of their emergency power system from 750 KVA to approximately 1 MW. This would allow them to meet their current emergency power demands, with some headroom for future expansion on the critical distribution system.

GPHC had included Item 2 and 3 above in a $1 million loan request to the IDB. This was diverted, however, to cover budget shortfalls in the new expansion project.

4. SELF-GENERATION OF ALL POWER:

The GPHC personnel feel that self-generation may be the best solution to the power quality problems, and be cost effective, but they feel that this may not be an option for political reasons, since GPHC is a big rate payer to GPL – both government entities.

RECOMMENDATIONS:

The existing GPHC personnel are extremely competent and should be given complete support to pursue their current plans for upgrading the power system. This could include political assistance to push for a dedicated power line and re-funding of the $1 million proposal they had previously submitted for power system upgrades.

LINDEN REGIONAL HOSPITAL:

Linden is currently planning a new Regional Hospital to be constructed with a loan from the IDB. Linden currently has a stable (1 short outage every 1 or 2 months) and relatively cheap

($0.05 per kWh) power supply generated at the local OMAI bauxite facility. Construction of the new hospital is scheduled to begin in 2007 and be complete in July 2008. Given the pending construction of a new facility no time was spent reviewing the power needs of the old hospital.

The designers of the Linden hospital paid a lot of attention to the power reliability of the facility, and assuming no major change in the power supply Linden will be in the best shape, power – wise, of any of the hospitals visited during this assessment.

Linden will take power from two utility company supply lines. The operator chooses which incoming power source to use by use of interlocked main switches at the incoming service entrance. (So, if there is a problem with one source, they can switch to the other quite easily.)

There are two different levels of emergency power distribution systems within the hospital. This design is similar to what would be done in the US. There are critical loads, and then emergency loads, but not quite as critical, in regards to the absolute continuity of the power supply.

Each of the two emergency distribution systems has a 400 amp, Automatic Transfer Switch. So, in the case of a power outage, the emergency generator starts automatically, and the load transfers automatically to the generator when the generator is running. The emergency generator is 450 kVA. (By way of comparison, this is approximately twice the load of the entire New Amsterdam hospital.)

There is also a 200 kVA UPS system designed to provide continuous power to the critical loads. This would primarily be for the time period between when the utility power goes out, and when the generator starts. With this UPS system, the critical loads would be unaffected by power outages.

This system design should result in power of comparable quality and continuity to that utilized by many of the hospitals in the U.S.

Two factors should be monitored which could affect this scenario:

- The recent sale of OMAI to IAMGOLD Company
- Reduction in government subsidy resulting in increased power costs.

RIBBONS OF LIFE NGO:

In addition to health care facilities, USAID is supporting several NGO's who work to implement different components of the PEPFAR program. While in Mahdia, the offices of Ribbons of Life (ROL) were visited and their energy needs were analyzed.

ROL's office is currently on the second floor of a church building. This building has no electricity, and is not connected to either of the quasi-grids that are available in Mahdia. They do have a small (approximately 500 watt) petrol powered generator in the office that they use when they need to run the computer or lighting at night.

According to ROL, this generator is not large enough to meet their electricity requirements, and they have submitted a funding request to USAID for a larger generator to better meet their electrical needs.

In light of the continuing costs of the fuel based power generation system, it would be good to consider a solar system for this NGO and any others working in similar off-grid areas.

A somewhat standardized system approach could be used (allowing flexibilities for the different anticipated loads) that would define the costs and the equipment that should go into such a system.

The NGO office was found to have the following load requirements:

Table 1: Load Requirement of NGO Offices

Qty	Load	Watts	Hours/day	Energy Whrs/Day
1	CB Radio-Xmit	20	1	20
1	CB Radio-Receive	10	6	60
4	CF Light	20	6	480
1	Computer-Desk Top	150	4	600
1	Miscellaneous	10	4	40
	Total			**1200**

A solar system to power these loads would include a solar array of approximately 400 watts peak with an initial cost of about $6,000. It would provide electricity at a long-term cost of energy at around $1.00 per kWh.

To provide the same electricity with only a generator would cost several times this on a long-term basis (with a significantly smaller initial cost.)

Based on the pricing from the local IPP suppliers, currently the household electricity costs are running between $1.50 and $2.00 per kWh, for poor quality electricity that is not available during normal business hours. It is likely that if ROL were to connect to the IPP quasi-grid, they may obtain a rate that would be similar.

If the funds are available to cover the initial capital costs, and if sufficient maintenance and training infrastructure is in place, stand-alone solar electricity would be a good option to power small NGO offices such as ROL.

APPENDIX 5: NOTIONAL FACILITY BUDGETS

Throughout this report many different options have been discussed for addressing the energy challenges at a variety of health facilities in Guyana. The following tables summarize these recommendations and provide budget estimates for energy upgrades at Category I, II, and III facilities based on the needs of a representative facility within that category reviewed during the assessment. These estimates are meant to provide ballpark figures for discussion and planning purposes and should not be considered actionable budgets for any specific facility. In order to develop a detailed facility-specific budget for Category I and II facilities a comprehensive power systems analysis will need to be performed which was beyond the scope of this assessment.

Table 1: Budget estimates by Facility Category:

Category I (e.g. New Amsterdam)	Cost (USD)	Cost (GD) millions
Comprehensive power systems analysis	$30,000	$5.7
Training program for on-site engineers and facilities manager	$30,000	$5.7
Procure / install 200 kVA on-line UPS system	$400,000	$76
Upgrade backup generation capacity and wiring	$200,000	$38
Total	**$660,000**	**$125.4**

Category II (e.g. Mahdia)	Cost (USD)	Cost (GD) Millions
Training program for solar technicians – local, regional, national (initial training only)	$50,000	$9.5
Solar system and Diesel backup for complete self-generation (equipment only)	$60,000	$11.4
Installation of solar/diesel hybrid system	$60,000	$11.4
Annual O&M, replacement investment	$5,000 per year	$0.95 per year
Total	**$170,000**	**$32.3**

Category III (e.g. Micobee)	Cost (USD)	Cost (GD) Millions
Establish Basic Design Standards and Prototypes for the MOH – focus on small and medium systems.	$75,000	$14.25
Training program for technicians – local, regional, national. (initial training only)	$50,000	$9.5
Procure / Install small remote health post system.	$20,000	$3.8
Annual O&M, replacement investment (per site installation)	$1,000 per year	$0.29 per year
Total	**$145,000**	**$27.55**

APPENDIX 6: PEOPLE INTERVIEWED

Colin Singh, Director of Projects, Guyana Power and Light

Kumar Sharma, Construction Manager, Un-served Areas Electrification Program, Guyana Power and Light

Farfan and Mendes LTD, Hardware Store

Roland R. Clarke, Ph.D., Project Manager for the Caribbean Renewable Energy Development Programme (CREDP), Caribbean Community Secretariat

Kwame Asiedu, Chief of Party, USAID/Guyana HIV/AIDS Reduction and Prevention (GHARP) project

Keith Burrowes, Executive Director, Health Sector Development Unit (HSDU)

Maxine Nestor, Principal Project Coordinator, Un-served Areas Electrification Program, Office of the Prime Minister

Hydar Ally – Permanent Secretary of the Ministry of Health (MOH)

Dr. Douglas Lyon, Country Director, CDC Guyana

Dr. Amy Dubois, Deputy Director for Programs, CDC Guyana

Edris George, HIV/AIDS Technical Development Officer USAID Guyana

Julia Rehwinkel, Population, Health, and Nutrition Officer, USAID Guyana

Mahendra Sharma, Head of Fuel Marking Unit, Guyana Energy Agency (GEA)

Dr. San San Min, Resident Advisor, Supply Chain Management Systems Project

Lisa Thompson and Simone Sills, Program Managers, USAID/GHARP

Carla Khammar, Resident Representative, United Nations Development Programme (UNDP)

Patsy Ross, Energy Advisor, UNDP

Dr. Behri Ramsarran, Minister within the Ministry of Health

Laulteram Harryram, Manager Regional Health Services, Ministry of Health

Honorable Dr. Leslie Ramsammy, Minster of Health

Nurse Simon, Maternal Child Health Division, Ministry of Health

Sherman Charles, acting Superintendent of Works, Region 8

Carl Amsterdam – Regional Health Officer, Region 8

Roger Hinds, Entrepreneur and Independent Power Producer in Mahdia

Aubrey Skeete, Project Coordinator, Ribbons of Life

Cornell Edwards, community health worker – Micobee

Henry Rodney, Regional Executive Officer – Region 10 (previously Regional Executive Officer in Region 9)

Mr. Gumbs, Linden Hospital Administrator, and staff

Mr. Rose, Facilities Manager, New Amsterdam Hospital

Medex Corlette, Williamsburg Health Center

Christopher Persaud, Energy Advisor, Inter-American Development Bank (IDB)

Michael Khan – CEO, Georgetown Public Hospital

Parmanand Samaroo – Facilities Manager, Georgetown Public Hospital

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