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POWERING HEALTH

ENERGY MANAGEMENT IN YOUR HEALTH FACILITY

"Consistent energy management by health clinic managers and staff is essential to ensure that their facilities have power when they need it, so they can better serve their local communities. Good energy management is not just about how to use an energy system—it also encompasses the active role that the facility manager and staff can play in balancing the energy they have available with the requirements of the facility. Successful energy systems necessitate constant work on the part of health facility staff to understand what their energy system can, and cannot do, and to use their available energy wisely. Failures to understand, manage, and maintain energy within health clinics have led to many broken, useless systems, which prevent health workers from providing the services their communities so desperately need."

– ROBERT FRELING, EXECUTIVE DIRECTOR, SOLAR ELECTRIC LIGHT FUND

Cover photo courtesy of Walt Ratterman of Sun Energy Power International, SunEPI.

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www.poweringhealth.org

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Walt worked with the USAID Energy Team to improve the supply of energy to schools and health facilities in Rwanda, Haiti, Guyana, Zambia, Ethiopia, Senegal, and Ecuador. He was also a principal contributor to many of the tools the Energy Team developed over the past few years to improve understanding and use of clean energy technologies. On January 12, 2010, while working in service to USAID, Walt was a victim of the devastating earthquake that hit Haiti. Not only did Walt contribute significant on-the-ground insight, technical knowledge, and wonderful photographs to the development of this publication, he selflessly worked to improve the quality of life of those most in need. Walt dedicated his professional career to working in some of the most difficult areas across the globe—often in dangerous situations—to help people obtain health care, water, and electricity. Most importantly, he provided the knowledge, skills, training, and friendship to help the poor lift themselves out of poverty. Walt was a tireless and gentle spirit who touched many people worldwide. He will be greatly missed by those of us who worked with him.

PHOTOS COURTESY OF PAM BALDINGER AND JEFF HAENI, USAID

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PHOTO: WALT RATTERMAN

A row of electrical devices commonly found in a health center laboratory.

INTRODUCTION

"Health and energy are interdependent factors." – THE WORLD HEALTH ORGANIZATION

As a health clinic manager, doctor, nurse, or technician, the most important part of your job is keeping patients healthy. There are many things that you depend on, including:

- Trained personnel
- Physical facilities
- Medical equipment and instruments
- A supply chain system to ensure consistent availability of drugs and medications
- Effective staff management
- Communications, data collection, and outreach capabilities

Each of these will benefit from access to reliable energy service!

Electricity keeps the clinic lights on. It enables the vaccine refrigerator to run, keeps blood supplies safe, provides power to lab equipment, and allows your staff to communicate via phone or computer. As your clinic adds new programs and serves larger populations, the demand for electricity will rise. These increases in energy demand may be sudden, such as during the preparation period for a vaccination program; or may happen gradually, for instance when lighting and equipment are used for longer periods of time each day to serve growing numbers of patients. Health facilities, particularly those located in rural areas, typically lack "grid power" and are forced to generate their own electricity to meet energy needs. In contrast to grid-connected facilities, when off-grid sites increase their energy use (which can result from both adding new equipment and poor use of existing equipment), the impacts can be more severe than just paying higher electricity bills. If electricity runs out, lives can be lost. Thus, effective management of off-grid energy systems needs to be given as high a priority as management of other vital medical systems at your facilities (e.g., vaccines, sterilization, and blood bank supplies).

Regardless of the off-grid energy source—diesel/kerosene generator, solar panels, wind, or hydropower—the cost of electricity from on-site generation systems tends to be expensive. Careful management of energy consumption can help to minimize the risk of electric shortages as well as capital investments in energy equipment, thereby reducing operating expenses.

Powering Health: Energy Management in Your Health Facility is a resource for health professionals seeking to make better use of limited energy supplies. The guide assumes your health care facility already has electricity access, but presumes that more effective management of this limited resource will improve your ability to provide routine, quality health services on demand.[1] Its focus is on three areas:

- Why and how to implement energy management in your facility
- Forming an energy team, with associated roles, responsibilities, and tools for support
- The importance of energy-efficient practices and equipment

The primary audience for this guide is facility managers who must ensure their facilities can supply energy for health care delivery. The information provided here should also help health care staff to perform their jobs more effectively and can help guide decision-makers—including government ministries and donors—to make informed choices when supplying appliances and equipment to health facilities that require energy to operate.

[1] This serves as a companion document to *Powering Health: Electrification Options for Rural Health Centers*, which assists facilities that do not have power in the design of energy systems to meet their needs (http://pdf.usaid.gov/pdf_docs/PNADJ557.PDF)

A STEPWISE APPROACH TO ENERGY MANAGEMENT

WHAT IS ENERGY MANAGEMENT?

Energy is a necessary resource for all health care facilities, whether a large health clinic with electronic and diagnostic equipment or a small rural health post. Energy management enables health facilities to realize more benefit per unit of electricity. Managing energy is similar to managing money—you want to make sure the money you have now is enough to purchase the food you will eat today, as well as to pay your child's school fees at the end of the month. In the same way, you want to make sure you have enough energy to power your facility today, while ensuring sufficient energy to operate your facility tomorrow and the next day. *This takes careful planning*.

Energy management is as much about human behavior and management as it is about technology. The actions of your staff will have a major impact on the amount of energy your health center consumes. This manual will help explain this critical relationship and guide you in developing an effective energy management strategy for your facility.


PHOTO: WALT RATTERMAN, SUNEPI

A lab technician performs blood tests at a health clinic in Haiti. All staff can play a role in effective energy management.

WHY IS ENERGY MANAGEMENT IMPORTANT?

Energy management determines not only how much electricity you have available to run your facility, but also how you use that power. Energy management will help you to:

- Maximize the lifespan of energy systems through proper operation, use, and maintenance.
- Keep energy costs as low as possible so more money is available for medicines and other important medical necessities at your facility.
- Ensure that energy is available whenever and wherever it is needed.

Having reliable energy can save patients' lives. As health care services improve through new equipment and practices, a reliable energy supply becomes increasingly important.

In many instances, energy equipment and supply decisions may occur outside the health care facility. For example, a national government agency or donor may provide a diesel or solar system to meet the needs of a rural facility, often without input from you or your staff. Energy use and management decisions, on the other hand, take place at the facility level, and therefore the long-term success of the energy system is one of your responsibilities.

This guide will help empower facility managers and staff so that regardless of where energy supply decisions are made, you will have procedures in place to get the most out of your energy system—and will know how and where to obtain assistance when necessary.

A rural health clinic in Ethiopia.

PHOTO: WALT RATTERMAN

HOW IS ENERGY MANAGEMENT ACCOMPLISHED?

This manual lays out five basic steps for effective energy management. Following these steps will help to keep your energy system functioning on a consistent basis, and even prevent system failure and theft.

Additionally, this guide contains practical tools for energy management, including energy usage logs, training guidelines, and other useful tips. The tools are specially designed for use by you and your staff—typically non-energy experts—and may be adapted to meet the specific needs and conditions of your health facility.

Further, to help you understand the best ways to put these tools into practice at your own health care center, this guide uses a hypothetical facility—the "Sanitas Clinic"—as an example to explain the concepts contained in each step. The Sanitas Clinic examples are found in boxes throughout the document. Additional case studies illustrate concepts found in each of the steps.

STEP 1: Identify and Prioritize Your Facility's Energy Needs

↓

STEP 2 : Understand Your Energy System

↓

STEP 3: Establish Your Energy Management Team

↓

STEP 4: Operate and Maintain Your Energy System

↓

STEP 5: Improve Energy Use

PLEASE NOTE...

Before making changes or implementing your energy management program, seek assistance from an expert familiar with the equipment and wiring in your facility in order to develop the most appropriate energy management strategy.

PHOTO: JEFF HAENI, USAID

This solar-powered vaccine refrigerator installed by the World Health Organization in Port Salut, Haiti, has worked well for two years, thanks to proper energy maintenance and management.

EXAMPLE SCENARIO

THE SANITAS CLINIC

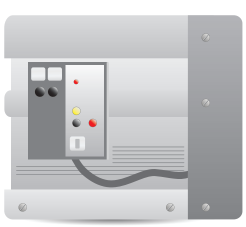
Throughout this guide, the Sanitas Clinic will serve as a hypothetical case study or example to demonstrate typical energy usage at a rural health facility. The intent is to provide examples of a good energy management plan, suggestions for efficiency improvements, and the types of energy challenges that you may encounter as you follow Steps 1–5 in this guide.

The Sanitas Clinic is located in a tropical climate in a rural area, about 40 kilometers from the nearest town. The clinic has the following equipment that requires energy: indoor and outdoor lighting, a vaccine refrigerator/freezer, a radio/cassette player, a laptop for record-keeping, an all-purpose microscope, laboratory equipment for blood typing and screening, and a small blood bank refrigerator. Staff quarters have lighting and one outlet for phone charging or radio use. The clinic needs heat only for sterilization of equipment. Staff meals are cooked using an improved charcoal cook stove. Water is supplied from the community hand pump located nearby. The clinic has a waste incinerator built of bricks that uses firewood.

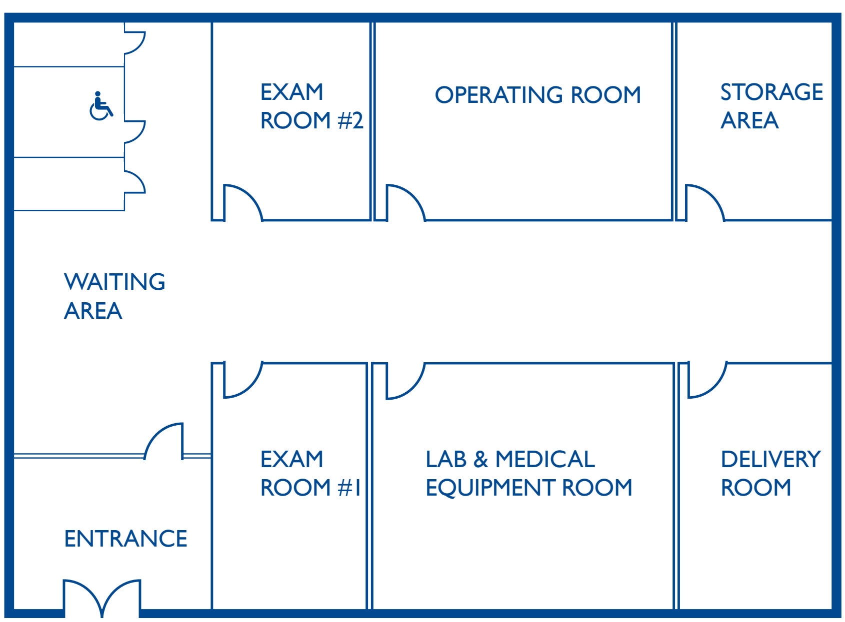
The clinic gets its electricity from a solar system that consists of solar panels mounted on the clinic roof; a battery bank of sealed batteries; and a charge controller and inverter (these components are described in Step 2). The vaccine refrigerator has its own dedicated solar panel and battery. The nearby staff quarters receive energy from a line that comes from the clinic building. The clinic also has a small generator provided by the Ministry of Health that is used only as back-up power during emergencies, due to the high cost of diesel fuel. The clinic is run by a head nurse and ten other staff members, including four nursing assistants who cover 12-hour shifts, two midwives, a social worker, a technician who administers vaccines, a security guard, and an office manager. The medical staff sees about 50 patients per day.

THE SANITAS RURAL HEALTH CLINIC (Hypothetical)

Solar power system to charge b[illegible] vaccine



Diesel generator as needed – for both clinic and living quarters



Representative power-consuming equipment – lighting, refrigerator, radio, laptop, microscope, lab equipment, etc.

STEP 1

IDENTIFY AND PRIORITIZE YOUR FACILITY'S ENERGY NEEDS

Understanding the ways in which energy is used in your facility is the first step in creating an energy management plan. Effective energy management will make the energy available to your facility last longer, which saves energy and reduces costs.

Figuring out your energy needs will require you to do the following:

- Determine your current energy load, or total consumption for all appliances or devices, as well as for the facility overall.
- Prioritize energy loads, including identifying those that are "critical" to the operation of the facility.
- Estimate future energy requirements.

DETERMINE YOUR ENERGY LOAD

In order to manage energy use, it will be necessary to determine the amount of electricity consumed by the appliances/devices at your facility—a calculation frequently referred to as the "energy load." This information should be obtained from the original energy system designer. If this is not possible, the following activities should be undertaken to estimate your energy load.

- **Make a list of all appliances/devices that use power in the facility.** Include energy-dependent appliances and lighting in medical rooms, office space, staff quarters, areas around the perimeter of the facility, etc. This should also include any appliances/devices in use by facility staff for non-medical purposes, such as radios, irons, and cell phone chargers. Everything that uses electricity should be considered.
- **Identify how much power each appliance consumes.** A label should be located on the appliance or device that identifies the amount of power it uses, typically provided in watts. The label may be printed directly on the device, or it may be located on the power adapter that connects the device to a power outlet on a wall or to a surge protector. If this information is not readily available, consult the operating manual that came with the device. Appendix A includes a list of equipment commonly used in many health care facilities, with estimated energy consumption levels of each appliance or device.
- **Estimate how many hours each piece of equipment is used every day.** Provide your best estimate of how many hours per day energy-consuming equipment is used.
- **Calculate the total energy load of the facility each day.** To measure total electricity consumption, multiply the wattage for each appliance or device by the number of hours that it is used each day. This calculation will give you a number measured in watt hours per day.

As an example, Table 1 demonstrates how the daily energy consumption levels in watts per day (Column E) are derived for eight compact fluorescent light bulbs (multiply columns B, C, and D).

TABLE 1

CALCULATING ENERGY LOAD FOR COMPACT FLUORESCENT LAMPS (CFLS)

A	B	C	D	E (Multiply Columns BxCxD)
Energy-Consuming Device	**# of Devices**	**Power Consumption Device (watts)**	**Hours Used Per Day**	**Energy Consumed Per Day (watt hours)**
Compact fluorescent light (CFL) bulbs	8	18	8	1,152 watt hours (= 8x18x8) or 1.2 kilowatt hours

Do this calculation for all electricity-consuming appliances/devices in the facility, and add up the total number of watt hours used by all to determine the overall energy usage, or system load per day. A blank template for use in calculating the energy consumption at your facility can be found in Appendix A and online at http://tools.poweringhealth.org/. Though this calculation will not give an exact load estimate for your facility, it provides a good start and can be modified as better information becomes available. The Sanitas Clinic example at the end of this chapter illustrates this process in more detail.

PRIORITIZE LOADS

Each health clinic will have a mixture of critical and less-critical loads. Descriptions of key load categories are provided below.

- **Critical load:** Critical loads are those appliances or energy-consuming facility services that must be running at all times. Interruption or loss of power for critical loads can endanger patient's lives. For most rural or off-grid health facilities, the most critical load will be a vaccine refrigerator, which might also store blood and other medications. Appendix B has information on the pros and cons of various refrigerators for meeting vaccine and other health care needs.

  Ideally, critical loads are protected by a dedicated power supply. This refers to a single source of energy—such as a diesel generator or a battery bank—that is dedicated or used for only one critical load (e.g., all operating room equipment) or one piece of critical equipment (e.g., vaccine refrigerator). In these cases, the operating room or vaccine refrigerator would be wired directly to the generator or solar power system—ensuring that the critical equipment receives a reliable source of power at all times.

- **Important load:** Refers to appliances/devices that are important as power is available. For example, when a patient comes to a clinic during the evening for emergency surgery, lighting is vital to perform the task. While it is not impossible to perform surgery by candlelight or a lantern, having electric lighting available clearly would be the preferred option. Other important loads include computers, printers, and radios.

- **Non-critical load:** Refers to appliances/devices that are helpful but not essential. This could include a fan to make a patient more comfortable on a hot evening, or an iron to press staff uniforms or bedding. Off-duty staff needs or personal use of equipment, such as computers, are also non-critical load. Non-critical equipment should only be used if there is extra power after critical and important equipment have been accounted for in the energy mix.

Facility management and staff will need to determine which loads are critical for meeting their needs and ensure that these priorities receive the energy required. Prioritization of other loads in terms of essential and non-critical will also need to be conducted so staff members explicitly understand how to allocate energy supplies in the event of a power shortage.

ENERGY MANAGEMENT FOR CRITICAL LOADS

Even though critical energy loads may have their own dedicated power source, effective energy management is still necessary—as it is for all electricity-consuming appliances. For example, each time you open the vaccine refrigerator to take out an ice pack, you likely will make the refrigerator consume more energy to maintain the desired temperature. By planning in advance, you can reduce the number of times the refrigerator is opened and therefore minimize its energy consumption.

ESTIMATE FUTURE REQUIREMENTS

When assessing energy loads, it will be important to include information about appliances and devices that will be added to the health facility in the near future (e.g., 12-18 months). This should include appliances that your facility plans to purchase directly, or is scheduled to receive from other sources such as a government agency or donor organization. For each appliance/ device it will be necessary to estimate expected energy usage—both watts and estimated hours to be used per day—as you did to calculate the current energy load. Appendix A includes a section on estimating energy requirements for future appliances.

This information will be useful in determining whether there is sufficient power available for the new equipment, given present loads. If not, some appliance operations will need to be curtailed or halted altogether, new power generation equipment added, or the installation of the new appliance will need to be deferred until additional energy system capacity is available.

STEP 1 TASKS:
Document facility energy needs, establish critical loads, and identify additional energy requirements for the near future.

PHOTO: JEFF HAENI, USAID

Determining the critical load as part of a training session in Haiti.

SANITAS CLINIC

THE STAFF MEASURES THEIR ENERGY USE

The Sanitas head nurse and two nursing assistants make a list of all the equipment that uses energy in their facility and staff quarters, and try to find out how much power each piece of equipment consumes. In some cases, they find the power consumption listed on a label on the bottom or side of the device; in other cases, they have to make a few phone calls. The district health office is able to give them some information; the service provider who installed their solar power system is also helpful at estimating how much energy certain types of equipment will consume. Finally, the staff sits down and estimates how many hours each piece of equipment is used per day. They put all of this information into a table. To get the total energy consumed at the clinic each day (column E), they multiply columns B, C and D. The staff also prioritizes the importance of various appliances according to critical, important, and non-critical facility needs.

A	B	C	D	E (Multiply B x C x D)	F
Energy-Consuming Device	**# of Devices**	**Power Consumption (watts)**	**Hours Used Per Day**	**Energy Consumed Per Day (watt hours)**	**Device Priority**
Blood bank refrigerator	1	70	24	1,680	Important
Blood chemistry analyzer	1	50	2	100	Important
CFL bulbs, clinic (indoor lights)	8	18	8	1,152	Important
CFL bulbs, staff quarters (indoor lights)	5	18	4	360	Non-Critical
CFL bulbs (outdoor lights)	4	26	8	832	Important
Clothes iron for bedding, sheets, towels, clothes, etc.	1	1,000	1	1,000	Non-Critical
Examination lamp (CFL)	1	18	4	72	Important
Laptop computer	1	35	8	280	Important
Microscope	1	30	3	90	Important
Operating table lights	2	100	3	600	Important
Phone charger	1	20	6	120	Non-Critical
Radio/cassette player	1	60	18	1,080	Non-Critical
Vaccine refrigerator/freezer	**1**	**60**	**24**	**1,440**	**Critical**
TOTAL LOAD (in watt hours consumed per day)				**8,806 or 8.8 kWh**	
Future Loads					
Electronic centrifuge machine	1	575	2	1,150	Important

STEP 2

UNDERSTAND YOUR ENERGY SYSTEM

In developing and implementing a successful energy management program it is important to understand the nature of the energy system that is currently powering your facility and the "capacity," or total potential power, of the system. Understanding the total amount of power available to you, and coupling this with the power needs of your facility as determined in Step 1, enables you to manage your energy supplies more effectively to meet demand.

HOW DO YOU GET YOUR POWER?

Your energy system will generally fall into one of three categories.

1. **Grid-connected electricity** that is provided by the national power grid or a regional grid, and is normally operated by an electric utility company. This will typically be the least expensive of the energy options if it is available. However, the power can still be expensive for your health facility.

Ideally, where a national or regional grid connection is available, your facility should be able to obtain the amount of electricity it needs for daily operations. As your energy demand increases, the utility should be able to meet your needs. In many countries, however, the local electricity grid can have power shortages, blackouts, and brownouts, making your energy supply unreliable. In these instances, a back-up power generation or storage source such as a diesel generator and/or a renewable energy-based system may have been obtained for your facility. This back-up power source provides more limited power supply than does the grid, but can be invaluable during times when the grid is "down." The disadvantage is that diesel fuel to power the back-up generator can be costly and difficult to obtain.

2. **Partial-grid electricity**, whereby the facility is connected to a local power producer or a locally operated grid. This power can also have reliability issues, and may therefore require a back-up energy system.

3. **No grid, or off-grid power**, where your facility utilizes on-site power generation. For smaller off-grid health facilities with relatively low load requirements, a solar power system that is properly designed and maintained often provides the most economical source of power. For larger facilities, a diesel generator, generator with battery, or hybrid system (e.g., a system that uses a combination of diesel generator, photovoltaic array, and batteries) are the preferred options. These systems are designed to provide a limited, specific amount of power and require facility staff to monitor their energy usage closely so they do not use more energy than the system can produce.

A brief description of typical on-site energy systems that can service rural health clinics is provided in Table 2. In general, this guide focuses on option 3 above—rural or off-grid health facilities that are required to generate their own electricity to provide energy for lighting, critical medical equipment, refrigeration, office and communications functions, and other purposes. However, much of the information in this manual also applies to facilities connected to a grid, particularly in cases where battery back-up or uninterruptible power supply (UPS) systems are used to provide electricity in times of blackouts.

DETERMINING THE AMOUNT OF POWER AVAILABLE TO YOUR FACILITY

To determine your energy supply, the first point of contact would be the facility engineer or maintenance person who oversees the system, if one exists. Alternately, you should contact the system supplier who installed the system or the energy service provider you work with. If none of these attempts are successful, the following descriptions will help you estimate the supply yourself.

For diesel and renewable energy systems, power ratings are typically found on the energy-producing equipment. This information also will be available in the operating manuals that should have been provided when the equipment was

TABLE 2

BRIEF OVERVIEW OF ON-SITE ENERGY SYSTEMS

PHOTOVOLTAICS (PV): PV panels convert sunlight directly into direct current electricity. PV panels, having no moving parts, are highly reliable, long lived, and require little maintenance. In addition, PV panels are highly modular. It is easy to assemble PV panels into an array that can meet any given size load. The main disadvantage of PV is that it has a relatively high capital cost up front— though these costs are rapidly declining. Despite the high initial costs, especially for small systems, PV is often a cost-effective option as it does not require expensive fuel for operation.

WIND: Wind turbines convert the energy of moving air into useful mechanical or electrical energy. Wind turbines need somewhat more maintenance than a PV array, but with moderate winds (greater than 4.5 meters per second) will often produce more energy than a similarly priced array of PV panels. Like PV panels, multiple wind turbines can be used together to produce more energy. Wind turbine energy production tends to be highly variable; therefore wind turbines are often best combined with PV panels or a generator to ensure energy production during times of low wind speeds.

HYDRO: Hydropower systems use the energy in flowing water to produce electricity or mechanical energy. Although there are several ways to harness the moving water to produce energy, run-of-the-river systems, which do not require large storage reservoirs, are often used for micro-hydro, and sometimes for small-scale hydro projects. Small hydropower projects offer emissions-free power solutions for many remote communities throughout the world. In Haiti, for example, localized hydropower systems are being considered for on-site power generation at health care facilities to augment or replace poor quality grid or diesel generator power.

DIESEL- OR GASOLINE-POWERED GENERATOR: Generators consist of an engine driving an electric generator. Generators run on a variety of fuels, including diesel, gasoline, propane and bio-fuel. Generators have the advantage of providing power on demand. Compared to wind turbines and PV panels, generators have low capital costs but high operating costs.

PROPANE/KEROSENE: Many rural health clinics in developing areas are without electrical power. In a variety of cases, propane-fueled refrigerators are used to provide vaccine preservation; more widely used kerosene-fueled refrigerators are also available but do not provide adequate vaccine preservation. (See Appendix B)

BATTERIES: Batteries are used to store energy that is used as direct current (DC), but can be converted to alternating current (AC) using an inverter. Batteries are an essential component of nearly all off-grid solar and wind systems, can provide power for critical loads during blackouts at grid-connected facilities, and can help reduce the operations cost of diesel generator-powered facilities.

HYBRID SYSTEMS: Hybrid systems integrate two or more energy sources to help satisfy a facility's power needs. A hybrid energy system can consist of two or more renewable energy sources (e.g., PV and wind) used together to provide increased system efficiency as well as greater balance in energy supply. Alternatively, diesel generators can be combined with renewable energy equipment to ensure greater reliability of power supply. Examples of hybrid systems include wind/PV, wind/diesel, wind/PV/diesel, and PV/diesel/battery system.

delivered and installed. The power rating tells you the equipment's electricity generating capacity. You can calculate the amount of energy that the equipment produces in a day by multiplying the capacity by the number of hours that the equipment generates electricity, as shown in the examples below.

For diesel engine generators, power ratings are provided in kilovolt-amperes (kVA). You can convert the kVA rating into kilowatts by multiplying the kVA by the generator's power factor (generally estimated at 0.8) to get the comparable kilowatt rating. For example a 3 kVA diesel generator with a power factor of 0.8 = 3 x 0.8 or 2.4 kilowatts. If the generator runs for three hours per day, then it produces 7.2 kilowatt-hours per day (2.4 x 3). If your facility uses a diesel generator, it will also be necessary to know the amount of fuel your generator needs to run (measured in gallons or liters per hour).

For renewable energy systems (e.g., solar, wind, hydropower), equipment is typically rated in watts or kilowatts. For example, if a facility has five PV panels, each rated at 100 watts, then the PV capacity would be 500 watts (100 x 5) or 0.5 kilowatts. If the facility usually gets full sunlight for about four hours per day, then that system produces a maximum of 2,000 watt-hours per day (500 x 4), or 2.0 kilowatt-hours per day.

To enhance renewable energy system availability, batteries often are added to store energy produced and make it available when the renewable energy resource is not available, e.g., when the sun is not shining or wind is not blowing. The storage capacity of batteries is typically provided in amp hours (Ah). When multiplied by the battery's nominal voltage (e.g., two, six, or twelve volts), this gives the storage capacity of the battery in kilowatt-hours. For example, a 200 Ah, 12 V battery can store up to 2,400 watt-hours, or 2.4 kilowatt-hours of energy.

COMPARING ENERGY SUPPLY AND DEMAND

Regardless of the energy source, the limited power availability of off-grid systems makes it critical for facility management and staff to understand their system constraints and to plan accordingly. If your energy demand (calculated in Step 1) is higher than what your system can produce (calculated in Step 2), you will overload the system and not have energy available when you need it. You also risk severely damaging the energy system and other equipment in your clinic.

By knowing the total amount of power available, the power needs of your facility, and the critical load priorities, you should be able to manage energy consumption more effectively and obtain the power needed to satisfy facility demand. This information will help to prioritize limited energy resources, to determine if there is any power left over for running existing appliances for longer periods of time throughout the day, and whether the energy system has sufficient capacity to handle new equipment.

If in this process you find that you do not have sufficient power supply, a number of alternatives exist. These can include: load shedding of non-critical equipment; developing schedules for when you can and cannot use certain appliances/devices; and, if the shortages persist, installing additional power generation.

STEP 2 TASKS:

Understand your energy system's capacity and how it compares to your facility's energy demand.

How Long Will My Power Last?

Renewable energy resources such as the sun, the wind, and the water are free—but not always available when they are needed. Facilities need to plan ahead for times when the renewable energy resource(s) are not at full potential. The power produced by locally based renewable energy systems depends in part on the capacity of those systems to store and then deliver energy later, as needed. During times when the renewable resources (the sun for PV and solar thermal, wind for windpower, and running water for hydropower) are not available for some period of time (days or weeks), facility staff will need to know how much energy storage they have available, and how long their power will last. Knowing this enables staff to prioritize and plan their consumption accordingly—to conserve power and cut down on energy usage until the renewable resource is able to recharge the system adequately. Adding a small diesel generator to renewable energy systems can be one way to mitigate against prolonged periods when the renewable generation source is not available.

For **diesel or gas generators**, there can be interruptions in supply of diesel due to budget constraints or delivery challenges. Facility staff need to work in concert with their maintenance staff to predict when those occasions will occur, and use energy accordingly. Each facility needs to do its own calculations about how long its fuel will last. This will depend on the nature of the power system, combined with the nature of energy use.

This is similar to asking how long it will take to use up a full tank of gas in a car. The answer depends on how large the car is and how efficiently (or inefficiently) it utilizes fuel. Also it depends on how fast the car is being driven, the actual driving conditions, and if there is a lot of stopping and starting—or if it is smooth highway driving. In the same way, the facility staff should have a general understanding about how much fuel their generator(s) can hold in the tanks, how quickly (or slowly) the fuel is consumed, and how much electricity the generator produces.

SANITAS CLINIC

MANAGING ENERGY SUPPLY

As noted in the prior Sanitas example, the clinic has a total load of 8,806 kilowatt-hours per day. This includes 7,366 kWh/day to meet general energy needs, and 1,440 kWh/day for the clinic's most critical load—the vaccine refrigerator.

Sanitas currently operates two solar power systems:

- A dedicated solar panel and battery to meet the needs of the 1,440 kWh/day consumption level of the vaccine refrigerator.
- The main solar power system, which provides the facility with 7,500 kWh/day to meet the bulk of the clinic's energy needs. Because the demand estimate is 7,366 kWh/day, the clinic has a very small margin of error—in other words, there is very little room for making mistakes in executing the energy management plan.

With this energy system, the clinic cannot support any more energy usage than it currently consumes, so overloading the system is a real concern. For example, if the staff uses the radio/cassette player one day for 24 hours, or leaves the laptop turned on overnight, the energy usage will exceed the system's capacity to generate electricity. This would likely cause the batteries to discharge so deeply that the system will not work for several days (or even a full week) until the batteries get charged again.

Recently, the district health office has contacted the head nurse to offer the clinic an electronic centrifuge machine to replace its manual machine. The electronic version requires 575 watts of power. The head nurse now realizes the clinic will not be able to add this machine at this time, unless non-critical appliance use is reduced, or new power generation equipment is added to the site.

STEP 3

ESTABLISH YOUR ENERGY MANAGEMENT TEAM

With knowledge of the facility's energy needs and supply availability, the next step is to formulate an energy team to establish and implement sound energy management practices. This involves the following steps:

- Make a facility commitment to manage energy use effectively.
- Form a dedicated energy team to deliver results.
- Ensure the team has the training and tools to do the job.
- Engage other groups outside the facility that have a role to play in ensuring success.

MAKE A FACILITY COMMITMENT TO MANAGE ENERGY USE EFFECTIVELY

Management of energy consumption and energy systems is crucial to ensure reliable access to adequate power supply at health care facilities. Implementing an energy management program requires commitment by the highest ranking staff member on site who should demonstrate leadership and show the staff that the energy management plan has strong internal support. Ideally, the program should also have the backing of management at the national and regional levels involved in setting policies and programs on the country's health care facilities and infrastructure support (e.g., the Minister of Health or designate, regional health program director, etc.). This will help to raise the visibility of the facility's energy management program in the country, establish a channel for reporting progress, offer a model for other health care facilities in the country and region, and potentially assist in securing additional resources for facility program expansion.

FORM YOUR ENERGY MANAGEMENT TEAM

Sound energy management relies first and foremost on people. Without the correct people and support systems in place, no amount of energy services will adequately address the facility's energy needs. Building local capacity at the facility level and among other key stakeholders will be important to the successful operation of facility energy systems.

All of the health facility staff members must be responsible for understanding the facility energy management plan, and for contributing to its execution and ultimate success. The facility manager should form an energy management team to ensure that the facility's energy system meets health care needs on a day-to-day basis. The number of team members will vary depending on the facility's size. Each energy team member should understand his role and responsibilities, and be empowered to perform her energy management tasks. These tasks will be a small part of their overall work responsibilities as health care providers.

At a minimum, the core team should consist of the following:

- **Facility Energy Manager**: The facility energy manager plays a critical role in the delivery of a successful energy management program. This person may be the officer in charge of the health care facility, or a designate. The facility energy manager does not need to be an expert in electrical or technical systems, but should have a good working knowledge of how the energy system works, the facility's energy requirements, and where to go for help. The facility manager should understand why energy management is important and how it can help the facility achieve its goals and objectives for health service delivery.

Although energy management is only one of the facility manager's many responsibilities, it is vital to the facility's ability to provide health care services. The manager has the ultimate authority to make decisions regarding energy use in the facility, and is responsible for selecting energy team members and assigning their roles.


PHOTO: WALT RATTERMAN, SUNEPI

Clinic staff review the energy system at a health facility in Burundi.

- **Facility Energy Monitor**: The medical staff will be the main users of the equipment and so it is important that they are represented on the management team in a monitoring capacity. The facility energy monitor ensures that the needs of the facility are met when energy management and equipment purchasing decisions are made. This person is responsible for keeping a record of how equipment is being used, and providing support and guidance to other staff members when they have energy-related questions or concerns. The monitor posts signs and keeps energy consumption logs, and must have the authority to disconnect equipment if it is being used incorrectly, or for unauthorized purposes. The facility energy monitor reports directly to the facility manager for energy-related responsibilities.

- **Facility Energy Technician**: The facility energy technician understands how the energy system works, and has the technical skills and knowledge to perform routine operation and maintenance tasks, including minor repairs as necessary. The facility technician can identify maintenance or repair tasks that require a professional technician. The technician is also responsible for the system manuals, and for keeping an inventory of spare parts for the system. The facility energy technician reports to the facility manager for energy-related responsibilities.

- **External Energy Service Providers**: The external energy service provider performs periodic maintenance and repairs that are beyond the technical ability of the facility staff. The service provider should inspect the energy system on an annual, semi-annual, or quarterly basis depending on the complexity of the system. These inspections should involve facility staff and include a meeting with staff to discuss the energy system's operation. The energy service provider also must be available to respond quickly to unplanned service requests from the facility. Often, the energy service provider may work through a contract with the health facility to perform these services.

Additionally, other members of your core energy team may be added as appropriate based on your facility energy needs and situation. Table 3 provides an illustrative list of the roles and responsibilities of various members of the Energy Management Team. In selecting these team members it should be recognized that their energy responsibilities are likely to be a small part of the roles they play in the facility. Once systems are put in place to conduct these activities, energy-related matters should not account for a major portion of their time.

TABLE 3

ILLUSTRATIVE ROLES AND RESPONSIBILITIES OF THE HEALTH FACILITY ENERGY MANAGEMENT TEAM

FACILITY ENERGY MANAGER Example: facility director/ manager, head doctor or head nurse	• Develop and enforce facility energy management practice guidelines • Manage funds for system operation and maintenance • Select energy team members • Assign energy-related roles and responsibilities to energy team members and facility staff • Ensure facility staff have the skills and knowledge necessary to complete their energy-related assignments • Communicate with energy service providers for technical issues the staff cannot address • Communicate with higher-level management within the government or donor organization about system needs and equipment efficiency • Work with local communities to convey importance of facility's energy system • Use emergency shut-down procedures and meet safety requirements as needed
FACILITY ENERGY MONITOR Example: nursing assistants, vaccine administrators	• Monitor energy use (record hours of equipment used in an energy log) • Make sure that energy is used efficiently • Label outlets and ensure that equipment is used properly • Inform facility staff and patients about energy-related issues as appropriate • Work with facility energy manager to ensure that the staff and local community realize the value and benefits of your clinic's energy system
FACILITY ENERGY TECHNICIAN Example: technical or logistical person in charge of equipment	• Develop energy system operation and maintenance plan • Oversee operation and regular maintenance of energy system • Keep records with system operation and maintenance logs • Report operation and maintenance issues to management • Perform periodic equipment maintenance checks and tasks • Protect the system and energy components (including light bulbs) from tampering or theft • Use emergency shutdown procedures and meet safety requirements as needed
ALL FACILITY STAFF	• Understand the facility energy management plan and contribute to plan implementation (e.g., shutting off lights and equipment when not in use) • Contribute ideas for improving energy management in the facility
ENERGY ENGINEER	• Provide technical expertise and training to facility managers and staff • Ensure equipment and service meet quality standards • Collect and review system logs filled out by facility technician • Perform periodic maintenance checks and service • Respond to repair service requests • Ensure that installed equipment meets design requirements

TRAIN THE FACILITY ENERGY MANAGEMENT TEAM

Managing your facility's energy use requires group involvement, and a sense of ownership and responsibility by all facility staff members. All staff must understand the role of energy in the facility's ability to provide health care services. It is possible that staff members do not have access to modern energy resources at home, which may tempt them to use the facility's energy system for personal use. Some staff members may not have experience using electrical appliances and not understand that energy is a limited resource. The facility manager must work with the health facility staff to change these attitudes toward energy use so that everyone at the facility understands the importance and value of the energy system. In particular, they must understand the system's limitations. The best way to accomplish this goal is to engage the staff as active stakeholders in managing the facility's energy supply and its energy-consuming equipment.

A training program will help ensure that staff members have the skills and knowledge to manage and use the energy system. Some of the key elements of an effective energy management training program are listed below. Your energy service provider is a good point of contact to help design the program and conduct the training. Typically, a private sector provider will not provide such training on its own accord, so a concerted effort to identify training funds may be required. Additional information sources are provided in the References and Resources section at the end of this document.

Different levels of training are appropriate for different members of the health care facility staff. These include:

- Understanding the energy system [for all staff]
- Recording energy use [for all staff]
- Operation and maintenance training [for the facility energy technician]

The facility energy manager should participate in all of the energy-related training, to the extent possible.

Understanding the Energy System—Basic Training for all Facility Staff

- *Introduction to the energy system:* How the system produces and stores energy, and its benefits and limitations. Why an unlimited resource like the sun becomes a limited resource when used for heating water or creating electricity for use at the clinic.
- *Understanding equipment:* Equipment energy consumption and power ratings, and how this compares to available energy supply. Description of critical, important, and non-critical loads and how these have been prioritized in your facility. How to use the energy system properly and avoid misuse.
- *Behavioral training:* How staff behavior impacts energy production and use, and the importance of energy efficiency and energy conservation. The role of energy logs and maintenance checklists and what the labels mean on circuits and plugs in your facilities. Basic wiring and labeling of energy-using appliances and why this is important.

PLANNING FOR ELECTRICAL LOADS

Health care facility staff must understand that if a room has been wired with outlets specifically designed for high-voltage equipment or critical loads (such as in the lab in the diagram on p. 4), these appliances cannot be moved to another room with standard outlets. Each piece of medical or electrical equipment has specific electrical requirements that must be met for the system to operate safely and effectively.

In one facility in Ethiopia, facility directors reorganized their facilities without taking electrical requirements into account. For example, a room designed as a document storage area with low electricity demand was turned into a lab with high electricity demand even though it lacked proper wiring for the lab equipment. The facility staff improvised a wiring solution that created an electrocution and fire hazard.

Recording Energy Use

- *Energy monitoring:* Proper monitoring of facility energy consumption, data recording, use of energy logs, reporting procedures, and other administrative responsibilities.
- *Equipment familiarization:* Understanding of each piece of equipment and its energy needs, identification of critical equipment and its requirements; and how to label plugs and outlets.

Training courses should be approximately 3-4 hours in length and should be repeated yearly. More details on specific tasks are provided in steps 4 and 5.

Technical Training

- *Operation and maintenance:* Methods and procedures necessary to prolong the life of the energy system and reduce energy use, wiring and its importance, understanding the difference between critical and non-critical loads at the facility, fail-safe measures that may have been installed to protect the energy system, procedures for energy system shutdown, and who to contact if there are problems with the equipment or how it is being used. Also, review of energy system operation and maintenance (O&M) manuals and user guides.
- *Theft prevention:* Activities that can be undertaken to protect the system and individual energy components from tampering or theft.

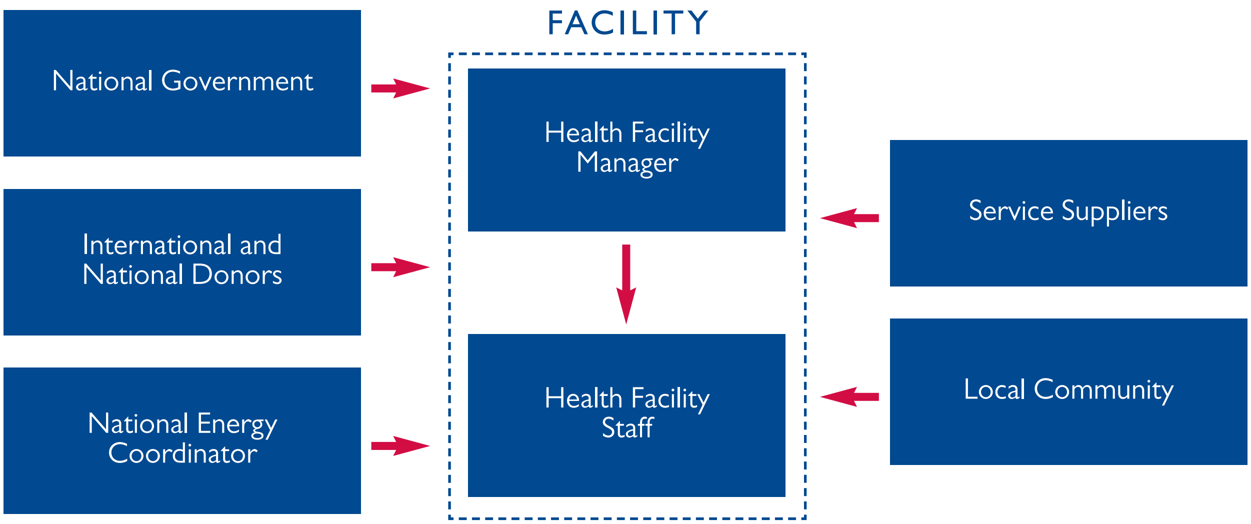
Energy technician training sessions will generally be longer in length as they cover more technical details. Depending on the technical skills desired, technical training could range from a day to several months. Training materials can be found at http://www.poweringhealth.org/topics/ training/index.shtml

ENGAGE OUTSIDE ORGANIZATIONS AND COMMUNITY MEMBERS IN YOUR ENERGY MANAGEMENT TEAM

Decisions that affect your facility's energy use are made every day by people in many different health care roles, and it is important that these decisions be coordinated and communicated. Figure A depicts a sample energy management team structure that includes the energy facility and staff as well as external players at the national, regional, and other levels. Though every country, and in some cases individual regions, have their own unique characteristics and requirements, this figure provides a basic blueprint for the structure of an Energy Management Team. Examples of key stakeholders who are involved in some aspect of facility policy, planning, and implementation that will impact energy decision-making (directly or indirectly) include:

- *Decision-makers at the central and local government levels* (e.g., Ministry of Health, regional health program managers, etc.). These entities are involved in setting policies related to a country's health facilities and infrastructure support, making purchasing decisions that affect system design and operation budgets, approving design proposals and operation plans, establishing and enforcing policies and standards for equipment maintenance and efficiency measures, managing communications with technical consultants and funding institutions, and providing consistency when staffing changes occur.
- *Representatives of international donor agencies.* These organizations, including bilateral aid agencies, multilateral organizations (e.g., World Bank, regional development banks, UN agencies, etc.), NGOs, and others, can make purchasing or technology decisions, and provide funding for installation, operation, maintenance, and repair of energy systems. If agency representatives are not engaged, poorly planned decisions can result. For example, sometimes a donor or aid organization donates high-powered medical equipment such as an ultrasound machine without considering the amount of energy that is available—or not available—at the health facility. This equipment cannot be used if there is not enough energy to power the device.

FIGURE A
A TYPICAL ENERGY MANAGEMENT TEAM'S STRUCTURE



- *Members of the private sector.* These organizations manufacture, market, and sell energy equipment and end-use appliances. Also, banks may be involved in system finance.

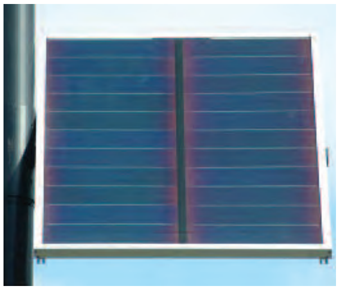
- *Local community members.* Members of the local community should understand that the energy generated by the facility contributes to delivery of essential health services, such as vaccinations. Misusing the energy system, for example, by paying clinic staff to charge a cell phone battery at night or iron clothes may mean that the clinic has no power the next day when medical attention is needed.

STEP 3 TASKS:
Identify energy team members both within and outside the facility, assign their roles and responsibilities, and provide necessary training.

CASE
STUDY

Solar-Powered Energy System

Training Lessons Learned



Micobee Health Clinic is a small clinic located in a remote interior area of Guyana. The clinic serves 360 residents and 300 miners from a small village, with one part-time health worker on staff (the same person also staffs a nearby clinic with no electricity). A small photovoltaic system was installed to power a communication radio, an indoor light, and an outdoor security light.

When the photovoltaic system was installed at the clinic, the local health worker was not given any training on the system. He was told not to touch the batteries because the regional health office decided that since he had not been properly trained, he might damage the system by using trial and error methods to resolve problems. He did not monitor the system or log any type of energy use. No maintenance contract with the local service provider was in place.

When the USAID Energy Team visited the clinic, the electrolyte levels were critically low in many of the batteries. The distilled water needed to refill the batteries was not locally available. The health worker did not know how to refill the batteries to the appropriate water level, and was unable to maintain the system without some basic knowledge of system maintenance and operation. This example provides a clear reason why simple training—and including health facility staff as part of the energy team—can go a long way toward prolonging the life of an energy system.

SANITAS CLINIC ESTABLISHES ITS ENERGY MANAGEMENT TEAM

The head nurse at Sanitas Clinic creates an energy management team consisting of the following members:

- Team Manager: Head Nurse
- Energy Monitor: Assistant Nurse 1
- Energy Record-Keeper: Assistant Nurse 2
- Energy Technician: Office Manager
- Community Coordinator: Vaccine Administrator

As the Team Manager, the head nurse is responsible for making sure that the rest of the team understands and carries out their duties. She is also responsible for contacting any outside organizations (the Ministry of Health, district health officers, or the equipment service provider) when the issue cannot be resolved within the clinic.

The Energy Monitor, Assistant Nurse 1, is responsible for posting signs next to the equipment with any special use rules (high voltage, dedicated outlets, etc.), and for making sure the staff follow the rules set by the team manager. These rules include turning off equipment and lights when not in use, enforcing restrictions on using personal items such as cell phone chargers, and keeping good records in the energy usage logs. (In this case, Asst. Nurse 2 also helps record energy usage in appropriate logs). When any staff member breaks the rules, the energy monitor has the authority and responsibility to report them to the team manager. The energy monitor is also in charge of making sure that any high-efficiency light bulbs, which tend to have a high market value, are not stolen or replaced by low-efficiency ones. If possible, she locks up bulbs not in use.

The role of Energy Technician is served by the office manager because he has previous experience maintaining diesel generators and understands mechanical tasks. The equipment service provider provides the technician with training on how the solar power system works, instructs him when to shut down one or more of the circuits, and how to record the battery charge levels in the log on a daily basis. He is also taught routine maintenance tasks, such as how to clean the solar panels one evening each week. The technician has another important task: to make sure the solar panels are safe from theft. He reports directly to the team manager and knows when a maintenance issue is serious and needs to be presented to the equipment service provider.

Because the vaccine administrator has a lot of contact with the community, at the clinic as well as in patients' homes, he is assigned to be the Community Coordinator. He helps the technician by making sure community members understand the importance of their solar-powered system, a tactic that may help prevent theft. He also meets with community elders to ensure that they are aware of new programs and activities at the clinic, and to get their support and input for such activities. The community coordinator reports directly to the team manager.

STEP 4

OPERATE AND MAINTAIN YOUR ENERGY SYSTEM

Sound operation and maintenance (O&M) practices are essential to ensure that your energy system performs as expected. Proper implementation of the O&M plan has proven to be one of the most challenging aspects of health facility energy system improvement programs. Insufficient O&M funding, training, and load enforcement often lead to system failure in short order. Alternatively, if a well-designed O&M plan is implemented, benefits will include:

- Keeping the system in good working order.
- Guaranteeing that the system is working properly.
- Ensuring optimal equipment performance.
- Detecting potential problems before they arise and making necessary corrections.
- Reducing potential for premature system failure.
- Extending the life of the system.
- Saving money for your facility.

All health care facilities—both large and small—should develop a basic O&M plan for their energy system. This should be based in part on the manuals provided with your energy equipment. O&M plan preparation should be led by the facility energy technician, with assistance provided by the equipment service provider as needed.

An effective O&M plan includes the following:

- Labeling and wiring of critical and non-critical equipment.
- Identifying and conducting routine O&M activities.
- Creating an inventory of spare parts.
- Setting up a dedicated budget for energy system O&M costs.
- Addressing theft prevention.
- Preparing for the worst-case scenario.

Each of these plan elements is discussed in more detail below.

LABELING AND WIRING

- Label all outlets that can accommodate high-power appliances and devices and use the outlet only for that piece of equipment. This will help your staff avoid damaging the wiring in your building by plugging the wrong equipment into the wrong outlets.
- Clearly label all critical loads and make sure that they have a dedicated power outlet that is also labeled.
- Clearly label all circuit breakers and power connectors in the equipment room in case the power needs to be disconnected or the power in one part of the facility needs to be shut off.
- Ask your equipment service provider to check the wiring in your building to make sure that devices with high power consumption (such as X-ray machines) are connected to outlets that can accommodate them (See Figure B). Ensure all system components are correctly grounded.
- Ensure that existing wiring is up to date and not overloaded. As facilities expand and new equipment is added, the result can be inadequate electrical

supply to the appliances and outdated wiring which can lead to low voltage, high conductor temperatures, intermittent power supply, and electrical fires.

- Post wiring diagrams of the system in the room with the energy generating equipment. Even if staff do not participate in system operations and maintenance, it is important that they know where the information is located so that they can direct a technician to the diagram for repairs or in an emergency.
- Post operation and maintenance instructions for all devices in the room with the energy equipment.

CREATING CHECKLISTS FOR EFFECTIVE SYSTEM OPERATION AND MAINTENANCE

A checklist of O&M tasks for your energy system should be developed as part of the energy management plan. The list should include specific activities to be conducted for each key piece of energy system equipment, such as generators, photovoltaic panels, batteries, controllers, and inverters; and for each appliance and device, such as lighting and medical equipment. The list should include a schedule and identify a specific person responsible for each task. A sample checklist of O&M activities for key components of off-grid energy systems is provided in Table 4.

This outlet is clearly labelled for the use of a specific piece of electrical equipment.
PHOTO: JEFF HAENI, USAID

FIGURE B
GOOD WIRING IS ESSENTIAL, BUT BAD WIRING IS COMMON

The pins on this autoclave plug have been taped by staff so it can be used in an outlet designed for low-voltage appliances. This practice could damage the equipment.
PHOTO: WALT RATTERMAN, SUNEPI

Poor wiring is typical of many clinics, posing a serious safety hazard.
PHOTO: JEFF HAENI, USAID

TABLE 4

SAMPLE OPERATIONS AND MAINTENANCE CHECKLIST FOR OFF-GRID SYSTEMS

Task	Frequency	Responsible Staff Member
THE ENERGY SYSTEM		
Monitoring and log keeping of system use	Daily	Facility Technician
Training in emergency shutdown procedures	Periodic	Facility Manager & Energy Technician
Maintaining a spare parts inventory	Daily	Energy Technician
LIGHTING		
Check electrical connections	Weekly	Energy Technician
Clean lamps to maintain brightness levels	Weekly	Energy Technician
Replace burned out lamps and ballasts	As needed	Energy Technician
MEDICAL END USE EQUIPMENT		
Follow manufacturer's maintenance recommendations	Daily	Facility Medical Staff
Clean equipment, and check for worn insulation on electrical wires and loose electrical connections	Weekly	Facility Medical Staff
Check that power quality is sufficient. If power quality deteriorates, it may be necessary to invest in power conditioning equipment (i.e., UPS)	Monthly	Energy Technician
BATTERIES (may be part of a back-up system)		
Check electrical connections	Weekly	Energy Technician
Check for corrosion and clean terminals	Weekly	Energy Technician
Check water levels and top up (for lead acid battery types only)	Weekly	Energy Technician
Ensure that batteries are fully charged on a regular basis	Weekly	Energy Technician
Replace the battery bank	Typically every 3–5 years (lead acid) and 5–10 years for (sealed gel) if well maintained	Energy Service Provider
Manage hazardous materials storage and disposal: recycle spent batteries, manage electrolyte spills for lead-acid batteries	As needed	Energy Technician & Energy Service Provider
GENERATORS		
Maintain fuel and lubricating oil levels	Weekly	Energy Technician
Change oil and oil filter	See manufacturer's recommendations	Energy Technician & Energy Service Provider
Routine servicing: check and tighten bolts, replace fuel filter	Periodic	Energy Technician
Conduct minor and major overhauls at regular intervals	Periodic	Energy Technician & Energy Service Provider
Manage hazardous materials storage: diesel fuel, motor oil; and used motor oil disposal*	As needed	Energy Technician
PHOTOVOLTAIC PANELS		
Clean solar panels with water and a soft cloth—do this task with care in the morning or evening; solar panels and rooftops will be extremely hot during peak sun hours	Daily during the dry season; monthly in less dusty areas/seasons	Energy Technician
Check system wiring for loose connections/corrosion	Weekly	Energy Technician
Check all fuses and circuit breakers	Weekly	Energy Technician
For systems equipped with adjustable mounting racks, the array must be seasonally adjusted	Quarterly	Energy Technician
Check the array for shading from growing trees or new buildings; the solar panel will not work properly if it is in the shade. Trees may need to be removed or, in the case of a larger building, the solar panel relocated. Also look for dirt and debris.	Quarterly	Energy Technician
BATTERY CHARGE CONTROLLER (may be part of a back-up system)		
Check electrical connections	Weekly	Energy Technician
INVERTERS (may be part of a back-up system)		
Check settings	Weekly	Energy Technician
Check electrical connections	Weekly	Energy Technician
Replace	Typically every 5–7 years	Energy Service Provider

** Note that fuel and oil can be extremely flammable so it is important that there is never any smoking or possibility of sparks near the generator. If you do not expect to use the generator for over 21 days, completely drain the fuel tank. When disposing of used oil or old fuel, collect in sealed containers (e.g., oil drums); do not dump oil and leftover fuel into the ground or rivers.*

IDENTIFYING WHEN BATTERY CAPACITY IS LOW

In energy systems that utilize batteries, it is important that the operator is fully aware when the battery capacity is dangerously low, or approaching that point. Most inverters include programmable Low Voltage Cutoff Points that will disconnect all of the loads when the batteries reach a certain voltage (seek help from an energy expert for initial setup). To provide further protection, you can: (a) program this setting to disconnect automatically the loads requiring a higher voltage; and (b) provide an alarm system that informs the clinic staff that the battery capacities are becoming too low.

The sequence of the alarm operation is as follows:

- If the battery voltage drops to the programmed alarm point, a light on the power system turns on (specifically reserved as an alarm light), and sounds a very loud horn, indicating that the batteries need to be charged.
- The facility technician, on hearing the alarm, goes to the system and can silence the horn for up to a maximum of six hours with the timer. The light stays lit. The operator can then take action to raise the voltage of the system. Usually this will entail starting a generator, or checking to see that the PV charging system is working.
- If the timer times out (in this case after six hours) and the batteries still need charging, the horn will turn on again.
- When the battery voltage rises as the batteries recharge to a safe point (programmed by the user), both the horn and the light will be turned off by the system.

Maintenance logs should be completed for all on-site energy supply equipment. These logs serve as a record that maintenance and service was performed on the system, and provides a way for facility staff and service providers to communicate. Service providers can review the logs to help identify technical problems with the energy system, or problems with the way the system is being used or operated. The logs also provide a historical record of the energy system that can be used in planning system expansions or other improvements. Maintenance checklists and maintenance log sheets should be developed by the facility technician, with the support of a qualified engineer or energy service provider, as needed. In general, it may be useful for the facility to enter into a maintenance contract with a local service provider for support to the facility technician and provision of non-routine O&M.

Keeping maintenance logs requires the use of measurement devices, which should be provided with the energy system when it is installed. The operator will take measurements such as battery voltage, current from the solar power system and generator, and charging currents from the generator.

System control equipment should warn facility staff when there are problems with the system or when the system may fail. This essential equipment should be installed with the system, but can be added after installation.

Special O&M considerations are required for any system using storage batteries. Typical problems include:

- Improper battery maintenance: Keep batteries clean and free of corrosion.
- Improper battery operation: Make sure the batteries are operating in a partial state of charge—between 50% and 90% of their total capacity. Allowing the battery state of charge to fall regularly below 40% shortens the total life of a battery.
- Faulty solar charge controlling equipment or loose wires in the solar panel connections.

Appendices D and E provide more information on operating and maintaining solar energy systems and diesel generators, including those with battery back-up, along with sample log sheets.

INVENTORY SPARE PARTS AND MAINTENANCE SUPPLIES

Maintaining an inventory of spare parts is essential to ensuring that your energy system runs efficiently and minimizes system outages. If a part fails and is not available, other parts of the system could be damaged, or staff may not be able to provide critical health care or perform other duties until a spare part is ordered, delivered, and installed.

For example, the first time a part fails it is typically a serious situation as the system will limp along at less than optimal output, or could stop altogether. These situations will cost the health care facility in terms of patients that cannot be adequately treated. The clinic also pays in terms of time and money. Millions of dollars worth of energy systems sit idle at developing country health facilities because of inadequate planning for spare parts.

In many instances, replacing a spare part may not be expensive, but without the specific item on hand, the costs can add up quickly. Waiting to purchase parts when they fail may seem like the most inexpensive solution, but this approach adds hidden costs. For example, if you need to replace a critical fuse on your photovoltaic system that takes days or weeks to obtain from the supplier, electricity will not be available for that period. Facility staff may be tempted to bypass the fuse or make other inappropriate repairs that could cause more serious damage to the system. By planning in advance to have replacement parts readily available you reduce risks to clinic operations.

Another benefit of keeping a spare parts inventory is that you can purchase the parts as your budget allows, rather than having to make an emergency purchase when funds may not be available.

Check your system manuals and work with your energy service provider to determine which parts to include in the spare parts inventory. You should also purchase any tools that are required to install the parts or for other maintenance.

Being proactive in creating an inventory and keeping it well stocked and up to date will enable you to have the right parts and tools available when you need them. Recording stock levels will also help to prevent theft, and warn you in a timely manner if thefts do occur.

Table 5 provides a sample listing of spare parts, supplies, and tools for commonly used solar electric and diesel generator systems. Note that all maintenance and servicing should be conducted in accordance with the manufacturer's instructions for your equipment. Maintenance procedures that require disassembly of the diesel generator or PV system should generally be performed by the energy service provider, and not by facility staff. Long-term maintenance contracts with energy service providers are generally recommended.

TABLE 5
RECOMMENDED SPARE PARTS AND SUPPLIES FOR DIESEL AND PHOTOVOLTAIC SYSTEMS

Diesel Generator	Photovoltaic System	Batteries
• Fuel filter • Air filter • Lubrication oil • Engine coolant • Oil • Transfer switches • Voltage regulator • Starter • Belts • Battery cables	• Spare fuses • Wire nuts • Wire • Mild detergent for cleaning solar panels with water • Spare switches • Connector strips • Energy efficient lightbulbs	• Distilled water • Baking soda to neutralize spilled battery acid; vinegar if working with alkaline batteries • Petroleum jelly to protect battery terminals • Sandpaper to clean corroded battery terminals • Spare battery terminals

CASE STUDY

Ababa Health Clinic, Ethiopia

HYPOTHETICAL EXAMPLE

The Ababa health clinic is located near a provincial center in Ethiopia. Since the electricity supply coming from the nearby town is variable and uncertain, the clinic relies on a solar PV system and a diesel-powered generator to provide electricity for its basic services—which include lighting, refrigeration, and a wall outlet that is often used to charge a cell phone. The Ababa clinic director (or manager) is in charge of maintaining the PV system, checking daily to make sure the batteries are charged. She also orders all the diesel fuel for the clinic's generator and has control of the finances to pay for fuel. The rest of the staff understand that these are her duties, but do not understand how to maintain or operate the electrical systems themselves.

When the director had to leave the clinic for a family emergency, the clinic staff left the generator running and the PV system unattended. When they arrived at the clinic on the third day of the director's absence, they found that the solar system's batteries had no charge and that the generator had run out of fuel. The clinic had no power and the staff was unable to treat patients. The vaccines in the refrigerator were at risk of spoiling, so they had to be transferred immediately to another clinic—leaving the Ababa clinic without any vaccines to dispense. Because no other staff member was familiar with the PV system operating procedures, and nobody knew whom to call in case of emergencies, the O&M plan failed and the clinic had no power. Even if there is one person fully in charge of energy operations and maintenance, it is important that there is a chain of command in place, and that information is easily accessible for all employees. The clinic director should train at least two other employees to understand how to keep the system operational. Further, these employees should work with the director to perform system maintenance on a regular basis, and have access to written instructions in case of problems.

ESTABLISHING A DEDICATED O&M BUDGET

The routine monitoring, operation, and maintenance tasks outlined earlier in this chapter will cost relatively little beyond the staff salaries already being supported by the facility, especially if your equipment service provider has been contracted by the government or supporting organization to provide regular checkups as part of a service package. Nonetheless, there will be ongoing costs associated with the energy equipment and it will be critical that an O&M budget be established to address these issues. Further, it is important that this budget not be used for any other purpose—such as facility operation and maintenance costs—even if the energy system is currently working well. Co-mingling of system maintenance funds with the overall facility's operational budgets is not a good idea.

These are some of the common items that will need repair and/or replacement:

- Light bulbs—ideally these should be high-efficiency bulbs.
- Batteries—which are designed to last 3–5 years if well maintained. Old batteries should be collected or recycled to avoid being an eyesore and an environmental liability.
- Miscellaneous items—light switches, circuit breakers, power supplies, surge protectors, etc.
- Photovoltaic system components—the inverter and charge controller, which are often imported, should last up to 10 years. PV panels should last approximately 20 to 25 years when properly used and maintained.

Batteries and other PV system components are expensive one-time expenditures. Health facilities and ministries of health must begin budgeting for their replacement at the time of initial system installation.

PREVENTING THEFT

Since energy equipment is valuable and often installed in areas with little or no reliable energy sources, theft of generators or solar panels or other system components can be a problem. Historically, solar power systems have been particularly susceptible to pilfering and theft, which has led to system failure.

PHOTO: JEFF HAENI, USAID

At the Clinique Des Maladies Infectieuses in Haiti, an inverter was not functioning because the battery cables had been stolen. Placing the batteries in a locked compartment helps to discourage theft.

PHOTO: WALT RATTERMAN, SUNEPI

Installing theft-resistant solar panel frames on a clinic roof in Haiti.

Ensuring that sufficient funds are available to cover lifetime maintenance and replacement costs—which may be required after the donor community has left—can pose a significant challenge.

Actions that can be taken to reduce theft include:

- Proper installation of solar systems.
- Routine system maintenance.
- Tamper-free mountings to make it difficult to remove the systems.
- Putting ground-based PV systems in a locked area. Also, cages can be used to protect batteries. It is important to remember that the use of theft-prevention measures such as cages or locked areas should not interfere with the ability of the system to produce and deliver power.

Staff at this site in Senegal built a cage to protect their solar panels from theft, but by covering the panels they reduced the amount of power their system could produce. A different configuration could have protected the panels without interfering with their function.
PHOTO: PAM BALDINGER, USAID

Perhaps the most successful way to reduce theft is to engage the active support of the local community. It is important for your team to communicate that theft of the energy system will have negative consequences, such as a reduction in local health care services. Community support, involvement, and appreciation of energy systems have been shown to reduce the risk of theft.

PREPARING FOR THE WORST CASE SCENARIO

A standard set of back-up procedures should be put in place in event of the worst-case scenario—when the on-site energy system fails. Standard back-up procedures include:

- Deciding when it is advisable or necessary to operate the back-up generator (if you have one).
- Making sure you always have an adequate fuel supply available in times of prolonged outages, or in the case of a solar battery system, enough back-up battery power to keep critical loads running until you can find another source of power (or until you can transport vaccines and other items in danger of spoiling to another clinic).
- Managing periodic maintenance of the back-up generator, including oil changes, minor overhauls, and major overhauls.
- Turning off all non-critical loads before using any back-up power source, and coordinating with other clinic staff to determine whether patients have an urgent, immediate need for specific medical equipment to be turned on.
- Developing a plan for dealing with unscheduled maintenance, including setting aside emergency funds for repairs and other back-up options for critical loads.
- Knowing whom to call for help if the system cannot be fixed by your team.

STEP 4 TASKS:
Create your facility's O&M plan

SANITAS CLINIC ESTABLISHES AN O&M PLAN

Sanitas Clinic has had its solar energy system for about a year. It was installed by a solar engineer whose business headquarters are in the nearest large town. The Ministry of Health overseeing the clinic made sure that the engineer signed a contract with the Ministry to perform periodic maintenance checks as well as respond to service calls as needed, for a five-year period. For this service the Ministry of Health pays the engineer a flat sum; unexpected service calls are billed as they occur, and these are handled by the district government health office.

When the system was installed, the engineer sat down with the head nurse and the office manager assigned to be the clinic's energy technician, and together they prepared a list of tasks for the technician to carry out on a regular basis. They also prepared daily logs for the technician to fill out; he keeps these handy for when the engineer makes a routine visit.

The O&M routine for the clinic's energy technician is as follows:

- Daily recording of system battery voltage—this helps compare energy production with energy use.
- Monthly cleaning of solar modules and control equipment—this ensures the system is free of dust and other environmental debris for optimum efficiency.
- Ensure visits by the external engineer every 4–8 weeks to:
    - Collect and review battery voltage charts
    - Advise staff if systems are being overused or misused
    - Help with an energy-saving strategy
    - Check functionality of the energy system
    - Fix any problems found and identify any potential or expected problems
    - Verify that the technician is properly cleaning the systems and keeping a daily log
    - Update the training of the clinic staff at least once per year, and/or when turnover occurs.
- Check the spare parts inventory every 4–6 weeks and notifying the engineer and local/national health office or organization when additional parts need to be ordered.
- Check and tighten all wire connections every year—poor connections are a leading cause of decreasing system performance over the long term.

In addition, the head nurse has established a monthly "check-in" phone call with her superiors in the Ministry of Health to discuss any energy issues that arose during the period, including budgetary and new equipment needs. Her constant communication with her superiors has had an added benefit: she has elevated the visibility of her clinic and her successful Energy Management Team, so when visiting donors and dignitaries want to see a health clinic, they are brought to visit Sanitas. The clinic staff enjoys the heightened attention by the dignitaries, and this attention has led to increased funding for the clinic as well.


Installing solar panels on a clinic in Liberia.

PHOTO: GAURAV MANCHANDA, CLINTON FOUNDATION

STEP 5

IMPROVE ENERGY USE

Once you understand your facility's energy demand, you can start to consider ways to reduce the demand without reducing the quality of services provided by the equipment. Reducing demand lowers the cost of fuel as well as the cost of operating and maintaining the system, and may make it possible to add new equipment to your facility to improve the health services you provide. You can control and reduce energy demand in three ways: energy monitoring; purchasing energy-efficient appliances; and managing staff behavior.

- Energy monitoring ensures that you know how much energy the facility is using so that you can manage it. Experience has shown that people tend to be more careful about using energy when they know how much they are consuming.

- Energy-efficient appliances use less energy to provide the same level of service or operation as less-efficient models. Reducing energy consumption equates to more cost effective power systems and smaller expenditures on fuel and electricity.

- Staff behavior is key to conserving energy. There are many ways to reduce electricity usage without compromising the quality of health services, including simple steps such as remembering to turn off appliances when they are not in use. Why use more power than you need to, especially when it is there only to help patients and is already in short supply?

ENERGY MONITORING

Energy monitoring involves developing a record of the amount of energy your facility uses. Monitoring energy use can help to:

- Increase your facility's energy efficiency (using less energy to do the same amount of work).
- Lower operating costs (e.g., fuel) and the costs of repairs due to system misuse.

If You Can Measure It…
You Can Manage It

- Signal increases or changes in energy use—for example, energy demand is increasing due to some new development or change in staff behavior, or appliances are aging and becoming less efficient.
- Diagnose specific areas of energy waste.
- Track energy consumption trends (e.g., weekly, seasonal, operational).
- Control energy consumption rather than accepting it as a fixed cost that the facility has no control over.

Energy monitoring can be conducted in a number of ways.

- Manual monitoring. As part of the O&M activities, the facility technician can track energy consumption levels at the facility level.

- Know your base consumption. Base consumption is the constant consumption which goes on in your facility, whether or not anyone is actually there. This will reflect appliances on standby or appliances that run continually, such as the vaccine refrigerator. If your base consumption is a large part of your overall energy consumption, look at how many appliances are on standby and whether any of them can be turned off completely or unplugged when not in use. Alternately, you may want to replace these appliances with more energy-efficient options.

- Track how much energy your appliances use. Today, low-cost electricity meters are available to show where your electricity goes. These meters are placed between the appliance and the electrical outlet and tell you exactly how much power the appliance is using. These meters can also measure the standby consumption of appliances at your facility. (See Figure C). This information should be entered into a daily log sheet that tracks the amount of energy used per appliance. (See Table 6). When the log is complete, the energy monitor or staff member in charge of record-keeping should add up the time spent using each piece of equipment and add this information to a log book maintained in your facility. These log books are important for your energy management team and the external engineer to be able to track energy use over time and can also be very helpful if something goes wrong with the system. If an energy meter is not available, a log sheet can be placed next to each piece of energy-consuming equipment in your facility. Every time a staff member uses the equipment, they can write down the time they started, the time they finished, and their name. A sample log sheet is provided below, with a blank template provided in Appendix C.

This information should be used to track energy consumption on a weekly, monthly, and yearly basis. In cases where the energy used is greater than the energy produced, you can go back to these logs to identify where energy is being wasted by staff that may be spending excessive time on certain pieces of equipment. Finally, the information within the logs should be shared with regional managers, donor organizations, and NGOs to facilitate better coordination on energy decisions.

Monitoring makes inefficient energy usage and high-consuming devices become apparent, and encourages strategies to be put in place to reduce energy misuse or abuse.

TABLE 6

SAMPLE ENERGY CONSUMPTION LOG FOR USE OF DESKTOP COMPUTER

Day and Date	Time Started	Time Finished	Name of Staff	Total Time
Monday 9/1	10:00 a.m.	10:15 a.m.	Josephine	15 min.
Monday 9/1	12:15 p.m.	12:32 p.m.	Josephine	17 min.
Tuesday 9/2	9:10 a.m.	9:42 a.m.	Paul	32 min.
Wednesday 9/3	9:40 a.m.	10:20 a.m.	Hady	40 min.
Wednesday 9/3	11:00 a.m.	11:22 a.m.	Vanessa	22 min.
Thursday 9/4	2:00 p.m.	2:35 p.m.	Josephine	35 min.
Thursday 9/4	4:00 p.m.	4:40 p.m.	John	40 min.
Friday 9/5	9:30 a.m.	10:15 a.m.	Hady	45 min.
TOTAL FOR WEEK OF 9/1				246 min.

FIGURE C

LOW-COST DEVICES FOR MEASURING APPLIANCE ENERGY USE AND POWER SUPPLY

There are easy-to-use devices that can be utilized by staff to show the amount of energy consumed when an appliance is in use, and also when the appliance is in standby mode. These devices can provide a cumulative reading of energy consumption per kWh (kilowatt hour), and they also display voltage, amps, and frequency.

Three examples of such devices are the "Kill a Watt," the SparoMeter, and the Mains Energy Monitor. These meters, which are available online, range in price from US$20 to US$100.

ENERGY-EFFICIENT APPLIANCES

Energy-efficient appliances save energy, save money, enhance performance, and can result in fewer mechanical problems, longer equipment life, and in many cases extended product warranties. When obtaining new appliances for your facility—whether for exam rooms, public areas, kitchens, offices, or staff quarters—energy-efficient options are the preferred way to go.

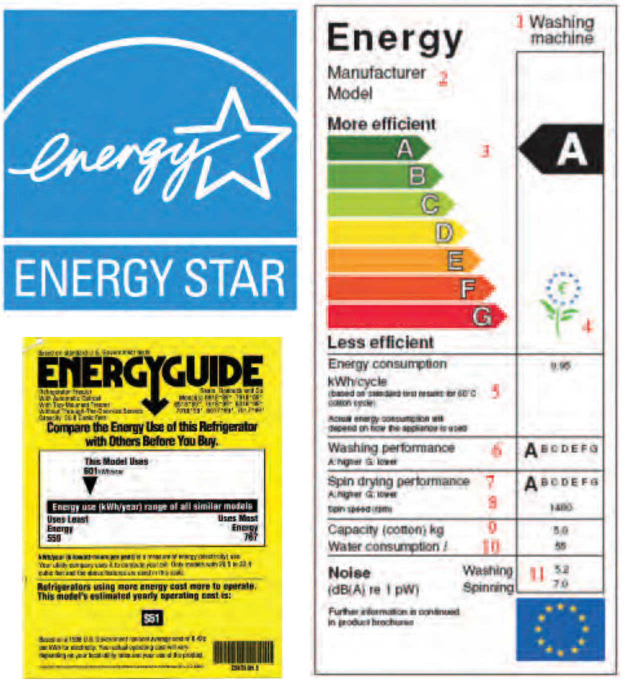
Selecting Energy-Efficient Appliances

High-efficiency products exist for many types of equipment, appliances, and devices. However, making the selection of which product to buy can be a challenge. To help in this process, there are a variety of organizations that provide reliable information for identifying energy-efficient products, primarily through product labels which help buyers quickly and easily make the right appliance selection. Organizations such as the United States ENERGY STAR program and Energy Guide, the United Kingdom's Energy Saving Trust, and the European Union's Energy Label, among others, rate products according to their energy use or provide minimum efficiency guidelines. Almost all equipment used in health facilities is now available in an energy-efficient version (e.g., vaccine refrigerators, fans, and microscopes). When requesting new equipment, devices, or appliances, always request that your Ministry of Health, donor, or NGO partner procure certified energy-efficient products.

Energy-efficient appliances initially may be more expensive than less-efficient products and it can be tempting to buy the cheaper product—especially if your facility is on a tight budget. However, the additional initial expense is usually more than fully recovered through the cost savings generated over the life of the energy-saving product—as they require significantly less electricity to operate. Thus, those purchasing energy-efficient appliances need to look beyond the initial price tag, to include the operating costs over the life of the product (or life-cycle cost). An appliance's life-cycle cost is a better indicator of the true cost of the appliance than the purchase price because it accounts for all related expenses, including the initial investment, cost of operating and maintaining the appliance, and the cost of supplying energy to the appliance. Energy labels on efficient appliances show the anticipated energy costs to help you make more informed purchasing decisions.

Before purchasing or accepting donations of new equipment, health facilities should evaluate both the need for the equipment from a medical perspective, and the availability of energy that can power the equipment. Remember this previous example from our hypothetical Sanitas Clinic? The clinic realized that even though they were offered an electrical centrifuge (needing 575 watts of power), their energy supplies were not sufficient to power it—making a manually operated centrifuge their only option. Whenever possible, the facility manager should communicate with his/her procurement teams and Energy Management Team to make sure the facility is getting the equipment it needs.

FIGURE D
ENERGY EFFICIENCY LABELS AND RATINGS



Energy efficiency labels indicate that an organization has certified that the equipment meets the organization's requirements for energy efficiency. For example, in the United States, equipment carrying the ENERGY STAR label means that it meets the minimum energy efficiency requirements set by the program. A similar label called Energy Saving Recommended is certified by the Energy Saving Trust in the United Kingdom.

Energy efficiency rating labels provide information about the expected energy consumption of a piece of equipment over a specified period of time, typically one year. Rating labels are useful for comparing different models of equipment that carry the same type of label. Many types of equipment sold in the United States are required to carry the Energy Guide label. In the European Union, the E.U. Energy Label provides similar energy consumption ratings to help select efficient equipment.

Note there are a number of items on the market that claim to be highly efficient and actually are not, or are of very low quality. It is important to choose equipment that has been certified and tested based on a reputable standards organization.

Energy-Efficient Lighting

Health clinics typically require lighting for three uses: specialized lighting for medical diagnosis and procedures, general lighting for indoor spaces, and security lighting for indoor and outdoor spaces. There are several lighting options available with varying costs and levels of efficiency: standard incandescent light bulbs; compact fluorescent lights (CFLs) and tube fluorescents; and light-emitting diodes (LEDs), which are newer to the market.
Evaluating these different options involves considering trade-offs between the quality of light, local availability of lighting equipment, initial cost, replacement cost, availability of power, and energy consumption costs.

Examples of CFL bulbs
PHOTO: ENERGY AND SECURITY GROUP

Table 7 provides a comparison of various lighting options. As the table demonstrates, though incandescent bulbs have the lowest purchase price, they use more energy and must be replaced more frequently than the more efficient lighting alternatives.
The upfront costs for CFLs, tube fluorescent bulbs, and LEDs are higher than the incandescent bulbs, but they have a longer life span and consume less energy, lowering overall energy costs.

Choosing Wisely

Regardless of the power source, when choosing medical equipment and appliances, you should always

TABLE 7

LIGHTING SYSTEMS COMPARATIVE ANALYSIS

	Incandescent	Fluorescent (CFL)	Tube Fluorescent	LED
Lifespan (How many hours will the light bulb last?)	1,200	10,000	22,000	60,000
Watts per bulb (Wattage equivalent to 60w)	60	14	17	6
Cost per bulb	$1.25	$2.98	$6.43	$15.98
KWh of electricity used over 60,000 hours	3,600	840	640	360
Electricity cost (at $US 0.20 per kWh)	$720.00	$168.00	$102.00	$72.00
Bulbs needed for 60,000 hours of usage	50	6	3	1
Equivalent 60,000 hour bulb expense	$62.50	$17.88	$19.29	$15.98
Total cost for 60,000 hours of usage	**$792.50**	**$185.88**	**$121.29**	**$87.98**

aim to purchase equipment with higher energy efficiency ratings. If an instrument with a lower wattage rating can accomplish the same task as another instrument with a higher wattage rating, choose the lower wattage option, even if it has a higher initial cost. In the long run, the lower wattage option is almost always a better investment. Today there are low-wattage vaccine refrigerators available with very high energy efficiency, which are designed for use by facilities in off-grid areas. Regular domestic refrigerators consume much more power, even though they might seem like the better option because they are cheaper and familiar to your staff.

Table 8 compares the equipment efficiencies of various types of medical and office equipment.

The use of energy-intensive medical equipment such as electric sterilizing equipment, X-ray machines, and incubators should be determined based on the energy supply you have at the facility. Small facilities with solar electric systems are unlikely to provide sufficient power for this equipment. Larger facilities with diesel generators or with reliable periods of high-quality grid power may be better suited for energy-intensive equipment, as long as its use is well managed to avoid damaging the equipment.

INTERNET SOURCES FOR ENERGY-SAVING PRODUCTS AND PRACTICES

ENERGY STAR and Energy Guide:
www.eere.energy.gov/femp

Energy Saving Trust:
www.energysavingtrust.org.uk

EU Energy Label:
www.energy.eu

Topten:
www.topten.info

Additionally, some types of equipment are available in hand-powered versions, which may be a

TABLE 8
COMPARING EQUIPMENT EFFICIENCIES

Many types of medical and office equipment are available at various levels of efficiency. The following five examples illustrate wattages for high versus standard-efficiency models. Standard-efficiency models will cost, in fuel or electricity, more than double or even triple the cost of the high-efficiency options to run on a daily basis. Even if the high-efficiency refrigerator costs a few hundred dollars more than the standard-efficiency option to purchase, the high-efficiency option will end up saving the clinic money on energy costs. This is money that can go toward better health care for the patients at the clinic, or better pay for health facility staff.

Equipment	High-Efficiency Model	Standard-Efficiency Model
Computer	20 – 40 Watts (laptop computer)	40 – 80 Watts (desktop computer without monitor)
Computer monitor	30 Watts (15" LCD monitor)	65 – 120 Watts (15–21" CRT monitor)
Electric lamp	15 Watts (compact fluorescent or CFL)	60 Watts (incandescent with comparable light output)
Refrigerator/freezer	800 Wh/day	1,800 – 2,500 Wh/day
Air conditioner	5,400 Wh/day	8,170 Wh/day

good choice if your facility has very limited access to electricity. For example, a hand-powered centrifuge could be used in place of an electric one, a choice explained in the prior Sanitas Clinic example. Similarly, non-electric autoclaves should be considered for off-grid facilities.

STAFF BEHAVIOR

Changing the behavior and attitudes of staff to improve energy management will be instrumental in achieving success.

Motivating Staff

As a facility manager, the following concepts should be considered for motivating staff behavior.

- *Link to job performance:* Consider including efficient individual energy use as a responsibility in employee job descriptions and as an effectiveness measure in performance reviews. Also, add an energy efficiency component to the roles and responsibilities for each office, department, and staff member.
- *Promote peer pressure:* Create a sense of peer pressure, shared responsibility, and friendly competitiveness among staff to use less energy, find new ways of saving energy, and to use energy with restraint.
- *Build your team:* As part of your energy management team-building process (Step 3), make sure that everyone in your facility feels part of an "energy saving team." Unifying all staff behind this goal will help achieve results and teams can then introduce improved energy strategies as a group.
- *Make energy efficiency a routine:* Practice energy conservation and efficiency in daily staff activities. Discuss energy consumption and efficiency issues during staff meetings.
- *Set targets and timetables:* Establish goals for reducing energy use and a timeframe for

achieving this. For example, a short-term goal could be to reduce overall energy use by 5% per month until your staff is familiar with energy management and can readily incorporate these routines into their day-to-day activities. A longer-term goal could be to reduce energy use by 10% across the facility in the next year. Make sure all staff members are engaged in achieving this goal.

- *Conduct special group meetings:* Hold special team meetings to solicit and discuss new energy management ideas. Encourage all staff to provide feedback on the facility's energy management program and to suggest areas for improvement.

- *Consider establishing a rewards/penalties program:* Promoting efficient energy use behavior can be facilitated by a rewards program. For example, rewarding a staff member who practices good energy management can help to motivate the rest of the staff to perform well. On the other hand, for anyone who does not properly follow procedures or is found to be using energy against the well-being of the health care facility's mission, corrective actions should be taken.

In the long term, staff motivation to improve energy behavior can be sustained only if driven by a facility manager who is fully committed to achieving facility energy reduction.

Using Less Means More

Using less energy does not only mean purchasing more energy-efficient equipment. You can make a big difference by making a few small changes in how you and your staff use equipment. The facility's energy monitor can lead strategies to reduce energy misuse and abuse, including these types of activities:

- *Non-authorized appliances:* Display lists of non-approved appliances and devices that are not allowed at the facility (e.g., DVD player, televisions, etc.). Enforce strict schedules for cell phone charging.

- *Scheduling*: Schedule energy-intensive tasks for times when energy supply is adequate. For example, in the case of a solar system, schedule these tasks when the sun is shining brightly.

- *Alarms:* Install alarms that notify staff when to turn off equipment due to low power availability.

USING REFRIGERATORS AND FREEZERS

Energy to power refrigerators and freezers can account for a large portion of a health care facility's energy needs. New, energy-efficient models of electric refrigerators and freezers that use between 800 and 1,500 watt-hours per day are suitable for use with renewable energy systems. Self-powered refrigerators that burn propane or natural gas may also be a good option for some facilities. Here are a few tips concerning their use:

- Smaller capacity units use less energy than larger capacity units. Use the smallest size possible to meet facility needs.
- To minimize energy loss, keep door seals clean and only open the door when necessary.
- Clean condenser coils at least once per year.
- Keep the refrigerator unit in a cool place—out of direct sunlight and away from stoves and other heat-producing appliances.
- Keep the unit full. Mass in the refrigerator will help keep the cold air in.

- *Lighting:* In areas with sufficient daylighting, use natural lighting. Adjust blinds, if available, to reduce glare. In rooms where lower lighting levels do not impact safety or productivity, use task lighting (e.g., desk lamp) and turn off overhead lighting. Turn ALL lights off when not in use.

- *Photocopiers:* Encourage employees not to use copiers during peak energy demand periods. Ensure that the power

REWARDING GOOD ENERGY MANAGEMENT PRACTICES AND PENALIZING BAD

Putting incentive programs in place can be an effective way to improve staff participation in energy management at your facility. Although incentive programs need to be tailored to the specific needs and constraints of each facility, they should ideally share the following characteristics:

- Incentive programs should be carefully developed and thoroughly evaluated before they are launched. Backtracking or changing the rules of an incentive scheme after it starts can negatively affect staff morale and participation in the energy management program.
- The program must be explained clearly to the staff to ensure there are no misunderstandings over their rules, rewards, and duration.
- The process or criteria used to select those who receive the awards must be clear and transparent.

Although monetary awards often tend to have the greatest appeal, they can cause negative results and can be unsustainable. Many facilities that operate successful incentive programs offer various types of non-monetary awards such as phone cards, small gifts, food, additional days or half days off, and even assistance with school fees for staff or their children.

In addition to positive reinforcement to inspire your staff to save energy, you should enforce penalties for improper use and waste of electricity. If staff are wasting power or using equipment improperly, particularly on a recurring basis, corrective action should be taken. This could include reminding the individual of proper practices, sending him/her to retraining, temporarily revoking staff privileges, etc. Do not reduce salary or financial incentives. Naturally, if any employee steals energy- generating resources (fuel, solar panel, CFLs, etc.), official action should be taken immediately.

While the violations may not seem very important, "energy wasters" must understand that their actions are putting the operations of the entire clinic at risk. Imagine if the lights suddenly turned off during an emergency because an employee left the computer on. In the end, you are responsible as the facility manager.

[3] The facility manager may need to consult with the Ministry of Health if financial rewards are offered.

AIR CONDITIONING

Although air conditioning is often required for sensitive laboratory equipment, minimizing its use is critical. Reducing the space that needs to be air conditioned by establishing special dedicated cool rooms in the lab, and utilizing efficient air conditioners are two viable options. *Typically, air conditioners are not a good match with off-grid solar systems, due to their high power requirements and not being of the highest priority in rural health clinic applications (as compared to other electrical needs).*

saver switch on copiers is enabled (as available). Encourage staff to make copies in batches to reduce the amount of time a copier is in high power mode.

- *Fans:* Keep blinds, drapes, or shades closed during the day. Use fans instead of air conditioners; if you MUST use an air conditioner, do not turn it below 74 degrees Fahrenheit (23°C). Turn fans and air conditioners off when not operational.
- *Computers and printers:* Turn off computer monitors and printers when not in use. Activate the "sleep" and "hibernate" features on computers so the machine uses less power when not operational
- *Other appliances and equipment:* Instruct staff to turn off radios, medical equipment, and other devices when they are not in use.

- *Use visible reminders:* Post flyers and signs with energy messages around the clinic; decorative and informative flyers can instruct and remind staff about how to save and monitor power.

Automating Energy Use

Using lights and equipment when they are not needed can waste significant energy in health facilities. The most cost-effective way to prevent needless power use is for your staff to be aware of the need to conserve energy and make this goal a regular part of their daily work routine. When this is not sufficient, however, your facility can take a number of steps to reduce your energy requirements:

- Install switches for every light bulb, as opposed to using one switch to turn on multiple overhead lights in a room. When possible, encourage your staff to use "task lighting"—using the light just in their work space, rather than lighting the entire room.
- Install motion sensors or timer switches in rooms where lights tend to be left on. These devices will turn off lights and equipment after letting them run for a specified period of time.
- Utilize programmable timers that turn lights and equipment off automatically according to a predetermined staff schedule.
- Install master disconnect switches to turn off all power to the room during the night. This is especially important for rooms that see high energy use during the day, such as computer rooms and labs.

Addressing "Phantom Loads"

A phantom load is the power that is consumed by electronic appliances or equipment even while they are turned "off" or in standby or "sleep" mode. Equipment that typically generates these phantom loads includes computers, printers, air conditioning systems, appliances with remote controls, and devices with stand-by lights or digital displays (like DVD players and computer monitors). Although phantom loads are relatively small, they can account for up to 10 percent of total electricity consumption, which is especially noteworthy if you have a limited energy supply (as would be the case for diesel generators, solar energy, or battery-based systems).

To reduce the impact of phantom loads, here are some measures to take:

- Unplug phantom load devices, such as computers, when they are not in use.
- Use a power bar or surge protector with multiple sockets and an on-off switch to turn off devices that are normally used together, such as a computer, monitor, and printer.
- Request or purchase devices that offer a real "off" switch, or have low standby power requirements. A list of recommended and "best available" standby power levels for a wide range of electrical devices can be downloaded at www.eere.energy.gov.

STEP 5 TASKS:
Specify activities to improve your facility's energy use through monitoring, efficient appliances, and staff behavior.

CONCLUSION

As the manager of a health facility located in a rural or "off-grid" area, you are often forced to generate your own electricity to supply power for lighting, critical medical equipment, refrigeration, office and communication functions, and staff quarters. Even if your facility is in an urban area, you may lack access to reliable grid-supplied electricity, and therefore depend on back-up systems to meet your energy needs.

Regardless of the energy source—diesel generators, solar panels, wind power, etc.—the cost of electricity created by these systems can be high, and its availability limited. Even so, having reliable electricity greatly improves the range and quality of critical health services that can be provided to the community at large.

As the facility manager, it is your responsibility to manage energy consumption carefully in order to minimize capital and operating expenses while meeting power demands for health care delivery. Fortunately, there are several ways to accomplish this. These include monitoring and reporting energy use, performing routine maintenance, keeping a clinic budget for repairs and spare parts, securing more energy-efficient equipment, and including your staff, community, and broader stakeholders in energy-related discussions and decision-making. These activities will put your energy team in control of its own success and destiny, ensuring that electricity for vital clinic operations is always available when needed by patients or facility staff. In fulfilling these duties, and appreciating the value of your energy system, you can prevent energy system misuse and failure.

Children in Ngarama, Rwanda, are impressed by the improved electrical service to their local district hospital.
PHOTO:WALT RATTERMAN, SUNEPI

Energy should be considered in all aspects of clinic operations, from powering medical devices, to providing indoor lighting for night operations and outdoor lighting for safe access to the clinic. Energy is needed to make computers run, provide critical health information, and track patient information. Energy allows for refrigeration, which helps to preserve medications, serums, and other liquids. The availability of electricity helps to sterilize equipment and contributes to attracting and maintaining health care workers in rural areas.

This document has laid out a stepwise approach for facility managers and staff to understand the principles of energy supply, consumption, and use. Use it as a guide on how to implement energy management practices and procedures in your facility, identify staff roles and responsibilities, and describe the importance of energy-efficient practices and equipment.

And why? If your health facility is run well—employing practices of energy efficiency and careful energy use—you can help ensure the continued delivery of quality health services to your patients, thereby improving people's lives and livelihoods.

Notes

GLOSSARY

AC – Alternating current, where an electric current periodically reverses direction in a circuit – and is the type of electrical power available from a wall socket.

Amp – A basic unit that measures the electrical current in a circuit. Multiplying "amps" times "volts" derives "watts," the total measurement of power.

Battery – A device that stores energy and makes it available in an electrical form.

CFL – Compact fluorescent lighting

Critical load – The minimum amount of energy that must always be available to power essential equipment.

DC – Direct current, an electric current flowing in one direction – most commonly from batteries, solar cells, and fuel cells.

Dedicated power supply – A single source of energy that is dedicated to or used by only one critical piece of equipment.

Engine-generator set – An internal combustion engine joined to an electric generator that uses fuel to produce electricity. Also called a generator or diesel generator.

Energy – The ability of a physical system to do work.

Energy conservation – The protection and careful management of the environment and of limited natural resources, such as fossil fuels (see definition below).

Energy efficiency – Using less energy to provide the same level of energy service.

Energy management – Using energy in the most efficient way possible to complete daily tasks while planning for future potential uses of energy.

Fossil fuels – Non-renewable fuels derived from underground hydrocarbon sources such as coal, oil, and natural gas.

Grid electricity – Electric energy delivered to a business or household from a public or private electricity network. The network consists of transmission lines, distribution lines, and transformers used in central electric power systems. ("Off-grid" locations are not connected to a grid.)

Hybrid energy system – An energy system that is composed of more than one type of electricity generation, such as a combination of a generator and a photovoltaic system.

Inverter – A device that converts direct current (DC) electricity to alternating current (AC) electricity.

Kilovolt ampere (kVA) – A measure of power, most commonly used for generators. (1 kVA = approx. 0.8 kW)

Kilowatt (kW) – 1,000 watts. A measure of power used to describe the electricity-generating capacity or size of an electric generation system. (1 kW = approx 1.25 kVA)

Kilowatt hour (kWh) – A unit of energy representing the quantity of work performed by one kilowatt of electric power in one hour.

LED – Light-emitting diode

Life cycle cost (LCC) – The total and true cost of an energy system over the life of the system. LCC accounts for the initial capital costs, maintenance and operation costs, fuel costs, and the salvage costs. A life-cycle cost analysis can be helpful for comparing costs of different systems and designs, and for determining what type of energy system would be the most cost-effective option over its life.

Lifetime – The length of time a piece of equipment or system is expected to operate before failure due to age. Photovoltaic and wind equipment lifetimes are typically expressed in years; engines in hours of operation; and batteries in number of charge-discharge cycles.

Operating cost – The day-to-day expense of using and maintaining property, including fuel, labor, and spare parts.

Phantom loads – Electric power consumed by electronic appliances while they are switched off or in a standby or "sleep" mode.

Photovoltaic (PV) system – A system that produces electricity from sunlight through the use of photovoltaic or solar panels; commonly referred to as "solar electric."

Renewable energy – Energy derived from non–fossil fuel resources, including energy produced by the sun, wind, water, and biomass (plant materials or organic waste).

Thermal power – Power used for heating or cooling.

Uninterruptible power supply (UPS) – Equipment inserted between the normal power supply and the load that has sufficient battery capacity to allow the load to operate for a specific 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 the generator is no longer available.

Voltage – The rate at which energy is drawn from a source that produces a flow of electricity in a circuit; expressed in volts.

Watt (W) – A unit of power. The size or capacity of electric power equipment and devices is often given in watts.

APPENDIX A

Energy Consumption Estimates for Commonly Used Health Facility Equipment

	A	B	C=AxB	D	E=CxD	F= E/1000	Device Priority**
(A) CURRENT ENERGY-CONSUMING DEVICES	**Quantity**	**Power (watts) ***	**Total Watts**	**Hours used per day**	**Watt hours per day**	**kWh/day**	
Blood bank refrigerator		70					
Blood chemistry analyzer		50					
Centrifuge		575					
CFL bulbs, clinic (indoor lights)		18					
CFL bulbs, staff quarters (indoor lights)		18					
CFL bulbs (outdoor lights)		26					
Clothes iron		1,000					
Computer monitor (CRT)		65–120					
Desktop computer		150					
Examination lamp (CFL)		18					
Hematology mixer		28					
Incubator		400					
Laptop computer		20–80					
Microscope		30					
Operating table lights		45					
Phone charger		10-20					
Radio		60					
Small refrigerator (non-medical use)		300					
Sterilizer oven (lab autoclave)		1,564					
Vaccine refrigerator/freezer		60					
(a) Total Current Load							
(B) FUTURE ENERGY DEVICES							
(b) Total Future Load							
(c) Total Current/Future Load							

*CONVERTING FROM AMPS TO WATTS: If the label only gives the number of amps and not the number of watts, multiply the number of amps by the number of volts to get the number of watts. Many countries use 240 volts, though much of Latin America and the Caribbean use120 volts. If a device is powered by a transformer (usually enclosed in a black plastic box that plugs into the electrical outlet), then the transformer has converted the electricity from AC to DC, so you need to multiply by the DC voltage, not the AC voltage. For example, if the device says "INPUT 9V, 0.5A," then your calculation will look like this: 9 volts x 0.5 amps = 4.5 watts.

Your device might actually list a huge voltage range, like 100–240V. That means it will work with any country's voltage. For your calculations, use the voltage for the country where you are plugging in the device.

*** Assign priority: critical; important; or non-critical, in order of priority by device.*

APPENDIX B
Refrigeration Options

For off-grid health facilities, electric vaccine refrigerators are typically the largest electricity user, often consuming well over half of the facility's electricity. Health facilities require refrigeration for vaccine, blood, and drug storage, and may also use refrigeration to store food and beverages for staff and patients. Some medical storage specifications require freezing temperatures, while vaccine refrigeration must avoid freezing.

For this reason, special care must be given to choosing a properly sized refrigerator based on the facility's cold storage requirements. Refrigerators and freezers should be kept as full as possible to avoid wasting electricity to cool air in partially empty units. The mass of the contents of a full refrigerator also helps maintain cold temperatures inside the unit, and reduce its energy consumption.

There are five main categories of refrigerators that can be used for medical purposes in health facilities, as shown in the table. Some refrigerators are designed for intermittent electricity supply and maintain storage temperatures using an ice lining. Some designs can maintain storage temperatures for up to five days. Refrigerators typically have a 10-year lifetime when properly operated and maintained. A refrigerator's useful life depends on climate, power quality, and operating procedures.

The World Health Organization (WHO) provides good resources for choosing and maintaining refrigerators for medical use. A list of WHO-certified refrigerators, freezers, and solar equipment is available online[3] (it may also be available at the WHO office in your country or region). All WHO-certified vaccine refrigerators have passed strict performance tests, including durability, icepack freezing capacity, temperature control, power consumption, and holdover time. The certified equipment must carry a two-year minimum warranty, but make sure to select a model with a "maximum rated ambient temperature" that is able to handle the temperature and humidity of your local environment. For more information and costs, refer to the References and Resources section at the end of this manual.

One of the most important operational variables for refrigerators and energy use is the number of times they are opened and closed each day. User behavior, thus, can greatly affect efficiency and operation. Battery maintenance for solar vaccine refrigerators is also of particular importance.

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[3] http://www.who.int/immunization_standards/vaccine_quality/pqs_e03_fridges_freezers/en/index.html

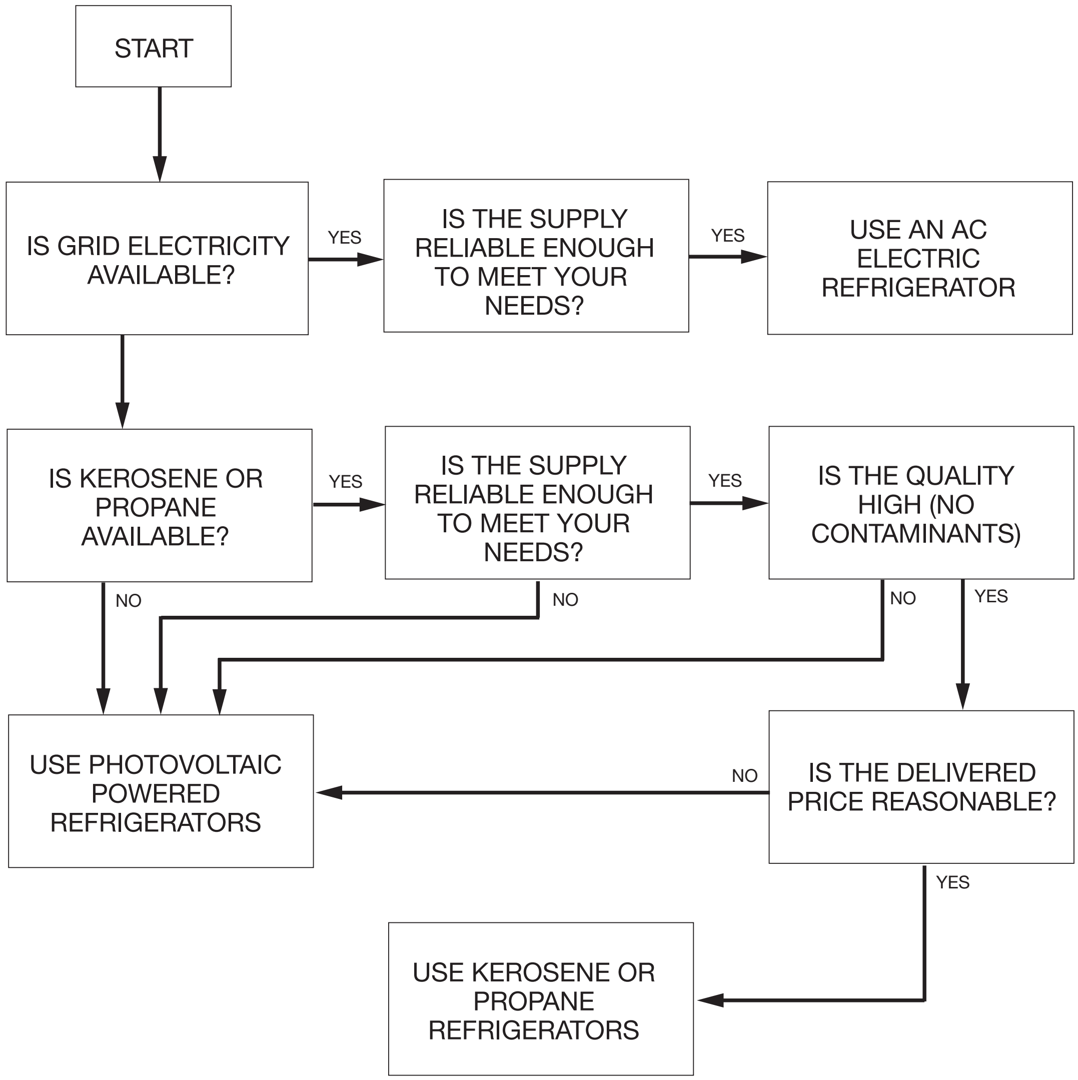
Table B-1
COMMON MEDICAL REFRIGERATORS

REFRIGERATOR TYPE	REFRIGERATOR TYPE
Compression	**Electrically powered vapor-compression refrigerators** are the most common type refrigerator in the world; they are also very reliable, durable, and relatively easy to maintain. Compression refrigerators and freezers require a source of electricity to run a compressor, and can be powered either by **AC or DC power**. AC refrigerators can be operated by grid power or by battery power through an inverter. DC refrigerators can be powered directly by batteries. Compression refrigerators for medical use are heavily insulated, and include cooling fans and temperature monitoring equipment. Some medical refrigerators have two compressors to provide redundancy in case one compressor fails. Compression refrigerators are a reliable option when there is a high quality electricity supply, either from the grid or an on-site energy supply system specifically designed to meet refrigeration loads.
Solar	**Solar electric refrigerators** are a type of compression refrigerator. They are self-powered units that typically include a top-opening refrigerator with no internal fans or lights; solar panels, and batteries. Solar refrigerators require careful study of the refrigeration requirement, number of sunlight hours, and a specification of the number of days of storage for cloudy periods. Solar refrigerators also require the use of high-quality batteries and battery charge control equipment, properly sized electrical wires, and a supply of spare parts. Solar refrigerators are an option for remote facilities without access to reliable electricity or fuel supplies.
Standard domestic	**Domestic refrigerators** are not as reliable or efficient as medical refrigerators, but are often more easily available and less costly. They may be of the compression or absorption type, and are typically front-opening with poorly insulated magnetic seals. Because domestic refrigerators are usually poorly insulated, internal temperatures can rise quickly during power failures and result in uneven temperature distribution, including cold spots in some parts of the unit. Domestic refrigerators may be a suitable option when high-quality AC power is available and reliability is not critical.
Absorption	**Absorption refrigerators** require a heat source, which is typically either a kerosene or propane burner, but can also be supplied by an electric resistive heater. Kerosene refrigerators are more difficult to control than propane refrigerators, and electric absorption refrigerators are typically less efficient. Absorption refrigerators have similar disadvantages to domestic compression refrigerators, and are only a suitable option when fuel is readily available, when the electricity supply is inadequate, and when reliability is not critical.
Hybrid	**Hybrid absorption/compression refrigerators** can operate on either electricity or gas. These refrigerators offer the flexibility of operating on whichever energy source is available at the lowest cost. They are a good option for any type of small facility with inconsistent electrical power—provided the facility has access to fuel.

For help selecting a dedicated power source to meet the needs of your vaccine refrigerator, see Figure B-1, which contains information from Polar Power, Inc. and a study conducted by the Ministry of Health Indonesia and the Program for Appropriate Technology in Health (PATH).

Figure B-1

CRITERIA FOR VACCINE REFRIGERATOR ENERGY SOURCE SELECTION



SOURCE: "Solar Powered Refrigerators - Summary Sheet." Polar Power Inc.

APPENDIX C
Sample Energy Consumption Log

The blank energy consumption log should be placed by all appliances that use energy so you and your staff can track energy use. Either you or an appointed member of your staff should collect these once a week to reconcile the amount of energy actually used to what you planned to use and adjust accordingly (for example, if the microscope is used 4 more hours a day than planned, make sure there is enough power—either through cutting back on usage, or by not using some other equipment).

Equipment: ____________________________

Wattage: ____________________________

Week: ____________________________

Day and Date	Time Started	Time Finished	Name of Staff	Total Time
TOTAL				

APPENDIX D

Operation and Maintenance Tasks for a Solar Battery System

Almost all energy systems that are not completely grid connected, including those that are connected to an unreliable grid, are based on batteries and other electrical equipment with limited lifetimes. Batteries have quite a variable life expectancy, and are expensive. They can last over five years, but can also last only six months if improperly maintained. Part of the responsibilities of your Energy Management Team is to assure that the batteries are maintained correctly, to extend their lifetime as long as possible. When used with a solar power system, basic battery maintenance includes making sure that batteries are working properly, they are clean and not corroding, and that the energy is being delivered to recharge the batteries on a regular basis equal to the loads on the batteries.

Basic system operation: Batteries are the heart of any solar power system as they deliver available energy whenever it is needed regardless if it is sunny or not. Batteries like to operate in a partial state of charge. The battery life span will be greatly extended if the battery is operated in the range of 50% to 90% of full charge. Discharging the battery below 40% will reduce the number of cycles the battery will perform. A discharged battery must be re-charged as soon as possible. The use of an engine in the case of a hybrid system is one way to get the battery back to a charged position. A large group or bank of batteries should be equalized so that all batteries reach full charge every few months. This uses more water but is important to prevent weak cells from developing.

Cleaning batteries: Batteries must be kept clean and free from corrosion on the terminals. Cleaning terminals and adding distilled water to batteries is dangerous and requires eye protection such as goggles or safety glasses, and rubber gloves. Cleaning can be accomplished with a wire brush and an alkaline solution like baking soda. There are special greases that reduce corrosion by coating metallic surfaces and preventing oxygen from contacting the metal.

Battery storage and monitoring: Batteries should be kept in a cool place, spaced apart so that they can eliminate any heat from charging or discharging. They must be checked regularly for water consumption. Water usage should be logged in a maintenance log. For very remote sites, a solar still to create the distilled water is a good idea. A still is easy to make and can also sterilize instruments and drinking water. Distilling is critical as rural water contains minerals that can destroy the battery's chemical properties and reduce its ability to exchange electrons and store energy.

Inspecting the system: It is important to inspect the system on a scheduled basis to ensure that the system is functioning properly and all parts are clean. As the facility manager, it is your job to either do all the tasks below or to assign one of your energy management team members to complete them.

Weekly maintenance inspection:

1. Measure battery voltages in the morning, noon, and night at the same time each week (make sure modules are clean and free from dust and shade when measurements are made).
2. Check electrical connections on batteries, inverters, and charge controllers.
3. Check for corrosion and clean terminals.
4. Check water levels and fill up (for lead-acid battery types only).
5. Record array voltage (and if available) currents from solar array to battery.
6. Ensure batteries are fully charged on a regular basis.

Monthly maintenance inspection:

1. Check water volumes in flooded batteries.
2. Inspect battery connectors—they should be free of corrosion and not loose.
3. Ensure that system is performing in its capacity.
4. Trace battery voltage for the four weeks.
5. In large battery banks, equalize the battery array by charging all batteries to achieve equal voltages.
6. For solar panels: check for shading from growing trees or new buildings—solar panels will not work properly in the shade. Trees may need to be trimmed; in the case of a new and larger building, the solar panel may be relocated.

Annual inspection:

1. Conduct monthly inspection as above.
2. Check connectors on alternating currents.
3. Conduct current testing to determine amps flowing from modules to batteries and amps flowing to inverter under a constant load.
4. Test battery capacity with hydrometer or by load testing.

The sample inspection form below should be used on a weekly basis to log the system performance. Your clinic's energy technician should be the one in charge of checking the system and should work with you to track the system operation over time. You should keep these forms and show them to an engineer or the system installer when they come to do any routine checks to make sure everything is functioning correctly.

Sample Inspection Form

MONTH: ______________________________

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
Date				
Time				
Weather				
Ambient temperature				
Battery voltage				
Charging voltage				
Delivered energy kW/hrs AC				
Delivered energy kW/hrs DC				
Module condition				
Battery condition				
Battery temperature				

APPENDIX E

Operation and Maintenance Tasks for a Generator System

Note: If your facility is using a generator system with battery back-up or a hybrid solar/generator system, please use the checklists and forms below in addition to those found in Appendix D.

For electricity generation, by far the most common system for remote locations is a diesel engine-generator system. Although the initial installation cost for diesel generator systems may be attractive, facility operators must deal with fuel transportation, on-site fuel storage issues, noise and pollution from electric power generators, and price volatility. Diesel engine-generator set lifetimes depend on how the systems are operated, and the level of maintenance. A well-maintained diesel generator will typically last about 25,000 operating hours before it needs replacement or a major overhaul.

Part of your team's duties is to not only make sure the generator is running well but also has fuel stored for future use as well as spare parts when it breaks down. Many generators are connected to a battery back-up so the generator does not need to run 24 hours a day. One benefit of using a generator with a battery system is that it will allow discharged batteries to be charged more quickly than using a solar system.

Basic System Operation:
Diesel engines run most efficiently at maximum power. During periods of low electric demand, engines consume more fuel per unit of electrical output and experience additional wear and tear on the engine. In some cases, using multiple smaller engine-generator sets instead of a single large one may improve efficiency and reduce maintenance requirements.

Inspecting the System:
It is important to inspect the system on a scheduled basis to ensure that the system is functioning properly and all parts are clean. Be sure to keep the generator room clean and free of any equipment not directly associated with the generator. As the facility manager, it is your job to either do all the tasks below or to assign one of your energy management team members to complete them.

Daily maintenance inspection:

1. Check the unit hourly to make sure all parts are moving smoothly and that the system is running efficiently.
2. Track how much fuel is being consumed daily by the generator, and how many hours it runs.
3. Maintain fuel and lubricating oil levels and check to see how much back up fuel you have in stock.

Periodic/as-needed maintenance inspection (see manufacturer's recommendations):

1. Change oil and oil filter.
2. Routine service by a qualified mechanic: check and tighten bolts, replace fuel filter.
3. Conduct minor and major overhauls at regular intervals.
4. Manage hazardous materials storage: diesel fuel, motor oil, and used motor oil disposal.

The sample inspection form below should be used on a daily basis to log the system performance. Your clinic's energy technician should be the one in charge of checking the system and should work with you to track the system operation over time. You should keep these forms and show them to an engineer or the system installer when they come to do any routine checks to make sure everything is functioning correctly.

Sample Daily Inspection Form

WEEK: ________________________________

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Date							
Time							
Weather							
Ambient temperature							
Gallons of fuel consumed							
Hours run							
Gallons of fuel in stock							

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Additional information on energy applications for health facilities may be found at

www.poweringhealth.org

For information and resources on other USAID/Energy Team activities, see the team's website at

http://www.usaid.gov/our_work/economic_growth_and_trade/energy

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