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A Guide to the Energy Audit for Specifying Energy Systems in Off-Grid Health Facilities

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1 INTRODUCTION

This guide is designed to be used with USAID's Audit Reporting Worksheets as an overall off-grid energy information package for energy experts and procurement officers managing the design, procurement, and after-sales service of PV systems in health centers. It is based on a series of training courses held in Rwanda for the President's Emergency Plan for AIDS Relief (PEPFAR) in 2007 and 2008, but has been expanded so that it can be utilized for health centers in other countries.

Off-grid energy is not like normal "grid power." It is a commodity that has to be created and replenished at the site every day (by solar panels, a wind generator, micro-hydro plants, or fossil fuel generators). Unlike grid-connected sites, when off-grid sites start consuming more energy – either by adding equipment, or by using less efficient equipment – the results are a lot more drastic than just paying higher electricity bills at the end of the month

Therefore, the management of off-grid energy systems has to be given the same emphasis as the management of other medical systems, such as the electronic medical records system, blood bank equipment, or the storage and delivery of vaccines. The energy system must be considered a central piece of equipment, as it affects every function across the board.

When planning to design or procure an off-grid energy system, the first step is to be sure that all appliances and management practices are as energy efficient as possible. Without this preliminary step, any energy system is likely to be expensive to buy and maintain.

1.1 The Process for Energy Audits in Preparation for Design of Energy Systems

This guide presents a methodology for conducting comprehensive energy audits in off-grid health facilities, so that the audit information can be used in the design, procurement, and maintenance of an effective energy system. The guide outlines a procedure for auditing and specifying systems using one or more of the following off-grid configurations:

- Hybrid generator/PV systems
- Isolated PV systems
- Thermal-based technologies (including kerosene-powered refrigerators or sterilizers, and biomass-powered stoves)

Section 1 provides an introduction to the guide and the steps in auditing, designing, and procuring off-grid energy systems.

Section 2 explains how an energy audit is conducted using the accompanying Audit Reporting Worksheets.

Section 3 discusses the preparation of energy audit reports that can be used to analyze energy systems in off-grid clinics.

The guide DOES NOT replace the need for professional service providers. Specifically, there is a need for qualified energy engineers, procurement officers, and managers in this process. The

steps presented here are generally based on a methodology presented in the USAID document *Powering Health: Electrification Options for Rural Health Centers*.[1]

Before embarking on the design and purchase of an energy system, it is critical that the management and sponsors of the health center define specific energy goals. For example, is powering the lab a key priority? Is powering the communications equipment the most important thing? What are the funding limitations? Without considering these practical aspects, it is difficult for a planner to develop a practical solution to meet a center's energy needs.

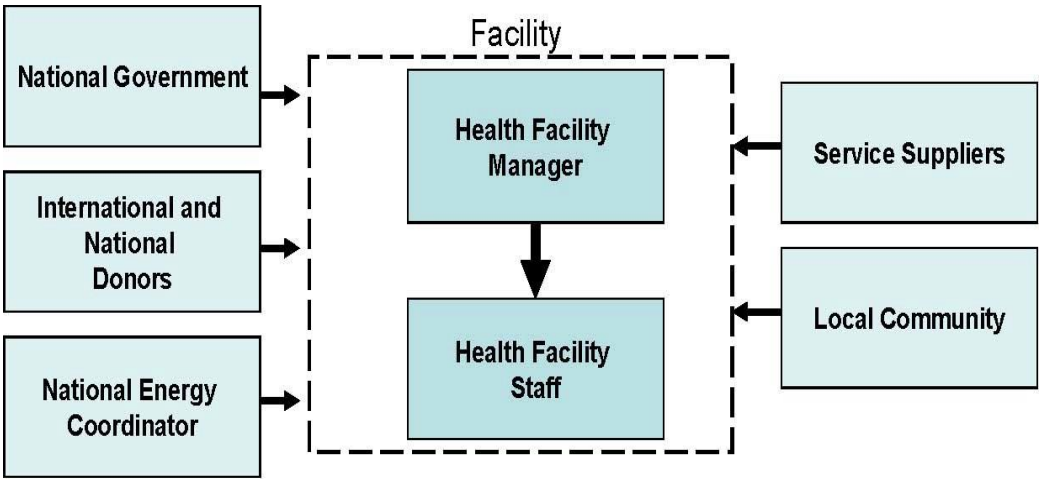

Figure 1: Key stakeholders in the energy decision-making process

Figure 2: Key steps in designing viable energy systems include the following

1.	**Identify the Health Center's Current Energy Demands and Energy Management Practices**	This is done using the energy audit process and Audit Reporting Worksheets.
2.	**Account for Near-Term Change**	Determine how much the energy demands of the health center will change in the near term. This is also part of the energy audit.
3.	**Establish Target Energy Use (kWh/day) Amounts and Types**	Calculate electricity use that accounts for increase in energy use over time and also is realistic in terms of available budgets as well as technology that can provide the energy.
4.	**Provide a Basic Analysis of the Situation and Options Available to Client**	The client must understand the realistic options available and their approximate costs before moving to the next step. As well, they must be willing to allocate the resources to an agreed solution.

[1] The publication is available in hard copy or as a download from USAID EGAT Energy Team, 1300 Pennsylvania Avenue, NW, Washington DC 20523 http://pdf.usaid.gov/pdf_docs/PNADJ557.pdf

5.	**Select Energy Solutions Based on Options and Resources Available**	An accompanying guide on ***Energy System Bid Preparation and Technical Specifications*** provides further information on PV systems, generator/PV hybrid systems, and appropriate non-electric technologies.[2]
6.	**Design, Procure, and Install the Energy System**	This guide does not provide actual system design, as this requires the intervention of energy specialists.
7.	**Maintain and Finance the Energy System over the Long Term**	This important aspect of energy systems is not covered in this guide.

Developing well-run energy systems begins with an analysis of the current status of the health center. Therefore, building a good energy system starts with a professionally conducted energy audit that looks at the health center's current technology available to provide and use energy, its condition, and the practices of the staff in the operation of the energy system and appliances.

The purpose of this comprehensive site energy audit is to provide a basis for decisions that staff and implementing partners will make about energy needs of the health facilities. This information can then be used to review current energy systems and to suggest the type of systems the center needs. This information can also assist supporting government agencies or non-governmental organizations (NGOs) in specifying and/or writing tender documents for energy system upgrades or new designs.

The audit will lay the groundwork for the design of the following types of systems:

- One or more stand-alone PV system(s) in the health facility.[3]
- Combined PV and generator power systems that utilize a battery back-up system to power 240 VAC loads. Some equipment will be powered from the generator directly (i.e. thermal loads).

In order to design the best energy system for a specific health facility, the current situation must be analyzed. The audit worksheets and energy analysis framework in this report provide a simplified methodology for developing an energy system that analyzes (1) the present conditions of the health facility, (2) the existing energy equipment, (3) the current energy demands, (4) the future energy demands, and (5) the resources available to improve the energy system.

Note that the process described here is technology neutral. This means that the energy auditors and system designers are not biased for or against any specific energy technology. What is important is that the most cost-effective, reliable, and sustainable source of energy is used for the given requirement, be it a generator, solar PV, or a fuel source such as kerosene or wood. For example, even though solar PV costs have come down considerably, there are still advantages of using generators. Costs, advantages, and disadvantages should be factored into the decision process at each site.

[2] Some sites may also choose wind electric, biomass or other energy systems.
[3] It is likely that these systems will be smaller than 500Wp in size depending on the load.

1.2 The Energy Audit Reporting Worksheets

The Audit Reporting Worksheets tool has been designed to help energy experts collect and analyze site energy information. It gives a complete review of:

(a) the current energy situation at the site,

(b) the current energy production equipment and how it is being used, and

(c) anticipated future loads

This data should enable professionals to plan PV and generator systems in off-grid sites and to develop specifications and bidding documents. With information collected in the worksheets in hand, a designer can choose between potential system options and configurations. The Audit Reporting Worksheets Excel file contains the following sections:

- **Checklist** of major documents required from the health center.
- **Worksheet 1: Site Description and Information.** This sheet collects basic information about the site. It also contains a data sheet on fuels and energy costs.
- **Worksheet 2: Energy Use Overview.** This provides a basic summary of energy technologies used on site and the applications of the various energy sources.
- **Worksheet 3: Assumptions.** Key assumptions should be documented about amount of solar resource, costs, efficiencies, and other factor that can affect the calculations in other worksheets. They can be changed in different locations and countries, or as situations change.
- **Worksheet 4: Electric Systems.** This contains multiple worksheets that can be filled out with information on up to 2 generators and up to 12 PV systems on a site.
- **Worksheet 5: Generator Applications.** This sheet is to be filled out with information about 240VAC appliances run by the generator set (or dedicated AC power source).
- **Worksheet 6: PV Applications.** This sheet is to be filled out with information about appliances run by the PV arrays at the site.
- **Worksheet 7: Future Electric Applications.** This sheet is to be filled out with information about appliances and equipment that will be added to the health center in the near future.
- **Worksheet 8: Non Electric Applications.** This sheet is for compiling information about non-electric appliances such as wood stoves and kerosene refrigerators and sterilizers.
- **Worksheet 9: Load Profile – Gen Set.** This sheet provides an analysis of the existing load profiles and kilowatt-hour use breakdown of generator loads.
- **Worksheet 10: Load Profile** – Solar **PV.** This sheet provides an analysis of the existing load profiles and kilowatt-hour use breakdown of PV loads.

Worksheets are interlinked so that analysis can be completed easily and quickly.

NOTE: It is important to leave the yellow highlighted cells in all of the worksheets unchanged, as these cells contain calculation formulas. These cells must not be used to record any data.

The Auditing Reporting Worksheets, when completed accurately and in full detail, are intended to be a preliminary guide for analyzing present and future energy systems. These worksheets do not substitute for the process of designing or selecting equipment, which requires specialized training and experience.

2 PLANNING AND EXECUTING AN ENERGY AUDIT

The primary objective of any energy audit is to calculate the amount of energy that a facility will need to produce on a daily basis for the anticipated energy loads on the health center's premises. Energy supplies must be carefully managed because each watt-hour costs money to produce. However, energy supplies also need to be flexible enough to allow the facility to function with fluctuating energy demands and solar energy resources.

An energy audit should help funders of health centers decide which types of energy – solar PV, generators, LPG, grid power extensions, or even biomass – make the most sense at the site.

Thus, the major tasks of health facility energy audits are to:

- Provide a description of the site's energy use patterns and management practices
- Identify areas of potential energy cost savings and more efficient use
- Identify energy management interventions that can achieve further potential savings and efficient use
- Provide recommendations that will enable the design and or expansion of appropriate energy system solutions at the site. For example, the system manager can be guided to decide on a larger generator, a PV/genset hybrid, or better thermal systems.

The implementing partner and health facility should manage the on-site energy audit with assistance from an independent energy expert. Worksheets 1-10 form the basic energy audit template and help guide the process of describing an energy system in a health center. The use of these worksheets is explained carefully in this section.

Before conducting an energy audit, the energy experts should arrange to conduct a field survey of the site. This should be on a normal working day when the staff members are present and using equipment normally. Energy auditors should gather as much information about the site as possible before going there, including floor plans and basic descriptions of the site. Auditors should send the **Checklist** (the first sheet within the Audit Reporting Worksheets) of required documents to the site manager in advance, so these materials can be prepared for the field survey visit. In general, *a full day* should be allocated to conduct an energy audit of a small health facility, though hospitals will require much more time-intensive efforts. By the implementing partners, or government officials responsible for the center should accompany the auditors so that their work is properly facilitated.

Energy auditors should come fully equipped to carry out the survey. Equipment required for conducting the audit includes:

- Notebooks (with graph paper for drawings and floor plans)
- Drawing set
- Worksheet data forms (or laptops to fill data directly into computer worksheets)
- Digital camera (for taking pictures of equipment)
- Voltmeter (a clamp meter is preferred as it can measure current accurately without disconnecting wires) and a multi-meter
- Basic tool kit
- Compass and tape measure

- Solar Pathfinder™ can be useful to identify sun paths.

2.1 Basic Site Information

2.1.1 Initial Meetings and Site Walkthrough

The audit process starts with a meeting with staff administrators at the site to explain the purpose of the energy audit. Before beginning the task of gathering information, the auditing team should engage in a general discussion about energy audit procedures. Usually, a short tour of the site is done at this time so that the auditors can get the "big picture" of the site. Health centers should appoint staff to assist and accompany the audit team during their work.

The auditor will collect basic information on the site as follows (see Worksheet 1, Site Description and Info):

- Size of facility and building configuration
- Number of beds, patients served per month, outreach facilities and/or programs
- Number of staff, departments, and where staff are working (in offices or in clinics/wards/laboratories)
- Operating hours, including normal operating hours, reduced weekend and holiday hours and emergency hours
- Date of establishment, expansion plans
- Distance from the grid and water supply

Auditors should always keep their eyes and ears open. Data collected in worksheets are only as valuable as the overall picture the auditor gathers from *observing* what is happening in real time. For example, the staff may report that a generator is run two hours a day but the actual conditions may differ greatly. This type of informal information is particularly valuable and should be included in the report.

2.1.2 The Site Map and Floor Plans

To design an energy system that will provide service over the long term, a full "picture" of the facility must be drawn up. This picture must include its present status and planned expansions.

A map of the site should be collected or carefully drawn, as well as a floor plan of each building with a north/south orientation description. This should be done to scale, with indications where there are trees or antennas (and any areas of shade that will affect solar module output), the distances between buildings, and the types and inclinations of roofs throughout the facility. The functions of each building should be clearly listed:

- Administration block and/or data processing areas
- Wards (with number of beds in each)
- Operating rooms
- Laboratory
- Counseling blocks (including - audio-visual and training areas)
- Staff houses

- Walkways, corridors, and others areas where there is a need for security lighting or other electricity
- Lavatories, washrooms, laundries, kitchens, storage buildings, guard houses, and other areas.

2.1.3 Fuel Usage and Costs

The next step is to interview the director of the health center or the accountant about energy expenditures (see Section 1.4 of Worksheet 1). The Audit Reporting Worksheets should list the costs and/or prices of energy sources and fuels in the local market. Listing fuel costs will help establish baseline cost comparisons between solar PV, generator sets and other alternatives.

The team should determine all fuel costs by source (petroleum fuels, biomass, PV) and other energy-related costs over the course of a year. This will require an analysis of invoiced fuel consumption using financial records, if possible. It is important to identify the costs of spare parts, maintenance, servicing, and other incidental expenses.

Additional care should be taken to:

- Note whether financial records are available for energy costs – if institutions do not maintain adequate financial records of energy use, this is important. Often poor energy management practices start with poor cash accounting for energy systems.
- Identify the types of fuels that are bought each month and how much is spent on each type of fuel. If the site is remote, the fuel transportation costs should be included.
- Establish the units (liters, kilograms, bags of charcoal) and unit costs of each fuel source at the site.
- Identify the source of these fuels (local market, government delivery), and whether there are any difficulties obtaining fuel.
- Get a clear idea of how much the center spends on all energy sources per month. This information can later be compared with the *operational* data from the various pieces of equipment to get a "reality check."

2.2 Survey of Energy-Supplying Equipment, Energy Management Procedures, and Energy Expenditures

The audit should list all energy supply equipment and their features. All generators, solar equipment, battery back-ups, and other equipment should be catalogued. The condition of each piece of equipment should be ascertained. Photos of equipment are helpful.

2.2.1 Energy Use Overview

During the initial discussions with staff, fill in the Energy Use Overview (Worksheet 2). The purpose of this worksheet is to provide a simple overview of the different sources of energy used for various end-uses at the site. For example, the information recorded on this worksheet may reveal that the wards are lit with generator, PV, and kerosene fuels – a clear sign of redundancy, and an area to be highlighted for possible overall improvements.

Use the table to establish the major appliances in use in the health center and their sources of fuels. Place a check mark to indicate which appliances are used, and give priorities to the major sources of fuels. For example, if a health center lights wards for two hours a night with a generator, and then uses kerosene lamps for the rest of the night, make two or three check marks

for the generator, and one check mark for kerosene to indicate the relative importance of the generator in lighting.

When completing this table, it will quickly become apparent which fuel sources are the most important, and which are most highly prioritized. Do not forget to ask about use of wood and/or charcoal or other non-electric energy sources.

When completing the overview, also complete Worksheet 3, Assumptions, with local information from the country or site. As can be seen in Worksheet 3, design solar radiation, PV equipment costs, equipment efficiencies and other factors will affect the ultimate analysis of the energy system.

2.2.2 Electric Systems

Energy equipment and systems should be observed in use during the survey period to determine their condition, efficiency, and possible wastage of power. In particular, generators and PV systems (especially battery banks) should be examined to determine whether they adequately meet loads and whether they are in good condition.

All required information about generators and PV systems should be listed in Worksheet 4, Electric Systems. Be clear about the condition of generators and PV systems. Are they working? Why or why not? What do staff members think about them? Are these generators and PV systems sited for optimal power generation, and are they installed properly? Are there inverters or power conditioning units in place?

Make careful diagrams of PV and generator circuits and take photos of gensets and PV systems. Do not forget to gather information about generator circuits and system conditions. In particular:

- Existing wiring throughout the site plan should be identified and sketched out by the audit team. It is critical that the audit incorporates information on *existing* facility wiring into energy system designs and plans so that decisions can be made on whether to install new wiring systems or to incorporate the existing wiring set-up into the new design.
- Many off-grid buildings are pre-wired by the builder, based on assumptions that the facility will be connected to the electrical grid. In such cases, schematics or single line diagrams of existing wiring plans are required.
- Some facilities have several power systems (i.e., multiple solar PV systems) or a generator power distribution system. Such systems often each have separate wiring systems. While it might be faster and simpler to just add another new set of wires, the best solution may be to integrate separate wiring systems into a new, comprehensive wiring overhaul.
- In cases where facilities are run primarily on a generator, with some critical loads on PV, it is important to know how the loads are wired (or *not* wired) together. The existing wiring could have a major affect on what the new wiring plan should look like and would also have a large affect on the costs of a resulting request for bids. For example, the installation may require utilizing some existing wiring, and re-routing, separating, or disabling other existing wiring.

Auditors should be aware of any unsafe procedures in place at the site during the survey, including:

- Unsafe equipment operation practices (i.e., filling petrol generators near kitchens)
- Dangerous appliances, including any ungrounded appliances
- Faulty circuitry
- Generators or batteries not properly housed or installed without ventilation

- Fuels that are not properly stored
- Any other safety concerns

2.2.3 Non-Electric Energy Systems

Identify all major non-electric and fuel based systems in use at the health center, using the Worksheet 8,"Non-electric applications". Be on the lookout for alternative energy systems (biogas, wind pumps, solar thermal) and hand-powered devices like centrifuges and hand pumps that play important roles in hospital operations

In particular, identify and characterize use of the following appliances in the center, being sure to identify and quantify fuel use:

- Absorption refrigerators (note if they are dual kerosene/electric use)
- Lighting (paraffin, pressure, gas lamps)
- Sterilization (gas, pressure cooker, etc.)
- Water heaters (solar, wood, charcoal)
- Cooking equipment. How is food cooked for patients and staff? Please note type of stoves, fuels, practices, and conditions.

2.3 Census of Present Appliances and Planned Appliances

2.3.1 Current Electric Appliances

Use the Generator Applications and PV Applications worksheets (Worksheets 5 and 6) to list all appliances and their respective condition, energy consumption, duty cycles (hours per day), and source of power. The location of each of the appliances also should be listed. Note any lights and appliances that are broken, performing poorly, or simply not in use.

When asking staff about daily use of appliances, avoid taking everything that is said literally. For example, if a staff member says a computer is used 8 hours – and this seems to be an "over-estimation" – try to get an accurate figure from someone else. Energy use is often over/under-estimated by poorly "guessed" end-use data. Energy auditors should plan to think twice about what people say on site. One strategy is to ask several different people discreetly the same questions about appliance usage, and consider the range of answers when filling in the worksheets.

If possible, measure the energy use of electrical appliances that are not clearly marked.

2.3.2 Future Electric Appliances and their Use

List all appliances that the facility plans to obtain in the future in Worksheet 7. Future lab or appliance acquisitions should be noted. To get an idea of future appliances to be installed and budgets available, speak with all players in decision making, including the health center executive officer, the NGO administering the center, and government officers.

It is important to discuss future loads with government officials, NGO sponsors, program officers, or other players involved in procurement for health centers. Responding accurately to this question *requires* the involvement of people off the site.

Details of existing and future loads should include the following:

- Lighting
- Medical and lab equipment
- Information and communications technologies
- Cold chain and refrigeration
- Sterilization
- Water purification
- Cooking
- Water heating
- Water supply and feed
- Staff housing

The end result of the calculations on future electrical appliance use should be an estimated increase in electric energy use (in kWh) and peak energy demand (in kilowatts).

2.4 Quality of Existing Energy Supply

Audits should include views of the administration, staff, and management on the quality of the energy systems and their effectiveness.

- Which appliances are not functioning well and why?
- Find out what appliances the staff does not wish to use any more, and the reasons why.
- Find out whether the staff has a strong preference for a certain type of appliance and why this is the case (i.e., electric refrigerator over kerosene refrigerator, electric autoclave over kerosene).

Questions to ask about energy system quality include:

- Generator operation
- PV systems performance
- Quality of appliances (lamps, sterilizers, refrigerators, etc.)
- What is the staff's first priority in improved energy availability?
- Would staff like an improved energy supply? Which aspects, in particular?
- Are there parts of the energy system that prevent staff from conducting their job adequately?

2.5 Energy Management Practices, Procedures, and Problems

Often, the problems with energy systems in off-grid areas reflect management and maintenance problems to a large degree, rather than poor equipment. The audit team should therefore gather information about energy management by asking questions, checking maintenance records, and observing how equipment is handled and maintained at the site.

Important components of energy management that need to be captured are:

- Who is responsible for maintaining, fueling, and servicing *all* the energy systems? To what extent is this work monitored and completed? If no one is responsible, note this fact.
- Who is responsible for management of energy systems (allocating funds for purchase of equipment, setting up timetables for operation of generators, PV appliances, and other similar tasks)?
- Are there any *established* procedures for operating gensets, PV appliances, and major loads? Are these procedures written down?
- Does the head of the health center play a role in energy management?
- Are records kept for use of fuels and purchases of equipment?
- Is there any established program for energy conservation or management (especially in PV systems where energy availability decreases during cloudy periods)?
- Note major problems related to poor energy use management. For example, does the generator appear to be used ad hoc? Are PV systems misused or by-passed by staff? Are batteries empty because of a lack of energy end-use management or because of poor design? Remember that *observations* of actions by staff are as important as questions asked in this section.

3 WRITING THE ENERGY AUDIT REPORT

3.1 Analysis of Collected Data

Use Worksheets 1 – 8 to analyze the collected data and develop a profile of the energy situation at the site. A basic analysis of energy loads will be completed in Worksheets 9 and 10. Worksheet 9 provides an analysis of the existing generator loads and Worksheet 10 provides an analysis of the existing PV loads as illustrations.

- If possible, any questions that come up during the analysis should be raised with the facility and implementing partner. In addition, any key data that was not available on the day of the survey should be pursued.
- Analyze all energy sources (generator electricity, PV electricity, fuels, etc.) and their costs over an annual period. The actual measured used of each fuel and the fuel purchase costs should be used to determine which sources of energy are most cost effective and pragmatic.
- A break up of appliance energy peak demand load demand should be done carefully. This analysis should also list the appliances having high demand load requirements.
- An analysis of planned site expansions should be made, with the energy requirements of the expansions and the implications of these on the choice of energy systems
- Opportunities for fuel switching, use of more efficient appliances, and changes in energy technologies should be considered based on the data.
- Important factors in energy systems including human resources, security, isolation of the site, and long-term financing also should be considered.

3.2 Preparation of Energy Audit Report

The analysis of the data and potential recommendations for the site should be presented in a report. This should be prepared in a short form, according to a standardized Audit Report template (see Annex).

The report should detail findings and recommendations in the following areas:

- *Executive summary.* This outlines the major findings of the audit. The summary should also show tables of individual recommendations that demonstrate both low-cost measures and capital expenditures. The summary should recommend which types of energy systems should be used in future expansions.
- *Site description and information*. The site, its functions and services should be described. Building plans or site plans should be included.
- *Energy system and use descriptions.* This section should outline the existing uses and future needs. It should contain information about all energy systems in the location.
- *Energy use and costs summary.* Based on information obtained from fuel expenditure records, observed consumption, and the corresponding analysis and calculations, the following should be shown in the report:
    - Current energy use and targeted future energy use

    - Table showing consumption, unit costs, and total costs for all purchased fuels for the previous 12 months
    - Table showing percentage changes in energy costs over the previous 12 months
    - Table(s) and pie chart(s) showing breakdowns of fuel types and costs for each major fuel user[4]
- *Energy management*. This section should describe energy management procedures (or lack thereof) at the site.
- *Recommendations*. This section should outline the steps that should be taken to improve the energy situation at the site, taking into account future costs, expansion plans, manpower, and local supplies. This analysis should estimate the size and type of equipment to be added as well as their operating and maintenance costs. See below. It should also recommend energy management strategies at the site. In recommendations, try to work within *estimated budgets* available for improvements.
- *Appendices.* The final section of the audit report should include floor plans, energy system wiring diagrams, calculations, and miscellaneous data relevant to the energy audit report (worksheets can be attached).

[4] Although it may not be possible to get exact numbers on non-electric energy use or costs, it is extremely useful to estimate amounts of energy used and costs to end-users.

ANNEX: OFF-GRID ENERGY AUDIT REPORT TEMPLATE

1.0 Executive Summary

2.0 Site Description and Information

2.1 General Information

- Location, environs and distance nearest urban center and the grid.
- Size of facility and building configuration
- Number of beds
- Number of patients served per period
- Operating hours, including normal operating hours, reduced weekend and holiday hours, and emergency hours
- Date of establishment, expansion plans
- Water supply
    - ✓ Source
    - ✓ Usage (cubic meters per month)
    - ✓ Storage capacity
    - ✓ Problems (quality, shortages)
    - ✓ Pumping requirements (gravity, electricity).

2.2 Staff

- Number of staff members
- Departments
- Leadership and terms served
- Deployment of staff members in offices
- What office equipment is ideally expected by these staff

2.3 Facilities

Describe all major facilities and/or buildings and their functions. If there is more than one facility list each building and describe the sections located in each including:

- Administration block and/or data processing areas
- Wards (with number of beds in each)
- Operating rooms
- Laboratory (indicate whether standard HIV testing equipment has been installed)
- Counseling blocks (including audio-visual and training areas)

- Staff houses
- Walkways, corridors, and others areas where there is a need for security lighting or other electricity

The floor plans of all buildings should be included in the appendices to the energy audit report.

3.0 Energy Systems, Applications and Use Descriptions

3.1 Electric Power Systems

3.1.1 Generators

For each generator, the following information should be included:

- Size, model, serial number
- Technical details (fuel type, phases, kVA, etc.)
- Record output of genset under normal load and peak load (using meter on genset). Observe behavior of generator during peaks and normal loads
- Date installed, hours operation (hours/day)
- Condition – Have there been major overhauls? If the generator has broken down, record when it stopped being used and why.
- Appliances – List all appliances on each generator. Fill a data sheet with characteristics (load, number, surge load, hours of use) of all generator-powered appliances. Is the load balanced? Is the generator adequately sized? Is it over-sized?
- Fuel consumption
- Housing (is there a shed?)
- Wiring (circuit breakers, fuses, observed problems in wiring)
- Maintenance (who is responsible, how often are services made, are there service records?)
- Other relevant details (layout of generator wiring, switching, etc)

If generators are used independently of PV systems (other generators) note which loads they serve. Note also if there are parallel wiring systems (i.e., if there are 240V AC and 12VDC loads in the same room)

Make careful diagrams of generator circuits and take photos of the genset–. Include this documentation in the audit report appendices.

Provide a short analysis of the generator circuits and system conditions.

3.1.2 Solar PV

For ***each*** PV system, the following information should be gathered:

- Date of installation and company
- Components: Size, model, serial number of batteries, modules, regulators, inverters
- If possible, measure output (Isc) of modules during peak sun period
- Technical details (fuel type, phases, kVA, etc.)

- Appliances. Fill a data sheet with characteristics (load, number, surge load, hours of use) of all PV-powered appliances. Is the PV system adequately sized? Is it over-sized? Are there unintended appliances that have been added at a later date?
- Maintenance history and records (if any)
- Condition and performance
- Observed problems or misuse of system
- Power conditioning units. Describe each (voltage, capacity, waveform, surge, manufacturer). Mention if inverter is integrated with generator.

Compile a summary of the PV systems in the following table.

PV System/ Location/ Condition	**Size & Voltage**	**Components**	**Appliances Powered**	**Installing Company & Year of installation**

If there are specialized/single use PV systems (i.e. radio call, water pumping) mention them and describe.

Make careful wiring diagrams of each PV system's circuits *including* load side. Take photos of interesting features to include in the appendices.

Provide a short analysis of the PV systems and their operating characteristics.

3.2 Fuel-based and/or Non-electric Energy Systems

List all non-electric equipment and devices that are powered by fuels, including kerosene, LPG, wood, charcoal, etc. These should include:

- Absorption refrigerators (mention if they are dual use)
- Lighting (paraffin, pressure, gas lamps)
- Sterilization (gas, pressure cooker, etc)
- Water heating (solar, wood, charcoal)
- Cooking, noting type of stoves and how food is prepared for patients and staff.

For each fuel type provide specific details on price, usage, and availability:

- Kerosene: Monthly use, price, availability
- LPG: Monthly use, Availability (nearest source), price
- Charcoal: Monthly use, price, availability, seasonality
- Wood: Monthly use, price, availability, seasonality

- Dry cells; Monthly use, price, availability, seasonality
- Other biomass
- Biogas (size, dates of installation, applications, condition)
- Solar thermal (whether used for cooking or water heating, etc.) (size, dates of installation, applications, condition)
- Wind mechanical
- Hand pumps
- Human-powered devices

Take photos of sample energy systems (i.e., inefficient wood stoves, method of sterilizing)

Collect information about monthly use and expenses of fuels for each non-electric system.

3.3 Future Energy Needs

Provide details on the critical future energy needs of the site, including:

- New appliances to be added
- New energy systems to be purchased
- Plans for grid extension

4.0 Total Energy Use and Costs Summary

The audit should attempt to estimate energy use at the site in kilowatt hours/day and month (for electricity) and MJ per month for fuels. It should them break down these uses by categories and appliances. The point of the exercise is to identify inefficient or expensive uses of energy (i.e., use of PV for heating) and be able to inform the system owners of these problems.

Include table in appendices for base numbers (energy densities, cost of fuels) to use in calculations.

Energy Source	Total Use (kWh or MJ)	Total Cost	Unit Cost/MJ or kWh
Electricity (Generator)			
Electricity (PV)			
Kerosene			
Biomass			
Etc.			

4.1 Electricity Systems

Develop pie charts showing appliances and systems where energy is being used and estimate which appliances use the most electric energy. Do this for PV and generator systems.

4.2 Thermal and Fuel-Based Systems

Develop pie charts showing appliances and systems where energy is being used and estimate which appliances use the most electric energy.

5 Energy Management Practices, Procedures, and Problems

The audit team should therefore gather information about energy management by asking questions, checking maintenance records, and observing how equipment is handled and maintained at the site. Important components of energy management that need to be captured are:

Energy Management	Responsible Agent Name	Comment
Maintenance of fuel stock		
Allocation of funds for new and spare equipment procurement		
Established procedure for record keeping		
Energy Conservation Program		

6.0 Recommendations

The recommendations should provide the system managers with a basic practical list of things they can do to improve the energy system's functionality and lower its costs. All suggested improvements and changes should be given an indicative cost level (no-cost, low cost, medium cost, high cost[5]), This section should lead to the next stage of the process in system investment, which is consultation with the client on actions and cost of actions, and suggestions on design of system improvements.

Zero-cost and low-cost improvements have to do with management and scheduling of system operation. For example, putting light circuits on timers, or having staff turn lights on and off at set times can save considerable amounts of energy.

Medium-cost improvements usually have to do with upgrading systems, making major repairs, or buying better appliances. For example, switching all bulbs from incandescent to fluorescent, or replacing a battery or solar module that is broken, can yield significant savings at a reasonable cost.

Higher-cost recommendations have to with investments in new equipment or altogether new systems.

6.1 Summary of Recommendations

Provide recommendations in a short table. This table should also appear in the executive summary.

[5] No cost: $0, Low Cost <$500, Medium Cost $501-$5000, High Cost >$5000.

Suggested Improvement	Potential Energy Use Improvements (Functionality, Cost)	Priority	Cost

6.2 Appendices

A Floor Plan

Map of the site be prepared with a floor plan of each building with a north/south orientation. This should be done to scale, with indications where there are trees (and shade which will affect module output) the distances between buildings, and the types of roofs of each site. The functions of each building should be clearly listed.

B Electric System Configurations

Generator set configurations

PV system configurations

C Photos

D Worksheets