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Michael Bycroft

ENERGY FOR RADIO

A GUIDE FOR PRACTITIONERS

02

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Michael Bycroft

Energy for Radio. A Guide for Practitioners

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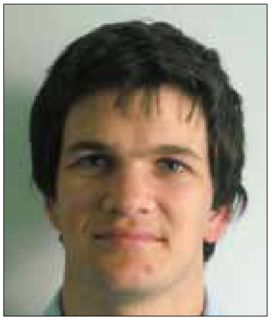

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CAMECO Practice Series:

Michael Bycroft

Energy for Radio

A Guide for Practitioners

Preface

Without a reliable energy supply, a radio station cannot operate. Of course, this is not unique to broadcasting. Often, we realize our dependency only when a shortfall of electricity occurs. However, in Africa and many other parts of the world, radio practitioners daily face the widespread lack of a reliable public energy supply.

In consequence, about everywhere in Africa, a complementary and/or alternative energy supply must be secured. Most commonly used are generators, although solar systems are now a viable option.

Selecting the most adequate energy generation system is a complex undertaking. There are many requirements and constraints to be considered, apart from financial aspects and environmental impact.

The guide intends to support radio managers and operators as they tackle the energy issue at their station. It helps to understand the various sources and technologies of energy, especially gensets, wind and hydro turbines, solar and hybrid systems; it also views many other aspects requiring attention before "informed decisions" can be taken, including assessment of the energy needs, storage, protection and regulation.

This publication is not a "how-to-do" book. The on-site assessment, configuration and installation of a specific energy system for a radio station should rest on the expertise of technicians or reliable suppliers. However, thanks to this guide, the station management will be in a position to raise relevant questions and assess the solutions offered.

Advances in energy technology are continual, and this publication should be considered "work in progress". We aim to improve and adapt it according to technology development, and the needs and experience of its users. To make this possible, we request your feedback, your comments and the sharing of your experiences. How are you able to apply the information? Which chapters do you consider most helpful? Which ones deserve to be adapted or more elaborated? Which of your questions remain unanswered? Which information is lacking?

As part of our consultancy work, we at CAMECO constantly deal with energy concerns of radio stations. Publishing a guide on energy management for radio practitioners, as part of the CAMECO Practice Series, was therefore a logical consequence.

We are very grateful that the Dutch foundation Stem van Afrika shares our keen interest in the development of material on energy issues for radio practitioners, and provided financial backing towards the production of this guide. The information made available by various radio stations, experts, companies and organisations is greatly appreciated, and thanks are due to Michael Bycroft for his expertise and dedication.

CAMECO, January 2011

Contents

List of frequently asked questions

Below is a list of all the Frequently Asked Questions (FAQ) boxes in the guide. The numbering of the boxes refers to the respective chapters where they can be found. FAQ 1.1 is in Chapter 1, FAQ 7.1 in Chapter 7, and so on. FAQ boxes are spread throughout the guide and contain answers to common questions about energy management that are not answered in detail in the main text of the guide.

Abbreviations

Below are some abbreviations frequently used in this guide. A full glossary appears on p. 229.

A = Amp: The standard unit for current (current is the rate at which electrons flow through a wire).

AC = Alternating current: A type of electric current in which the direction of the flow oscillates at frequent, regular intervals.

Ah = Amp-hour: A unit for the amount of charge stored in a battery. A battery with 2,000 Ah can deliver 20 A current for 100 hours, 50 A current for 40 hours, and so on.

CFL = Compact fluorescent light: An energy efficient light bulb that uses electrical current in a gas, rather than heat, to produce light.

DC = Direct current: Electrical current flowing in one direction only (in contrast to AC or alternating current).

kW = kilowatt: A unit of power equal to 1,000 Watts.

kWh = kilowatt-hour: A unit of energy equivalent to the energy produced or consumed by a device operating at 1 kW for 1 hour.

LED = Light emitting diode: An energy efficient light form, often used as a light source in electronic displays.

MMPT = Maximum power point tracker: A feature of a charge controller that holds the electricity from a solar panel at a current and voltage that results in the maximum possible power being delivered to the batteries.

m/s = metres per second: A measure of speed. 1 m/s is 3.6 km/hr.

PV = Photovoltaic: An adjective to describe the process of converting the energy from sunlight into electrical current (solar panels, PV cells, PV modules, and PV arrays are names for devices that carry out this process).

RET = Renewable energy technology: A technology that converts the energy of natural resources into usable energy, often electrical energy.

UPS = Uninterruptible power supply: A device that monitors (and sometimes refines) an incoming power supply, and provides back-up power when the supply fails.

V = Voltage: The standard unit for voltage (voltage is the amount of energy carried by electrons in an electrical circuit).

W = Watt: The standard unit of power (power is the rate at which energy is produced or consumed).

Wp = Peak Watts: The amount of electrical power a photovoltaic device (such as a solar panel) will produce under ideal sun conditions.

Note on units and terminology

Below are some conventions used in this guide. A full glossary appears on p. 229.

In equations, units are given in square brackets e.g. "Power [W] = voltage [V] x current [A]."

Currency values are denoted by "$" and are given in **US dollars,** unless otherwise stated.

The following currency conversions are used:
1 Euro = 1.23 USD;
1 Kenyan Shilling = 0.012 USD;
1 South African Rand = 0.133 USD;
1 Sierre Leone Leone = 0.000253 USD (conversion rates are valid as of August 2010).

Temperatures are given in degrees Celsius (°C).

Energy technology refers to any device that helps to generate, store, or regulate the energy at a station, or protect station equipment from defects in the electrical supply.

Energy generating technology refers to any technology that converts chemical, mechanical, solar or other energy into electrical energy – solar panels, wind turbines, gensets, etc.

Electrical generator refers to a device for converting mechanical energy (usually the energy of a rotating shaft) into electrical energy. Some energy generating technologies (including gensets, wind turbines, and hydro turbines) contain electrical generators.

Genset refers to any device that converts the chemical energy of a fuel (diesel, propane gas, jatropha oil, etc.) into electrical energy, using a combustion engine and an electrical generator.

Introduction

A reliable energy supply is essential to running a successful radio station. Yet many stations in Africa struggle with unreliable energy, whether it is a fluctuating public power supply or a diesel generator that is prone to breakdown and has high fuel costs. This guide shows how stations can make better use of their existing energy supply as well as take advantage of alternative energy sources, including renewable energy technologies (RETs). Through case studies, worksheets and information about key energy technologies, this guide aims to help radio station practitioners plan for improved energy management. This introductory chapter describes the current energy challenge for stations and the main approaches to the challenge. It ends with advice on how to use the other chapters in this guide.

The energy challenge

Energy is a serious concern for radio stations, making up to 50% of a station's budget. Without a strong and consistent supply of electricity, stations cannot perform even their most basic functions, from recording interviews to transmitting news bulletins. There are persistent problems with the two main energy sources which stations in Africa currently use: the public power supply and diesel generators.

The public power supply is unreliable in many places or non-existent. In practice, although rural stations are permanently connected to the grid, they may only have access to the public supply for a few hours each day. Regular and unpredictable power outages make it hard to broadcast continuously even during the few hours when the public supply is nominally available; severe voltage fluctuations contribute to this problem while reducing the lifetime of sensitive electronic equipment and posing the risk of electrical blow-outs. Urban areas usually have more regular access to public power, but this supply is often as variable and as unpredictable as the rural supply – sometimes even more so. African governments continue to invest in improved access to public energy (see **Chapter 11** for some examples of this). But population growth in cities means stresses on the supply are always increasing. And the sparseness of rural populations in Africa means it is often uneconomical to extend the public grid to those areas. So the public power supply is unlikely to improve dramatically in the near future. The public supply has the advantage of being cheap and convenient, but it places strict limits on the capacity of a radio station that does not supplement it with alternative energy sources.

Gensets (combustion-based generator sets, especially diesel generators) are a common source of power for stations, either as the sole energy source, as a primary supply, or as a back-up when the public supply fails. Diesel gensets are an attractive option because of their low initial cost compared to renewable energy technologies. Their widespread use in Africa, and their similarity in design to car and truck engines, mean that they enjoy a strong service infrastructure: spare parts are relatively easy to find, and expertise in repairing and maintaining the units is widespread. But, the chief disadvantage of diesel gensets is their high running cost, which includes not only the cost of fuel but also the expense of transporting fuel from its point of sale to the radio station. (FAQ 4.2 in **Chapter 4** contains advice on estimating the true long-term cost of fuel for a genset). Gensets running on fossil fuel also contribute to mining, deforestation, and global warming, and are vulnerable to changes in the global fuel supply. They are also reliant on government fuel subsidies, which are not stable. Finally, although it is notoriously difficult to predict exactly, fuel prices are likely to increase in the future. According to one U.S. energy authority, global oil prices doubled between 2000 and 2010, and may well double again between 2010 and 2030 [1]. It is prudent to anticipate rather than ignore such a trend, especially bearing in mind the effect that a slight change in the oil price can have on a station's overall operations budget.

Five steps towards better energy management

Good energy management makes stations better able to meet their energy demands. This guide is loosely structured around five steps towards improving the energy management at a station. Each chapter, or group of chapters, focuses on one or more of the steps below. These steps are summarised below, as well as in the Planning Checklist in **Appendix A.1**.

Step 1. Assess energy needs. An accurate energy assessment – a study of the energy needs of the station – is essential to any project for improving the energy management at a station. An energy assessment indicates how much extra energy (if any) the station needs in addition to what is drawn from the public supply, and what type and size of energy generating technology is required to meet those needs. Energy assessments also help to identify potential energy savings by identifying the largest energy consumers at the station. Assessments involve calculating the quality, timing, variation and prioritisation of a station's energy loads. **Chapter 2** includes a short guide to conducting an energy assessment at a radio station.

Step 2. Identify potential energy savings. Reducing the energy used at a station is the best and fastest way to save money on energy. Energy savings are especially important if renewable energy technology (RET) is used at the station. Energy can be saved by replacing inefficient devices with efficient ones, reducing the amount of energy wasted through careless use, or redistributing the energy load so it coincides with periods of strong energy supply. **Chapter 2** describes the main energy consumers at a radio station and gives suggestions for reducing their energy consumption.

Step 3. Select appropriate energy system and technology. The bulk of this guide consists of descriptions of the main technologies that stations can use to reduce the cost of their energy supply and/or improve the size, reliability, safety, and electrical quality of the supply. **Chapter 3** describes the main types of energy system that a radio station may consider, and summarises their advantages and disadvantages. **Chapters 4, 5 and 6** are devoted to energy generating technologies, and **Chapter 7** is about technologies that store and regulate electrical energy. These chapters are summarised below.

Energy generating technology. Technologies for generating electrical energy include diesel gensets and renewable energy technologies (RETs) such as wind turbines, solar panels and hydro turbines. It is not always obvious whether a given technology will be able to meet the energy demands of a station (see Box 0.1 for

Box 0.1
Will a 1 kW windturbine power a 1 kW transmitter?

At first glance, you would think that a 1 kilowatt (1 kW) wind turbine would be suitable to power a 1 kW transmitter. But this is far from true. A transmitter that produces a signal of 1 kW consumes considerably more than 1 kW of energy – up to 3 kW for an inefficient device. The rating of a wind turbine is also misleading, since it applies only under ideal wind conditions – during a windy day or a light storm. On an average day, the 1 kW turbine is unlikely to deliver more than a fifth of its rated power. If the station runs 24 hours a day, the turbine will deliver no more than a tenth of the transmitter's energy needs. This does not mean that wind turbines are not worthwhile, but it does mean that care should be taken when selecting the best technology for a station. Chapter 4 summarises the factors to consider when evaluating the cost and performance of energy generating technologies.

an illustration of this point). **Chapter 4** describes the main factors to consider when evaluating the cost and energy output of these technologies. This can help to assess whether such systems can serve a station's energy needs at a realistic cost, and to compare one system with another.

The chapter includes sample analyses showing the likely cost and performance of two renewable energy systems (one based on wind power and the other on solar power). It ends with a summary table showing how key energy generating technologies compare on the main factors that determine their cost and performance. **Chapter 5** covers renewable energy technologies (RETs). It describes the physical construction, natural resource requirements, energy output, de-rating factors, standards, and industry and policy conditions for key RETs (solar panels, wind turbines, and hydro schemes). It also includes information on two emerging technologies (animal power and biogas). **Chapter 6** describes the main features of gensets, including ways in which fuel costs for gensets can be reduced.

Energy storage and regulation technology. Stations can make the most of all energy sources by storing energy in batteries so that excess energy is used in times of need rather than being lost. Charge controllers increase the lifetimes of batteries by feeding electricity to them at the correct rate, and inverters ensure that batteries deliver a smooth supply to the station's sensitive electronics. Electrical regulation equipment (such as an Uninterruptible Power Supply, or UPS) smoothes out the supply and immediately switches to emergency backup power when the supply fails without warning. This technology makes the most of the existing power supply and protects electronic equipment from fluctuations in voltage, current, and frequency. Another form of protection is to shield the station's critical loads – the equipment that is essential to the station's functioning – from the failure or overuse of the available energy sources. This means the available sources can keep the station running for longer, even when they are depleted. **Chapter 7** summarises these technologies.

Step 4. Plan for the long-term management of the system. Energy technologies are long-term investments, with lifetimes counted in years and even decades. Long-term planning is needed to ensure that the equipment is effective until the end of its rated lifetime. It is recommended that each station appoint an "energy manager" to plan, oversee and manage the tasks described in **Chapter 8**. These include: maintenance; evaluation; identifying and responding to changes in the energy load; overseeing energy savings; training technicians, operators and users; and sharing experience, expertise and (in some cases) energy with other members of the community.

Step 5. Select and work with energy technology providers to plan and install technology. Energy technology providers are the individuals and companies that procure energy equipment and help to plan, install, and service the equipment. As well as assessing the energy requirements of the station, it is important to assess the know-how and technical expertise the station will need to carry out an energy project. Energy technology is a long-term investment with high initial costs, where the relevant expertise at the right moment can make a big difference to the cost and success of the system. It is strongly recommended that stations consult professional energy providers and experienced independent specialists at each stage towards adopting energy technology, from estimating the cost of the technology to working out a maintenance schedule. **Chapter 9** contains advice on selecting an energy technology provider and working productively with them to see the project through.

How to use this guide

This guide *does not* serve as a Do It Yourself manual for manufacturing, installing, or maintaining energy technologies; nor does it give a simple formula for deciding which technology is best for a given station. Every station has different energy needs that require different solutions. This guide is not a substitute for an experienced energy expert or consultant. But it can help in making informed choices and formulating the right questions to ask the specialists.

This guide *does* summarise the main technologies for saving, generating, storing, and regulating energy. It examines ways to protect valuable electrical equipment, and describes the main factors to consider when deciding between various options for improving the energy situation at a radio station. The guide is designed to inform stations about the risks and benefits of various energy technologies, to advise on the planning and management of an energy project, and to help stations work with energy dealers and consultants to find the best solution for the station.

The guide also includes the following:

Basic concepts in energy and electricity (Chapter 1). This chapter gives an overview of key concepts related to energy and electricity, and the units used to measure them.

Case studies (Chapter 10) describe the experiences of radio stations in Africa and elsewhere that have adopted a range of energy technologies, especially renewable energy technologies (RETs). Contact details for these stations are listed in **Appendix D.2**, under Chapter 10.

Energy policy and enterprise (Chapter 11) gives some background to small-scale energy technology in Africa by describing local energy enterprises (including how to build an energy enterprise) and summarising the contribution that government policy can make to small-scale energy technology.

FAQ boxes are spread throughout the guide and contain answers to frequently asked questions about energy management. These questions range from "How can I estimate the long-term cost of fuel for a diesel generator" (FAQ 4.2, in Chapter 4) to "Is there enough wind in my region to justify a wind turbine?" (FAQ 5.2 in Chapter 5). A list of all FAQs appears on page 10 of this guide.

Quick reference summaries appear at the start of key sections in the chapters, and summarise the contents of the section. They are designed to give a quick introduction to the main topics of the guide for readers who do not wish to read the entire guide.

Worksheets (Appendix A) provide space for filling in energy-related data about a station, and lead the reader through the calculations required to (for example) estimate a station's daily energy load, or compare the annual cost of different energy sources. Online versions of the worksheets are available at **www.cameco.org/publications/.**

Appendix B gives semi-technical information relevant to energy management, including the typical energy consumption of common radio station equipment, and wind and solar maps for Africa.

Sample data sheets (Appendix C) are annotated examples of technical data sheets for two energy technologies (solar panels and wind turbines).

Further resources (Appendix D) are companies, individuals, organisations, books, websites, and software tools that can assist with energy management. Resources are organised by chapter in **Appendix D.2**, with a Key resources list in **Appendix D.1** giving some important general resources.

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1 The basics of energy and electricity

In order to plan, monitor and maintain energy technology, it is useful to know some of the principles behind energy and electricity. This chapter gives a short introduction to energy and electricity and the ways in which they are measured. Later chapters will make use of the concepts and units in this chapter.

Quick reference summary:

Electricity and energy

Voltage is the energy gained or lost in components of an electrical circuit. Voltage is measured in **Volts (V).**

The **current** in an electrical circuit is the rate at which electrons flow. Current is measured in Amperes or **Amps (A)**.

Energy is the capacity to do physical work.

Power is the rate at which energy is produced or consumed. It is measured in Watts (W) or **kilowatts (kW)**. 1 kW is 1000 W.

Kilowatt-hours (kWh) is used to measure energy consumption in homes and businesses. 1 kWh is an amount of energy equivalent to the energy produced or consumed when 1 kW of power is maintained for 1 hour.

Power [kW] = energy [kWh] ÷ time [hours]

Energy [kWh] = power [kW] x time [hours]

Electrical power [W] = voltage [V] x current [A]

Electricity

Circuits and circuit diagrams

A circuit diagram such as the one below is a schematic way of showing how electricity delivers power to electrical loads. In the case of Fig. 1.1, a battery powers a light and a transmitter, and a switch allows the flow of current to be turned on and off.

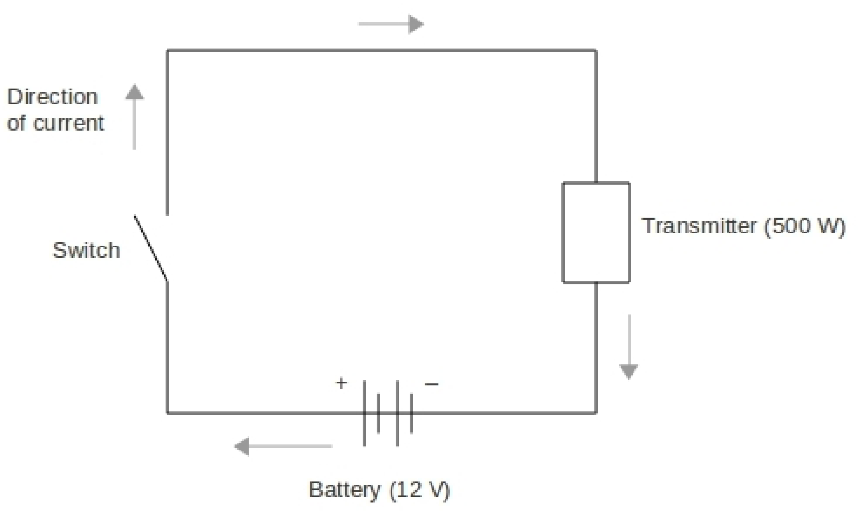


Fig.1.1
A **basic circuit diagram** consisting of a battery, switch, and transmitter. When the switch is closed, current travels around the circuit in the direction shown.
Diagram: author

Series and parallel circuits

Electrical circuits consisting of a single loop (such as that in Fig. 1.1) are series circuits; circuits consisting of multiple "branches" (such as that in Fig. 1.2) are parallel circuits. Voltage and current sum differently in series and parallel circuits. For example, a set of batteries connected in *series* will together deliver a voltage that is the *sum* of the voltages in each battery. The same set of batteries connected in *parallel* will deliver a voltage that is just the voltage of a single battery. For current, the situation is reversed: the current in a series circuit is the same all the way round the circuit; but in a parallel circuit, the current in the main part of the circuit is the sum of the currents in the branches of the circuit. These laws mean that batteries, solar panels, and other electrical components, can be wired in different ways to give different overall voltages and currents.

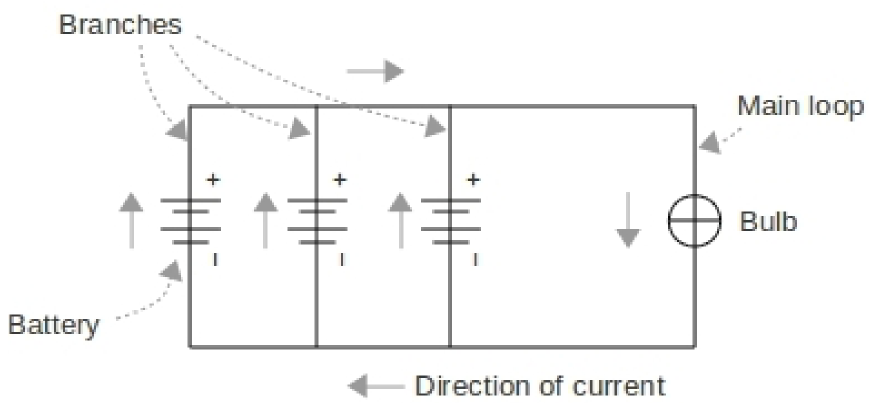


Fig. 1.2
A parallel circuit.
It is assumed that each battery has the same voltage. Because the batteries are connected in series, the voltage across the light bulb is equal to the voltage of one battery. But the current in the main loop is the sum of the currents in each of the branches.
Diagram: author

Current

Electrical current – like the current in a river or stream – is the rate at which a quantity flows through a medium. In a river, the quantity is a volume of water and the medium is the river bed. In an electrical circuit, the quantity is a certain number of electrons and the medium is the conducting wire. The unit for electrical current – Amps (A) – reflects the fact that current is a rate of flow. If a wire has a current of 1 A, this means that about 6 billion electrons pass through each point in the wire every second.

Voltage

Voltage is the energy that is gained or lost by an electrical current when it passes through a battery (gaining energy) or through electrical loads (losing energy). The unit for voltage is the Volt (V). Typical voltages are 12 V for batteries and 110 V or 220 V for a public power supply.

Alternating current

The diagrams so far have described direct current (DC): current that does not change direction. Alternating current (AC) changes direction at constant, frequent intervals. The **frequency** of AC current is how often the current changes direction. The standard unit for frequency is Hertz (Hz). Current of 1 Hz changes direction once every second. Typical household current of 50 Hz or 60 Hz changes direction 50 or 60 times every second. The **wave form** of AC current describes the way in which the current varies over time. Square wave AC changes direction abruptly. Sine wave AC changes direction smoothly in the shape of a sine curve. Modified sine wave AC is an intermediate form that changes direction in small steps (see Fig 1.3).

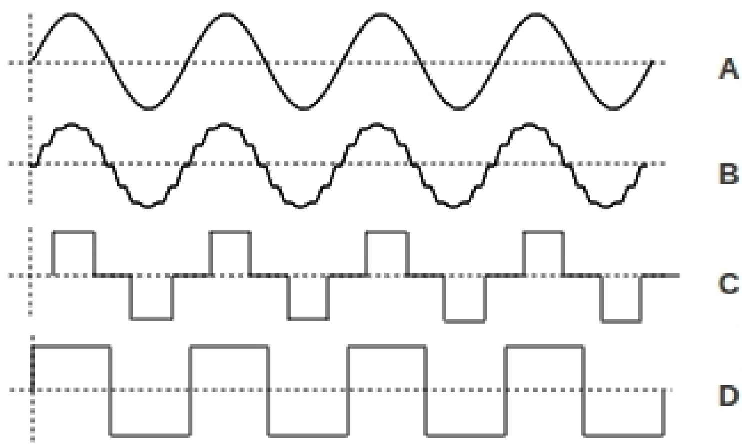


Fig. 1.3
Four wave forms, ranging from a pure sine wave (A) to a square wave (D). The two intermediate wave forms are a modified square wave (C) and a digitally synthesised wave made up of many small steps (B).
On each graph, the parts of the wave above the dotted line are moments when the current is going in one direction; parts of the wave below the dotted line are moments when the current is going in the other direction. Diagram: author

The advantage of AC current is that it is relatively easy to change its voltage, making AC current common in large grid systems where the voltage needs to be stepped up for high-voltage transmission and stepped down for domestic use. Because AC current is the most common form of grid electricity, AC devices and appliances are usually more easily purchased and serviced than the equivalent DC equipment. On the other hand, solar panels and batteries deliver DC electricity, and conversion from DC to AC in inverters can involve significant energy losses, especially if the inverter often operates at low power (**Chapter 7** has more information on inverters).

Energy and power

Energy

Energy is roughly defined as the capacity to do physical work. The standard unit for energy is the Joule (J), but for businesses and households the kilowatt-hour (kWh) is a more common unit of energy (see FAQ 1.1). Energy comes in many forms, from the kinetic energy of a projectile or moving water to the chemical energy in fossil fuels. Electrical energy is essentially the kinetic energy of electrons moving in wires. This energy is used in electrical circuits in computers, transmitters, and other devices; to create light in bulbs and heat in electrical kettles; and to power the electric motors that drive everything from fans in transmitters to the pop-out rack in a DVD or CD player.

FAQ 1.1

What is a kilowatt-hour (kWh)?

1 kWh is the amount of energy consumed by an appliance running at a power of 1 kW for a time of 1 hour. It is approximately the energy consumed by a 20 W bulb left on for 2 days, or by a desktop computer running for 3 hours. It is important to note that:

kWh is a unit of energy not power, even though there is a unit for power (kW) in it. This makes sense because the kWh unit also has a unit for time in it (the hour). And an appliance with a given power, maintained over a given time, gives a fixed amount of energy.

For an appliance to consume (say) 2 kWh does not imply that the appliance runs for 1 hour at 2 kW. The appliance may run at a power of 2 kW for 1 hour. But it may also run at 1 kW for 2 hours, or 4 kW for 0.5 hours, and so on – in all of these cases it will consume 2 kWh overall.

Power

Power is the rate at which energy is produced or consumed. (Strictly speaking, it is the rate at which energy is converted from one form to another, such as from chemical energy in a battery to electrical energy in a wire). The standard unit for power is the Watt (W). A device that produces 1 W of power is producing 1 Joule of energy every second. 2 W is 2 Joules per second; 1000 W (also written as 1 kW) is 1000 Joules per second, and so on.

The power produced by an energy source (such as a solar panel or diesel generator) is often called its power output (and sometimes its power capacity). The power that an electricity regulating device (such as an inverter or voltage regulator) can handle without shutting down is usually called its power capacity. The power that is consumed by an appliance is usually called its power draw or simply power consumption.

Power is different from energy, but the two are closely related. The link between them is time. Power is the amount of energy produced or consumed per unit of time. And a given power maintained for a given length of time gives a fixed amount of energy. The same amount of energy can be produced or consumed at different powers: the energy in a battery bank, for example, can be used rapidly over a few hours or slowly over a few months. And the same power can produce or consume different amounts of energy, depending on how long that power is maintained: a 60 W light bulb that is left on throughout the night consumes more energy than the same bulb that is used only in the evening.

The following formulae help to convert energy values into power values:

$$\text{Power [kW]} = \text{energy [kWh]} \div \text{time [hours]}$$

$$\text{Energy [kWh]} = \text{power [kW]} \times \text{time [hours]}$$

For example, using the second formula: a solar panel that delivers a power of 0.5 kW for 5 hours a day will deliver 2.5 kWh of energy per day (0.5 x 5 = 2.5).

Fig. 1.4
Each set of solar panels of Radio Pacis' (Uganda) solar park generates about 1.8 kW of electrical power in full sunlight. On a day with 5 hours of full sun, it will generate about 9 kWh of energy (1.8 x 5 = 9).
Image: CAMECO

Energy and power in electrical circuits

The power delivered by a battery (or consumed by an electrical load) depends on the voltage across the battery and the current in the circuit:

$$\text{Power [W]} = \text{voltage [V]} \times \text{current [A]}$$

For example, a battery delivering 24 V with a current of 10 A has a power of 240 W (24 x 10 = 240). Power depends on the size of both the current and the voltage in the electricity – increase or decrease either of these, and the power will increase or decrease accordingly.

Strictly speaking, the formula above does not find the **actual power** (in W) in a circuit. Instead it finds the **apparent power** (in Volt-Amps, or VA). For AC current, the apparent power delivered by a device is usually 1.2 to 1.5 times greater than the actual power (to put it round the other way, the actual power is usually 0.7 to 0.8 time smaller than the apparent power). For example, a generator with an apparent power of 5,000 kVA may only have an actual power of 3,500 W (5,000 x 0.7 = 3,500). This is because of an electrical phenomenon known as **power factor.**

2

Energy saving and assessment

The first step towards better energy management is to find out how much energy the radio station uses on an average day. An energy assessment identifies the main energy loads of a station and estimates the total daily energy use. It may also capture more detailed information about the quality, timing, and variation in energy use. This can help to identify the main sources of energy loss at the station. An energy assessment also helps to select and size the energy technologies described in **Chapters 3 to 6**.

The second step to improving the energy supply – and the easiest way to save money on energy – is to use less energy. This means identifying the main forms of energy use at the station and finding ways of making them more efficient – either by reducing wasted uses of energy, replacing inefficient consumers with more efficient ones, or redistributing the energy load across a day.

This chapter consists of a summary of the principles of energy saving and energy assessment, followed by a summary of the energy use and energy saving possibilities for the main energy loads at a radio station.

Energy saving: the basics

Saving energy means decreasing energy use while maintaining the station's ability to perform its essential tasks. Energy saving is especially important when gensets or renewable energy technologies (RETs) are used, since those sources are usually more expensive than the public power supply. Reductions in energy use translate into reductions of energy costs and reductions in the initial and future costs of energy technology (see Box 2.1 for an illustration).

The main kinds of energy saving are:

Reducing waste by using equipment carefully. This is the cheapest way of saving energy, but it requires a long-term effort from staff. This effort can be aided by the appointment of an "energy manager" and the use of a roster of tasks for supervising energy use at the station. Simple ways to reduce waste include turning off lights when they are not in use, switching off electronic devices at the wall when not in use, and closing doors and windows when air conditioning is on. (For more ways to reduce waste, see "Key energy loads at a radio station," below.)

Replacing inefficient appliances with efficient ones. This includes replacing old and worn-out devices with new ones. Energy efficient devices perform the same tasks using less energy than inefficient devices. For example, laptop computers perform essentially the same functions as desktop computers while consuming about a third of the energy; and compact fluorescent light bulbs produce the same amount of light as incandescent bulbs while drawing much less power. Energy efficient equipment sometimes has a higher initial cost than inefficient equipment. However, these costs are often cancelled out by the consequent reduction in the energy bill. The time it takes for the initial cost difference to be cancelled out is the payback period. (**Appendix A.5** contains a worksheet for calculating the payback period of efficient equipment). When comparing the energy consumption of

Box 2.1

Cost savings and energy efficiency

Energy generating technologies such as wind and solar power are usually more expensive per kWh than the public power supply. As a result, energy saving at a station is even more important for these "off-grid" energy sources. For example, a solar energy system costs roughly $10,000 per installed kW. On average, solar panels in Africa deliver roughly 6 kWh of energy per day for every installed kW. So a station relying on solar power that saves (say) 3 kWh per day will save roughly $5,000 on the initial cost of the system.

Fig. 2.5 in this chapter gives a more detailed breakdown of the potential cost savings due to energy efficiency at a station.

Box 2.2

The cost and energy savings of energy efficient equipment

When making an economic comparison between energy efficient and energy inefficient equipment, it is important to take into account the reductions that efficient equipment will make to the energy bill. The value for money of a device is also affected by its lifetime.

For example, an incandescent light bulb draws roughly 100 W to give the same light as a compact fluorescent bulb (CFL) that draws roughly 15 W. Assuming the bulbs are used for 5 hours every day, the CFL saves about 155 kWh a year. This equates to roughly $75 in annual savings if each bulb draws on genset or solar power, and roughly $8 in annual savings if public power is used.* In both cases the extra initial cost of the CFL bulb will be quickly cancelled out by the cost savings due to energy efficiency.

This analysis assumes that the bulbs operate for the same amount of time. In fact, CFL's last around 10 times as long as incandescent bulbs. This extra lifetime is usually enough to cancel out the extra cost of CFL's even before the savings in the energy bill are taken into account. **Appendix A.5** contains a worksheet for estimating the payback period: the time taken for energy cost savings to cancel out the extra cost of efficient equipment.

In some countries, the sale of incandescent bulbs is already being phased out as governments stimulate the change to CFLs. Another even more efficient technology is also appearing in Asia and parts of Europe. So called Light Emitting Diode (LED) technology has not yet reached a price-performance level for applications in radio stations, but that situation may well change in a couple of years. (The industry site http://www.lightingafrica.org is a good source of news on this topic.)

Fig. 2.1
A compact fluorescent light bulb (left) and an incandescent light bulb (right).
Images: All energies.net, Cambridge Energy Alliance

*Energy cost assumptions: solar system and genset at $0.5/kWh; public power supply at $0.05//kWh

Data: World Bank and National Renewable Energy Laboratory [2] different devices it is important also to consider the amount of energy each device will deliver over *its whole lifetime,* as the example of energy efficient lighting shows (see Box 2.2).

Redistributing the energy load to match the needs of the power supply. Energy can be saved by working in periods when the cheapest supply of energy – usually the public power supply – is available. This means that devices which consume a lot of power should preferably be used when public power supply is available. Also, redistributing the power demands of a station over the course of a day eliminates high-power peak periods that drive up the cost of energy generating technology, batteries, and electrical regulation equipment. (Inverters, charge controllers, uninterruptible power supplies (UPS) and voltage regulators are usually rated in terms of their power capacity, which largely determines their cost.) Evening out the power usage over the day also helps to avoid the losses associated with running equipment such as gensets and inverters at powers well below their maximum power.

Energy assessment: what it is and why it is important

An energy assessment – a study of the patterns of energy use at a station – serves two functions. It helps to identify opportunities for saving energy. And it helps to select and size energy technologies. Energy assessment is especially important for stations that intend to use renewable energy technologies (as opposed to gensets) because the main cost of RETs (the initial cost of the equipment) is fixed by a prior estimate of the station‘s energy needs. By contrast, the main cost of a genset (fuel costs) does not require a prior estimate of the station‘s energy needs – the amount of fuel used can be controlled over time depending on the station‘s need. However, even for gensets, an energy assessment is needed to correctly size the genset: a too-large genset may run below full power and thus make inefficient use of its fuel; and a too-small genset may not be able to serve the larger loads at the station.

The simplest form of energy assessment is to calculate the energy used at the station on a typical day. The daily energy demands of most electrical devices can be estimated from the power rating of the device and the number of hours it is used during a typical day:

Energy per day [kWh/day] = power [kW] x on-time per day [hours/day]

An energy assessment can also provide information about:

Existing power supply. The available supply from public power and other existing sources (such as a genset) needs to be known in order to calculate how much extra energy (if any) the station needs.

Daily variation and peak load. The **peak load** is the highest total power consumption occurring at a station during the course of a typical day. Peak load is important because most energy technologies have limits on the *power* they can sustain (not just on the *energy* they can sustain per day). This includes energy generating technologies, storage technologies (batteries), and technologies for regulating the electrical supply (including inverters and charge controllers). If there are times of the day when the load is particularly high, a station can save energy by distributing the load more evenly across the day. It is also important to know how much overlap there is between the periods when the station needs power and the periods when the public power supply is available: this helps to determine how much storage or extra generation is required.

Seasonal variation and the design month. The **design month** is the month when the ratio of the station's energy load and the energy supply is highest; in other words, the month when the station's energy sources have the most trouble meeting the demand. (Hence it is not possible to find the design month until the annual variation in the energy sources is known.) Energy technologies should be selected so that they are powerful enough to meet peak demand during the design month.

Electrical quality. This includes the kind of sine wave the station needs (square wave, modified sine wave, or pure sine wave) and how much fluctuation in the voltage and frequency of the power supply the station's equipment can handle. These factors affect the quality of inverter and the kind of voltage regulation that the station needs.

Reliability and critical loads. Some consumers are essential to the working of a station and require extra protection against failures of the power supply, whether this is the public power supply, an alternative energy source, or both.

Quick reference summary:

Energy assessment

An energy assessment is a **study of the patterns of energy use** at a station.

Energy assessments help to **identify opportunities for saving energy** and to **select and size energy technologies.**

Energy assessments are **especially important for sizing renewable energy technologies (RETs)**: once the RET is installed, the user has little choice (as they do with genset fuel) about how much generating capacity they pay for.

The most **basic energy assessment** is to find the daily energy consumption of all consumers and add them up. Appendix A.2 contains a **worksheet** to help with this.

Advanced energy assessments may take into account the existing power supply, critical loads, future changes in demand, the remoteness of the station, daily and annual variation in demand, and the electrical quality needed.

Daily energy consumption [kWh] = average power [kW] x on-time per day [hours].

The **average power consumption of appliances** can be found using (in order of accuracy) data tables such as that in Appendix B.1, manufacturer's ratings, and direct measurement using electrical meters.

FAQ 2.1

How can I estimate the energy consumption of station equiment?

The simplest form of energy assessment is to find the daily energy consumption of the main loads at the station and add them up. The power consumption of equipment can be found through:

Standard energy consumption data. Tables showing the typical power consumption of key equipment can give a first approximation of a station’s power draw. The table in Appendix B.1 is an example. Power draw varies widely depending on the type and condition of the equipment used, so this table is no substitute for finding the actual consumption of the station’s equipment.

Manufacturer’s ratings. Most electrical equipment and appliances have a rated power draw. This figure can be found either on a label or panel on the device, in the user’s manual, or both. This is a useful approximation of the actual consumption, but it may be an overestimate (due to the manufacturer playing it safe) or an underestimate (due to the deterioration or misuse of the equipment). In many cases manufacturer’s ratings are accurate enough to be a sound basis for sizing and selecting energy technology. For example, if a computer monitor is rated 30W, it is safe to assume that it uses 30W.

Direct measurement. A meter can be used to measure the power consumption of each load. This measure takes into account inefficiencies in the equipment that the manufacturer rating may ignore. The disadvantage is that it requires a reliable electrical meter and a technician to use it.

Future changes in demand. New equipment, extra staff, and longer on-air hours can all increase (and sometimes decrease) the energy demands of the station. New energy technology should be sized to handle these increases, either because it is oversized for the current demand or because it can be expanded in the future (a set of solar panels that can accommodate extra panels, for example).

Self-sufficiency. Stations with little local equipment or expertise, such as those in remote areas, are more vulnerable to faults and breakdowns in energy technology. Simple, durable, low-maintenance equipment is essential for such stations, as well as extra training for staff in the use and maintenance of the equipment.

Appendix A.5 includes a self-assessment questionnaire that estimates the average daily energy used at a station.

Fig. 2.2
Two sources of data on the energy consumption of equipment. The label of an air conditioner (left) and a power quality meter (right).
Images: CAMECO, B.BEAM

Key energy loads at a radio station

The following are the main energy loads at a radio station and some ways of reducing their energy consumption.

Transmitters

Since transmitters usually have relatively high power consumption, and operate all the time a station is on air, they make up a large proportion of the energy used at a station (typically between 20 and 60% of the daily energy used). Hence efficient transmitters can significantly reduce the total energy bill.

Transmitters are rated according to the energy they transmit, but they consume more energy than they transmit. An efficient transmitter of 1 kW, for example, is unlikely to consume less than 1.8 kW: almost 2 times the energy of transmission. Inefficient transmitters can consume much more than this due to inefficient fans and heat loss from wires and the electronic parts of the transmitter. For example, a 1 kW transmitter of poor quality can consume over 3 kW of energy. In other words, replacing an inefficient transmitter with an efficient one can reduce the energy consumption of the transmitter by a third, and the energy consumption of the station by 10-20%.

Maintenance of transmitters can reduce their electricity consumption. The heat sink should usually be cleaned every six months, and the transmitter's internal fans replaced approximately every two years. Some radio stations aim to reduce the chances of a transmitter overheating by putting an external fan in front of the transmitter (see Fig. 2.3). However, this should be avoided! External fans have the added problem that they blow dirt and dust into the transmitter.

Some modern quality transmitters can function at sites where the temperature is up to 40° Celsius, provided the transmitter is not exposed to direct sunlight. The temperature in the transmitter room can be reduced with proper natural ventilation. If artificial ventilation is used it should channel the hot air from the transmitter's internal fans out of the transmitter room. Otherwise the hot air from the internal fans simply heats up the room and the transmitter.

A high-quality cable between the transmitter and antenna saves energy by reducing the energy lost as heat in the cable. Studies in Niger have shown that a station that built a second transmitter and tower to reach outlying audiences, could have saved the entire investment simply by installing better quality (thicker) antenna cables between the transmitter and antenna. Stations can measure the radiated energy from the antenna to find out how much power from the transmitter is actually reaching the antenna. The measurement does not need to be conducted many times during the life-time of a transmitter, and a technician with suitable equipment can be hired for the task. The measurement is especially worthwhile at the beginning of a radio project or when listeners complain of a weak signal.

Fig. 2.3
Not recommended: A transmitter cooled by a standing fan. External fans blow dirt and dust into the transmitter.
Image: Jonathan Marks

Air conditioners

Air conditioners use large amounts of energy, and any investments in improved air conditioners or better insulation is likely to pay off in the long term through reduced energy costs. Badly maintained air conditioners are a common drain on energy. The worst of these losses can be avoided by:

Clearing the outside condensing unit of obstructions. The unit needs to draw air into the system in order to have something to cool and circulate inside, but the process is hindered if it cannot pull in enough outside air. Some people intentionally cover their condenser to protect it from the elements – but this is unnecessary since these units are designed for outdoor installation.

Changing or replacing the filters regularly. Dirty filters restrict air flow and reduce efficiency. Disposable fibreglass filters are usually designed to be replaced about once a month. Electrostatic or electronic filters need to be washed every few months.

Ensuring all inside access panels are secure, with all the screws in place. Clean obvious obstructions such as newspaper and leaves from around the exterior of the unit.

Another way to reduce the consumption of air conditioners is to cool the station by other means, such as:

Keeping electronic equipment out of direct sunlight.

Shading the station interior with an awning or overhang.

Painting the outside walls and roof of the station in a light colour (silver or white). Black or brown absorbs heat more quickly.

Keeping windows and doors closed as much as possible when an air conditioner is operating (otherwise the cool air from the conditioner, and the energy used to generate it, is lost to the outside world).

Using a fan or fans to circulate cool air in a room (fans use about a tenth of the energy of air conditioners).

Installing ventilation to remove hot air from high-energy equipment (especially transmitters) out of the area that needs to be kept cool.

Fig. 2.4
"Cyclone" ventilators on the roof of Voice of Life Radio, in Uganda. These ventilators – along with other measures such as using as little electronic equipment as possible, and installing equipment that can withstand high temperatures – mean that the station does not need air conditioners, reducing its energy needs. Chapter 10 contains more details on Radio Voice of Life and its energy situation.
Image: CAMECO

Using energy efficient lighting (fluorescent or compact fluorescent bulbs, or light-emitting diodes) to reduce the waste heat due to lighting. About 90% of the energy consumed by incandescent bulbs is lost as waste heat, and it only takes a handful of 100 W incandescent or halogen bulbs to have a significant heating effect. (See Box 2.2 for an example of the cost savings that can result from energy efficient lighting.)

Computers and printers

Computers have lower power demands than transmitters and air conditioners, but their high number and constant use in some stations means that they make up a sizeable chunk of the station's energy consumption. Some ways to reduce the consumption of computers and printers are:

Use laptops rather than desktop computers (where possible given the requirements of processing power and hard disk capacity). Laptops use about a third of the energy of desktops. They also have the advantage of portability, and their batteries give backup power when the main supply fails. Note, however, that in some cases laptops are not appropriate for security reasons.

Use power-saving functions or modes installed in computers, such as "sleep", "power-down," "hibernate", "suspend", and "screen-dimming."

Turn computers off when they are unused for extended periods. A rule of thumb for desktop computers is to turn off a monitor if it will be unused for 20 minutes or more, and to turn off the entire computer if it will be unused for 2 hours or more.

Replace CRT (cathode ray tube) monitors with LCD (liquid crystal display) monitors. Cathode ray tube monitors attract dust, take up a lot of space, and by generating large amounts of heat they counteract the cooling effect of fans and air conditioners. Some stations have reduced their air-conditioning consumption by up to 30% by simply replacing CRT monitors with more efficient LCD displays.

Fig. 2.5
A liquid crystal display (LCD) monitor (left) and old cathode ray tube (CRT) monitors (right).
Images: Jonathan Marks

Don't rely on screen savers – they do not save energy, and may even use more energy than a screen during normal operation. Modern LCD (liquid crystal display) screens do not require screen savers.

Look for Energy Star approved computer equipment. Energy Star (www.energystar.gov) is a US-based programme that rates common household equipment (including computers) according to energy efficiency.

Pay special attention to computers that are used only intermittently, such as a computer that is needed in a playout centre for security reasons. These devices can consume a lot of unnecessary energy if they are not fitted with an energy saving (LCD) monitor and power-saving modes or functions.

Lighting

Energy efficient lighting and sensible use of lighting is well worth the effort, both in economic and energy terms – especially if the station is on air through the night. Many forms of lighting (including candles, kerosene lamps, and incandescent bulbs) make use of the light produced by a heated material. This is an inefficient form of illumination because the bulk of the energy is lost as heat: for example, incandescent bulbs convert only about 10% of the energy they consume into light, with the rest lost as heat.

FAQ 2.2

What are the most effective steps towards saving energy at a radio station?

Install an efficient transmitter. Transmitters make up roughly 30-60% of the energy load at a station, and good quality transmitters can be up to a third more efficient than lower quality models.

Measure the radiated energy from the antenna, to check that all the power from the transmitter is actually reaching the antenna. Install higher quality antenna cables if necessary.

Unplug appliances or turn off the wall-switch when they are unused for longer periods, to minimise stand-by power draw. A power strip or surge protector can make it easier to disconnect devices.

Replace incandescent bulbs with LED (light emitting diode) or CFL (compact fluorescent) bulbs. They use less energy, produce less heat, and are cheaper in the long term.

Use task or spot lighting in place of ceiling or general lighting.

Replace desktop computers with laptops (and CRT screens with LCD screens) where possible.

Buy (new) energy efficient equipment.

Clean up the station's wiring (a trained electrician is needed for this). Messy wiring, with the wrong cables, dissipates electrical power. If a cable gets warm it is too thin and looses power - use a thicker cable.

Ventilate. As an alternative to air conditioning, assess the adequacy of installing cyclone ventilators on the roof.

Insulate. Good quality insulation in walls and ceiling can keep rooms cool and improve sound quality at the same time.

Replace one or more air conditioners with fans and close windows and doors when air conditioners are running.

Appoint an "energy manager" to take responsibility for saving energy at the station, and/or ensure that one person on each shift is responsible for energy saving on that shift.

Box 2.3

Case Study: Energy saving

APM, Radio Ecole, in Porto Novo, Benin, was re-built from scratch in 2007 to improve the coverage of the station and reduce its use of gensets. Energy saving measures at the station include:

A higher gain antenna replaced the old simple dipole antenna. The antenna points in the direction of the commercial capital of Cotonou, focusing the transmitted energy in the area with the maximum potential audience.

Higher quality antenna cables allowed a 600 W transmitter to replace the former 1 kW transmitter.

An audio processing unit was put between the audio mixer and transmitter to even out the modulation (peaks smoothed out). The unit increases the station's loudness and improves the signal on the fringe areas of reception. The result was improved coverage for a lower transmitter power.

Air conditioning is only used when necessary. Otherwise fans provide adequate cooling in the offices. Offices on the top floor of the building are cooled through air-ducts, and heat-reflecting paint was used on the roofs. Wood panelling in the studio keeps the room cool as well as improving acoustics.

Energy efficient computers and monitors were purchased, though laptops were not appropriate for security reasons.

Information provided by Jonathan Marks

Partly by eliminating waste heat, compact fluorescent (CFL) lights give four to seven times the light per Watt of incandescent lights, and last up to ten times longer. Light emitting diodes (LEDs) are another energy efficient light source which is becoming less expensive. In general, the light output from LEDs is lower that CFL, though LED technology is rapidly improving.

Aside from investing in more efficient lights, the best way to save energy on lighting is simply to turn off lights when they are not needed. One way to achieve this is with motion sensors that detect when a room is occupied and switch lights on and off accordingly. Getting the right number and type of lights is also important. For example, a small spot light provides more brightness on a desk or book than a big room light, and uses a fraction of the energy.

Radio electronics

Mixers, CD players, tape decks, TVs, photocopiers and other electronic devices can together draw a considerable amount of power. The following measures can reduce their contribution to the energy bill and lessen their strain on energy technology:

Turn devices off at the wall when they are unused for long periods (such as overnight). Many electric devices draw power even when they are in "standby" mode. This waste can be easily avoided by unplugging the devices or connecting multiple devices to a power strip or surge protector that can then be switched off.

Buy energy efficient equipment. This may cost more than inefficient equipment, but the extra cost will be cancelled out over time by reductions in the energy bill (Appendix A.5 can be used to estimate the payback period of efficient equipment).

Maintain equipment and replace in good time. Old, dirty, and broken devices tend to be less efficient.

Other energy loads

Refrigerator. Some stations may use a refrigerator for the comfort of station staff. There are two main classes of refrigerators, compression and absorption. Compression refrigeration offers great convenience and good temperature control, and is ideal for storing temperature-sensitive substances such as vaccines in health clinics. However, compression fridges are expensive and energy-intensive. Absorption refrigerators use propane or kerosene to drive an absorption cycle

Fig. 2.6
Radio Ecole APM, Benin. The station's energy saving measures included using a higher quality (i.e. thicker) antenna cable which meant that the station's 1 kW transmitter could be replaced with a 600 W transmitter. Box 2.3 shows more detail on energy saving measures at the station.
Image: Jonathan Marks

that keeps the compartment cold. Their internal temperature is relatively unstable, but adequate for food storage, and the use of fossil fuels reduces the burden on the electricity supply. Modern refrigerators usually show their energy consumption on the label.

Water heating (e.g. for kitchen facilities). Like cooking and space heating, the energy used for water heating usually exceeds the potential for power generated by small, electricity-producing renewable energy systems. Normally the water heating load can be met by simple solar water heaters or fossil fuel/biomass-combustion water heaters.

Kitchen appliances. If the station is equipped with a kitchen, energy-intensive appliances such as electric toasters, irons and electric kettles should be avoided. For example, a typical kettle draws almost as much power when operating than a typical 1 kW transmitter. Since kettles only operate in short bursts, the total daily energy consumption of a kettle is much less than that of a transmitter. But a short burst of high power consumption can raise the peak load (i.e. the maximum power consumption) of the station, placing a strain on batteries and other energy technology.

Workshop. Depending on the remoteness of the station and the need for repairs, it may be useful to run some simple power tools, such as electric drills, sanders, and portable saws. It pays to check the rating of these devices – they uually consume a lot of energy, albeit for short periods.

Energy saving potential: an example

Fig. 2.7 summarises the potential energy savings of a sample medium-sized radio station (with a 1 kW transmitter, 4 computers, and 5 air conditioners). The table assumes the following energy savings:

Air conditioners: air conditioners made more efficient due to maintenance; insulation, natural cooling, and 2 standing fans mean that 1 less air conditioner is needed.

Fans: 2 fans using 1.2 kWh per day, replacing an air conditioner using 6.4 kWh per day.

Transmitter: more efficient transmitter used.

Computers: desktops replaced by laptops.

Lighting: incandescent bulbs replaced by energy efficient bulbs, and lighting use cut by 25% due to sensible use.

As Fig. 2.7 shows, these savings can reduce energy use at the sample station by more than a third, saving over $6,000 *each year* if the station draws its power from solar panels or a genset.

Note: this is an example only. A station's energy use and potential for energy saving varies widely according to its size, condition and power costs.

*Assumes a public power supply cost of $0.05/kWh.
**Assumes a genset or solar system cost of $0.5/kWh.
Data: BBEAM, Begeca, World Bank, author's analysis

Fig. 2.7
Potential energy and cost savings for a middle-sized station with a 1kW transmitter.

KEY CONSUMERS	Before savings				After savings				Savings details		
	No.	Power W	Time hr/day	Energy kWh/d	No.	Power W	Time hr/day	Energy kWh/d	% saved	$/year, public power supply*	$/year, solar or genset**
Air conditioners	5	800	8	**32**	4	750	8	**24**	25%	$146	$1,424
Fans	0	0	0	**0**	2	60	10	**1.2**	N/A	-$22	-$214
Transmitter	1	3000	15	**45**	1	2000	15	**30**	33%	$274	$2,670
Computers	4	300	10	**12**	4	65	10	**2.6**	78%	$172	$1,673
Mixer	2	30	15	**0.9**	2	30	15	**0.9**	0%	$0	$0
CD + tape decks	5	20	8	**0.8**	5	20	8	**0.8**	0%	$0	$0
Lights	6	60	10	**3.6**	6	10	7.5	**0.5**	88%	$57	$561
TOTAL				**94 kWh/d**				**60 kWh/d**	**36%**	**$627**	**$6,114**

3 Types of energy system

Once a station has reduced its energy use, further savings in the cost of energy – and increases in the energy supply – may be possible by adopting appropriate energy technology.

Energy technology can provide energy **generation** for stations where the public supply is inadequate or is not available at all. It can also be used to **regulate** the existing supply – whether this is the public supply or alternative sources – so as to make the most of that supply and to protect electrical equipment. **Storage** technology such as batteries can make the energy supply more reliable by storing excess energy for later use.

Later chapters go into more detail about technology for generating, storing and regulating energy (**Chapters 4, 5 and 6** cover generating technology, and **Chapter 7** covers storage and regulation technology). This chapter summarises the kinds of energy system that may be appropriate for a station. Most energy systems consist of more than one energy technology – for example, a solar system usually contains solar panels for generating energy as well as batteries for storage and a charge controller and inverter for regulating the flow of electricity. When considering the suitability of energy technology, it is important to think in terms of the energy system that will host the technology.

This chapter describes the pros and cons of seven common kinds of energy system, summarised in Fig. 3.1. These systems range from simply regulating the public power supply (System 1) to a hybrid system in which extra energy is generated using a genset and a renewable energy technology or RET (System 7).

There are more than seven kinds of energy system, and those in this chapter have been chosen to make the most positive difference to the typical African radio station. For example, the chapter considers a system for storing genset power but not for storing RET power. Both of these are important and common aspects of energy systems. But a large number of stations have gensets without storing the energy from them, and this storage can make a big difference to genset efficiency and therefore fuel use; whereas any station that gets an RET installed will use batteries as a matter of course, so it is relatively less useful to emphasise the system of storing RET power.

FAQ 3.1

How can my station get help in analysing and assessing different energy systems?

Stations can get more in-depth analysis of energy systems through:

Energy dealers and consultants. Good consultants have practical experience with the technology and can find the best solution for the specific needs of a station. Experts should always be consulted for advice on the assessment, system design, procurement, installation, and maintenance of energy technologies. **Chapter 9** gives more information on dealing with energy technology providers.

Energy analysis software. Appendix D.2 lists some free downloadable programmes that can perform complicated comparisons between different energy options. These programmes are only as good as the data they use, however, so a station needs to have a good idea of its energy needs and potential solutions before consulting this software. These analytical tools are a supplement to, but not a replacement for, expert advice.

Simple worksheets. Appendix A of this guide includes some simple worksheets that can be used to compare the costs of different energy options and assess the energy needs of a station. These worksheets are designed to give “first approximations” and are not a substitute for expert advice.

Systems 3-7 in Fig. 3.1 may be used with or without a public power supply. Most stations will have little control over their public power supply. If a station does not currently have a public power supply, it is unlikely to be able to acquire one at will in the short term. And if a station does currently have a public power supply, it is likely to be the cheapest long-term energy option and should be exploited as far as possible: that is, energy technology should only be used to make up for the inadequacies of a public power supply, through energy storage, regulation, or extra energy generation; new energy technology should not replace the existing public supply or make it redundant.

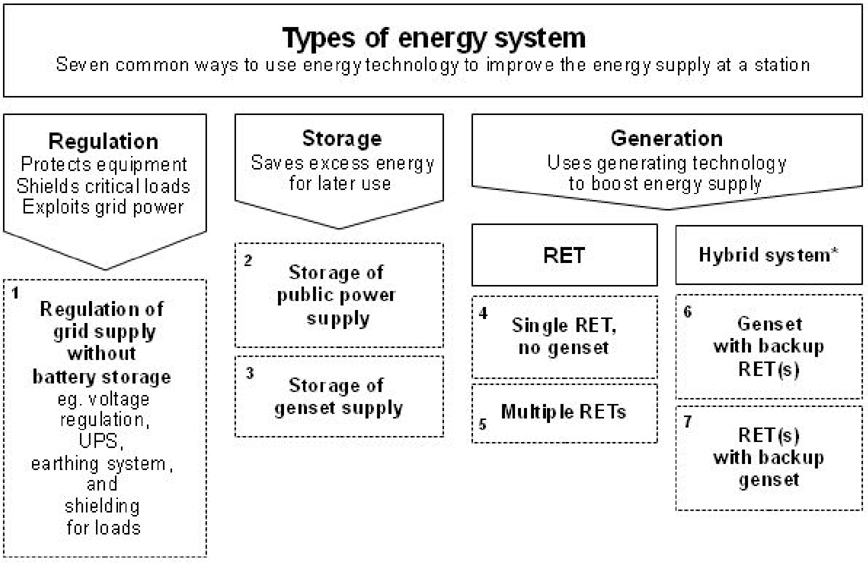


Fig. 3.1
Seven types of energy system
Diagram: author
* In this diagram, as in the rest of the guide, a "hybrid" energy system is one that uses both an RET (or multiple RETs) and a genset.

SYSTEM 1. Regulation of grid supply without battery storage. The public power supply is regulated at the radio station so as to protect electronic devices from power fluctuations and failures. The station thereby makes better use of the available power supply, without needing to add expensive energy generating technology. (**Chapter 7** contains more information on electrical regulation and protection).

This option is most suitable when:

Public power supply is cheap and readily available i.e. available most of the time the station needs power (even if the supply fluctuates during this time). Simply regulating the public power supply will not produce power for the station at times when the public supply is continuously off.

Alternative generating technologies are not readily available. If solar panels or a genset are installed (for example), they may benefit from batteries; in that case, storing the public power supply in batteries may be a better way of regulating and protecting the supply than a voltage regulator or uninterruptible power supply (UPS).

SYSTEM 2. Storage of public power supply. Batteries are used to store energy from the public power supply. The station gains a smooth power supply from the batteries and is free to draw from this supply when necessary. Short power cuts of the public power supply can be easily bridged by switching to the use of batteries. For stations with AC equipment, the downside is that the public supply needs to be converted from AC to DC for storage in batteries, and from DC back to AC for use in the station; this results in high energy losses compared to using a regulator to smooth the public supply.

This option is most suitable when:

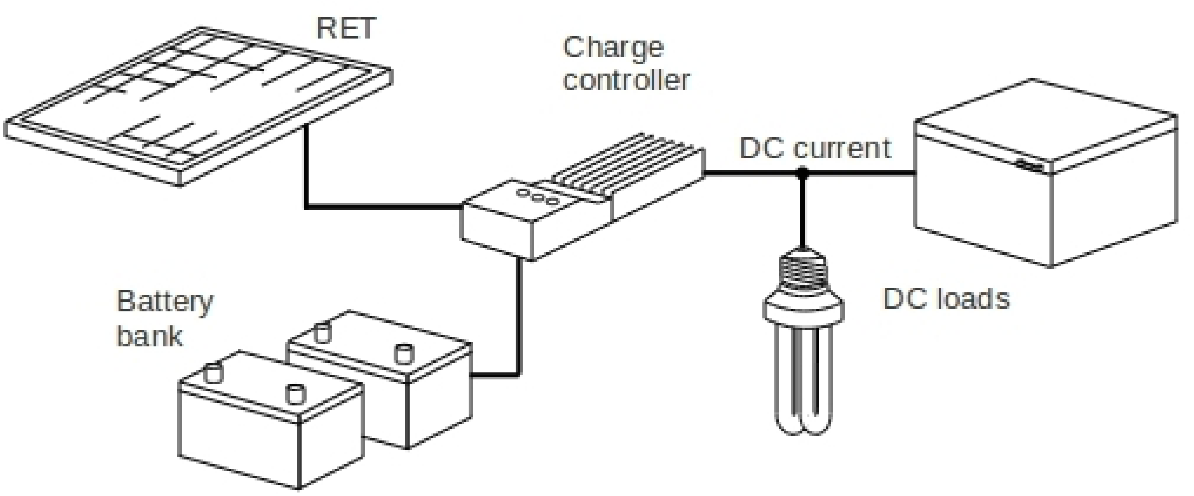
Public power supply is readily available, but not at the right times, or if short power cuts regularly occur. For this scenario to work, the average daily energy from the public power needs to be enough to meet the daily energy needs of the station. This is because batteries do not generate energy; they only store it for future use.

SYSTEM 3. Storage of genset supply. In this scenario the station already has a genset (such as a diesel generator), and batteries are added to store energy from the genset. The station may or may not have a usable public power supply. The effect is to increase the efficiency of the genset, because it can now be used at full power to charge the batteries, and then turned off. The genset no longer wastes energy by operating inefficiently on small loads. Also, the battery supply can be used when the genset is unavailable due to breakdowns or fuel shortages. The battery's inverter can be connected to sensitive equipment without the need for a UPS or other protection equipment (which are required if a genset is used directly with a sensitive appliance). The downsides are that energy is lost through the battery's inverter, and batteries that are large enough to serve the station's full daily energy requirements can be expensive. Also, if batteries are charged using a genset, they need to be capable of high-powered charging (this is not the case for many batteries designed for solar or wind systems, since they are designed for slow charging). Lastly, batteries (less so than gensets or the public power supply) have trouble starting up high-power heat-producing devices such as a microwave oven, water pump, or electric iron.

This option is most suitable when:

A station's genset(s) is oversized for the station's power needs, and is often run inefficiently at low power.

Fig. 3.2
A simple RET-only energy system, such as that in system 4, below. An RET such as solar panels supplies current to a charge controller, which regulates the flow of charge to a battery bank. The charge controller also controls the flow of current to electrical loads. In this example, the loads use DC current and no inverter is required. (Chapter 7 contains more information on batteries, inverters, and charge controllers.)
Diagram: author



Box 3.1

Case study (System 4, with no genset or grid power)

Radio Pikon Ane is a remote station in Indonesia that recently installed a 9 kW **hydro system**. This is a stand-alone system, without a genset or a public power supply to make up for periods of low river flow. Also, the station does not use batteries. Although the power supply sometimes falls due to a decline in water level, the station is not seriously affected by this since the 9 kW system far exceeds its energy demands (these consist of a 1 kW transmitter and station equipment). Most of the hydropower is used by local houses, a church and a school. **Chapter 10** contains more details about the hydro system at Radio Pikon Ane.

Information provided by the Media Development Loan Fund (MDLF), the Indonesian Association for Media Development (PPM), and the KBR68H news agency.

Fuel costs are low and/or natural resources are poor (e.g. lack of sun or wind in the location), making a genset cost-effective compared to RETs.

SYSTEM 4. Generation by RET, without a genset. An RET is used without a genset (see Fig. 3.2, above). Loads are powered by the RET directly (as in the case study in Box 3.1) or (for solar and wind power) by batteries. In the latter case batteries have the disadvantages mentioned in System 3. The RET may provide power without a public power supply (as in the case study in Box 3.1) or with a public power supply (as in the case study in Box 3.2).

This option is most suitable when:

Either the loads are small, the natural resource is high, or both. The greater the loads and the poorer the natural energy resource, the more it will cost to meet the station's needs without drawing on a genset.

Fuel is expensive and/or hard to obtain.

Occasional power failures are tolerable at the station. Natural resources are inherently unpredictable, and without a back-up genset the station may occasionally find itself without power. For this reason, an RET is usually used along with a genset (as in Systems 6 and 7), or a complementary RET (as in System 5). A single RET with a functional power supply can also be a reliable system, provided the RET is correctly sized (see Box 3.2 for a case study of this kind of system).

SYSTEM 5. Generation by multiple RETs. In this system, two or more RETs are used to power a battery bank (see Fig. 3.3, below). This option is preferable when two RETs complement each other. For example, if the windy period of the year is the period with the least sun (and vice versa) a combination of wind and solar power is often a good option. This option may be used with or without a usable public power supply and with or without a genset.

SYSTEM 6. Generation by genset, with a RET as a backup. This is known as a hybrid system (see Fig 3.4, below). Energy is supplied by a genset and one or more renewable energy sources; the station may or may not have a functional public power supply. This is a popular option, since it makes use of natural resources but is also reliable and can be cheap compared to an RET-only or genset-only system. When renewable energy is used as a backup, the RETs only serve the station when the load is light (for example, batteries powered by solar panels might be used to power lights during the night). In this case the genset does not charge the batteries, and the batteries only need to be large enough to support the light loads. Money is saved by using a small battery bank and by not running the genset at low power on light loads (which would otherwise cause the genset to run inefficiently).

Box 3.2
Case study (System 4, with grid power)

Fadeco Community Radio is located in a remote town in North-West Tanzania. Most of the time it uses the **public power supply** to power its 300 W transmitter and other studio equipment. However the public supply is expensive and unreliable, with a total blackout of 12-14 hours at least twice a week. To improve the energy supply the station installed two 65W **solar panels** and **batteries** totalling 640 Ah. The system automatically switches from grid power to battery power when the grid power fails, and switches back when grid power returns. The station is still sometimes without power, since the batteries and solar panels are not large enough to cover all failures in grid power. However, the station has more on-air hours than before. Also, failures in battery power (unlike failures of grid power) are predictable, and the station can inform listeners about the problem well before the station shuts down. **Chapter 10** contains more details about the solar system at Fadeco Community Radio.

Information provided by Fadeco Community Radio

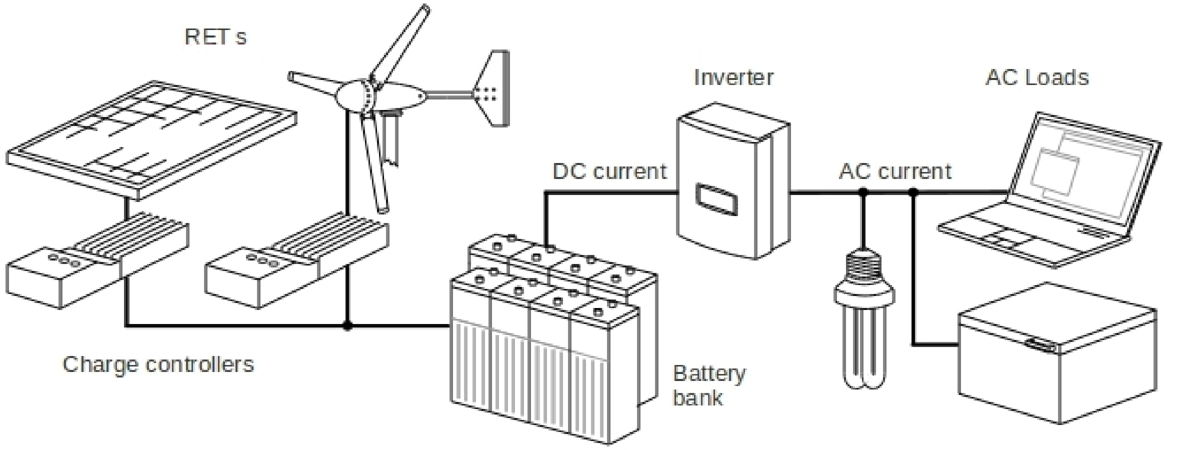


Fig. 3.3
A system with two RETs and no genset, such as system 5. The RETs supply DC current to a battery bank, which passes the current to an inverter when it is needed by the loads. In this example, the inverter converts the current from DC to AC for use in AC loads.
Diagram: author

This option is most suitable when:

Fuel costs are low and/or natural resources are poor, so it is cost-effective to run a genset regularly.

There are long periods when the total load of the station is light compared to its normal load.

SYSTEM 7. Generation by RET, with a genset as backup. This is also a hybrid system, in which the RETs are sized to cover the station's average day-to-day needs, and a genset is used occasionally when loads are unusually high or the natural resource unusually low (see Fig. 3.4). The station may or may not have a functional public power supply. Money is saved by minimising fuel costs and by making RETs smaller than is required to meet peak loads.

This is a suitable option when:

Fuel costs are high and/or natural resources are strong.

There are occasional periods during which the total load of the station is greater than the ordinary load of the station.

Note: System 7 is a popular option, and is often the best one for systems that need extra energy generation.

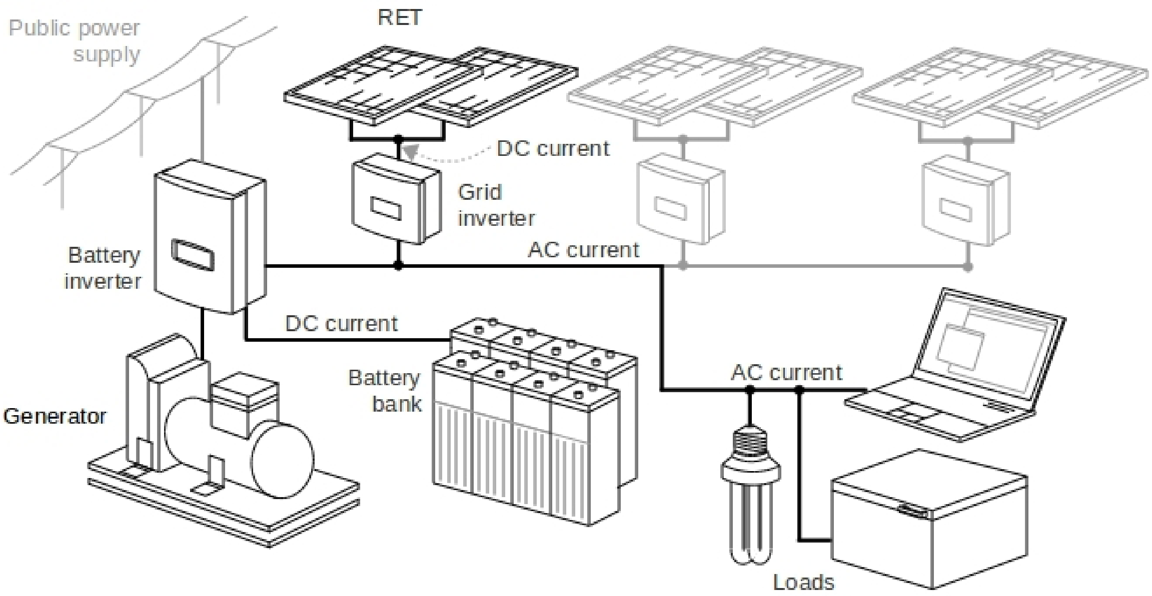


Fig. 3.4
A possible configuration of a hybrid system (system 6 or 7). Optional elements are shown in grey. Grid inverters convert DC from one or more RETs into AC that can power loads directly, without going through the battery bank. A battery inverter delivers AC to loads, drawing on energy from batteries, a genset and (optionally) a public power supply. (**Chapter 7** contains more information on batteries, inverters, and charge controllers.)
Diagram: author

Box 3.3
Case study (System 7, with grid power)

Radio Pacis is a large station near Arua, Uganda. It runs two 2 kW transmitters with a total power consumption of 10 kW, along with eight air-conditioners and a total of 56 computers in offices and an internet cafe. The station is on air 24 hours a day, but **public power** is available only eight hours a day on average. In 2009 the station installed twenty-five 5 kW solar **panels**, two diesel **gensets**, and 5 kAh worth of **batteries**. This is a hybrid system in which the gensets are used when the solar panels are idle (during the night, for example). The public supply is only used when the batteries are discharged to their maximum allowable level (the station can run on batteries alone for three hours). With this system the station saves around $3,000 a month on public energy bills. Chapter 10 contains more details about the solar system at Radio Pacis.

Information provided by Radio Pacis

Evaluating energy generating technologies

4

This chapter focuses on energy systems that include one or more energy generating technologies, such as a genset, solar panels, wind turbine, or hydro turbine. The aim of this chapter is to describe the main factors to consider when evaluating the cost and performance of these systems. This can help to assess whether such systems can serve a station's energy needs within a realistic budget, and to compare one system with another. The chapter ends with sample analyses showing the likely cost and performance of a solar system and a wind system, and a summary table showing how key energy generating technologies compare on the main factors that determine their cost and performance.

How much energy will the technology provide?

Generating technologies usually come with an official "rating" that describes how much power they can produce or store. The following factors should be taken into account when interpreting this rating.

A. Natural resources. Renewable technologies such as solar panels, wind turbines and hydro schemes rely heavily on the natural resources at the site of use. A resource assessment – a study of the size, variation, and availability of the natural resources at a site – is essential. Resource assessments help to **size** a technology: a site with a lot of sun (for example) will require fewer solar panels to generate the same energy than a site with a moderate amount of sun. They also help to **select** a technology: for a site with a lot of wind (for example), a wind turbine might be more cost-effective than solar panels; for a site with little wind, solar panels may instead be the best option.

Resource assessments should take into account:

The physical and geographical features of the site. A wind turbine (for example) may be useless even in areas with high winds, if it is surrounded by obstacles.

Quick reference summary:

Factors to consider when evaluating energy generating technologies

The energy output of the technology depends chiefly upon:

A. Natural resources. RETs depend heavily on the strength and availability of natural resources.

B. Daily generating time. For a technology with a given power, the longer it operates each day the more energy it will provide each day.

C. De-rating factors. The rated power of a technology should be de-rated to take into account electrical and mechanical losses and differences between real-life conditions and the manufacturer's test conditions.

The cost of the technology depends chiefly on:

A. Durability. The longer a technology lasts, the less often it needs to be replaced.

B. Running costs. Include maintenance, replacement parts (especially batteries), and fuel.

C. Initial costs. Include generating equipment, storage and regulation equipment, resource assessment, staff training, and other expenses.

Other factors that affect cost and performance are:

A. Local industry and policy conditions. A strong industry or government subsidies can make high-quality equipment more accessible.

B. Trustworthiness of technology. Technology is more likely to function as it should if it meets international standards and is planned and installed by competent experts or companies.

Possible long-term changes of the resource. Streams can dry up and make a hydro scheme unusable; trees can grow and shade solar panels.

Daily and seasonal variation in the resource. The output from wind turbines and solar panels varies dramatically over the course of the day and the year.

In some cases a professional energy consultant can quickly and easily assess the level of a natural resource. For solar power, non-experts can get a rough idea of the solar resource in their area by consulting online solar maps. But in other cases, such as wind and hydro energy, a more thorough resource assessment may be necessary. The greater the required output of the technology, the more important it is to get an accurate resource assessment.

Fig. 4.1
Workers on the hydro system at Radio Pikon Ane in Indonesia. As for other RETs, a sound resource assessment is needed before proceeding with a large project such as this one.
Image: Indonesia Media Development Loan Fund

System component	Value to be de-rated	De-rating factor (% of energy lost)	Cause of loss	Notes
Solar panels	Manufacturer's power rating standard testing conditions (STC)	20–30	High temperatures Dust, dirt and shading Wiring Imperfect sun tracking	The energy loss due to imperfect tracking of the sun depends on whether the array is mounted on a tracking system.
Wind turbine (blades and electrical generator)	Manufacturer's estimates of long-term energy output	10–30	Inaccuracy in manufacturer's figures Turbulence and product variability	The maximum rated power of a turbine is highly misleading and would require much more de-rating. Likewise for the "power curve." Losses in the turbine's rectifier (up to 12%) may or may not be included in manufacturer's rating.
Hydro turbine and penstock	Potential power found using the formula: Power = flow x head x g	50	Friction losses in penstock Mechanical losses in the turbine	
Batteries	Manufacturer's rating of battery capacity	5–10 (sealed) 15–20 (flooded)	Energy is lost (mainly as heat) in chemical reactions in the battery	This de-rating factor only considers **energy losses** in a battery. There are other reasons for de-rating battery capacity: batteries can only be discharged by 20-80% (depending on battery type), and back-up storage is needed.
Wiring	N/A (de-rating factor applies to energy entering the wire)	5 +	Energy lost as heat in wires	Energy loss in transmission wires can be considerably higher for wind and hydro schemes, where the energy source is not always close to the point where the energy is used.
Inverter	N/A (de-rating factor applies to energy entering the inverter)	10–20	Energy lost as heat in the inverter	10-20% is an average daily energy loss for a typical inverter. In addition, when sizing an inverter, a safety factor of 20-25% is usually recommended.

Fig. 4.2
Some de-rating factors due to energy losses in technologies discussed in this guide. These figures are a guide only, and assume that the technology is properly sized, used, and maintained. Losses due to the deterioration of equipment over time are not included. For more information on the concepts, technology and de-rating factors in the table, see the relevant sections in this guide.
Data: various contributors

B. Daily generating time of the technology. Generating technology is usually rated in terms of its **power** – that is, the rate at which it generates energy. But the most important indicator of the energy needs of a station is its daily **energy** use. A technology that delivers low power for many hours a day (such as a hydro scheme) may deliver more energy per day than a technology that delivers high power for a few hours a day (such as solar panels).

C. De-rating factors. The manufacturer's rating of a technology is usually substantially higher than the actual power the technology will provide. Fluctuations in the natural resource, electrical losses, breakdowns, and general wear and tear, can all reduce the output of the equipment in the short- and long-term. The quoted performance of technology therefore needs to be decreased or de-rated when the energy output of the technology is evaluated (this procedure is also known as under-rating). Figure 4.2 lists some common de-rating factors for energy technologies that are discussed in this guide. In a real-life energy system, small losses in a number of components can result in a large overall loss. For example, a typical solar system will experience energy losses in solar panels (20-30%), batteries (5-20%), wiring (5%), and an inverter (10-20%). The overall energy loss in such a system can easily reach 45%. If these losses are not taken into account when planning a solar system, the station will have a serious energy deficit when the system is installed.

How much will the technology cost?

When comparing the costs of technologies, it is essential to take into account all costs associated with each technology, including running costs as well as initial costs. An analysis that takes into account all of the costs of a technology over its life-time is called a **life cycle cost (LCC)** analysis. An LCC analysis is especially important when comparing the costs of gensets with the costs of RETs. This is because RETs typically have high initial costs and low running costs, whereas gensets have low initial costs and high running costs. If only initial costs are considered, gensets usually appear more cost-effective, whereas in the long term they may not be. FAQ 4.1 contains a simplified example of an LCC analysis comparing a solar system with a genset. Fig. 4.4 and 4.5 contain more realistic LCC analyses.

Appendix A.4 contains a worksheet for conducting an LCC comparison between up to three energy systems.

When the cost of energy technologies is considered, the up-front or **initial** costs are usually the first things that come to mind. In an LCC analysis, **durability** and **running costs** are just as important – sometimes even more so – than initial costs.

A. Durability. The durability of a technology – the length of its useful lifetime – has a big impact on its overall cost. Simply put, the shorter the lifetime of a technology, the more often it needs to be replaced. The replacement costs of a technology are often ignored because they require such a long-term view: a set of well-constructed and well-maintained solar panels (for example) usually lasts for 20 years or longer.

B. Running costs are often ignored or under-estimated. They include:

Maintenance. All energy systems require regular maintenance. Batteries and gensets are relatively high-maintenance pieces of technology. In most systems that include batteries, battery care is crucial to the success of the whole system – not just to its continued functioning but also to its cost-effectiveness (see "Replacement parts" below). RETs themselves require relatively infrequent or light maintenance (except, in some cases, hydro power). However, with zero maintenance their power output and useful lifetime will decline rapidly. Maintenance requires:

Trained personnel. Some equipment requires occasional attention from professional technicians; all equipment requires periodic attention from people who have had at least some training in how to spot faults and keep the machines running smoothly.

Extra equipment. The station may need to purchase tools, spare parts and/or back-up technology to help with maintenance and to keep electricity flowing when the equipment is not functioning properly.

FAQ 4.1

How can the costs of different energy generating technologies be fairly compared?

To fairly compare two technologies that have the same output it is necessary to:

Identify all costs of the technologies during their lifetimes. This is called Life Cycle Cost analysis (LCC).

Express all costs in the same form and add them up. Costs are often expressed in $ per year or $ per kWh. These are sometimes called levelised costs or amortised costs.

Below is a simplified comparison between solar panels and a diesel genset. All costs are expressed in terms of dollars per year ($ per kWh could also be used). It is assumed that both options deliver the same amount of useful energy, 5 kWh per day. Some simple arithmetic is shown in brackets.

1. Solar panels initial cost: $14,000 for a 25 year lifetime

Cost per year: **$560** (14,000 ÷ 25 = 560)

2. Solar panels maintenance cost: 1% of capital cost per year

Cost per year: **$140** (14,000 x 0.01 = 140)

3. Solar panels replacement cost: $2000 every 5 years

Cost per year: **$400** (2,000 ÷ 5 = 400)

Solar panels cost per year: **$1100** (560 + 140 + 400 = 1100)

1. Genset initial cost: $2,000 for a 10 year lifetime

Cost per year: **$200** (2,000 ÷ 10 = 200)

2. Genset maintenance cost: $0.1 per kWh

Cost per year: **$183** (0.1 x 5 x 365 = 183)

3. Fuel cost: $0.67 per kWh

Cost per year: **$1,223** (0.67 x 5 x 365 = 1223)

Genset total cost per year: **$1,437** (200 + 183 + 1223 = 1606)

On this analysis the solar panels are better value than the genset. **This is a simplified example only, to illustrate the technique.** It does not mean that solar panels are, in general, better value than gensets. Fig. 4.4 and 4.5 contain more realistic LCC analyses.

Replacement parts (especially batteries). The lifetime cost of the technology in an energy system can increase significantly if components need to be replaced regularly. The most dramatic example is batteries, as illustrated in the sample analyses below (**Chapter 7** has more information on batteries). There are two important consequences of the need for regular replacement batteries:

Good battery maintenance is an effective way of keeping the lifetime cost of an energy system down. A poorly maintained flooded lead-acid battery may well need replacing every two to five years rather than every ten, more than doubling the lifetime cost of batteries.

The reliability of the energy sources feeding a battery has a considerable effect on the cost of the system. The longer an energy source goes without providing sufficient energy to run a station, the more energy the batteries need to store to keep up the usual supply. All else being equal, a less erratic energy source requires smaller batteries, and hence a smaller outlay each time the batteries are replaced. Energy sources can be made more reliable by choosing a reliable RET, or by supplementing a RET with a back-up genset. The second option results in the popular "hybrid system" (Systems 5-7 in the previous chapter).

Fuel. The cost of fuel over the lifetime of a genset is almost always greater than the initial cost of the genset, often several times the purchase price. (FAQ 4.2 gives an example of a genset that runs for 6 hours a day, with fuel costs exceeding the genset's initial cost by over 30 times.) Indeed, many radio stations own gensets that cannot be run because of the cost of fuel. As indicated in the **Introduction**, fuel prices are likely to increase in the future.

C. Initial costs of generating technology include:

Electricity generating equipment. The heart of an energy system is the machine that captures energy – whether it is solar energy, wind energy, water energy, or the energy in fuels – and converts it into electrical energy. Solar panels, wind turbines (including towers), and hydro schemes (turbine + civil works) cost in the order of $2,000 to $8,000 per kW of rated power. Hydro schemes occupy the lower part of this range, with wind and solar panels in the middle and higher parts. The cost of these technologies *per usable kWh delivered per day*, is of course

FAQ 4.2

How can I estimate the long-term cost of fuel for a diesel genset?

Fossil fuel gensets have low initial costs compared to RETs, but high operational costs. Over the lifetime of a genset, the cost of fuel – including transport – usually far exceeds the initial cost of the genset. The long-term cost of fuel can be easily found if the following are known:

C = cost of fuel per unit volume ($/litre, for example)

T = average hours per day the genset operates (averaged over a year)

V = volume of one tank of fuel (litres, for example)

H = hours of operation for one tank of fuel

The annual cost of fuel is: 365 x C x T x V ÷ H

For example: According to the manufacturer, a certain 3.5 kW genset operates at full power for 8.2 hours on a tank of 23 litres [3]. Suppose fuel costs $1.50/litre, and the genset runs at full power for six hours a day on average. The annual fuel cost will be **$6,142** (365 x 1.5 x 6 x 23 ÷ 8.2 = 9,214). So the genset consumes over $70,000 of fuel in eight years. The retail price of this genset is $2,249. If the genset lasts for eight years, **its lifetime fuel costs will be over 30 times its initial cost.**

Notes:

This calculation excludes travel, security, and maintenance costs. It also assumes the fuel cost is constant over time, when in fact it is likely to increase. Appendix A contains worksheets for finding the annual cost of fuel for a genset (Appendix A.3), and for comparing the annual cost of energy of up to three different energy options (Appendix A.4).

different from their cost *per rated kW*, and depends on the factors described above: the available natural resources, the daily generating time of the technology, and de-rating factors. There are also economies of scale, with technologies getting cheaper per kW for larger purchases. The economies of scale are especially pronounced for wind turbines, since a small increase in the diameter of a turbine's blades or the height of the turbine leads to a large increase in the energy output of the turbine.

When an energy system includes generating equipment, that equipment is usually the highest initial cost of the system (but not necessarily the highest cost in the long term). The case studies in **Chapter 7**, and the sample analyses below, suggest that it typically makes up around **two thirds** of the initial cost of a system that also includes batteries, a charge controller and inverter. Components such as mounts and tracking devices for solar panels, the tower for a wind turbine, and the civil works for a hydro scheme, should not be forgotten.

Storage and regulation equipment. Aside from generating equipment, batteries are usually the largest initial cost in an energy system. In the case studies and the sample quotes below, batteries make up 10-20% of the cost of a system that includes a RET. If the system includes one or more RETs, an inverter, charge controller, and long-distance transmission wires may also be necessary.

Other initial costs. The following initial costs should also be taken into account:

International and domestic transport of equipment, including import taxes.

Resource assessment (if conducted by a paid consultant).

Installation of generating equipment and batteries.

Staff training (this may be offered by the company that sells the energy technology).

Security (this may be an initial cost or a running cost, depending on the kind of security used, e.g. a security fence for a solar panel is an initial cost, whereas a guard for a solar park is a running cost).

Insurance.

Other factors affecting cost and performance of technologies

A. Local industry and policy conditions. The costs of energy technologies depend partly on the availability of the technology in the area of the station. Some industries, such as the solar industry, are widespread in Africa, but other equipment may be harder to obtain. Having locally available expertise and equipment can make a big difference not just to transport costs, but also to the cost of fuel, spare parts, and servicing. Some governments support certain energy technologies with subsidies, waivers of customs tax or other taxes, or through NGOs (see **Chapter 11** for more on energy and policy).

B. Trustworthiness of the technology. Manufacturers of most energy technology are expected to meet international standards to ensure the safety and quality of their equipment. Technology that meets international standards is likely to last longer and be more energy efficient. Standards are good for consumers, since

Fig. 4.3.
A carpenter works on a wind turbine blade in Mozambique. Locally manufactured energy technology (as opposed to imported technology) is often easier to service and operate using local expertise.
Image: The Clean Energy Company

they provide well-defined measures that enable consumers to distinguish between high and low-quality equipment. Buying equipment that meets the relevant standards will encourage dealers to supply more equipment of that kind.

The success of an energy system depends not just on the quality of individual components but also on the quality of the "fit" between the different components of the system. For example, a system with top-quality solar panels, batteries, and inverter, will perform poorly if the batteries are the wrong size for the solar panels. For this reason it is as important to select high-quality planners and installers of energy technology as it is to select high-quality technology. **Chapter 9** contains advice on selecting energy providers and consultants.

Sample energy and cost analyses

Below are examples of two complete energy providing systems – one based on a wind turbine and one on solar panels – that illustrate the ideas in this section on selecting energy technology. The aim of these examples is to show the relative size of the costs of different components in RET systems, and to show the main factors that influence the costs of components and the overall costs.

Note: The aim of these examples is not to compare the cost of a solar power to the cost of wind power. The relative merits of solar and wind power at any given station will depend on the factors described above. But it may be noted that:

The wind power example gives somewhat less energy per dollar than the solar example.

The wind power example assumes a high average wind speed (5 m/s) that is rare in Africa, while the solar power example assumes an average solar irradiation (5.5 sun-hours a day) that is common in Africa (sun-hours are explained in **Chapter 5).**

The examples below are for relatively small systems (each gives about 7 kWh a day). But the cost of each kWh of wind energy (more so than the cost of each kWh of solar energy) decreases quickly for larger systems, due to the economies of scale mentioned above.

Example 1. Solar-battery system. The following example is a solar system in Sierra Leone that includes solar panels with a rated power of 2.63 kW, a battery bank, charge controller, and inverter. The total initial cost of the system is $28,000.

SOLAR SYSTEM COMPONENTS	Lifetime cost ($)	Cost per year ($)	Cost per kWh (US cents)**	% of total cost
INITIAL COSTS	**28,000**	**1,120**	**0.41**	**43%**
Solar panels (2.63 kW)	15,200	610	0.22	23%
Batteries (4.8 kAh, 24V deep cycle, wet)	4,900	200	0.07	7%
Inverter (3 kW, 24 V)	3,000	120	0.04	5%
Charge controller (60A, 24V, with MMPT*)	900	40	0.01	1%
Solar panel mount	1,500	60	0.02	2%
Battery box (wooden)	500	20	0.01	1%
Cables for installation	500	20	0.01	1%
Installation and labour	800	30	0.01	1%
Transportation of materials***	500	20	0.01	1%
Training for staff (3 days)	200	10	0.01	0,3%
RUNNING COSTS	**37,300**	**1,490**	**0.55**	**57%**
General maintenance	7,000	280	0.10	11%
Battery replacement	30,400	1,220	0.45	46%
TOTAL COSTS	**65,300**	**2,610**	**0.96**	**100%**

Fig. 4.4
Life-cycle cost analysis of a solar battery system. Key figures are in green. Initial cost data: quote for a radio station from an African energy company. Running cost data: author's analysis, based on assumptions in main text below.

*Maximum power point tracker (see Chapter 7, under "charge controller," for a description of this device).

**Based on daily energy output of 7.43 kWh; see next page for calculation of usable energy per day.

***Transport costs can be considerably higher for remote stations.

How much energy will the technology produce?

Assumptions:

Average sun-hours per day: 5.5 hours (this value is common across the African continent)

Rating of solar panels under Standard Test Conditions: 2.63 kW (15 x 175 W modules)

Rated energy per day: 14.4 kWh (based on previous two assumptions)

Solar panels de-rating: 25%

Battery de-rating: 15%

Wiring de-rating: 5%

Inverter de-rating: 15%

Result:

De-rated (i.e. usable) electrical energy per day: 7.43 kWh

How much will the technology cost?

Assumptions:

Lifetime of solar panels: 25 years

General maintenance: 1% of initial cost per year

Battery lifetime: 4 years minimum

Battery replacement cost (assumed to be equal to initial battery cost): $4,900

Batteries are large enough to store the energy needed during periods of low sun.

Battery costs do not change over time.

The discount rate is not considered in this analysis.

Key points (for details see Fig. 4.4, especially numbers in green):

The running costs for the system are greater than the initial costs.

The largest single cost is that of battery replacements, which makes up nearly half (46%) of the total lifetime cost of the system.

The solar panels themselves are the second largest single cost, but they make up only about a quarter (23%) of the total lifetime cost of the system.

Some of the least costly components (charge controller and staff training) have a big effect on the cost of the most costly component (battery replacement cost). So money invested in a good charge controller and thorough staff training is likely to pay off in the reduced total cost of the system.

Example 2. Wind system. The following example is a wind system from South Africa that includes a wind turbine rated at 3 kW, a 12m tower, a battery bank, inverter and charge controller. The total initial cost of the system is $20,700.

WIND SYSTEM COMPONENTS	Lifetime cost ($)	Cost per year ($)	Cost per kWh (US cents)**	% of total cost
INITIAL COSTS	**20,700**	**1,140**	**0.57**	**51%**
Wind turbine (3 kW) and tower (12m)	12,500	690	0.35	31%
Charge Controller	900	50	0.03	2%
Divert Resistor	400	20	0.01	1%
Batteries (16 x 102 Ah, deep cycle)	2,300	130	0.07	6%
Inverter (3 kW, pure sine wave)	1,500	80	0.04	4%
Transport, cables, installation, labour*	3,100	170	0.09	8%
RUNNING COSTS	**20,100**	**1,120**	**0.56**	**49%**
General maintenance	7,400	410	0.21	18%
Blade replacement	4,300	240	0.12	11%
Battery replacement	8,400	470	0.24	21%
TOTAL COSTS	**40,800**	**2,260**	**1.14**	**100%**

Fig. 4.5
Life-cycle cost analysis of a wind energy system. Key figures are in green.
Initial cost data: quote from Solar Con, an alternative energy company based in South Africa.
Running cost data: author's analysis, based on assumptions in main text below.
*These costs are assumed to make up 15% of the initial cost of the system.
**Based on estimate of daily energy output of 5.4 kWh, see next page for calculation.

How much energy will the technology produce?

Assumptions:

Average wind speed at 12m: 4.5 m/s (a high value for Africa)

Wind turbine voltage: 24 V

Annual energy output: 3,400 kWh (based on manufacturer's long-term energy output figures)

Rated energy per day: 9.32 kWh (based on previous assumption)

Wind turbine de-rating: 15%

Battery de-rating: 15%

Wiring de-rating: 5%

Inverter de-rating: 15%

Result:

De-rated (i.e. usable) electrical energy per day: 5.4 kWh

Comparison of rated power to actual power:

Rated power of turbine: 3 kW (the manufacturer's one-figure power rating)

Actual average power output: 0.23 kW (5.4 kWh per day / 24 hours. This is strictly an average power; over time the power will vary widely around this value)

How much will the technology cost?

Assumptions:

Turbine lifetime: 18 years

Blade lifetime: 8 years

Blade replacement cost: $1,900 (includes blades and installation but not transport)

Battery lifetime: 5 years

Battery replacement cost (assumed to be equal to initial battery cost): $2,300

Maintenance cost: 2% of initial cost per year

Batteries are large enough to store the energy needed during periods of low wind

Battery and blade costs do not change over time

The discount rate is not considered in this analysis

Key points:

The points made in Example 1 above, about the high cost of replacement parts (in this case batteries and blades) and the low cost of the charge controller, also hold in this example.

The rated power of the turbine (3 kW) is a very poor indicator of the actual amount of usable electrical energy delivered (on average) by the wind system (0.23 kW). This is why the manufacturer's long-term estimates of energy output should be used instead of the one-figure power rating of a turbine (**Chapter 5** contains more information on power ratings for wind turbines).

Fig 4.4
A photovoltaic power station in a container in Lira, Uganda, temporarily out of order.
RET's themselves require only relative infrequent or light maintenance. However, with zero maintenance their power output and useful lifetime will decline rapidly.
Image: CAMECO

Summary of energy generating technologies

	Initial cost	O & M costs*	Natural resources	Resource assessment	Reliability of energy	Durability of technology	Availability of technology and expertise
Solar panels with batteries	Very high	Very low; about 1% of initial cost per year**	Sun; widely available in Africa	Easy	High (if maintained properly) or low (if not)	20–30 years (solar panels) 2–5 years (batteries)***	High
Wind with batteries	High	Very low – low; about 2% of initial cost per year**	Wind; available in some regions in Africa, but usually erratic	Moderate	Moderate (if maintained properly) or low (if not)	15–20 years (turbine) 5–10 years (blades) 2–5 years (batteries)***	Moderate
Hydro with batteries	High	Low – moderate; 3% or more of initial cost per year**	River; available at specific sites	Easy – hard (depends on size of scheme)	High (if maintained properly) or low (if not)	30–40 years (civil works and turbine) 8–10 years (turbine bearings) 2–5 years (batteries)***	Low (though may be high in some mountainous regions)
Genset (diesel)	Moderate – high	High	None	None	High	25,000 operating hours	Very high
Genset (gasoline)	Low	Very high	None	None	Moderate	1,000–2,000 operating hours	High
Hybrid system (RET + genset as backup)	Very high	Low – moderate	Varies; depends on RET used	Varies; depends on RET used	Very high	5–10 years (batteries)*** 10 years (generator)	Moderate (more complex than single-RET system)

Fig. 4.6
Summary of key energy generating technologies.
*Operation and Maintenance costs.
**Does not include the cost of maintaining or replacing batteries, inverters, charge controllers, or wiring.
***Batteries last considerably less than 10 years if they are poorly used or maintained, or are of poor quality to begin with.

Renewable energy technology (RET)

5

This chapter describes the main renewable energy technologies (RETs) that can be used to generate electricity on the household, business, or community-scale. RETs are technologies that use naturally occurring and naturally replenished sources of energy to generate electricity. They have little negative impact on the environment because they do not draw on unsustainable energy sources such as fossil fuels and do not produce harmful emissions such as carbon dioxide. The main RETs for electricity generation are solar power (also known as photovoltaics or PV), wind power, and hydro power. This chapter describes the physical construction, natural resource requirements, energy output, de-rating factors, standards, and industry and policy conditions for each of these RETs. It also includes information on three emerging technologies (animal power, biogas, and jatropha oil).

Note: This chapter describes *components* that *generate* energy. It does not describe the devices that *store* energy and *regulate* the flow of electricity in a system, such as charge controllers and voltage regulators (these devices are covered in **Chapter 7**). Nor does it describe how those components can be combined into energy systems. For example, solar panels could be used with a wind turbine, with a genset or with the public power supply. And RETs are usually used with batteries, increasing their cost and maintenance requirements. **Chapter 3** describes some common ways in which energy technologies are combined into systems.

Solar power (photovoltaics)

PV Construction

The basic unit of a PV array is the photovoltaic cell. The cell uses the sun's energy to stimulate the flow of electrical current inside the cell. Cells are then connected in series and/or parallel to give higher currents and/or voltages (**Chapter 1** has more information on series and parallel circuits). PV modules are the "building blocks" of a PV unit. They consist in a set of PV cells wired together to give the

Quick reference summary:

Photovoltaics (PV)

Solar power or PV is the **most popular RET** considered in this guide. Africa is well-served by sun energy, and PV is a proven technology whose output is relatively easy to predict.

PV has **high capital costs** compared to gensets and (for large loads) compared to wind and hydro technology.

Solar irradiation is the energy delivered to the earth by the sun, and is measured in **sun-hours** or in **kWh per m2 per day**. One sun-hour is the amount of energy delivered by a full sun in one hour. **Solar maps** estimate the average sun-hours at a site.

Maintenance costs for PV are relatively low but it is essential that maintenance is carried out regularly on the equipment, especially on the surface and the batteries of PV modules.

Shade on a small area of a PV array can greatly reduce the output of the entire array. PV arrays should be sited out of the path of **actual and potential obstacles**.

PV modules are rated in **peak Watts**, or Wp. The power a module provides to a battery is usually 20-30% of its rated power.

desired voltage and current, along with metal frame and a transparent covering to protect the delicate cells. Modules are combined to give mounted PV panels that are ready for use in the field. Panels can themselves be combined to give larger PV arrays. The modular construction of PV equipment means that arrays are easy to size according to a station's needs. It is also easy to increase the size of an existing PV array.

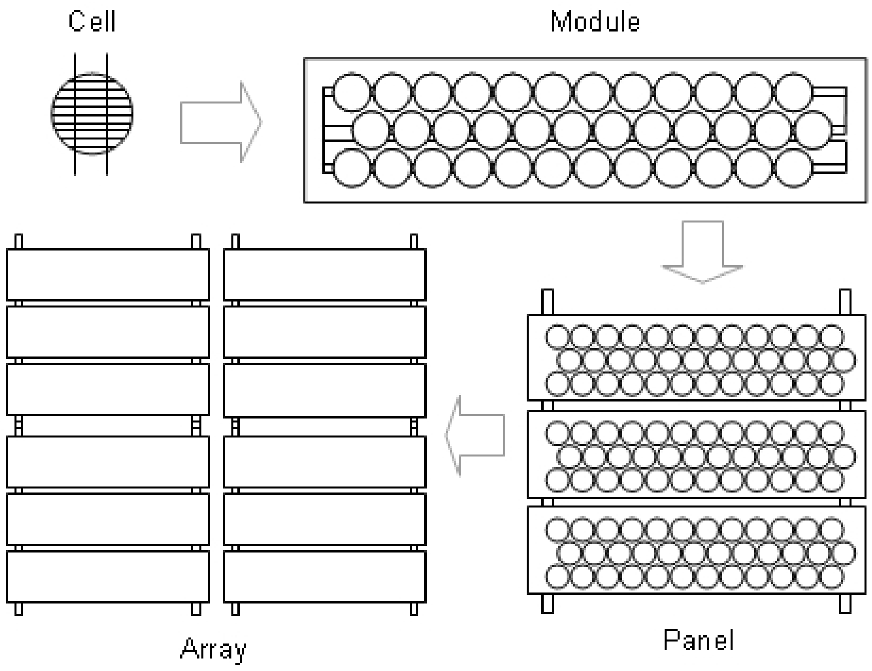


Fig. 5.1
PV Construction
PV cells are combined to give modules, panels and arrays. The cost and power of PV equipment is usually given in terms of the cost and power of PV modules.
Diagram: author

The three main types of PV are silicon-based mono-crystalline, poly-crystalline and amorphous (or "thin-film") cells. Mono-crystalline cells are slightly more efficient and more expensive than polycrystalline cells. Amorphous cells are generally less efficient, and may not last as long, but they are less expensive and easier to manufacture than mono or poly-crystalline cells.

Because amorphous cells are less efficient, modules made of amorphous cells need to be larger to give the same power output as smaller modules made out of mono or poly-crystalline cells. This makes them more expensive to transport and more vulnerable to wind, but harder for thieves to carry away. The fact that amorphous modules take up more space makes them less desirable for much of the PV market, reducing their cost. Hence amorphous modules may be a good option in regions where space is not a problem, such as rural Africa.

Fig. 5.2
A pole-mounted PV array, showing PV modules made up of cells and combined to form the 3 panels in the array. This array has a tracking mechanism that is just visible below the array (see below on tracking mounts).
Image: CAMECO

Natural resources

A number of natural factors affect the amount of power a PV array delivers. All of these should be considered when locating and sizing an array.

Solar irradiation

The amount of sun energy that reaches the surface of the earth is the main determinant of the output of a PV array. This is also known as the **solar irradiation**. Solar irradiation is measured in energy (in kW) per area (in m^2) per day. It is also measured in **sun-hours**. One sun-hour is defined as the amount of sun energy that reaches the earth's surface every hour when the sun is full (technically, "full sun" is the unclouded midday sun at sea level). This is equivalent to 1 kWh for every square metre of the earth's surface. For example, to say that a site receives "five sun-hours a day" is to say that it receives the equivalent of five hours of full sun a day. (This does not necessarily mean that the site receives full sun for five hours each day. The sun may deliver five sun-hours in a day by shining for eight hours with thin cloud cover, for example). The irradiation a site receives can vary widely between different parts of the year, especially between the rainy and dry seasons (although if the cloud during the rainy season appears mainly during the night, the rainy season output of the array may not be significantly less than the rest of the year). Solar irradiation at a site in Africa is typically between 4 and 7 kWh/m^2 per day (between 4 and 7 sun-hours per day).

Shading

A small amount of shading can have a large effect on the output of PV array. In extreme cases, shade on one cell (caused by a falling leaf, for example) can disable the entire module. Hence the locations of trees, buildings, cables and other obstacles are important to consider when locating the array. "Hidden" obstacles include future buildings, growing trees, and the leaves of deciduous trees. The shade at a site of course depends on the position of the sun in the sky and changes considerably over the course of a day (and, at high latitudes, over the course of a year).

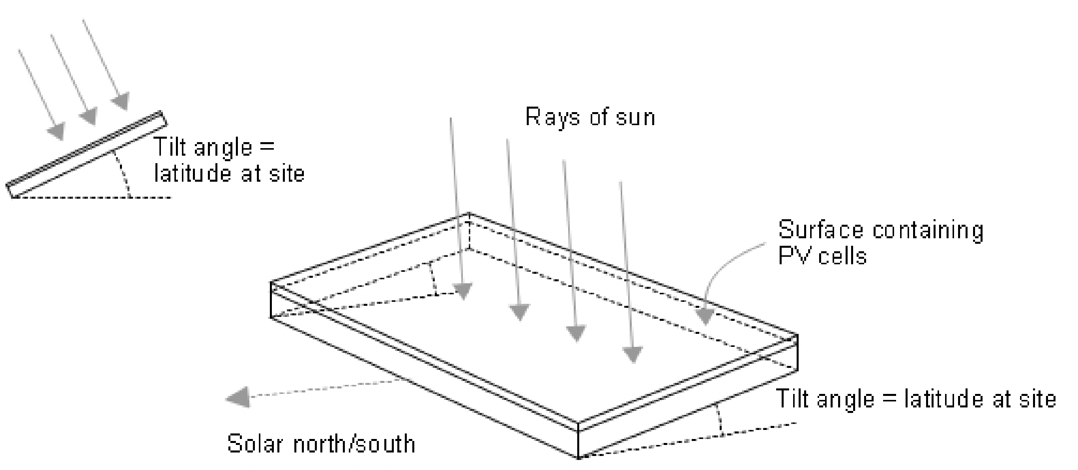
Angle of the sun

The change in the sun's position in the course of a day (and, at high latitudes, during the course of a year) affects how directly the sun hits the panels and hence how much power it generates. It also affects how much shade is on the array at different times of the day and year.

The number of sun-hours an area receives per day can be estimated using online solar maps of the region. **Appendix B.2** contains a solar map of Africa, generated using the popular online data compiled by NASA. **Appendix D.2** contains links to the NASA data, tools for estimating the effect of obstacles on the shade cast at a site, and information on how to find solar north or solar south (solar north is not the same as true north as indicated by a compass; likewise for solar south).

As a rule of thumb, stationary solar panels should be tilted at an angle equal to the latitude at the site, and should face solar north in the southern hemisphere and solar south in the northern hemisphere (as shown in Fig. 5.3). Tracking mounts are available that use electronic sensors and a rotating stand to keep a PV array facing the sun throughout the day and year. These are complex devices that are easily broken and hard to fix; however, if installed correctly and used at an appropriate site, they can lead to significant gains in the output of an array.

Fig. 5.3
As a rule of thumb, PV arrays should be tilted at an angle equal to the latitude at the site, and should face solar north (in the southern hemisphere) or solar south (in the northern hemisphere).
Diagram: author



Performance

The power output of PV equipment is usually given in terms of the peak power or **peak watts** of a single module (often written as Wp). This measure is standardised across all good-quality makes and models of PV module, so it is easy to compare the output of different modules. Wp is the amount of DC power the module will produce when it is operating in full sun. For example, if a region has 5 sun-hours a day, a 2 kW array will produce 10 kWh of energy a day (5 hours x 2 kW = 10 kWh). Modules range in size from about 50 Wp to about 300 Wp.

The rated power of a PV module needs to be de-rated to take into account:

High temperatures. Modules are rated at a standard temperature of 25 °C. Especially in Africa, the operating temperature of modules is considerably higher than this value, leading to losses of 10% or more.

Dirt and dust. Even if they are regularly cleaned, PV modules are affected by the fine layer of dirt and dust that gathers on their surface.

Manufacturer's tolerance. Module manufacturers cannot guarantee that their modules will deliver exactly the rated power, even under ideal conditions. Their actual output may be 5% more or 5% less than the rated output.

Wiring losses. PV ratings apply to modules, not to arrays. Small losses occur in the wiring between modules.

Imperfect tracking. Even with a tracking mount, PV arrays do not always face directly into the sun.

These losses mean that the electrical output of a PV array is 20–30% less than the rated value. For example, in full sun a module rated at 100 Wp is likely to deliver 70-80 W of electrical energy to its batteries. Once losses in batteries and an inverter are taken into account, a typical PV array delivers only 50–60% of its rated power. FAQ 3.1 shows how to estimate the amount of rated PV power a station requires.

FAQ 5.1

How much solar power is needed to meet a given daily energy load?

The rated PV power needed to meet a given energy load can be estimated using the sun-hours in the area (obtained from a solar map such as that in **Appendix B.2**) and the daily energy load of the station (obtained from an energy assessment as described in **Chapter 2).**

Required power [kWp] = energy load [kWh/day] ÷ sun-hours per day ÷ 0.55

0.55 is the de-rating factor, and assumes the PV system includes a battery and inverter. For example, a station with an energy load of 15 kWh/day and 5 sun-hours per day will require roughly 5.5 kWp (15 ÷ 5 ÷ 0.55 = 5.45) to serve the load.

Other factors that affect the performance of a PV array are:

Output in cloudy conditions. Two different PV modules may have the same output in full sun (say 100 W), and yet have different outputs in half sun (say, 50 W versus 90 W). All else being equal, the one that is more powerful in half sun is likely to be better value overall.

Vulnerability to shade. Some modules are specially constructed to be less vulnerable to shade. These modules are designed so that shade on one cell does not reduce the performance of other cells.

Short-term power decay. The power of an amorphous cell decreases over the first few months of use, before stabilising. The rated output of an amorphous module should be the output once the cells have stabilised.

PV modules last for 20 to 40 years if they are of good quality and properly maintained. Warranties are typically for 10 to 25 years. Most high-quality PV modules are warranted for five years operation at 90% efficiency or above, and 25 years operation at 80% efficiency or above. This decline in efficiency over time is an extra de-rating factor, in addition to those considered above.

Maintenance

Low maintenance is one of the virtues of PV. However, with zero maintenance PV arrays can perform well below their optimum. Modules should be inspected once a week to check for shading due to fallen leaves, dust, or other impediments. The module surface should be cleaned once a month to remove obstacles (or more often as needed, such as in desert areas). Cleaning a solar module is as easy as cleaning a window, and can be done with a soft cloth, water, and a mild detergent.

Electrical and mechanical connections on the PV array should be checked annually for tightness and freedom from corrosion. Ideally this will be done by a qualified technician or by trained staff. Correct installation can make maintenance easier by keeping the modules out of the way of dust, wind and other obstacles. Large arrays are vulnerable to high winds. The largest maintenance requirement of a PV system is usually the batteries, which are essential to ensure that the energy from a PV array is available even when the sun is not shining. **Chapter 7** contains more information about battery maintenance.

Fig. 5.4
Roof-mounted PV modules at the Bishop's House in Lira, Uganda.
Image: CAMECO

Security

Their modular construction and high value means that PV arrays are vulnerable to theft. There is a strong second hand market for solar panels in numerous regions and there are also examples of their use in non-generating purposes, such as roofing and coffee tables. (Theft and vandalism are far less of an issue for wind than they are for solar. This is due to the height, weight and risk of electrocution when removing wind equipment, as well as a smaller second hand market in most regions.)

Standard prevention measures include electric fences, security lighting, camera monitoring and alarms (although all of these measures require extra power). Small solar panels can be raised a few metres from the ground so they cannot be reached, but this is expensive for large systems. Some vendors use special screws that can only be unscrewed with tools that have limited availability; more simply, modules can be welded in place inside their metal frames or (for roof-mounted systems) they may be screwed on from the inside; bulkier modules are harder for thieves to carry away. Techniques for reducing the re-sale value of panels include putting company names on the back of panels using specific colour schemes, and using miniature serial numbers ('micro-dots') on the equipment. All of these approaches have been reported with mixed success.

Standards

The international standards for PV modules are the IEC 61215 ("Crystalline silicon terrestrial photovoltaic (PV) Modules – Design qualification and type approval") and IEC 61646 ("Thin-film terrestrial photovoltaic (PV) Modules – Design qualification and type approval"). Modules that have been tested according to these standards are likely to last longer and provide more energy than those that have not. If a module meets international standards of design and construction, this should be clearly marked on the product. The certification of a PV module can usually be verified by looking for the product in the online directories supplied by certifying bodies (two such directories are listed in the Further Resources section for this chapter, in **Appendix D.2**). Note: PV modules which can be bought on the local market in Africa are often cheaper but also of lower quality than the imported modules!

Market and policy

PV products are the most widely available RETs in Africa. This makes purchasing and servicing PV arrays easier than for other technologies. There are also many online resources relating to solar products, including the forums and company directories listed in the Further Resources list for this chapter. The downside is that PV technology is not yet manufactured on the African continent, increasing the cost of international transport and import taxes.

For stations with dysfunctional PV equipment it may be cheaper to have the old equipment repaired rather than investing in new equipment. A number of African companies offer service, repairs, and maintenance for existing PV equipment (including batteries and inverters). See the **Appendix D.2** for more details.

Wind power

Construction

Wind turbines consist of **blades** that convert the energy of the wind into the mechanical energy of the turbine's shaft (see Fig. 5.5). The shaft is linked to an electrical generator that converts the motion of the shaft into electrical energy, in the form of variable frequency or "wild" AC current. A rectifier then converts the AC current into DC for battery storage. The shaft, generator, and generator wiring are usually held in a casing called the **nacelle**, with the rectifier on the ground. The turbine's **tail** ensures that the blades face into the wind, and the **yaw bearing** allows the blades to turn on their **tower or pole**. **Guy ropes** ensure that the tower is stable in high winds. The height of the turbine is measured by the distance of the hub from the ground, also known as its **hub height**. The **blade diameter** is the diameter of the blade's **swept area**, the area that the blades sweep out as they spin around.

Wind turbines vary widely in hub height and blade diameter. Most radio station applications can be served by **micro** turbines (with a rotor diameter of less than 3 metres and a power rating of 50 W to 2 kW) and **small** turbines (a rotor diameter of 3 to 12 metres and a power rating of 2 kW to 40 kW).

Quick reference summary:

Wind turbines

In good conditions, wind turbines can be **more cost-effective** than PV arrays. Africa is not as well-served by wind as it is by sun, although **some areas are ideal** for wind turbines.

The output of wind turbines is highly sensitive to local climate and topography, and a **detailed wind assessment** should be carried out before investing in a turbine.

Compared to PV, the output of wind turbines is **erratic and hard to accurately predict**. For this reason more storage capacity (batteries) is required for wind turbines than for PV arrays, raising the cost of a wind system.

Manufacturers' ratings of wind turbines should be handled with care. A table showing the **long-term energy output** of the turbine for different average wind speeds is the most reliable rating.

Wind turbine maintenance is important but consists mainly in **detecting and responding quickly to faults**, as well as maintaining the turbine's batteries.

Turbines are less widely available in Africa than PV arrays, but **local manufacture** reduces the cost of turbines and adapts them to local conditions.

Construction

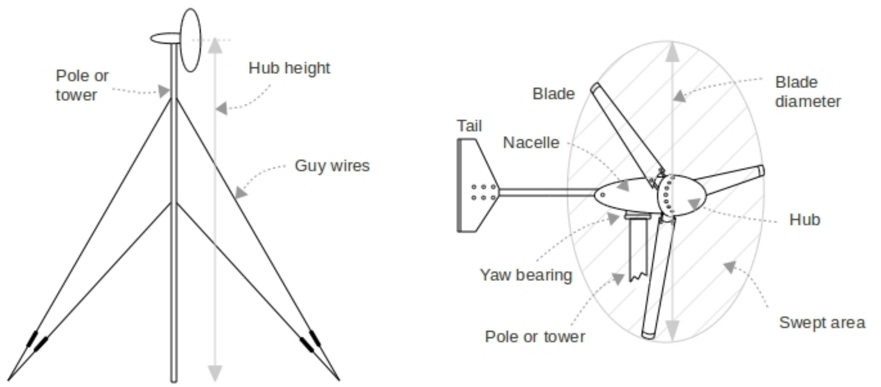


Fig. 5.5
A wind turbine mounted on a pole or tower (left) and a close-up of a turbine (right). Diagram: author

Turbines also vary in their **solidity**. Solidity is the relation between the swept area and the area of the blades themselves. High-solidity blades are usually not used for the purposes of electricity generation. **Vertical-axis** turbines (where the blades rotate around a vertical axis) are much less common than horizontal types and are not yet a proven technology in small-scale applications.

Wind turbines operate through **drag** or **lift**. Drag forces push directly against the blades, like a hand pushing a door. Lift is more subtle; here, blades have a curved upper surface, causing a difference in air pressure between the top and bottom surfaces of the wings when wind passes over the blades, as on an aeroplane wing. Drag operates in the direction of the wind, whereas lift operates perpendicular to the direction of the wind. Most turbines suitable for electricity generation are powered by lift.

Natural resources

Wind turbine output is highly sensitive to the available natural resource. Doubling the solar irradiation on a PV array roughly doubles the electrical output of the array. By contrast, doubling the wind speed incident on a wind turbine increases its theoretical power output by roughly *eight times*. This makes a resource assessment especially important in the case of wind turbines: a 25% error when assessing the wind resource could mean that a turbine supplies only half of the energy expected from it.

Also important is the variation in the wind speed at a site over the course of the day and year. This is not a major concern when wind turbines are connected to the grid (as they often are in Europe). However, it is a concern when turbines are used to charge batteries: the more erratic the wind speed at a site, the more storage capacity is required, and the greater the cost of batteries (this is significant given the high cost of replacement batteries, as explained in **Chapter 4**). The long-term variation in wind speed also has a significant effect on the energy potential of a wind turbine at a site (as discussed under "Performance" below).

The wind resource (or the "wind regime") at a site is also sensitive to local conditions. Wind speed depends upon the geography, altitude, climate, and physical obstacles in the area. Nearby buildings and trees cause turbulence that lowers the output of a turbine and places a strain on its mechanical parts. As a rule of thumb, the hub of the turbine should be at least 9 metres (30 feet) above any obstacles that are within a 90 metre (300 feet) radius of the base of the turbine tower. For a tower with guy ropes, a clear area (with a radius of at least half the height of the tower) is needed at the bottom of the tower.

The most reliable method for assessing the wind resource is a pole-mounted anemometer (such as that shown in Fig. 5.6). Commercial anemometers are relatively cheap compared to the cost of a wind turbine, and modern data-logging techniques make it easy to record and analyse the data from such devices. Anemometers are mounted on a pole for a few months to a year to measure the size and variation in wind speed and turbulence. For reliable results the anemometer should be positioned in the same place and at the same height as the intended turbine.

Simpler and cheaper methods of wind assessment methods include observing the state of trees in the area and drawing from the experiences of local residents. Wind data collected at meteorological stations may also be consulted. However, the latter can be misleading since anemometers are often placed 10m above the ground, lower than most wind turbines; and this data is sometimes collected at places unsuitable for turbines, such as airports.

FAQ 5.2

Is there enough wind in my region to justify a wind turbine?

A standard measure of wind speed is its average speed at 9m above ground level. On this measure, winds below 4 m/s (14 km/hr) are usually too low for wind turbines to be cost-effective; winds of 4 to 5 m/s (14 to 18 km/h) mean that wind power is worth looking into but may not be the best option; and winds above 5 m/s (18 km/hr) make wind a strong option.

The wind map in **Appendix B.3** can be used to estimate the general wind potential in regions on the African continent. The map indicates that much of Central Africa (the DRC, Cameroon and surrounding areas) has low winds, as do the southern regions of West Africa (including the Ivory Coast, Ghana, and large parts of Nigeria). Moderate to strong winds occur down the eastern coast of Africa, and especially in Somalia, Tanzania, and Mozambique; Saharan Africa and some countries in the South West (including Namibia and Angola) are also well-served by winds.

The wind map in **Appendix B.3** does not take into account local geography and topology, and a local wind assessment has to be carried out to determine the wind speed and direction at a site, and its variation over the course of the day and year.

Performance

Aside from the size of the wind resource, the key determinant of the performance of a wind turbine is the diameter of its blades (sometimes measured in terms of the turbine's swept area). The greater the area swept out by the blades of a turbine, the more wind energy it converts into electrical energy. All else being equal, doubling the diameter of a turbine will increase its power output by four times.

Since the output of a turbine is highly sensitive to wind speed, it is also sensitive to the turbine's height. The cost of installing and maintaining a large tower means that for turbines of 1 kW or less, 20 to 25 metres (60 to 80 feet) is a typical turbine height. For larger turbines, or if there are high obstacles in the area, a tower of up to 35 metres (120 feet) may be a worthwhile investment. The height of a wind turbine above sea level has a small negative effect on its output, due to the thinner air at higher altitudes. This effect reduces a turbine's output by around 5% for every 1000m above sea level.

Care must be taken when interpreting the power ratings given by turbine dealers and manufacturers. Three kinds of rating are common (examples of each of these can be found in the sample data-sheet for a wind turbine, reproduced in **Appendix C**).

Fig. 5.6
An anemometer consisting in a rotating blade embedded in a portable data analyser. The device is mounted on a pole with a vane to direct it into the wind.
Image: Richard Paul Russell Ltd

Rated power or maximum power. Turbines are typically advertised with a single figure describing their power output, such as "800 W" or "1 kW." The wind speed used for this rating is usually close to the optimum wind speed for the turbine, a speed that is rarely attained on real sites. Rated power gives a rough idea of the output of a turbine compared to other turbines, but it is by no means an accurate mea-sure of the power a turbine will deliver in the field.

"Nothing tells you more about a wind turbine's potential than rotor diameter."

Paul Gipe, US guru of small wind turbines

Power curve. This is a graph or table showing the predicted power of the turbine at a range of wind speeds. This has the advantage of showing the power of the turbine at realistic wind speeds. However, the power curve gives the turbine's output at constant speeds, not at average speeds. If a power curve indicates that a turbine delivers 500 W at a *constant* wind speed of 6 m/s, the turbine may deliver 1000 W or more, on average, on a site with an *average* wind speed of 6 m/s.

Long-term energy output. Many manufacturers supply a table showing the energy the turbine will deliver over a period of a month or year, for a range of average (not constant) wind speeds. This data takes into account deviations in the wind speed from its average, and it is the most reliable indicator of the turbine's performance. It can be used to find the average daily energy output of the turbine (though the turbine will of course not deliver this average amount every day).

Long-term energy data usually overestimates the actual energy the turbine will deliver. It is commonly de-rated by 10% to take into account turbulence, product variability, and other factors that affect performance. In general, manufacturer's claims for the output of turbines should be treated with care; they can overestimate the performance of a turbine by as much as 20 or 30%. The energy output of a turbine can also be estimated using the turbine's blade diameter and the average wind speed at a site (see FAQ 5.3 and **Appendix B.4**).

Losses in a turbine's electrical generator are usually taken into account in the manufacturer's ratings. However, there are also losses in the rectifier (around 3%

for a 48 V turbine, but around 12% for a 12 V turbine) and turbine data sheets usually do not make it clear whether these losses are taken into account in the ratings they quote; consumers may wish to contact the manufacturer to find out. As for PV arrays, further losses arise in the batteries, inverter and transmission cables. Typically these losses are 20–30%, but they may be greater for turbines at a distance from the site where the electricity is used (if the turbine is on a nearby hill, for example).

The useful lifetime of a turbine depends on the speed and turbulence of the wind as well as the presence of corrosive dust or sand. Turbine blades may last up to

FAQ 5.3

How much energy do wind turbines produce?

One way to estimate the energy output of a turbine is to use the manufacturer's data (see main text). Another way is to use the average wind speed at the site and the turbine's swept area (which is about 0.8 times the square of the blade diameter). The table below shows the theoretical maximum energy output per square metre of swept area at four typical average wind speeds. It gives annual energy output and average daily output (the actual daily output will fluctuate widely around the average). A very efficient small wind turbine may be able to convert half of the theoretical output into usable energy; an inefficient turbine may only convert a quarter.

Wind speed (m/s)	Annual output (kWh per year per m^2)	Daily output (kWh per day per m^2)
3	130	0.4
4	300	0.8
5	600	1.6
6	1,000	2.7

For example, a 1.5 m diameter turbine on a 4 m/s site would have about 1.8 m2 swept area (0.8 x 1.52 = 1.8) and have a theoretical output of about 540 kWh per year (1.8 x 300 = 540; the figure 300 is taken from the table). In the same conditions a 3.5 m diameter turbine (10 m2 swept area) would have a theoretical output of about 3,000 kWh per year. Appendix B.4 gives more detailed information about how to estimate the theoretical average output of a turbine. Data source: Hugh Piggott ten years in good conditions, but in rough conditions may last for three years or less. The other components of the nacelle, including the electronics, are also vulnerable to wear and tear. Lightly-built turbines with high tip-speeds are less likely to recover from damage than heavily-built turbines with lower tip-speeds. The tip-speed of a turbine can be calculated from its rotational speed (or RPM, usually quoted on the turbine's data sheet) and diameter. Tip-speeds should not be more than 80 m/s.

Fig. 5.7
A wind turbine (with an additional PV module) at a farm near the South African town of Badplaas.
Image: Solar Con Energy, South Africa

The following features of turbines are also relevant to their performance:

Start-up wind speed. The wind speed that will turn unloaded blades; that is, blades that are not connected to an electrical generator.

Cut-in wind speed. The wind speed at which the turbine will start generating electricity.

Furling wind speed. The wind speed at which the turbine's blades are turned out of the wind to prevent damage in high winds.

Maximum design wind speed. The wind speed above which damage could occur to the machine.

Maintenance

Maintenance for wind turbines is somewhat higher than for PV systems due to the turbine's moving parts. The most effective maintenance is early detection and repair of faults. Detection can be done most easily by listening to the sound the turbine makes. Most modern turbines make a fairly low swishing and humming sound, and rattling, whistling or hissing sounds are often an indication that something is wrong. The sooner a fault is detected and dealt with, the more likely the turbine will make a full recovery.

Routine maintenance includes lubrication of the moving parts, checking bolts and electrical connections, checking supporting guy wires for proper tension, and examining components for corrosion. This should not be necessary more than once a year. Turbines with gearboxes require considerably more maintenance than those without, but gearboxes are rare in turbines under 10 kW. Battery maintenance (see **Chapter 7**) is usually the most time-consuming aspect of maintaining a wind system.

Standards

The International Electrotechnical Commission (IEC) publishes standards for wind turbine design, construction, safety and performance. The relevant standard is IEC 61400-2, "Design requirements for small wind turbines." This standard is becoming relevant as countries such as the UK introduce independent testing centres for small-scale turbines. However, most turbines currently sold in Africa have not been independently tested, and many of these are of good quality and do not have misleading performance ratings (as long as care is taken in interpreting those ratings, as described earlier in this chapter).

Market and policy information

There are fewer wind turbine dealers in Africa than PV dealers. The advantage of wind turbines is that most parts – excluding magnets and some electronics – can be manufactured and assembled in Africa. The production of small turbines locally is generally cheaper than imported machines. It also enables manufacturers to make minor modifications during the production process, allowing them to suit systems to local end-uses and to the conditions under which they are expected to operate. For example, heavily built turbines with large diameters may be suitable for remote stations where wind speed is relatively low and servicing needs to be kept to a minimum.

Fig. 5.8
A welder works on a wind turbine part in a workshop in Mozambique. Wind turbines can be manufactured locally in Africa, using local materials. Image: The Clean Energy Company

It is possible to make simple, durable wind turbines by hand from materials that are largely locally available in Africa. This also makes the machines easier to service and repair. However, hand-made turbines require much time, enthusiasm, mechanical aptitude, and a well-equipped workshop.

Hydro power

Construction

Quick reference summary:

Hydro power

Hydro power schemes convert the kinetic energy of moving or falling water into electricity.

Because of **long life and continuous generation**, hydro power can be very cost-effective in the long term.

Hydro power requires considerable **civil works**, overseen by experienced professionals, and may require **regular and laborious maintenance**. Use of **local labour and materials** can reduce the cost of a hydro project.

A **professional site survey and hydrological assessment** is essential – each site is different, and hydro schemes are expensive to change once they are installed.

The potential power of hydro scheme is determined by the **head** (or height, in m) and **flow rate** (in m^3/s) of the scheme. Mechanical losses mean that the actual power of a system is about **50% of its potential power**.

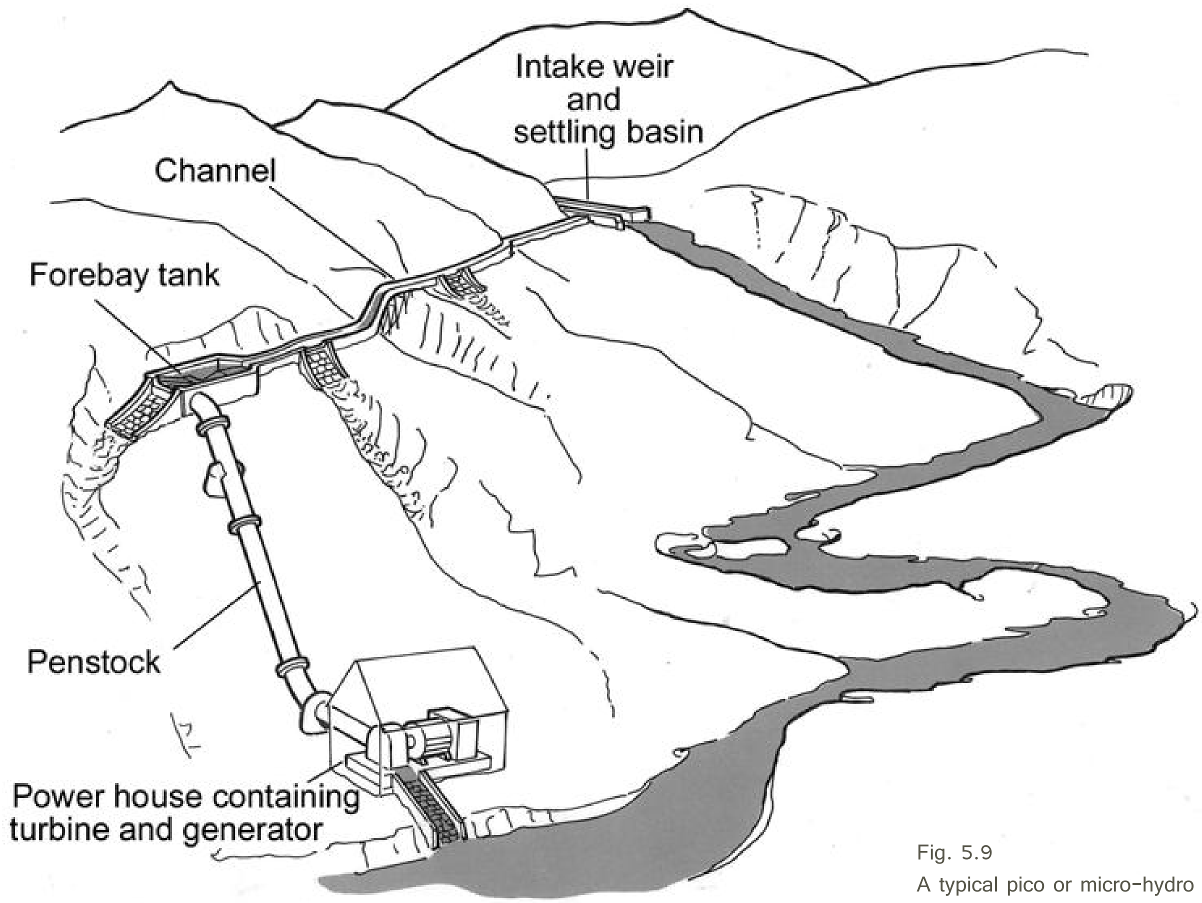


Fig. 5.9
A typical pico or micro-hydro scheme.
Diagram: Practical Action

Pico-hydro schemes are hydro schemes ranging from a few hundred watts to 5 kW; this is the most suitable class of hydro system for individual radio stations. Micro-hydro schemes (5 kW to 100 kW) may also be used to serve large stations or a small community.

Fig 5.9 shows a typical pico- or micro-hydro scheme. An **intake weir** and **settling basin** diverts water from a river to a man-made **channel**. The water gathers in a **forebay tank** to be conveyed under pressure through the **penstock**, before flowing through the **turbine** and back into the natural water system. The turbine converts the water's energy into the rotational energy of a shaft. In electricity generating applications, the shaft drives an electrical generator that converts the shaft's mechanical energy into AC current (and, less often, DC current). In electricity generating systems, a **load controller** is used to ensure that the AC current is regular. Load controllers add and subtract an artificial load from the turbine to compensate for the variations in the load supplied by the water flow. Electronic load controllers are the norm today, and are more efficient and require less maintenance than the old hydraulic controllers. A **dump load** – such as water heating, storage heating, or battery charging – is often used to absorb the excess energy from the turbine. Batteries may be used to store *all* the energy from the turbine, but this is less common for hydro turbines than for PV or wind turbines, since hydro turbines give a more consistent supply of energy.

The potential of a river or stream to produce hydro power is determined by **head** and **flow rate**. The flow rate is the volume of moving water (usually in m3 per second) that can be captured at the intake weir and conveyed down the

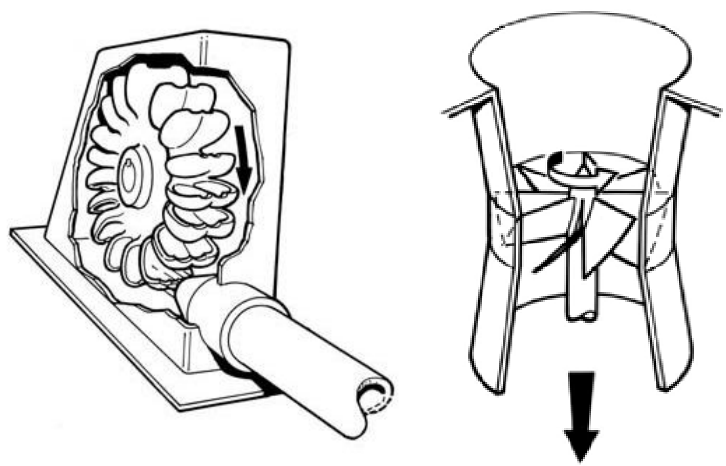


Fig. 5.10
Two kinds of hydro turbine: an impulse turbine (left) and a reaction turbine (right).
Diagram: Practical Action

penstock. The head is the vertical height from the turbine up to the point where the water enters the penstock. **Low head sites** have little vertical drop and a correspondingly large water flow. **High head sites** occur in steep areas where a small amount of water undergoes a large vertical drop.

The main types of turbine are **impulse** and **reaction** turbines. Impulse turbines direct a jet of water onto a set of blades or buckets that spin freely in the air. By contrast, the blades of a reaction turbine are completely immersed in the water. Reaction turbines are usually used on low head sites, and impulse turbines on high head sites.

River turbines are hydro turbines that are directly immersed in a natural river or stream. Since they do not rely on artificial channels or penstocks, river turbines do not require the extensive civil works that accompany an orthodox hydro system. However, they are less efficient and have lower lifetimes due to the strain of an uncontrolled natural water system. River turbines are a relatively new development, and are not as readily available as orthodox hydro turbines, but they are a promising technology that has generated commercial interest.

Natural resources

A resource assessment is especially important for hydro systems because they are not modular. To increase the power output of a hydro system it is necessary to upgrade the penstock and civil works, which is more expensive and difficult than adding another module to a PV array or erecting another wind turbine. Also, with proper maintenance a hydro system is designed to run for up to 50 years – so it is worth getting the system right at the beginning.

Resource assessments are more complex and expensive for hydro power than for wind and PV. Hydrological data – data on annual rain patterns and hence flow patterns – can often be obtained from the meteorology or irrigation department usually run by the national government. However, a professional site survey should be carried out to determine the head and flow rates of the water supply at the site. A site survey gives an estimate of the power that a turbine could supply, and also helps to select the appropriate kind and size of turbine. Seasonal variations in the flow rate need to be taken into account; hence flow data should be gathered over a period of at least one full year where possible. Pico-hydro systems (less than 5 kW) typically do not require such a thorough resource assessment.

Other site considerations are the ease with which a penstock can be installed in the landscape, and the distance the turbine is likely to be from the site of use (high transmission distances result in electrical losses, and may require

Fig. 5.11 The river and intake weir of a micro-hydro scheme in Kenya. The water entering the channel at the bottom-left of the photo generates around 18 kW of electricity, enough to serve 200 households in the area.
Image: Practical Action

expensive high-voltage transmission equipment such as a transformer). The interests of upstream and downstream dwellers should also be considered, as well as the ecological effect of diverting water from its natural course.

Performance

The potential power of a hydro site can be found using the formula:

Potential power [kW] = flow rate [m^3/s] x head [m] x g

g is a constant with a value of 9.81 m^2/s. For example, a river with a flow rate of 0.16 m^3/s and head of 10m will have a potential power of 15.7 kW (10 x 0.16 x 9.81 = 15.7).

The potential power should be de-rated by 50% to account for friction losses in the penstock and the inefficiency of the turbine (small water turbines rarely have efficiencies greater than 80%). This does not take into account losses in batteries and an inverter (if they are used). There may also be non-negligible losses due to transmission cables, if the turbine is located at some distance from the site where the electricity is used.

Because they provide power continuously, hydro systems can generate a lot of energy in a day even if operating at low power. For example, a 125 W hydro system can generate 3 kWh a day. By contrast, a 125 Wp PV module is unlikely to generate more than 900 W (0.9 kW) a day even in the middle of summer in a hot part of Africa.

Hydro turbines, like wind turbines, come with a **power curve** that describes the output of the machine for different levels of natural resource. The difference is that hydro power curves depend on two variables (head and flow rate) rather than just one (wind speed for wind turbines). Also, the relatively small daily variation in water flow does not lead to a great discrepancy between power output at average flow and at a constant flow (as noted in the wind turbine section, this discrepancy is high in the case of wind turbines). However, seasonal variations in the water flow must be taken into account when estimating the energy output of a hydro turbine.

As for wind turbines, there are no widely accepted standards for deriving the power curve for a hydro turbine. As noted above, losses in the civil works and turbine amount to 50% of the theoretical output of a turbine scheme, so consumers should ask turbine dealers which of these losses the power curve takes into account. The rated power output of a turbine, for a given head and flow rate, should not be more than 80% of the potential power (as found by the formula above).

Under ideal maintenance and environmental conditions, a high quality hydro system – including turbine, transmission lines, and civil works – can last up to 50 years. However, 30 years is a more typical lifetime. Some components may need to be replaced more regularly than this, especially the turbine's bearings (these usually do not last more than a decade).

The cost of hydro power can be minimised by:

Use of HDPE (plastic) penstocks, where appropriate.

Using existing infrastructure, such as a canal that serves an irrigation scheme.

Using pumps as turbines (PAT). In some circumstances standard pumps can be used “in reverse” as turbines. This reduces costs, delivery time, and makes for simple installation and maintenance.

Using motors as generators. As with the PAT idea, motors can be run “in reverse” and used as electrical generators. Pumps are usually purchased with a motor fitted and the whole unit can be used as a turbine/generator set.

Maintenance

Maintenance of hydro schemes consists mainly of inspecting the water channel and penstock to keep them free from debris. These inspections may be required as often as once a week, depending on the local conditions. For example, some rivers become silted and full of sand after heavy rains, necessitating laborious cleaning of the penstock and canal. The turbine should be examined annually by a qualified technician to ensure that it is operating correctly. The sooner faults in the turbine are detected and repaired, the longer the turbine will last.

Market and policy information

The cost of hydro power can be reduced by making use of local resources wherever possible. Community labour and local materials can be used for the civil works. Using pumps as turbines, as described above, can also reduce costs. Since centrifugal water pumps can often be found locally, this option avoids import taxes; and since the pump is a familiar technology to local pump and motor technicians, it can be serviced locally if problems arise. Converted pumps are generally less efficient than purpose-built hydro turbines, but in some cases they may be a better option overall. Similarly, motors can be run “in reverse” and used as generators; pumps are usually purchased with a motor fitted and the whole unit can be used as a turbine/generator set.

Hydro schemes are a long-term investment, and experienced professionals should be consulted at each stage of the project, from the site survey to the maintenance schedule.

Emerging technologies

Wind, solar, and hydro power are proven technologies that have been used successfully to generate electricity at suitable sites in Africa and around the world. This section describes three promising technologies that have been used in pilot programmes but have not been fully tried and proven on a large scale. In the future, they may become more important as renewable sources of electricity.

Animal power

Animal power systems consist of an electrical generator driven by an animal (usually a cow, bull, ox, or horse). The animal is harnessed to a metal arm that drives a set of gears fixed inside a frame. An alternator converts the motion of the gears into AC electricity, which can be used directly at a station or stored in batteries.

Unlike wind or solar power, the output of animal power systems is predictable and can stay constant throughout the year, depending on the availability of animals.

Quick reference summary:

Animal power

Animal power systems use the **motion of animals** to generate electricity.

Animal power systems are **low-maintenance** and suitable for rural areas that do not have ready access to expertise and equipment.

Unlike other renewable energy sources such as wind and solar power, the output of animal-driven systems **does not depend directly on climate or geography at a site** – but it does depend on the availability of animals.

The cost of the animals depends on whether the station already has access to animals and whether they are normally used for other purposes. The opportunity costs of permanently committing large farm animals to the system should be taken into account.

The maintenance costs of such systems are low. The main maintenance requirement is to take care of the animals, along with regular checks of the mechanical parts and electrical fittings.

PETRA (Production d'Electricité Par Traction Animal, or Electricity Production by Animal Power) is an animal power system designed for radio stations that is currently being trialled in Africa (see **Appendix D.2** for more information on PETRA).

Biogas

Biogas is the gas produced by the fermentation of organic matter in the absence of oxygen. A biogas plant can convert animal manure, plant matter, and waste from the agricultural industry and slaughterhouses into a combustible gas, usually

Quick reference summary:

Biogas

Biogas is the gas produced by the **break-down of organic matter** – usually animal manure or night soil – in the absence of oxygen.

Biogas can be used as a **substitute for fossil fuels in gensets**, but it needs to be treated first to remove impurities.

The need for **regular collection of organic matter** can make biogas plants a high-maintenance option compared to other RETs.

Big animal farms, agricultural plants, slaughterhouses, and market places are potential sources of material for biogas plants.

methane. The heart of a biogas plant is the digester, the container where fermentation takes place. In small-scale plants the digester is often constructed underground, using bricks or cement. Organic matter is fed into the digester, and biogas bubbles up through the matter to be collected from the top of the container.

Biogas can either be used in direct combustion (in lamps or stoves, for example) or as a fuel to generate electricity. In theory, most engines originally intended for cars, trucks, ships or stationary use can run on biogas as fuel. The main obstacle to electricity generation using biogas is impurities in the gas. In particular, the sulphur content of the gas must be kept as low as possible to avoid damage to the genset. Advanced fermentation or filtering techniques are also needed to maximise the amount of methane in the gas. However, once the biogas is properly refined, it is relatively simple to use it to generate electricity – a genset designed for diesel fuel, but run on refined biogas, does not require much more know-how or effort to operate and maintain than the same genset running on diesel.

Electricity from a biogas plant is only as reliable as the supply of organic matter. Collecting this matter and feeding it into the biogas plant can be time-consuming and energy-intensive, and biogas is most feasible for stations that are close to a reliable source of appropriate material, such as big animal farms, slaughterhouses, agricultural areas, or communal institutions like market places where plant and animal waste accumulates daily.

Some see biogas plants – producing biogas for direct combustion in stoves or lamps — as a promising solution to the problems of energy poverty and over-exploitation of woodlands. As of 2010, plans are in place to introduce tens of thousands of biogas plants for this purpose to Ethiopia, Rwanda and Tanzania in the next few years (for more information, see Appendix D.2). In Africa, as in other developing countries, the use of biogas for producing electricity is relatively rare and limited to a few pilot plants. For example, pilot projects are underway in Kenya to see whether electricity production from biogas is viable in large-scale plants.

Jatropha oil

Jatropha oil is vegetable oil produced from the seeds of jatropha curcas, a plant that can survive on dry and marginal lands. Jatropha oil is one of a number of crops – including sugar cane and oil palm – that have the potential to provide fuel for electricity generation.

When jatropha seeds are crushed, the resulting jatropha oil can be processed to produce a high-quality biodiesel that can be used in a modified diesel genset. The residue from the crushing process (also known as press cake) can be processed and used as a fuel source for electricity plants or as fertiliser.

The advantage of jatropha plants is that they can grow on marginal land where other crops cannot flourish. They are also effective at preventing soil erosion, and their dropped leaves act as a soil-enriching mulch. The plants are toxic to animals (as well as humans) and for this reason are effective as a “living fence” to contain

Quick reference summary:

Jatropha oil

Jatropha oil is extracted from the **seeds of the jatropha plant**.

Jatropha is a resilient crop that **can grow in marginal lands**. In addition to its oil yield, the plant helps to prevent soil erosion and can act as a fence for livestock.

Ordinary diesel gensets are not designed to be run on jatropha oil, but they can be professionally modified to run on both fuels.

Jatropha oil is a **promising fuel source** but has not yet been proven on a large scale in Africa.

animals. A disadvantage is that jatropha plants draw a lot of water from the ground, and some fear that they may compete with food crops if used on a large scale.

Ordinary diesel gensets are not designed to be run on jatropha oil. Purpose-built jatropha gensets can usually run on ordinary diesel, but they are expensive and not readily available in Africa. Diesel gensets can be converted to jatropha oil, but this is a complex process that usually takes place at a specialised conversion centre, of which there are few if any in Africa. Amateur conversion of diesel gensets to jatropha gensets is not recommended.

Jatropha oil has gained in popularity in recent years, and a number of foreign companies have invested in jatropha plantations in Africa and elsewhere, with the goal of selling the oil for fuel. While jatropha oil has been used successfully for fuel in some cases in Africa, it is not yet proven on a large scale.

Fig. 5.12
A purpose-built genset than can be run on both petrol and jatropha oil. Ordinary diesel gensets are not designed to be run on jatropha oil, but they can be professionally modified to run on both fuels.
Image: Energiebau, CAMECO

6 Gensets

Gensets, which use a combustion engine and electrical generator to produce electricity, are the most common source of non-grid energy in Africa, largely because they are readily available, have relatively low initial costs and provide power on demand (as long as fuel is available). However, running costs are high due to the cost of fuel. Regular maintenance and proper use of gensets can help keep these costs down.

Quick reference summary: Gensets

Gensets consist of a **combustion engine** fed by a gas or liquid **fuel**, and an **electrical generator**. Fuels include diesel, petrol, propane, biodiesel, and biogas.

Gensets are a popular source of energy in Africa because of their **low initial cost** and ability to provide **power on demand** (as long as fuel is available).

The cost of purchasing, securing and transporting fuel means that gensets have **very high running costs** compared to most renewable technologies.

Low-load inefficiency is the tendency of gensets to use more fuel per kWh when operating at low power (less than half the genset's rated power). This is a common cause of high running costs for gensets.

Maintenance tasks include checking the oil and coolant levels and changing the oil filter. Gensets that are used regularly should be examined at least once a year by a professional technician.

Construction

Gensets consist of an internal combustion engine, powered by a liquid or gas fuel, that drives an electrical generator. The engine converts fuel into mechanical energy, which the genset converts into AC electrical current. Mechanics sometimes refer to the **engine head** and **engine block**. The latter is the block of metal that contains the engine's cylinders. The former sits above the engine block and controls the air and fuel that drives the cylinders. The following are the main kinds of genset, classified by the fuel used in them.

Fig. 6.1
One of two 70 kW diesel gensets at Radio Pacis, Uganda. Chapter 10 contains more information on Radio Pacis and its energy technology.
Image: CAMECO

Fig. 6.2
A portable 3 kW genset (left) and an open 10 kW generator (right).
Images: Yamaha, Lister Petter

Diesel gensets are more expensive than gasoline or petrol gensets, but have a longer life, higher fuel economy, and produce less noise.

Petrol gensets (also called gasoline gensets) are also widely used in Africa. They are cheaper than diesel gensets and come in smaller sizes. They operate at higher speeds than diesel gensets (mostly around 3,600 revolutions per minute). As a result they have a short lifespan and low fuel efficiency. Unless the load is very small, they are best used as an emergency back-up supply, run for no more than roughly 400-600 hours per year.

Propane gensets are quieter, cleaner, and safer than diesel and petrol machines. They are well-suited for use in a hybrid system with solar panels or wind power, though they are not ideal as a primary energy source.

Box 6.1

Multifunctional Platform – an all-purpose genset

The multifunctional platform (MFP) is a genset designed to perform many different tasks simultaneously. The mechanical energy of the platform may power grinding mills, de-huskers, and water pumps; or be converted into electricity for lighting, refrigeration, or battery charging. The advantage of the MFP is that it is an all-in-one energy source. It can be easily transported to rural areas, and community members trained in its operation and maintenance.

MFP has been used as part of development programmes in Ghana and Mali. In past programmes, community based organisations – especially women's groups – have been encouraged to buy MFP's for their village at a reduced cost. MFP's are not commercially available and they are suitable for villages rather than individual users such as radio stations. However, some radio stations may be able to draw power from MFP's installed in their villages now or in the future.

Biodiesel gensets run on processed vegetable oils or animal fat. Jatropha oil is a promising genset fuel in Africa (see "Emerging technologies,' **Chapter 5**, for more information on jatropha oil).

Biogas can also be used in gensets, provided it has been treated to remove impurities and increase its methane content (see "Emerging technologies,' **Chapter 5**, for more information on biogas).

Cost and performance

Gensets are rated according to their power output, voltage, and fuel efficiency. Voltage is usually 120 V or 240 V AC current. "Small" gensets for off-grid use range from 1,000 W to 10 kW. Typical initial costs for diesel gensets in this range are $800 to $1,000 per rated kW. The initial cost of petrol gensets is roughly half that of diesel gensets. Genset ratings are often given in Volt-Amps (VA) rather than Watts (W). This is because the actual power of a genset depends on an electrical phenomenon called power factor (briefly mentioned in **Chapter 1**). Power factor means that for AC loads the actual power of a genset is usually smaller than the apparent power by a factor of 0.7 to 0.8.

> **"Poor low-load efficiency is the bane of many generator-only systems"**
>
> NREL, "Renewable Energy for Rural Schools"

Diesel genset fuel efficiency is generally 2.5 to 3.0 kWh per litre when it is driving a large load. Fuel efficiency decreases for lower loads, and light loads of 40% or less than the rated power can damage the genset as well as being inefficient. As a rule of thumb, a genset should not be operated at less than half its rated power, and the greater the operating power the more efficient it will be. Whenever possible, gensets should be used for short periods at high power levels rather than for long periods at lower power levels.

Genset lifetime depends on the type of genset used and the parts of the genset replaced. For diesel gensets, the engine head may need to be rebuilt after 8,000 hours (e.g. 3.5 years at 6 hours a day), and the engine block after 16,000 hours

FAQ 6.1

How can I keep genset fuel costs down?

Below are some measures that may be suitable for stations interested in reducing fuel costs.

Use gensets at high power wherever possible – they are considerably less efficient at low power. One option is to use the genset to charge batteries. Despite the initial cost of batteries, in the long run this may be cheaper than using a generator at low power for long periods.

Caution: many batteries (including most solar batteries) are not designed for rapid charging by a genset. Good battery selection is important when charging with a genset.

Multiple small gensets are preferable to one large genset. The former system can serve large loads by combining the small gensets, and small loads by turning off one or more of the gensets and operating the others at high power. By contrast, a single large genset can serve large loads, but can only serve small loads by operating at low power (and hence low efficiency).

If a genset is used as an emergency supply, a small genset may be enough if it is only used to power **critical loads** (such as computers and the transmitter) and not non-essential loads (such as air conditioners).

Use a battery-charging RET at times when the total load of the station is small (for example, if lights are kept on at night once the transmitter has been turned off). This will save energy by not using the genset on small loads for which the genset is inefficient.

Arrange **training** in genset maintenance for one or more staff members, so that they can perform daily and weekly maintenance tasks.

Pay a **professional** to examine the genset and overhaul it if necessary. The gains in fuel efficiency may well offset the mechanic's fees.

(e.g. 7 years at 6 hours a day). The lifetimes of petrol gensets are considerably shorter than those of diesel gensets.

Maintenance

Gensets require more regular maintenance than batteries and renewable energy technologies, though maintenance requirements are less if gensets are used as a back-up rather than primary power source. For gensets used as a primary power source, fuel, oil, and coolant should be checked daily for leaks. Oil and coolant levels should be checked weekly. The genset should be thoroughly examined by a professional on a monthly, semi-annual or annual basis (depending on how often the genset is used). Lastly, the engine oil and the oil filter should be changed after about 1,000 operating hours (e.g. 6 months at 6 hours a day).

7

Electrical storage and regulation

For energy generating technology to provide useful, reliable electricity, it usually needs to be stored and regulated. Storage is necessary because the timing of the energy supply does not usually match the timing of the energy load; batteries store energy so that it can be collected when nature (or availability of public power supply) allows it, and consumed when users need it. Inverters and charge controllers refine the electrical energy that enters and exits a battery bank; they ensure that the correct kind and quantity of electricity passes through the battery and through electrical loads. Electrical regulation includes dealing with the power outages and fluctuations that are a serious problem in Africa, and this chapter lists some equipment and strategies that stations can use to protect equipment from these defects while making the most of the public power supply. Regulation also helps to deal with critical loads – the loads that have the greatest need for continuous high quality electricity – and to shield those loads from power losses elsewhere in the system.

Batteries

Construction

Batteries convert the chemical energy of their active materials into electrical energy that flows through the terminals in the form of DC current. A typical lead acid battery is made up of a series of battery cells (Fig. 7.1), each of which contains a set of positive and negative **plates** (also called **electrodes**) divided by **separators** and immersed in an acidic solution (also called the **electrolyte**). The plates include a grid of non-active material that holds the active material in place. Each cell is enclosed in a battery **case** made of rubber or plastic. The **active materials** in a battery are the paste on the surface of the plates and the chemicals (usually sulphuric acid) in the electrolyte.

Quick reference summary:

Batteries

Batteries are used to **store** but also to **regulate** energy, since they deliver relatively smooth current.

Batteries are the weak point of energy systems that use them, but they perform well if they are correctly sized and maintained.

Batteries are rated according to their **voltage (V)** and **capacity (Amp-hours).** Amp-hours can be multiplied by the battery voltage to give the capacity in kWh.

Deep-cycle, lead-acid batteries, either flooded or gelled, are the best option for regular use in off-grid systems. Flooded batteries require more maintenance than gelled batteries but are tolerant of high temperatures and can cope with some imprecision in charge control.

Battery sizing depends on the reliability of the energy source. However, as a rule of thumb, batteries should be able to store **five times** the energy that a station is expected to draw from them daily. This gives two-three days backup supply and ensures that the battery cells are not discharged by more than 50%.

Proper dimensioning and use of a system ensures that batteries are not overcharged (causing gassing) or undercharged (causing sulphation and stratification).

Regular maintenance helps avoid inconsistent batteries (where one weak cell compromises all cells) and low electrolyte levels (causing sulphation). Battery care also slows down corrosion and self-discharge.

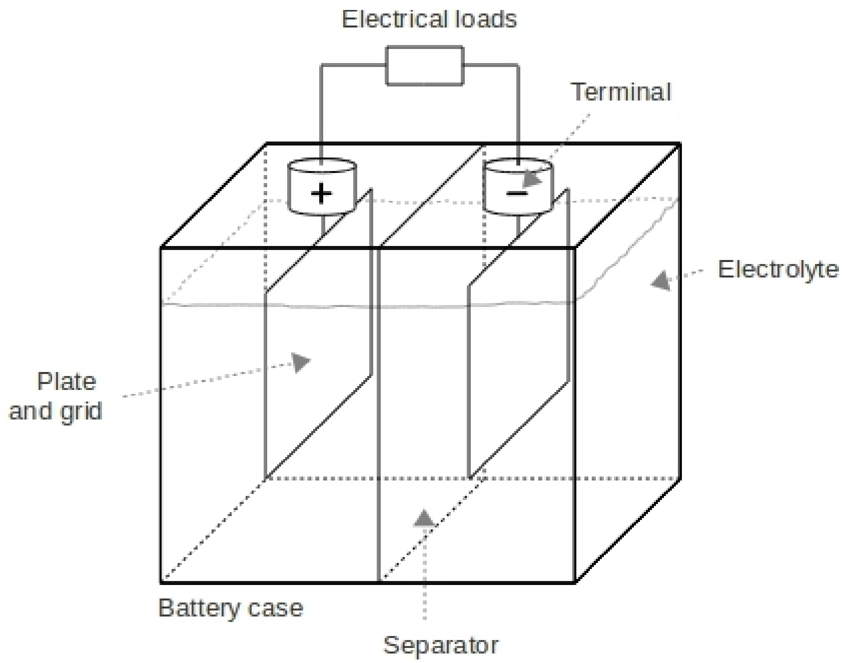


Fig. 7.1
A single battery cell. This is a flooded cell, meaning that it contains liquid electrolyte. Cells with non-liquid electrolyte are also available, but they operate on the same basic principles as flooded cells (see "captive electrolyte battery" below). Diagram: author

When the battery is connected to a load, the sulphuric acid reacts with the plates to drive electricity through the load. This reaction causes some of the sulphuric acid to be converted into solid sulphate, which builds up on the battery plates; the battery thus becomes **discharged**. When a battery is **charged** the reverse process occurs, the sulphate being converted back into sulphuric acid. A battery's **state of charge** corresponds to the amount of sulphuric acid that has not been converted into sulphate. The capacity of a battery is determined by the amount of active material inside it. Gassing occurs when batteries continue to be charged after all the sulphate has been converted into sulphuric acid, causing the battery to produce hydrogen and oxygen gas. **Self-discharge** occurs in a battery even when a battery is not connected to an electrical load.

Batteries vary in the chemicals used in the plates and electrolyte, the number and solidity of their plates, and whether or not they are sealed. These factors determine how deeply they can be discharged (their **deep cycle performance**), how tolerant they are of being overcharged and undercharged, their rate of **self-discharge**, and how much maintenance they require. The main kinds of batteries suitable for radio stations are:

Flooded, deep-cycle, lead-acid battery. These have a liquid electrolyte and thick, lead-antimony plates, making them robust in high temperatures and giving them good deep-cycle performance. The downside is that they have a high self-discharge rate and are susceptible to gassing; for this reason they need regular maintenance (including access to distilled water or clean rain water). Flooded cells are also called wet cells or vented cells (because electrolyte and gasses can escape through vents in the battery case).

Captive electrolyte battery. In these batteries the electrolyte is immobilised in some manner and the battery is sealed. The two main types are gelled batteries and absorbed glass mat batteries. They are often advertised as maintenance-free. The downside is that because they are sealed, it is not possible to replenish the electrolyte if gassing occurs. They should only be used with a good quality charge controller that includes temperature compensation. They have a shorter life-time than a well-maintained flooded battery, but a longer life-time than a poorly maintained flooded battery. These batteries are also known as sealed or VLRA (valve regulated lead acid) batteries.

SLI (starting, lighting and ignition) battery. SLI batteries, such as car batteries, are designed to give a high current for a short period, and have poor deep-cycle performance. They are cheaper than deep-cycle batteries, especially in developing countries, but have short life-times when used with a genset or RET.

Stationary battery. Often found in uninterruptible power supply (UPS) devices, these batteries are designed for infrequent use and low maintenance. They have lead-calcium plates, which have minimal gassing and a low self-discharge rate. However, they will perform poorly if they are repeatedly discharged by more than 25%.

Fig. 7.2
Two flooded lead-acid batteries. The battery on the right is fitted with a cylindrical “recombination cap”, a device attached to the battery vent that captures gasses from the battery and automatically “recombines” them with the electrolyte.
Image: CAMECO

Fig. 7.3
A captive electrolyte, or “maintenance-free” battery. Unlike flooded and vented batteries, maintenance-free batteries are sealed and do not contain liquid electrolyte.
Image: CAMECO

Performance

Batteries are rated according to their voltage and capacity.

Voltage is a measure of the rate at which a battery can supply energy to a load. The nominal voltage of a single lead-acid cell is 2 V. Connecting cells in series increases their voltage. A 24 V lead-acid battery, for example, is 12 lead-acid cells connected in series. The voltage of a battery varies depending on its state of charge and the kind of current that it is charged with.

Capacity is a measure of the amount of charge a battery contains, generally measured in Amp-hours (Ah). One Ah is enough charge to deliver current of 1 Amp for 1 hour. For example, a battery rated at 500 Ah can deliver 5 A of current for 100 hours, 50 A for 10 hours, and so on. Amp-hours is not a measure of the energy of a battery (see FAQ 7.1 on how to convert Amp-hours into watts or kilowatts). Batteries that are discharged slowly deliver more energy overall than batteries discharged quickly. Battery capacity also depends on the age of the battery; a battery at the end of its rated lifetime has about 80% of its initial capacity.

The battery capacity a station requires depends on the reliability of the energy source used: the greater the frequency and duration of cuts in the energy source, the more stored energy is required. For a system that relies on renewable energy technologies, the rated capacity of a battery should be roughly **five times** the energy that needs to be drawn from the batteries each day. There are three reasons for this large de-rating factor.

Maximum depth of discharge. Standard deep-cycle batteries should not be discharged by more than 20 to 30% on a regular basis, with occasional discharges of up to 50%.

Back-up energy. Stations that rely heavily on renewable sources such as solar panels or wind energy should store two to three days worth of energy in case of long periods without sun or wind.

Charge efficiency. The storage process in a battery is inefficient: some of the energy delivered to a battery is lost as heat by the battery. For sealed lead-acid batteries about 5-10% of the delivered energy is lost. For flooded batteries the figure is slightly higher, around 15-20%.

FAQ 7.1 describes how to calculate the required battery capacity once the desired daily energy output of the battery is known.

Battery lifetime is given in terms of cycles or years before the battery capacity and voltage fall below a given percentage of their original level. Cycles represent the cumulative energy flow through the battery; for example, discharging a battery five times by 20% is one cycle.

Float life refers to how long a battery that is connected to a system will last, in the case that it is never used or only lightly used. Float life is not a good measure of durability for batteries used with gensets or RETs, since they are frequently discharged.

FAQ 7.1

How much battery capacity does my station need?

The following formula can be used to calculate the battery capacity the station needs, once the desired daily energy output of the battery is known.

Capacity [Wh] = daily battery output [Wh] x days of autonomy [days] / (max discharge level x discharge efficiency)

"Max discharge level" is a ratio expressing the amount by which the battery can be safely discharged. This is usually about 0.5 (i.e. batteries should not be discharge more than 50%).

The "discharge efficiency" expresses the amount of energy the battery puts out for the amount that is put in. It is usually between 0.7 and 0.9 (i.e. the battery puts out 70 to 90% of the energy put in).

For RET systems, battery capacity should be roughly five times the energy that needs to be drawn from the batteries each day. For example, if a station intends to draw 5 kWh a day from batteries, a battery capacity of roughly 25 kWh is needed.

The following formula converts kWh into Amp-hours for battery selection:

$$C = E/V$$

E is the battery's energy (in Watts), V is the nominal voltage of the battery (in Volts), and C is the capacity (in Amp-hours). V is usually 24 or 48 V. For example, a 24 V system with a capacity of 25 kWh corresponds to a total capacity of 1040 Amp-hours (25 000 W/24 V).

Battery lifetime depends on the type of battery used, temperature, frequency and depth of discharges, average state of charge and charging methods. Deep-cycle flooded batteries can last up to 10 years if they are of high quality and well maintained. However, their lifetimes are shortened considerably if they are poorly maintained or badly used. Batteries are highly sensitive to temperature: as a rule of thumb, battery float life is halved by every 10°C increase in average ambient temperature.

Another important consideration is that batteries (less so than gensets or the public power supply) have trouble starting up high-power heat-producing devices such as a microwave, oven, water pump, or electric iron. Air conditioners are also best powered by a genset or public power rather than by batteries.

A note of caution: battery manufacturers often do not rate battery performance under the conditions of charge and discharge experienced by a battery linked to a RET or genset and used heavily and regularly. Consumers may wish to ask battery dealers about the conditions under which their products are rated, and how the battery performance might differ under the conditions of their own site.

Fig. 7.4
The battery bank at Radio Pacis in Uganda (see Chapter 10 for more details on Radio Pacis). This large battery bank consists in 200 batteries, each of 2V and 250 Ah, giving a total of 50 kAh.
Image: CAMECO

FAQ 7.2

What are the main causes of battery failure and how can they be overcome?

Deep discharge. Each time the battery is deeply discharged, some of the active material drops off the plates and falls to the bottom of the battery case, weakening the battery.

Solution. Size the battery and power supply correctly and use the right charge controller (see Chapter 6 on charge controllers).

Undercharging. Sulphate remains on a battery's plates when it is not fully charged. Over time this sulphate hardens and cannot be removed by recharging. Also, occasional gassing mixes the electrolyte and stops stratification (the build-up of acid at the bottom of the battery).

Solution. Size the battery and power supply correctly and use the right charge controller (see Chapter 6 on charge controllers). Do not disconnect batteries from the charger while the battery is in a discharged state. Check the battery's state of charge during "dark days" or periods of low power. Apply an equalisation charge (see "charge controller" below) a few times a year.

Excessive gassing. Some gassing is good for a battery. But too much gassing dislodges active material from the plates, shortening battery life.

Solution. Size the battery and power supply correctly and use the right charge controller (see Chapter 6 on charge controllers).

Low electrolyte level. Sulphate forms more on plates if the plates are exposed to air. If the electrolyte level remains low, the sulphate can harden and become impossible to remove through charging.

Solution. Top up the cells with water (not acid) when the electrolyte level drops. This should not be done when the cells are discharged: the electrolyte level always drops a little when cells are discharged.

Inconsistent charge. If cells differ significantly in their state of charge, sulphation and stratification can further weaken these cells and the output of the whole battery bank falls.

Solution. Check the state of charge of each cell once a month. Apply an equalising charge to the battery array if some cells are significantly weaker than others. Do not mix batteries of one type or brand with batteries of another type or brand.

Self-discharge. Lead-acid batteries discharge by themselves even if they are not used, making them susceptible to sulphation if they are not re-charged.

Solution. Keep batteries cool when they are not in use, and recharge stored batteries every six months. Check battery state of charge before purchasing, as batteries are sometimes left idle for long periods before being sold. If they are undercharged they may also have sustained sulphation or stratification.

Impure electrolyte. Impurities in the electrolyte can create an electrical short inside the battery.

Solution. Use distilled water to replenish the electrolyte. Clean rain-water is adequate but not ideal.

Corrosion. High temperatures accelerate corrosion of the battery plates and terminals.

Solution. Keep the battery in a cool area if possible. Clean the battery terminals once a month, or more often if necessary, to remove corrosive material.

Maintenance

Maintenance is essential for flooded lead-acid batteries, especially in hot climates. Battery maintenance takes roughly two hours a week and should be carried out by a trained technician or someone who has been instructed in battery maintenance by a trained technician. Battery lifetime can also be extended by sizing the battery and power supply correctly and by using a good charge controller (see “Charge controllers” below).

Battery safety

Batteries are potentially very dangerous and users should be aware of three main hazards:

The sulphuric acid in the electrolyte (of flooded batteries) is corrosive. Protective clothing, in addition to foot and eye protection, is essential when working with batteries.

Batteries have a high current generating capability. If a metal object is accidentally placed across the terminals of a battery, high currents can flow through this object. The presence of unnecessary metal objects (e.g. jewellery) should be minimised when working with batteries, and tools should have insulated handles.

Fig. 7.5
Batteries are a serious hazard and should be marked as such, as at Radio Pacis, Uganda.
Image: CAMECO

Explosion hazards due to evolution of hydrogen and oxygen gas. During charging, particularly overcharging, some batteries, including most batteries used in solar power systems, may develop a potentially explosive mixture of hydrogen and oxygen gas. To reduce the risk of explosion, ventilation is used to prevent the build up of these gasses, and potential ignition sources (i.e. circuits which may generate sparks or arcs) are eliminated from the battery enclosure.

Inverters

Inverters convert DC current into AC current (**Chapter 1** briefly describes AC and DC current). They are often used to convert the DC current from batteries, solar panels, or a wind turbine into AC current for use in station appliances. Inverters use transformers to step up the low voltage from a battery or RET to the high voltage required for studio use. Some inverters can also act "in reverse" as rectifiers, converting the AC current from generators, wind turbines, or hydro power into DC current for storage in a battery.

Fig. 7.6
Inverters at Radio Voice of Life in Uganda (for more on Radio Voice of Life, see Chapter 10). The two white objects and the black object are inverters for Voice of Life's 1 kW solar panels. The blue object at the top of the image is a charge controller.
Image: CAMECO

Sizing. Inverters are usually sized according to their maximum continuous power output. Most inverters can handle considerably more power than their rated size for short periods of time; this is useful for meeting occasional oversized loads such as starting a motor. It is a good idea to purchase an inverter that is rated about 25% higher than the estimated power of the loads it will serve, in case those loads increase. Inverter performance is dependent on temperature and typically declines by about 1% for every extra degree above 25°C. This effect should be taken into account when sizing and locating an inverter, and inverters should be kept out of direct sunlight.

Efficiency. Inverter efficiency is the percentage of the input energy that is available to the inverter's output. Inverter efficiency is usually well over 90% when the device is operating close to its maximum continuous power, but is poor at low power. Mid-range efficiency varies widely between inverters and may be an important selection criterion. Overall, inverter efficiency is roughly 80-90%; these losses should be taken into account when sizing the power supply. Inverters draw power from the supply even when they are not powering any loads. To minimise waste, some inverters have a sleep mode that keeps the no-load power draw to a few Watts.

Output wave form. The wave of AC current has three main forms, square wave, modified sine wave, and pure sine wave. A square wave inverter is the least expensive and gives the lowest quality output. It is suitable only for resistive loads such as resistance heaters and incandescent bulbs. Modified sine waves are intermediate in cost and quality between a square wave and a smooth sine wave. Most common household and business appliances can run on modified sine waves. For high-quality performance, radio equipment such as mixers, CD players and transmitters should be run on pure sine waves. It is possible to run them on modified sine wave AC current, but this will distort the station's sound somewhat and may reduce the lifetime of equipment with sensitive electronics. However, this equipment should not be run on square wave current.

Switched versus parallel. A parallel inverter can supply power to a load simultaneously with a genset. With a switched inverter, either the inverter or the generator, but not both, supplies power to the load.

Extra features. Inverters may come with extra features such as battery charging, low and high-voltage alarms and disconnect, automatic start and stop of a back-up genset, and a Maximum Power Point Tracker (see "charge controllers" below).

Fig. 7.7
Inverters and charge controllers are sometimes incorporated into the same piece of equipment, as in this device from B.BEAM.
Image: CAMECO

Charge controllers

Charge controllers regulate the flow of current from an energy source into a battery. Good charge controllers extend battery life considerably and make optimal use of the available power. **No battery system should be installed without a charge controller.** This is especially true for radio stations, where batteries are likely to be heavily and frequently used, and the costs of damaging the batteries (and the energy system) are high.

"Charge regulation is perhaps the single most important issue relating to battery performance and life"
Batteries and charge control in stand-alone photovoltaic systems, Florida Solar Energy Center

The main functions of a charge controller are:

A. Overcharge protection. Overcharge occurs when the supply to the battery is too large or the loads are too small. Too much charge causes excessive gassing, electrolyte loss, internal heating, and accelerated corrosion of the battery. A charge controller disconnects the power supply when it detects that the battery voltage is too high, and reconnects it when some of the charge has been removed from the battery. A **series controller** simply disconnects the energy source from the battery. A **diversion controller** “shunts” the excess supply to a dump load such as a water or space heating. Series controllers are suitable for solar panels, but wind and hydro turbines require diversion controllers so that they always operate under a load (an unloaded turbine may operate at overly high speeds that can damage the machine).

B. Undercharge protection. Batteries become undercharged when the power supply is consistently low or the loads consistently high. Too little charge in a battery causes sulphation (the battery plates become permanently coated in sulphate) and stratification (concentrated acid forms at the bottom of the battery, speeding up corrosion). The **low voltage disconnect** (LVD) is the battery voltage at which the controller disconnects the battery from electrical loads. Once the battery reaches the **load reconnect voltage** (LRV) the battery power is restored to the loads. **Critical loads** may be powered directly from the battery, so that they continue to receive power even when the non-essential loads (connected to the controller) are disconnected by the controller. In such cases an alarm or other signal should be used to ensure that the critical loads do not discharge the battery too much.

C. Controlling the rate of charge. Most controllers regulate the rate at which a battery is charged by regulating the current delivered to the battery. The greater the input voltage, the faster it will be charged; the higher the battery’s state of charge, the greater the voltage required to charge it further. A charge controller can operate in one or more of the following charging modes:

Bulk charging (also called the main charge or full charge) charges the battery up to a voltage level when gassing starts and the voltage rises; the battery is now 80-90% charged. Most chargers can operate in this mode.

Maintenance charging (also called the float charge) holds the battery at full capacity when it is fully charged but not frequently used for some period. Maintenance charging is designed to balance out the self-discharge of a battery. If used to increase the charge it is very slow – too slow for a battery in an active off-grid system. Two-stage and three-stage charges include maintenance charging. So-called "trickle chargers" operate *only* in this mode and are not suitable for off-grid systems.

Top-up charging (also called the tapering or absorption charge) carefully pushes the battery to full charge from around 90% charged. Top-up charging brings the battery to full capacity more quickly than a maintenance charge could do so. Three-stage chargers can operate in this mode.

Equalisation charging delivers a high voltage to the battery when it is at or near full capacity, resulting in overcharging and gassing. It is used periodically for flooded batteries (**not** sealed batteries) to remove charge differences between cells and to mix the electrolyte. Equalisation mode may be activated automatically (about once a month) or manually (when an operator detects that one or more of the battery's cells have an excessively low state of charge).

Fig. 7.8
Charge controllers suitable for use in RET systems.
Image: Xantrax/ Schneider Electric

Other features. The following features may also be included in a charge controller.

Temperature compensation is a must if the battery's ambient temperature regularly goes above 30⁰C or below 20⁰C. This is because batteries at high temperatures require a lower voltage to reach a fully charged state (and vice versa for cold temperatures). Without temperature compensation, a charge controller in a hot climate will overcharge the battery.

A step-down transformer enables a charge controller to efficiently charge a battery using a high voltage supply.

A state of charge indicator is a useful feature. Digital displays are only useful if the numbers displayed are meaningful to the user. For this reason, simple indicators such as a series of coloured lights can be more helpful than a numerical display.

Electrical protection such as lightning protection and overcurrent protection. Lightning protection on an inverter will not protect loads from lightning that strikes them directly, as in strikes on the antenna tower. Overcurrent protection, such as a fuse, protects loads from current surges. (See also "electrical protection", below).

Cables connecting the battery to the inverter should follow the manufacturer's recommendations; a cable that is too thin or too long will cause the inverter to overestimate the battery voltage and undercharge the battery.

***Maximum Power Point Tracking* (MMPT)** is a feature that increases the output of solar panels by holding their current and voltage at an optimal level. MMPT is less effective in warm climates than cold climates, but even in warm climates it can significantly increase the output of solar panels.

Charge controller settings. Good charge controllers usually have adjustable settings; for example, the setting for the voltage at which loads are disconnected or the number of hours for which a top-up charge is applied. These should be set by an experienced technician and should be adapted to the needs of the power supply and batteries.

Size. The main rating of a charge controller is its current. A charge controller of 20 A can accept a maximum of 20 A from a power supply. Since natural resources like sun, wind, and water are unpredictable, the controller should be sized so that it can handle considerably more than the rated or average current from a solar panel, wind turbine, or hydro turbine. For example, controllers for solar panels should be large enough to handle 1.4 times the rated current of the array at peak power: the effects of clouds and water can raise solar irradiation above the standard 1 kW per m^2.

Electrical protection

Electronic equipment is sensitive to changes in the voltage, current and frequency of the power supply. Excessive fluctuations, sudden power failures, and power surges can seriously damage sensitive equipment such as computers, mixers, and transmitters. Protecting equipment against these problems can save energy by keeping the equipment efficient and making the most of the available power. The following devices are commonly used to provide such protection.

UPS (Uninterruptible Power Supply)

The main function of a UPS is to provide short-term backup power (usually between a few minutes and half an hour) when the power supply fails. UPS's are typically used on critical or sensitive equipment such as a desktop computer, transmitter, or mixer. UPS's are rated according to how much power they can sustain, usually given in terms of VA (Volt Amps). VA is the apparent power of the UPS. Due to an effect called power factor (briefly described in **Chapter 1**), the actual power a UPS can sustain is somewhat less than the apparent power as given by the UPS rating. Because of this factor and the risk of exceeding the rated power of a UPS, consumers should consult a technician or dealer to help size a UPS. The run-time of UPS batteries is also important; the best battery size depends on how long the typical power outages are at the station. Stations should also check that the reaction time of the UPS (the time it takes to restore power when the main supply fails) is short enough to avoid damage to the equipment the UPS serves.

UPSs come in different levels of sophistication (and cost):

Offline or standby power supplies are the simplest kind of UPS. These devices remain idle until the main power supply fails, and then switch to their internal back-up supply (usually batteries).

A line-interactive UPS switches to a backup supply when the main supply fails, but it also regulates the voltage of the main supply by using its batteries to "fill in" dips in the main supply. This makes better use of the main supply than a standby UPS, but by drawing continuously on battery power it requires frequent charging and occasional replacement of batteries.

An online UPS regulates the main supply by converting it from AC to DC and back again. This system gives a smoother output and makes more efficient use of its batteries than a line-interactive UPS.

Voltage regulator

A voltage regulator smoothes out the main power supply but does not provide back-up power. Fluctuations in the supply are less visible than blackouts or brownouts, but they cause at least as much damage to equipment. The advantage of a voltage regulator over a UPS is that it does not include batteries, making it cheaper per rated Watt but more likely to leave the station without power when the main supply is inadequate. Regulators are also more resistant to major fluctuations in a power supply than UPS devices; regulators are commonly applied directly to the incoming public power supply so that appliances connected to the supply (including UPS devices) are shielded from the worst of the fluctuations in utility power. To some extent the function of a voltage regulator overlaps with a line-interactive or online UPS, and a station equipped with a good voltage regulator may only need offline or standby UPS systems.

Batteries

Batteries can perform a similar function to a voltage regulator, drawing fluctuating power from the public supply and delivering smooth AC power to a station's loads. The advantage of batteries over a voltage regulator is that the incoming energy can be used by the station when it is needed and not just when it arrives. This is valuable if there are periods during the day when the station is operating but the public power supply is systematically unavailable. It should be noted that batteries are also more expensive than a regulator, do not last as long, and (with the possible exception of maintenance-free batteries) require more maintenance. The extra cost and effort of storing the public power supply in batteries is minimised if a station already uses batteries to store energy from other power sources (such as a genset, solar panels, or wind turbine).

Box 7.1

Case study:
Radio Faraja, Tanzania

Lightning is a menace for Radio Faraja, situated in the Great Lakes Zone of Tanzania. Lightning strikes cause costly damage, especially to the transmitter. The station has installed a lightning protection system (Fig. 7.9 next page) including pure copper rods on top of the 60m antenna tower, a 400 m^2 network of cables at the base of the tower, and four holes 1.5m deep, each containing a copper earth rod.

The cable used to ground the tower is 16mm copper cable, and the arrangement is bonded – the transmitter and the main power supply are grounded by the same system as the antenna tower. The station also uses voltage regulators to protect both studio equipment and the transmitter.

Lightning damage to the station has been dramatically reduced since this equipment was installed. Lightning strikes are fewer and weak strikes cause no damage at all to the station's equipment.

Information provided by Radio Faraja

Lightning protection and earthing systems

Earthing is the process by which dangerous or unwanted electricity is dissipated by being physically connected to the earth. Protection equipment is ineffective unless the station has a good earthing system.

The key features of a good earthing system are:

Depth and width of the hole into which earthing rods are fixed.

A large earthing cable that can survive high currents.

Well-organised wiring inside the station.

Bonded earthing i.e. there should be one earthing point for the whole station, not different points for different appliances or different studios.

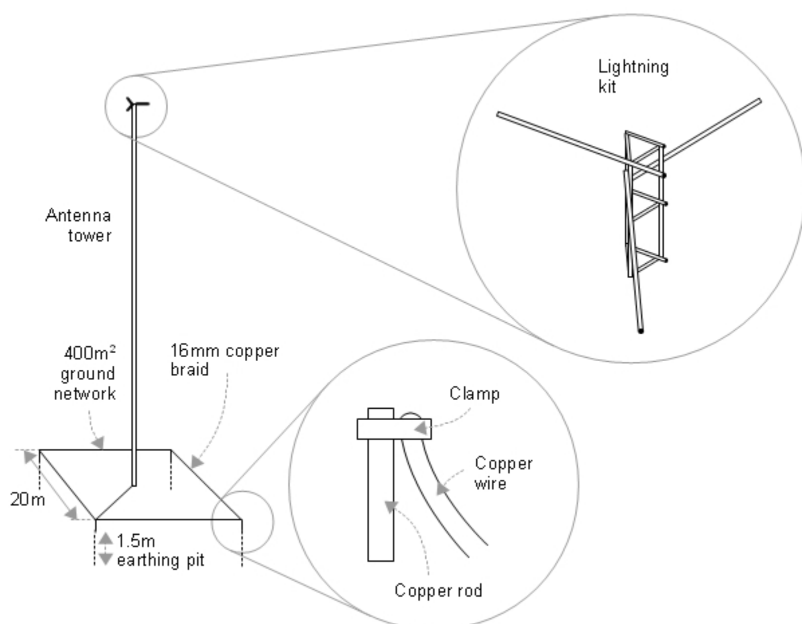


Fig. 7.9
An earthing system for lightning protection. The diagram shows the lightning kit on top of a 60m antenna tower, the ground network at the base of the tower, and the copper rod and wire assembly that directs electricity to earth.
Diagram: author

Shielding critical loads

Critical loads are the most important devices or appliances at a station. A well-designed energy system will make sure that critical loads have power, even when there is not enough power for all loads at the station. There are a number of ways to protect critical loads.

Turn off non-critical loads when the power supply is low. This is the simplest and cheapest option. It is also a time-consuming option, since it requires one or more staff members to keep track of the level of the power supply and to switch off non-critical loads by hand when it is too low. This works best if power is drawn from a battery or from a genset, since periods of low fuel or low battery are in many cases more predictable and infrequent than failures of the public power supply.

Use a charge controller's low-voltage disconnect. Charge controllers disconnect loads when the battery state of charge gets too low. A critical load that is connected directly to a battery bank can continue to draw power after loads connected to the charge controller have lost power.

Independent power source. In this scenario, critical loads always draw on a different power source – usually a different battery – to that of non-critical loads. At the very least, this protects critical loads against the careless use of non-critical loads (such as the use of energy-intensive appliances in sockets). Also, the critical power source may be oversized so that there is less chance that it will fail. (This option may be costly if critical loads are a large proportion of the station's total load).

Backup power source (UPS). A UPS draws on its own power source only when the main supply fails. This is strictly a short-term option: UPS's are designed to give back-up power only for long enough to safely shut equipment down.

8 Long-term management of energy technology

Energy technologies are long-term investments, with lifetimes counted in years and even decades. Long-term planning is needed to ensure that the equipment is effective until the end of its lifetime. It is recommended that each station appoints an "energy manager" to plan and oversee the tasks described in this chapter.

Quick reference summary:

Long-term management of energy technology

It is recommended that stations appoint an **"energy manager"** to plan and oversee the following long-term tasks:

A. Maintenance. Includes reporting malfunctions, replacing failed and worn-out components, and maintaining a stock of tools, spare parts and other supplies.

B. Evaluation. Includes an initial evaluation of the technology and periodic evaluation over the life of the technology.

C. Reacting to energy changes. Includes identifying and responding to changes in the energy load caused by new equipment, new staff, or longer on-air hours.

D. Overseeing energy savings.

E. Training of technicians, operators and users.

F. Sharing experience, expertise and energy with other stations and other members of the community.

A. Maintenance

A system for servicing energy technology is critical to the success of energy management. The maintenance tasks of most energy technologies are not great, but it is vital that they are carried out with the right tools, expertise, and frequency. Maintenance tasks, and questions relating to them, include:

Reporting system malfunctions. Who reports them, how are they reported, and to whom do they report?

Replacing failed and worn-out components. Is there a budget for replacement parts and components, and what is an unacceptable length of time without power?

Maintaining a local stock of critical supplies, spare parts, and test equipment. Who orders the parts or supplies, who supplies replacement parts, and how are these parts delivered (especially to remote areas)?

Recycling or disposing of old equipment. Which components of the energy system contain toxic chemicals and which of them retain some value, even when they no longer function in an energy system? Who will sell or dispose of these components, and where?

B. Evaluation

It is a good idea to have the equipment examined a week or so after it is installed, to ensure that it is functioning according to the manufacturer's ratings, and has stabilised. Some stations have written such an evaluation into the acceptance contract to ensure the company delivers what is promised. If the required technical expertise is available, it is worth evaluating the equipment on an annual or semi-annual basis. This can help to identify faults before they become destructive, as well as aiding other consumers by distinguishing between good and poor products.

C. Reacting to energy changes

Includes identifying and responding to changes in the energy load. New equipment, new staff, and longer on-air hours can increase the energy demands of the station and may call for expansion of the generating equipment, extra measures to save energy, or both.

D. Overseeing energy savings

Energy saving initiatives, especially those that require changes in staff behaviour, need to be supervised. Also, new ways of saving energy can appear as the equipment, architecture, and staff of the station change. **Chapter 2** contains more information on energy saving at a radio station.

E. Training of technicians, operators and users

Training of staff members in the maintenance and repair of energy technology can save time and money in the long run. Many of the important maintenance tasks – checking the electrolyte level on a battery, oiling a generator, cleaning solar panels, and so on – can be performed by staff members with minimal training (a few hours to a few weeks) in the upkeep of the equipment. Also, staff training in energy efficiency can ensure that the available energy is used wisely. The main kinds of training are:

Basic operation and maintenance. Some training of this kind should be carried out when new technology is installed. It should be carried out by someone who has experience in maintaining the technology, preferably by a professional/expert. Ideally it is carried out on-site by someone who has experience and understanding of the local conditions.

Advanced servicing of equipment, perhaps by up-skilling the radio station's technician(s). This training would enable the station to handle breakdowns and malfunctions, perform annual or semi-annual checks of the equipment, and evaluate the performance of the equipment. Some energy companies can perform this

FAQ 8.1

Where can station staff and technicians get training in energy technology?

Training courses can be found through:

Universities, polytechnics, and training centres; outreach programmes conducted by NGOs, government, or community groups; providers of energy technology may include a short training course as part of their service.

A list of some organisations that offer training courses in energy technology, or can help stations to find such courses, is in the Resources section of the guide.

service for a fee, especially for solar power systems. Remote stations might find it easier and cheaper to up-skill a radio technician, or a local mechanic or electrician, for these tasks.

Manufacture and construction of energy technology, either by converting existing technology (e.g. water pumps into hydro turbines) or constructing new equipment (e.g. wind turbines). Training courses or workshops of this kind are available in some communities in Africa, usually as vocational training for people who intend to work for small manufacturing businesses. Some station staff or technicians may find it useful to attend this kind of course in order to understand the technology or with a view to making “home-brew” equipment (such as wind turbines) themselves.

Energy awareness or energy efficiency training for station staff. This can help staff make better use of the available energy by advising them on energy efficient equipment and behaviour. It may also help the director of the station to manage the station’s energy needs.

When selecting a training course, these factors should be considered:

Local knowledge. Training is most effective when it is carried out at the station by someone who has experience and understanding of the local conditions.

Know-how, can-do. Understanding how a technology works is useful, but the goal of training is usually to maintain and service the technology on a daily basis. For this purpose, practical, hands-on training is preferable to theoretical knowledge.

Fig. 8.1. Apprentices look on as a craftsman constructs a wind turbine part. Energy training opportunities range from basic operation and maintenance to the manufacture of technologies. Image: Clean Energy Company

Remoteness of station. Remote stations should make as much use as possible of local expertise. This cuts down on the cost and delivery time of servicing by non-local specialists.

Refresher training may be needed on an annual or multi-annual basis to train new staff and refresh the memories of existing staff, especially for stations that have a high turnover of staff and technicians. Refresher training may be conducted by a long-term staff member who has received good initial training or has hands-on experience of the station's equipment.

Box 8.1
Case studies: training in energy technology

At Radio Pikon Ane, a remote station in Indonesia, the hydro system is maintained by a man from the local area, the station technician. He learned the basics of hydropower maintenance by accompanying the team of the company that set up the micro hydro system, and they explained to him what they were doing as they worked.

Réseau Étoile, a network of stations in Haiti, received funding to put one technician from each station through a 10-week intensive course on energy management. The national and international co-ordinators of Réseau Etoile, and an energy consultant (Mr. Gerd Zeitter) from the German company BEGECA, were both involved in the training course.

Radio Fadeco in Tanzania uses a solar power system. The director of programmes at the station received rudimentary training in renewable energy, including a course at the Centre for Alternative Technology (CAT) in Wales, UK. He also completed a certificate course in solar system installation from the Karadea Solar Training Institute in Karagwe, Tanzania. He passed on his knowledge to other station staff in the form of on-the-job training.

More information on each of these stations can be found in the case studies in **Chapter 10.**

F. Sharing experience, expertise, and energy

Radio stations can share experience and expertise of energy technology with other stations and other groups in the community. It is also possible to share energy generated by the station with nearby establishments.

Sharing experience. Stations that are yet to adopt energy technology can benefit from the contacts gained and lessons learned by stations that have experience in this technology. Information that can be usefully shared includes experience with particular dealers, products or training courses; with a kind of energy system or technology; with a decision-making procedure; or with a style of long-term management of the technology. As well as helping other stations to make their own decisions, sharing information about dealers and their products can make dealers more accountable for the outcome of their work, and hence more likely to do their work well.

The following can help stations to share experiences:

Radio networks. Using existing lines of communication between stations may be the most effective way of making use of the knowledge gained by stations that have already used energy technologies. This includes radio networks on the international level (such as the World Association of Community Radio Broadcasters, AMARC), and national community radio networks such as those in Benin, Burkina Faso, Ghana, Liberia, Mozambique, South Africa, and other countries. It also includes radio networks and associations organised according to specific criteria or themes, e.g. the VOX network (Associação Mundial das Rádios de Inspiração Christã de Expressão Portuguesa), an association of Christian radio stations located in Portuguese-speaking countries.

Case study contacts. Contact details for the stations considered in **Chapter 10** are listed in **Appendix D.2**.

Online forums. Online forums for discussing energy technologies, and especially renewable technologies, have been set up for groups and individuals that are interested in the technology and would like to find out more about them. These include technology-specific forums (such as solar power forums) as well as general forums; and forums designed specifically for African users as well as those for US, UK or global users. Some of these forums are listed in **Appendix D.2**.

Sharing expertise. Most stations will not themselves have sufficient expertise to select, size, install, operate and maintain energy technology. The cost per station of employing outside experts to perform these tasks may be reduced if stations in an area use the same set of people or companies to carry them out. In particular, radio networks may be well-served by a single "flying technician" (or pool of technicians) that is mobile enough to service all of the stations in the network, including responding to emergency requests for technical help.

Sharing energy. Stations that produce excess energy can share this energy with other members of the community, either for a specific task (such as mobile phone charging) or for the purposes of nearby establishments (if a nearby building draws on the station's battery supply, for example). The energy may also be used on-site for functions other than running the radio station – such as running an internet café or a catering service. Stations may also make use of energy generated by other establishments, such as a health centre or a school (see also Box 8.2).

Box 8.2
Case study: energy sharing

Radio Pikon Ane is a station in Anyelma, a remote village in the Papua province of Indonesia. The station recently installed a 9 kW hydro turbine to power its 1 kW transmitter and studio equipment. The hydro scheme was deliberately oversized for the needs of the station so that other locations could also benefit from the project. As a result around 20 houses, one church, one school and the office of the village head all now have electricity.

Electricity from the station's hydro scheme has had a large and positive impact on the community. As well as providing cheap electricity, the hydro project strengthened ties between the community and the radio station: the community was included in decision making regarding the construction and maintenance of the micro hydro system, ensuring a sense of community ownership and responsibility for the project. The fact that hydro power is a renewable energy source that does not harm the environment was also a very important factor for the local subsistence farming community.

Information provided by the Media Development Loan Fund (MDLF), the Indonesian Association for Media Development (PPM), and the KBR68H news agency. **Chapter 10** contains more information on the hydro system at Radio Pikon Ane.

9 Dealing with energy technology providers

Energy technology providers are the individuals and companies that sell energy technology and help to plan, install, and service the equipment. As well as assessing the energy requirements of the station, it is important to assess the know-how and technical expertise the station will need in order to carry out an energy project. Energy technology is a long-term investment with high initial costs, where the right expertise can make a big difference to the cost and success of the system. Using the right expertise for the right tasks, is as important as using the right technology for the station's energy needs. **It is strongly recommended that stations consult professional energy providers at each stage towards adopting energy technology, from estimating the cost of the technology to working out a maintenance schedule.** This chapter contains advice on selecting an energy technology provider and working productively with them to see a project through.

A. Selecting an energy technology provider. For most energy technologies there are a large number of companies and individuals involved in selling, planning and installing the technology. As well as the cost and quality of their products, the following questions can help to decide between providers.

Does the company have experience in the type and size of equipment or installation that the station requires? For solar power systems, for example, a company specialising in solar panels is preferable to a company that does some solar installation but specialises in solar thermal installations or electrical wiring. Hybrid systems require different skills from stand-alone solar systems, grid-connected systems require different skills from off-grid systems, and so on. The more closely matched the job to the expertise, the better.

How many years has the company been working with the technology? The longer they have spent in the business, the more experience they have and the more knowledgeable they are about how to compete with other companies.

Does the company have experience in the geographical area of the station, or areas like it? A company that is familiar with the local demands, resources, and expertise can take those conditions into account when advising on energy systems and equipment. For foreign companies a site visit may substitute for local knowledge (see **FAQ 9.1** for more on the relative merits of local and foreign dealers).

Quick reference summary:

Dealing with energy technology providers

Energy technology is a **major long-term investment**, and it is important to use the right expertise for the right task.

General qualities of an energy provider are:

Experience in the type and size of technology being considered.

Good references from past customers.

Several years in business to prove the quality of their work.

Little or no commercial interest in one particular energy technology.

During a project energy providers should offer:

A **site visit**.

Advice on and/or training in **operation and maintenance**.

Documentation including technical data and user manual.

A realistic and reliable **warranty.**

Information on the **standards** their technology meets.

Full costing information, including all components and running costs as well as initial costs.

FAQ 9.1

Should my station use a local or foreign technology provider?

The following factors should be considered when deciding between local and foreign dealers or manufacturers of energy technology ("foreign" may mean a different country in Africa or a country outside Africa).

Transport costs and border taxes. International transport can be expensive for bulky equipment, as can the process of clearing customs. Long-distance transport can also delay delivery.

Bounded warranties. The warranty of some foreign equipment does not apply once the equipment is shipped into Africa.

Local knowledge. A company that is familiar with local resources, stresses, and expertise can take those conditions into account.

Market conditions. The foreign market for energy products may be more advanced than the local market, lowering the cost and raising the quality of foreign versus local products.

Long-term servicing. Foreign dealers or manufacturers may be less capable of helping out when the equipment fails.

Can the company give an impartial and well-informed judgement about the best kind of technology for the station? A company that only sells solar panels (for example) may not be qualified to judge whether solar or wind power is better for the station. A good adviser should be able to suggest two or more energy options and compare their cost and performance. If it is not possible to obtain balanced advice about which option to choose, a station may wish to consult different companies specialising in different options and compare their advice.

What do past customers say about the company? Checking examples of their past work is the best way to evaluate a company. This is most valuable when the past work of the company has been properly assessed – for example, when an independent technician has compared the output of a solar panel against the company's ratings.

B. Working with an energy technology provider. If a station has energy technology installed, the company behind the installation should be able to provide the following before and/or after the installation.

Site visit. It is difficult to properly assess a station's needs without visiting the station. The company or person who advises the station on the correct kind and size of technology should base this advice on a site visit.

Training or advice in operation and maintenance. Ideally the installer will be able to give on-site tuition to a radio technician or other staff member in the use of the technology. At the very least the technology should come with written maintenance advice from the dealer or manufacturer.

Technical data and user manual. These documents usually contain advice about safety, maintenance, and the ideal operating conditions for the technology. They are also useful for technicians who service the equipment during its lifetime.

Warranties. Warranties for equipment are not always available, but companies should be encouraged to supply them. The terms of the warranty should be clarified before the technology is purchased, including: what kind of replacement does the warranty offer when the equipment fails; what counts as an equipment failure; and what proof does the customer need to give to the vendor as proof of a failure?

Standards information. Manufacturers of most energy technology are expected to meet international standards to ensure the safety and quality of their equipment. Technology that meets international standards is likely to last longer and be more energy efficient. Providers of technology should be able to explain which standards their products meet, and provide evidence of this.

Full costing information. Energy technology includes "hidden costs" such as inverters, batteries, cables, charge controllers, and replacement parts. A company selling the most visible parts of an energy system – like a solar panel or wind turbine – should either sell the "hidden" parts of the system or inform the consumer about them. **Chapter 4** contains more information on the cost components of energy technology, along with sample analyses of the costs of wind and solar systems.

FAQ 9.2

What can consumers do to increase the availability of good quality energy products?

Buy products that give the best value for money. These may not be the cheapest products, but they will give the most energy per dollar in the long run. Buying high quality products encourages dealers to supply those products. (Chapter 4 contains more detail on the factors to consider when evaluating energy generating technology.)

Insist on a warranty or certification, where possible. These help consumers to identify good quality products. Dealers may not provide them unless consumers ask for them.

Evaluate dealers by evaluating their products. A professional check-up once a year is enough to evaluate the performance of a product. Dealers are more likely to sell good quality products if consumers can distinguish between good and bad products.

Share experiences. Dealers are even more likely to sell good quality products if consumers who have good or bad experiences of products tell other consumers about those experiences.

Case studies

10

The case studies in this chapter are examples of community radio stations, in Africa and elsewhere, that have installed one or more energy technologies. The case studies illustrate some of the benefits of energy technology, as well as some of the lessons that stations have learnt from past experience with them. One case study (Haiti's Réseau Étoile) shows the value and complications of supplying energy technology to multiple radio stations in the same project. Contact details for the stations in the case studies are provided in **Appendix D.2**.

1. Radio Voice of Life (Uganda)

STATION CHARACTERISTICS	
Location	Arua, a town 500km from Kampala, capital of Uganda
On-air time	16 hours a day, 7 days a week
Load(s)	1600 W: 500 W transmitter (actually consumes 1000 W)
Public energy supply	16 hours a day
Installed technology	1000 W PV array, batteries
Cost of technology	$4000 (roughly) for PV array, inverter, charger (all bought in 1997)

Background

Radio Voice of Life was founded in Arua in 1997, in partnership with *Here is Life*. DIGUNA (Die Gute Nachricht für Afrika), a mission society, is in charge of the technical aspects of the station. Voice of Life was the first radio station in the West Nile region. The station targets communities (primarily Muslims) located in the Northern area of Arua up to the border of Sudan (80 km away). The station broadcasts in five languages and is on air 16 hours a day, 7 days a week; it has about 20 staff members. The station's profile is "evangelical" and open to other Christian communities.

The station has one on-air studio and one production studio, and the main energy load is the transmitter. Between 1997 and 2008, the station operated with a 250 W FM transmitter (with an actual energy consumption of 600-700 W), before upgrading to a 500 W FM transmitter (with an actual energy consumption of 1000 W). The station also runs a 17-inch laptop computer; various CD, MD and tape devices; a few light-saving lamps; a SAT receiver; and other small items. When all equipment is running the station consumes about 1.6 kW.

Energy technology

The station's building and studios were designed, under DIGUNA's management, to be as energy efficient as possible. The studio has no air-conditioners, and electronic equipment is kept to a minimum to reduce the need for artificial cooling. A "cyclone" roof ventilation system circulates cool air in the station, and to minimise heat from the sun all windows face north or north-east. Electronic

Fig. 10.1
The on-air studio at Radio Voice of Life.
Image: CAMECO

equipment at the station was selected to withstand high temperatures, reducing the need for air conditioning.

The station has used a solar-battery system from the beginning of its life. The solar panels (manufactured by Siemens in Germany) are installed on the roof of the studio building and have a maximum output of 1 kW. When the station operated with the smaller 250 W transmitter, the solar panels and batteries were enough to supply all of the station's energy needs. With the larger transmitter the solar panels serve as a back-up supply only; when the batteries are full they provide energy to the station for three to four hours.

Voice of Life uses sealed ("maintenance-free") batteries; currently it uses eight batteries each with 12V and a capacity of 200 Ah. In the experience of the station, the lifespan of sealed batteries is comparable to that of unsealed (flooded) batteries. The batteries installed in 1997 lasted ten years before they needed to be replaced. The station obtained the new batteries on the local market at Kampala, and in their experience the local batteries are as good as batteries from Europe.

Fig.10.2
The transmitter (500 W) and batteries at Radio Voice of Life. The station has eight batteries each with a capacity of 200 Ah, and when full they can meet the energy load of the station for three to four hours.
Image: CAMECO

Fig. 10.3
The roof of Radio Voice of Life, including 1 kW solar panels and “cyclone” ventilators.
Image: CAMECO

Other issues

Voice of Life benefited from the removal of import duties on solar power systems in Uganda. Also in force in Uganda is a 45% subsidy on all solar power equipment, a policy brought about by Uganda’s Rural Electrification Agency (REA) in 2007. It is available to solar power companies as well as customers, and is funded by the REA, the World Bank Credit, the United Nations Development Programme, and a range of microfinance institutions.

Information provided by Radio Voice of Life staff

2. Radio Pacis (Uganda)

STATION CHARACTERISTICS	
Location	4 km from Arua, Uganda
On-air time	24 hours a day (18 hours live)
Load(s)	440 kWh per day: 10 kW transmitters, 56 computers, 8 air-con
Public energy supply	8 hours a day on average, but varies widely
Installed technology	25.5 kW solar panels, 2 x 70 kVA gensets, 5000 Ah batteries
Cost of technology	$300,000 for solar panels, gensets, batteries and UPS

Background

Radio Pacis is a large radio station near Arua, Uganda, designed to serve communities in the West Nile. The station's three main buildings (an office block, studio block, and printing block) were completed in 2004, and Radio Pacis went on air in October of that year. Arua is located in the north of Uganda, has about 50,000 inhabitants and is 500 km away from the capital city Kampala. The radio covers an average of 200 km, including parts of the Democratic Republic of Congo (DRC) and Southern Sudan.

The station has two frequencies: 90.9 FM (for the languages Kakwa, Lugbara and English) and 94.5 FM (for the languages Alur, Madi and English) and is on air for 24 hours each day (from 6:00 am to midnight the station is live on air and from midnight to 6:00 am it broadcasts pre-recorded programmes or relays from Vatican Radio, American Catholic Radio, etc.). Topics include health, women's rights, domestic violence, agriculture, development, schools, family life, and children's rights. These topics are covered with programmes such as dramas, talk shows, features and up-to-the-minute news.

The public utility power is typically available for at most eight hours a day. With the solar panels, battery, and genset system installed, grid power costs the station between $1,400 and $1,800 per month. These energy sources power a large compound consisting of two on-air studios, one production studio and two work stations for editing purposes. The station runs eight air conditioners, including four that are used 24 hours a day, as well as 56 computers in offices and an internet café. The two transmitters are rated at 2 kW each and together consume about 10 kW.

Technology

Radio Pacis currently possesses the largest set of solar panels in Uganda (installed in 2009), as well as a large amount of battery storage and genset power. The main components are:

Solar panels, 25.5 kW, made up of 340 x 75Wp modules
$200,000 (including installation)

Gensets, 2 x 70 kVA, with "Deutz" engines
$35,000

UPS, 60 kVA, "Emerson"
$15,000

Battery bank, 200 x 2 V/250 Ah batteries, "Hoppecke"
$50,000

Fig. 10.4
The main building of Radio Pacis, Uganda. The station includes two on-air studios and one production studio as well as an internet café.
Image: CAMECO

This system was designed by the Austrian company BBM and implemented together with local experts. Most of the technology was sourced from European manufacturers. With the solar panels installed, the station saves between $2,800 and $3,600 per month on grid power. In other words, the installation cut the station's bill for grid power to a third of its original size.

The public power supply is only used when the supply from the solar panels is depleted. The two standby gensets are mainly used during the night (from midnight to 8:30 am) when the solar panels are idle. The batteries provide back-up power, but to avoid damaging the battery cells they can only serve the station for a maximum of three hours at time. The solar panels include tracker systems that automatically turn the panels to face the sun, and can be manually adjusted to protect the panels from heavy rain or wind.

Fig. 10.5
The solar park at Radio Pacis contains 340 modules with a total rating of 25.5 kWp.
Image: CAMECO

Other issues

The maintenance requirements of the solar panels are low – they are cleaned once a week during the dry season to remove dust. By contrast, the 240 batteries need to be checked each day for correct liquid levels, and topped up roughly every three weeks with distilled water. For a time the station's unsealed batteries were replaced with a sealed set (the unsealed batteries were discharged too deeply) but the sealed batteries were also short-lived, surviving only a year. So far the batteries at the station have typically had a life-span of two years, although in principle they could last for up to eight years.

For security, the solar panels are located inside the wall of the station compound. A security light stays on during the night, and three watchmen and three dogs each guard both the media compound and the transmitter site.

To manage the energy supply, the station has an IT department (responsible for the PCs and software) with two people and a technical department (another two people). Station staff was trained in the use of the solar system while it was being installed, and the BBM Austria provides technical support for the system.

To reduce its energy use, the station uses heat-resistant equipment (no air-conditioner is used at the transmitter site, for example), switches off microphones when there is no guest in the studio, switches off standby equipment completely, and asks watchmen to turn off unneeded lights and computers. Station management regularly brings up the issue of energy saving in staff meetings to remind the staff to apply energy saving behaviour.

Information provided by Radio Pacis staff and Norbert Demmelbauer (BBM Austria)

3. Radio Voice of Peace (Central Sudan)

STATION CHARACTERISTICS	
Location	Gidel, in a remote area in the Nuba Mountains, Central Sudan
On-air time	9 hours/day in theory (4 to 5 hours/day in the rainy season)
Load(s)	300 W transmitter, 6 laptops, 1 desktop, 11 lights
Public supply	None
Installed technology	1.68 kW solar panels; 400 W wind turbine; 1.6 kAh batteries
Initial cost	N/A

Background

Radio Voice of Peace is located in Gidel, in a very remote area of the Nuba Mountains, where neither roads nor other means of communication are available. The station broadcasts programmes in the languages of Tira, Otoro, local Arabic, and English, and in theory broadcasts around nine hours a day (although during the rainy season there is only sufficient energy to power the station for four to five hours a day). The staff includes three full-time staff, two support staff, and collaborators for health and civic education programmes.

As well as a 300 W transmitter, the station runs six laptop computers, one desktop and 11 lights. Occasionally, staff cell phones are also charged in the station, and a printer is used a few times nearly every day. When it is hot, two ceiling fans are occasionally switched on. The station does not have a diesel generator and is not served by a public power supply.

Technology

Radio Voice of Peace is powered by solar panels and a wind turbine. The station has eight solar panels of 130 W each and eight of 80 W each, for a total of 1.68 kW. The wind turbine is rated at 400 W at a wind speed of 12.5 m/s. The average wind speed at the station is unknown, but is certainly much lower than 12.5 m/s. The station draws power from two battery banks, one for the transmitter and the other for further appliances such as computers and lights. The transmitter draws on four batteries totalling 800 Ah in capacity, and the other appliances on eight batteries, also totalling 800 Ah. The equipment was purchased from Patech Solar Energy (Nairobi, Kenya), and the turbine manufactured in the USA.

The chief maintenance cost for the technology is the expense of flying a qualified technician to the station each year (usually from nearby Kenya). This amounts to about $240 a year. Also, batteries are checked on a weekly basis by a local trainee electrician. On one occasion a staff member needed to mount the antenna tower to fix a problem, but otherwise the system has been hassle-free.

Other

Seasonal variation of the wind and sun has been an issue for the station. During the dry season solar power is quite constant but overcast skies in the rainy season (lasting up to four or five months) have seriously disrupted the electrical supply from the solar panels. Similarly, wind power is only sufficient for the station's needs during certain periods of the year, usually the dry season. As a result, power cuts are a constant hassle in the rainy season, and during these periods the station's on-air time is cut from the desired nine hours a day to four or five hours a day.

Information provided by Sr. Anns James Thoompunkal of Radio Voice of Peace and Brother Alberto Lamana of the Sudan Catholic Radio Network

4. Fadeco Community Radio (Tanzania)

STATION CHARACTERISTICS	
Location	Kayanga, a remote rural village in North West Tanzania
On-air time	20 hours a day, 7 days a week
Load(s)	300 W transmitter; 7 computers; 2 air conditioners; low-power lights
Public energy supply	Nominally 24 hrs/7 days, but expensive and unreliable
Installed technology	130 W PV array, 2 x 200 Ah batteries, 2 x 120 Ah batteries
Cost of technology	$4,730 for PV array, batteries, inverter, and charger

Background

Fadeco Community Radio is located in the small, remote town of Kayanga, in the Kagera region of North-West Tanzania. The station broadcasts for around 20 hours a day, 7 days a week. The bulk of Fadeco's broadcasting is between 11 am and 12 pm (midnight), with about two-thirds focusing on development issues and the rest on news, entertainment, prayers and announcements.

The station typically uses two air conditioners and seven computers (three laptops and four desktops) while it is on air. As well as a 300 W transmitter, energy is used to run an on-air studio that includes a mixer, internet hub and modem; an internal telephone system; two low-power lights (14 W each); and a hot water kettle for staff teas and coffees.

Fadeco receives grid power from the Tanzania Electricity company, called TANESCO. In theory this power is available all day every day, but in practice it is unreliable. Power fluctuates a lot in the course of the day, and at least 2 days a week there is a total blackout of 12-14 hours. Grid power is also expensive, costing the station over $200 every month. Fadeco needed solar panels to reduce power costs and increase its on-air time. Also, the Tanzania Communications Regulatory

Authority (TCRA) requires that radio stations provide uninterrupted radio broadcasting throughout the licensed time frames.

Energy technology

The following equipment is installed at the station, totalling to an initial investment of about $4,730.

Solar panels, 2 x 65W, "Uni-solar"
$1,700

Batteries, 2 x 200Ah, "First Power" deep cycle batteries
$1,720

Batteries, 2 x 120Ah car batteries
$360

Inverter/charger, "Tripple-lite USA"
$950

The system is equipped with automatic switching: when grid power fails, the system automatically switches to solar power, and switches back when grid power

Fig. 10.6
Two 65 W solar panels on the roof of the Fadeco Community Radio station. The panels charge a battery bank that the station uses when the public power supply fails.
Image: Fadeco

is restored. This allows the station to make the most of grid power without any interruption to the broadcast. The solar system gives a warning signal when the power in the back-up battery is running low, so that (unlike failures of grid power) failures in the back-up power are predictable, and the station can inform listeners about the problem well before the station shuts down.

To save energy the station has changed many of its CRT (cathode ray tube) computer monitors to flat screens, and has replaced some desktops with laptops.

Other issues

Energy management at Fadeco is largely in the hands of the director of programmes, Joseph Sekiku, who is also the technical manager. Mr. Sekiku has received rudimentary training in renewable energy, including a course at the Centre for Alternative Technology (CAT) in Wales, UK. He has also completed a certificate course in solar installation from the Karadea Solar Training Institute in Karagwe, Tanzania. Mr. Sekiku has passed on his knowledge to other station staff in the form of on-the-job training. Marks on cables, and a wiring diagram of the back-up system, make it easier for staff members to switch the system on or off as necessary, and to do basic trouble-shooting. The telephone number of an external electrician is also clearly displayed at the station.

The main benefit of the solar system for Fadeco has been reduced electricity bills and longer broadcast hours. Even when the back-up system fails and the station shuts down, it is possible to warn listeners of the interruption well in advance. More broadly, the better performance of the station has improved its credibility among listeners, improved the self-confidence and self-image of staff, and increased revenues: customers are now more likely to treat Fadeco as a reliable radio station. Fadeco has shared its knowledge of solar technology with other stations in Tanzania and with listeners, to the extent of attracting a company to distribute LED lights in the community. The solar installation also attracts visitors to the station to find out about how it operates.

Information provided by Joseph Sekiku
(Fadeo Community Radio Director and Technical Manager)

Fig. 10.7
Catus Titus, a presenter in the on-air studio of Fadeco Community Radio. The electrical equipment in the studio is supported by grid power and a back-up solar system with batteries.
Image: Fadeco

5. Réseau Étoile (Haiti)

Background

Réseau Étoile is a network of nine Catholic radio stations in Haiti. Even before the 2010 earthquake struck Port-au-Prince, the whole of Haiti suffered from a lack of reliable and accessible electrical energy. When funding became available for the network, station directors unanimously agreed that the best way to use the funding was in the area of energy. The end result was each station (including stations Men Kontre and Tet Ansam, described below) receiving customised advice and equipment to serve their energy needs.

Initially it was proposed that each station receive an 11 kW genset to boost their energy supply. This solution had the advantage of simplicity, familiarity, and of "fairness" (since each station received the same equipment). However, after consulting an energy engineer (Mr. Gerd Zeitter from BEGECA), it became clear that this apparent solution to the energy problem of the radio stations was not well tuned to the precise needs of each station and that cost of the fuel needed to power the 11 kW gensets might quickly become a new "problem" rather than a solution.

A decision was made to ask the stations to make a precise assessment of their present and projected need for electrical energy. The assessment was done through a questionnaire and site visits from a Haitian technician and Mr. Zeitter.

Mr. Zeitter considered each station as a separate case, developing a solution that would meet the station's specific energy needs. It was not possible, with the available funds, to set up the stations with an off-grid energy system (i.e. a system that would not depend at all on public energy or a genset). The full "green" solutions (with solar panels, wind turbines or water mills) were too expensive. Hybrid systems became the most attractive options, with each station using two or three energy sources and running equipment off high efficiency batteries.

Technology

Two of the nine stations in the network are Men Kontre and Tet Ansam. Their energy situation and the proposed solutions are outlined below.

Radio Men Kontre is located in Les Cayes, the third largest city in Haiti. The station's solid two-storey building is well cooled by a large mango tree. Prior to the consultation, the station drew energy from a public power supply (12 hours a day), a back-up genset of 12 kW (though there was no budget for fuel) and a string of four solar modules. The batteries were charged using the public supply and the solar panels, and most of the radio equipment was run off the batteries; the batteries were in poor shape. The station's largest loads (air conditioners and a water pump) were only operated when the genset or public power was available, since they were too large to be powered from the batteries. The station required a total of about 51 kWh each day, with the air conditioners and water pump accounting for about half of this requirement.

RADIO MEN KONTRE CHARACTERISTICS	
Location	Les Cayes, a city of 100,000 people
On-air time	17 hours/day
Load(s)	50 kWh/day: 500 W transmitter, 2 desktops, water pump, fan
Public supply	12 hours/day, but unstable
Installed technology	12 kW genset, 3.6 kW inverter/charger, 25.5 kWh batteries
Initial cost	[see below]

Recommendations for Radio Men Kontre included:

The 12 kW genset should be used as a back-up only.
Regular maintenance of the genset should be included in the budget for the station.
The battery bank should be increased from 10 V to 24 V; this would

be enough to power the main loads (aside from the air conditioners and water pump) for five hours a day, without excessive discharge. It is not necessary to size the batteries for “dark days” since the genset and the public supply are relatively strong.

Separate wiring should be arranged for all the equipment fed by the genset.

Lights should be wired so that they can be powered by DC current directly from the battery bank, without the need for an inverter or the power losses that result from an inverter. DC transmitters could also be used, for the same reasons.

Make someone responsible for the management and maintenance of the energy technology.

Replace the existing wiring in the station with new wiring, to avoid unnecessary power loss.

The solar panels are unnecessary, and could be sold. Grid power is abundant enough to power the station, along with a genset, as long as excess grid power is used to charge the batteries for 12 hours a day or more.

Radio Tet Ansam is located in Jérémie, a city with around 50,000 inhabitants. The solid two-storey building is very hot due to its flat roof. The daily energy consumption of the station is around 30 kWh, with a desktop computer, three fans and an air conditioner being the largest energy consumers. The station also runs a water cooler, photocopier and microwave. Prior to the consultation, the station

RADIO TET ANSAM CHARACTERISTICS	
Location	Jérémie, a city of 50,000 people
On-air time	16 hours/day
Load(s)	30 kWh/day: 500 W transmitter, 1 air-con, 3 fans, 1 desktop, water cooler, microwave
Public supply	3-4 hours/day, in the evening
Installed technology	6 kW genset (to replace a 10 kW genset), 44 kWh batteries, solar panels
Initial cost	[see below]

drew its energy from an old 10 kW genset that was leaking oil, needed repairs, and was used only as a back-up. The largest non-essential loads were only used when the public power supply was available, reducing the strain on the batteries. Nevertheless the batteries were not in good condition, perhaps because of excessive discharging.

Recommendations for Radio Tet Ansam included:

Replace the 10 kW genset with a 6 kW diesel genset. This genset can power the air conditioners and charge batteries during a daily run of 6 hours. The smaller genset will operate at higher efficiency than the existing genset, because it will operate at close to its maximum power.

Extend the battery bank to around 44 kWh. This will extend the life of the batteries by ensuring that they do not drop below 50% of their capacity when powering the loads (totalling around 17 kWh a day) that are not powered by the genset and/or the public power supply.

The batteries may be charged with the genset in the afternoon and the public supply in the evenings.

The roof of the radio station's parish offices is ideal for solar panels. Installing solar panels will reduce the cost of fuel for the genset.

A shadow roof or canopy (made up of palm leafs or something similar) should be erected on the roof and outside walls to shade the station and cool the studios.

The costs of the equipment recommended by Mr. Zeitter for Réseau Étoile were as follows. These prices do not include transport or insurance costs.

Diesel engine, *9.5 kW, 110V/60Hz,* "Lister-Petter TR-2" *"village" type, single phase, open*	$2,900
Diesel engine, *5 kW, 110V/60Hz,* "Lister-Petter TR-2" *"village" type, single phase, open*	$2,400
Wind energy generating set, 1 kW, vertical axis *2 m blade diameter, 2 FGK rotor blades*	$4,500

Solar plant, 4 x 160 W modules, "Schott"	$1,900
Batteries:	
1000 Ah, "Hoppecke OPzS"	$3,900
1220 Ah, "Hoppecke OPzS"	$4,700
1620 Ah, "Hoppecke OPzS"	$6,800
2000 Ah, "Hoppecke OPzS"	$7,900

Other issues

In Haiti it is not easy to get access to the best quality energy equipment from local dealers. Local distributors and even their suppliers in Miami do not feel that the market for high-end products suffices to make them available in the country. This led to the equipment for the nine stations being purchased from European companies and transported especially to Haiti. The organisation of the shipment from Germany to Haiti has not been smooth: the stations have had to wait longer to get the chosen equipment than if they had ordered different equipment from Miami through their familiar channels. Some station directors also feared that they might not get much technical support from the local suppliers if they needed service or parts in the future. As of May 2010, this concern has been only partially answered.

On the plus side, using a foreign supplier meant that the stations enjoyed not only higher quality equipment but also better value for money: for its quality, local equipment was relatively expensive compared to foreign equipment.

The network obtained funding to provide one technician per station with a ten week intensive course (one week a month for ten months) in the area of energy. The project organisers expect that through this course the stations will be able to maintain most of their studio and energy equipment on a local basis, without having to wait for help from technicians from the capital city of Haiti.

Information provided by Gerd Zeitter (BEGECA) and
Pierre Bélanger (International Co-ordinator of Réseau International)

6. Radio Pikon Ane (Indonesia)

STATION CHARACTERISTICS	
Location	Anyelma, a remote village in the Papua province of Indonesia
On-air time	17 hours a day
Load(s)	2 kW in total: 1 kW transmitter; 3 computers; 6 lights
Public supply	None
Installed technology	9 kW hydropower system (no batteries)
Cost of technology	$70,000 for all initial costs, including site survey, installation, and dam building

Background

Radio Pikon Ane was set up with the goal of bringing information access to people in the Central Highlands of Papua, Indonesia. The station is located in the remote village of Anyelma, in the Yahukimo district of Papua. It broadcasts to an area suffering from one of the highest poverty rates nationwide, with over half the district's population living below the poverty line. Malnutrition and food scarcity is common.

The station was established in September 2007 after a famine in 2005 claimed the lives of 55 people in the region, a disaster that could have been averted if information about crop failures had been communicated quickly to other parts of Indonesia. The station was set up by Indonesia's only independent national radio news agency, KBR68H, and the Indonesian Association for Media Development (an NGO), with support from the Media Development Loan Fund (MDLF) and the Dutch government.

The station is on air 17 hours a day, with a potential audience of 70,000 and total power requirement of about 2 kW. The station has broadcast crop prices for the local subsistence farmers, advice on health and women's rights, announcements from the local government, and other news and information.

Technology

The hydro system is rated at 9 kW, placing it in the micro-hydro category. The station does not use batteries and does not have any source of back-up power such as grid power or a genset. Solar power was considered instead of hydro power, but the lack of sun in the region meant that solar panels were not cost-effective. Diesel generators were also considered but the cost of petrol and the difficulty of transport made this option untenable (diesel in Yahukimo costs around $3.20 a litre, over six times the retail price set by the diesel supplier).

The hydro system cost around $70,000 to install: this covered everything from the cost of the initial survey through to dam building, turbine equipment, and transmission lines. MDLF expects that this cost is higher than it would be in most other parts of Indonesia because the remoteness of the station increases transport costs. They estimate that a comparable system in a more accessible area would cost around $45,000. The system was made and installed by the company CV Energi Alternatif, in Sentani/Jayapura, Papua.

Maintenance costs are estimated at $1,000 per year (1.5% of the initial cost of the system). Maintenance tasks include changing the belt and lubricating the turbine, and are mostly carried out by a local man who is also the station technician. He accompanied the installation team as they set up the system, and they explained to him what they were doing and the basics of system maintenance. The technician did not have any other training beyond this. His tasks include regularly checking the water level, the state of the belt, and the state of the lubricant. In areas of higher ground above the hydro system, farmers also assist by avoiding the felling of trees, thus preventing lumber entering the river, clogging the dam and stopping the turbine.

Occasionally the turbine has stopped due to debris (mainly wood) blocking the flow of water to the turbine, but this is fixed by simply removing the debris. The power sometimes falls if the water level is low. However, the total power of the micro hydro system is 9 kW, of which the station only uses around 1 kW, so the lowering of the water level does not have a major impact on the station.

Fig. 10.8
The intake weir and channel under construction at Radio Pikon Ane.
Image: Indonesia Media Development Loan Fund (MDLF)

Other issues

The remoteness of the station meant that construction of the system was slow and burdensome. The supply of building materials (such as cement, corrugated roofing, sand, wood, and stone) was unreliable; an emergency bridge was built across a local river to convey materials for the system; and local residents initially objected to the 1 km transmission lines, and demanded high compensation for the pipes carrying lines that passed through their gardens.

Once the system was installed, however, the area had an electricity supply for the first time. From the start of the project it was decided that the system should not only benefit the station, but also the broader local community, which is why the power of the system was deliberately set at a level much above the needs of the station. As a result, around 20 houses, one church, one school and the office of the village head all now have electricity.

Fig. 10.9
The completed channel for the hydro scheme at Radio Pikon Ane.
Image: Indonesia Media Development Loan Fund (MDLF)

Electricity has had a huge and positive impact on the community, and the low cost of the supply means that it is sustainable over the long term. Engaging the community in the decision making process regarding the construction and maintenance of the system has also ensured a sense of community ownership and responsibility for it, and strengthened ties between the community and the radio station. The fact that this is an alternative energy source that does not harm the environment is also an important factor for the local subsistence farming community.

Information provided by Tessa Piper (Country Program Director, Indonesia Media Development Loan Fund, MDLF)

Fig. 10.10
The hut built to house the turbine and transmission equipment for the Radio Pikon Ane hydro scheme. Materials for the scheme, including the hut, were transported to the site over a purpose-built bridge.
Image: Indonesia Media Development Loan Fund (MDLF)

Energy policy and enterprise

11

The cost, quality and availability of energy technology in a region depend partly on the existence of strong energy enterprises and favourable government policies towards energy. This chapter gives some background on local energy enterprises in Africa and on the kinds of policies that governments can adopt to support the growth of energy technologies, especially renewable technologies.

Local energy enterprises

Energy businesses, often run for and by members of small communities, have become more common in Africa in recent years. National governments, NGOs, and local entrepreneurs have increasingly put effort into supplying off-grid energy and equipment to Africans. This includes not just electrical energy but also cleaner forms of energy for everyday tasks like cooking and heating water. Radio stations are in a good position to support these efforts and – in some cases – to set up local energy businesses of their own.

Varieties of energy enterprise

Local energy businesses come in many shapes and forms. There are local private operators generating and selling electricity in many African countries – mainly from diesel generators or small hydro schemes. Countries vary enormously in their approach to rural electrification depending on the size and topography of the country, its natural resources, the strength of the national grid, the size of the local private sector, and so on. But in many countries recent policy reforms have opened up the possibility of a locally owned and managed system of energy generation and distribution complementing the public grid. Such small-scale co-operatives or private sector operators are now encouraged and supported to implement local electricity solutions using a range of technologies, including RETs. The generated electricity is then distributed through a local network, often just the local town or villages.

Local energy businesses include those importing and selling solar systems and solar lanterns, as well as energy efficient lighting such as LEDs (light emitting diodes). There are also local manufacturers and installers of wind turbines. Non-electrical energy products are also locally fabricated and sold. For example, a number of businesses manufacture improved stoves for institutional and domestic use that can save expenditure on firewood or charcoal (see Box 11.1 for some examples). Others are bringing up alternatives, such as briquettes made from agricultural residues or charcoal waste (Fig. 11.1). Another kind of business provides farmers with biogas digesters that transform animal manure into gas which is used for cooking or generating electricity. At a local community level micro-businesses may be using solar panels to offer a battery charging service, or phone charging, or they may be a retailer of stoves, solar lanterns or other low cost consumer products. All of these businesses offer access to forms of energy which are healthier, less environmentally harmful, and in the long run cheaper than wood, charcoal and kerosene.

... in many countries recent policy reforms have opened up the possibility of a locally owned and managed system of energy generation and distribution ...

Forms of financing and support for local energy companies

Some of these companies are international, while others were started and are managed by Africans. Some are partnerships between Africans and people from other parts of the world. Larger businesses, for example a small hydro scheme and mini-grid, will almost certainly have required government or donor subsidies to help them meet up-front capital costs. Solar installation companies and fabricators of biogas plants may also benefit from donor-supported programmes, either through training and the provision of consumer subsidies or through procurement contracts for schools and health centres. Small retail businesses are often started using private sources of funds and do not usually require a large initial capital outlay. An energy entrepreneur may borrow from a micro-finance initiative (MFI) or bank to start their business. Usually the entrepreneur will have assets they can use

Fig. 11.1 Entrepreneur Mau Kazi in front of the briquettes that she manufactures and sells. Briquettes are compact fuel sources made out of charcoal, agricultural waste, straw, hay, coconut husks, wood chips, or other flammable matter. Image: GVEP International (Global Village Energy Partnership)

Box 11.1

Case studies: Improved stoves in Kenya and Uganda

More than 95% of Ugandans and many Kenyans rely on fuel for cooking, typically charcoal or wood for urban dwellers and wood for rural households. The current stoves used for cooking are inefficient and this increases the amount of fuel wood needed to prepare a meal. Joint projects between local businesses and foreign donors have helped to disseminate improved stoves that save fuel and reduce the health and environmental damage caused by inefficient stoves. Two such projects are:

Kenyan Ceramic Jiko and Maelewano Women's Group. Maelewano Women's Group is in Mwakoro, a remote village in Kenya's Coast Province. The members of the group use a kiln to fabricate stove products that include the Kenyan Ceramic Jiko (KCJ), a modified version of the traditional charcoal stove of Kenya. It has been estimated that the KCJ saves $65 in fuel costs per household per year, and costs between $2 and $5. The kiln was built by the German organisation GTZ, allowing the group to make stoves and sell them at a profit to individuals and government groups.

Uganda Rocket Stove. UGASTOVE is a Ugandan company dealing in a variety of biomass technologies that include the Rocket wood stove. Rocket stoves cook efficiently by ensuring that there is a good air draft into the fire, controlled use of fuel, complete combustion of volatiles, and efficient use of the resulting heat. UGASTOVE has received business advice from the global firm Accenture to expand what was formerly a small family business. They run training sessions in stove production for local people, and offer credit sales with a long payment schedule for low income neighbourhoods in Kampala, Uganda. UGASTOVE earns **carbon credits** for the stoves that it sells, as a reward for the carbon emissions that the stoves prevent.

Fig. 11.2
A Rocket Stove (left) and Kenyan Ceramic Jiko (right). Images: UGASTOVE and GVEP International (Global Village Energy Partnership)

as collateral or an existing profitable business. Unsecured loans are very hard to obtain for anyone starting out in business.

Some international development NGO's encourage lending to energy businesses because they believe access to modern energy is key to unlocking economic development. They may do this by setting up specific credit lines with lending institutions, or through guaranteeing loans.

For larger businesses there are also a number of specialised investors who provide debt and equity. Some investor networks and development funds run contests to attract interest from potential businesses. There are also a range of organisations, some international and some African, which seek to earn credits from carbon offsetting. International financing is available for projects which reduce emissions that cause climate change.

... successful local energy businesses work on basic market principles: they provide a product or service that people want to buy and which they can afford ...

However, this is a highly technical area of activity and there are few successful examples in Africa of local energy businesses benefiting from carbon markets.

Whilst various forms of financing may be needed to help get a business started, all successful local energy businesses work on basic market principles – they provide a product or service that people want to buy and which they can afford.

In an area without grid electricity, low cost, good quality solar lanterns are almost always better value than a kerosene lantern. While there is an initial cost for the lantern, the money saved on kerosene over the ensuing months quickly pays for the lantern; moreover, the light is much brighter and there are no toxic fumes. Briquettes or stoves may have a limited market in an area where firewood is abundant and can be collected free of charge. These products tend to sell in urban areas where they are cheaper compared to traditional wood or charcoal fires.

Potential roles for radio stations

One of the challenges local energy businesses face is lack of awareness of their products and the benefits these can bring. Radio stations can certainly play a valuable role in making people aware of the cost and health benefits of low cost solar products, improved stoves, briquettes, fireless cookers, biogas and other technologies. The appropriateness of the technologies to any local situation will vary so the station would need to do some of its own research (FAQ 11.1).

Solar companies are often also looking for local stockists of their products, and there are business opportunities for people in providing battery, LED and phone charging services. Again, awareness-raising about the possibilities can help the market to grow. Another major challenge is lack of access to loans for consumers wishing to purchase a lamp, stove or solar home system. Some local credit unions do provide loans and encourage members to become distributors of low-cost energy products. Radio stations could help publicise stories of where such credit schemes have helped people gain access to products.

Building an energy business

Radio stations might themselves become providers of energy services through selling power which is surplus to their requirements. This might take the form of battery or phone charging services. Some mobile phone operators have already started to provide these services from phone masts which typically have a bigger power supply than they need. For example, Safaricom in Kenya provides phone charging from some of its base stations. Having someone outside the facility also helps deter thieves. Before offering a service of this kind, some basic research to establish whether a market for this service exists would have to be carried out. FAQ 11.1 lists some key questions to research.

Future trends

Ultimately, Africa needs access to power for productive use. Lanterns and stoves can help save money and provide some improvements in people’s daily lives,

FAQ 11.1

Is it feasible for my station to operate as an energy business?

Radio stations that have excess energy some or all of the time may wish to generate income from that excess energy. Common kinds of energy enterprise in Africa are battery and phone charging businesses. The following questions should be researched to find out whether such a business is viable:

Where do people with batteries and phones currently charge them?

Could one **provide this service more conveniently** (e.g. saving customers a journey of several kilometres) and/or more cheaply?

How much demand would there be for a charging service and how much would people be prepared to pay?

Can the charging service be used as an incentive to help other businesses? For example, at a station in Northern Benin, people bringing a story or advertisement to the station can charge their mobile phone while in the building.

What would it cost to provide this service – including initial and running costs?

With this basic information it should be possible to work out whether the likely income from providing this service would be more than the cost. If it is, the business proposal is viable.

Box 11.2

Case studies: Mobile phone charging businesses in Kenya's Coast Province

In Kenya's Coast Province, biomass such as charcoal, firewood and dung is still the main source of household energy. Most households are not connected to electricity grids, and the country is struggling to produce enough energy to supply existing demand, let alone to expand capacity. To make things worse, forest clearance by loggers and by settler farmers is slowly shrinking Kenya's forests. Across Kenya, competition for depleted resources has forced up the price of biomass fuel, and people are spending an ever-greater proportion of their household budgets on fuel.

The following are two examples of Coastal Province businessmen who have used a renewable energy source - solar energy - so that they no longer depend on biomass for all their fuel needs. Both men started their businesses after attending a training session in micro-enterprise run by the Developing Energy Enterprises Project - East Africa (or DEEP-EA). DEEP-EA specialises in providing support to energy entrepreneurs, both individuals and groups, in rural and semi-urban areas of East Africa.

Eli Simeon Kondo recently bought two solar panels which he uses both for his own domestic needs and to sustain his own business charging mobile phones. Mobile phones (unlike electricity) are widely and cheaply available across rural Kenya, so such a service has the potential to be profitable. The business has started off so well that Eli has been able to open a bank account.

Athuman Ndoro Nyawa has also started up a small solar mobile phone charging business, in the Mwabila-Mlola district of the Coast Province. He started the business in October 2009 and now charges ten phones per day, earning an estimated KSh 150 (US-$ 1.80) a day in a country where the average income is around KSh100 (US-$ 1.20) a day. Athuman has also opened a bank account.

Information provided by GVEP International (Global Village Energy Partnership).

but it is electricity supply which will really make the difference. In many African countries we will see a growth in the coming decade of stand-alone mini-grids powered by a variety of technologies, typically with a number of large reliable customers such as a local factory, a phone mast, or a health post. Community radio stations will be amongst the customers for this power which will almost certainly be cheaper than the alternatives – unless, of course, an investment has already been made in a low-maintenance system such as solar panels, a wind turbine, or hydro power.

Energy and policy

Local and national governments in Africa are in a good position to contribute to energy technology. The degree of government engagement with renewable energy technologies, and the government approach to electrification, is a factor in deciding whether a particular technology is suitable for a station in the country. The following are some steps governments can take to promote off-grid energy technology, and some examples of African countries that have taken those steps.

Attractive financing for RET projects
Example: In 1997, the Botswana government set up a finance scheme which allowed rural communities in Botswana to purchase solar power systems repayable over four years, with interest.

Tax exemptions, including border taxes such as customs tax
Example: Starting in 1998, the Ghana government reduced import duties and VAT (value added tax) on solar and wind technology. As of January 2010, this technology was exempt from both import duties and VAT.

Blanket subsidies on energy technology
Example: In September 2007, the Ugandan government announced a 45% subsidy on all solar power equipment.

Feed-in tariffs: grid system operators pay a tariff to individuals and/or companies that feed power into the grid from renewable sources
Example: The Kenyan government introduced a feed-in tariff system in 2008, paying (for example) $0.09 per kWh for energy from wind farms up to 50 MW.

Promoting energy businesses

Example: Part of Ghana's Strategic National Energy Plan (see Box 11.3) is to encourage industrialists to partner with popular brand manufacturers to set up branches of production and assembly lines in the country.

Certification and licensing of energy technology providers

Example: Certification and licensing was one goal of Ghana's Strategic National Energy Plan (see Box 11.3).

Funding specific energy projects

Example: Mali's Programme to Popularise the Jatropha Plant included installing equipment powered by jatropha oil in villages and converting vehicles and facilities to run on jatropha. Other funded projects in African countries have provided solar-powered traffic lights, maintenance and replacement parts for solar systems, and solar installations in villages.

Encouragement of research and development of renewable energy sources

Example: Mali's Programme to Popularise the Jatropha Plant supported research into two successful types of extraction process for jatropha oil.

Appointing government energy advisers, signing agreements, and developing national energy plans

Example: In 2010, the Rwanda government sought an expert in renewable energy to develop a Renewable Energy Strategy for the country.

Box 11.3
Case study: Ghana's Strategic National Energy Plan

Ghana's Strategic National Energy Plan (SNEP, 2006-2020) is an example of government action in support of renewable energy technology. The goal of the plan is to create an energy market in Ghana that can provide sufficient, viable and efficient energy services. The Plan's policy recommendations include:

Ensuring that wind powered and solar energy generating sets, plants, machinery, and equipment are **exempt from import duty, VAT and excise duties.**

Encouraging Ghanaian industrialists to **partner with popular brand manufacturers** to set up branches of production and assembly lines in the country.

Establishing and enforcing **certification and licensing** of dealers in renewable energy technologies.

Encouraging local government in Ghana to provide electricity services to off-grid communities via **mini-grids and micro-grids** through alternative sources such as biomass.

Plans such as this do not guarantee that renewable energy becomes cheaper and more accessible to everyone who needs it - but they do help. In Ghana's case, the SNEP attracted over $210 million in support from the World Bank and other donors.

Information: International Energy Agency and the World Bank

Appendix A Worksheets

A.1 Planning checklist

A.2 Basic energy assessment

A.3 Long-term fuel cost

A.4 Life-cycle cost comparison

A.5 Payback period for equipment

are available as online worksheets

at www.cameco.org/publications

A.1 Planning checklist

TASKS and OPTIONS	Notes	Related chapters	Done?
1. Assess energy needs	An energy assessment helps to size and select technology, as well as identify areas where energy can be saved.	2	
Basic energy assessment	Use "Basic energy assessment" worksheet in Appendix A.2.		
Advanced energy assessment	Considers the existing power supply, critical loads, future changes in demand, the remoteness of the station, daily and annual variation in demand, and the electrical quality needed.		
Assess expertise	Which tasks can the station perform on its own and which require outside expertise? Consider the specificity, level, and availability of expertise.		
2. Identify potential energy savings	The cheapest energy is the energy that one does not use.	2	
Replace inefficient equipment	Use "Payback period" worksheet in Appendix A.5 to analyse the long-term cost savings of efficient equipment.		
Reduce energy use	From closing windows to turning computers off – the easiest way to save energy, requiring small but consistent staff effort.		
Redistribute the energy load	May include shifting work hours to match grid power, and/or evening out energy use over the course of the day.		
Revise energy assessment	Scale down energy assessment based on (realistic) future energy savings.		
3. Select energy system and technology	Technologies can provide regulation, storage and extra generation as needed. Care must be taken when evaluating the performance and cost of energy generating technology.	3, 5, 6, 7	
Regulation (and protection)	May include voltage regulator, voltage monitor, UPS's, lightening tower, batteries for protection, or rewiring to improve protection. May also include protection for critical loads.	3, 7	
Storage	Batteries may store pps, genset supply, RET supply, or a combination. Should also include a good charge controller and (for AC equipment) an inverter.	3, 7	
Generation	May include an extra genset or improved use of genset; one or more RETs on their own; or one or more RETs with a genset. Hybrid systems may use the RET as backup to a genset, or vice versa.	3, 5, 6	
Performance evaluation	Takes into account natural resources, the daily generating time of the technology, and de-rating factors (Fig. 4.2 in Chapter 4 contains common de-rating factors).	4	
Cost evaluation	Life cycle cost analysis takes into account all costs over the lifetime of a technology (see worksheet in Appendix A.4). Depends upon initial costs, running costs, and durability of the technology. Battery replacement costs are relatively high.	4	

continued TASKS and OPTIONS	Notes	Related chapters	Done?
4. Plan long-term management	Ideally an "energy manager" will be appointed to be responsible for the following tasks.	8	
Maintenance	Includes reporting malfunctions, replacing failed and worn-out components, and maintaining a stock of tools, spare parts and other supplies.		
Evaluation	Includes initial evaluation and periodic re-evaluations.		
Reacting to energy changes	Identifying and responding to changes in the energy load caused by new equipment, new staff, or longer on-air hours.		
Overseeing energy saving	Ensuring station staff implement the planned energy savings.		
Training	Includes training of technicians and station staff in operation and maintenance of technology, and in energy efficiency.		
Sharing experience, expertise and energy	Experience and expertise (including technicians) can be shared among stations. Energy can be shared with other members of the community.		
5. Dealing with energy technology providers	Know how to select a provider and what to expect from them.	9	
Select a dealer/consultant	Consider the provider's experience on the specific task, in the specific region; the length of their experience; whether they can judge a technology impartially and provide a warranty; and what previous customers say about them.		
Carry out the installation	The provider should be able to provide a site visit; O&M training and advice; technical data or a user's manual; information on standards; warranties; and full costing information.		

A.2 Basic energy assessment

Some common equipment is already listed on the worksheet.

Appendix B.1 includes a list of typical power ratings of common radio station equipment.

Chapter 2 contains more information on conducting an energy assessment.

The white boxes in the "Value" column are to be filled in using the station's own data; the grey boxes can be filled in using the suggested equation in the "Calculations" column. An online version, containing equations and ready for use, is available for downloading from www.cameco.org/publications.

CONSUMER	Power per unit (kW)	No. of units	Total power (kW)	Hours per day (hr)	Total energy per day (kWh)
	A	B	C = A x B	D	= C x D
Transmission					
Transmitter					
Audio processor					
Studio equipment					
Computer					
Mixer					
CD player					
Cassette deck					
Minidisc recorder					
Amplifier					
Speakers					
Microphones					
Appliances					
Fan					
Air conditioner					
Lights					
Fridge					
Office equipment					
Desktop computer					
Laptop computer					
Printer					
Photocopier					
Telephone					
Other					
TOTAL					

A.3 Long-term fuel cost

The fuel costs of gensets are usually much higher than their initial costs, yet fuel costs are often "hidden" because they are to be paid in the future. The worksheet below helps to estimate the long-term cost of fuel, the energy produced by a genset, and the levelised cost of fuel to produce 1 kWh energy from a genset, expressed in terms of dollars per kWh. This value can help to compare the cost-effectiveness of gensets with other energy sources.

Chapter 6 contains more information on gensets (including diesel generators).

The white boxes in the "Value" column are to be filled in using the station's own data; the grey boxes can be filled in using the suggested equation in the "Calculations" column. An online version, containing equations and ready for use, is available for downloading from www.cameco.org/publications.

PARAMETER	Unit	Value	#	Calculations
Cost of fuel per unit volume	$ per volume*		A1	
Volume of one tank of fuel	volume*		A2	
Hours of generating time per day averaged over 1 year	hours per day		A3	
Total generating time on one tank of fuel	hours per tank		A4	
Annualised fuel cost	$		A	= (A1 x A2 x A3 x 365) / A4
Average operating power of generator	kW		B1	
Energy of generator	kWh per day		B	= A3 x B1
Levelised fuel cost	$/kWh		C	= A / (B x 365)

*Any unit for fuel volume will work here (e.g. litres, US gallons, UK gallons). But the same unit must be used each time fuel volume is used in a calculation.

A.4 Life cycle cost comparison

The worksheet on the following page can be used to compare the cost per year of three energy systems, taking into account the main life cycle costs of each option. The options can be compared by their levelised cost (the cost per kWh they generate) and annualised cost (their cost per year).

The advantage of the levelised cost is that it takes into account the amount of energy generated by different systems – so it gives a fair comparison even if the systems produce different amounts of energy.

The advantage of the annualised cost is that it shows the long term cost of energy. If the different systems have different energy outputs the annualised energy cost is not a fair comparison between the options.

Other points to note:

Not all of the cost types listed are applicable to every energy system. For example, gensets usually incur a running cost per kWh generated (the cost of fuel), but renewable technologies do not.

Some of the cost types are different ways of expressing the same kind of cost. For example, the annual maintenance cost can be expressed as an absolute cost or as a percentage of the initial cost of the option. The cost types that are used for each option depend on how the dealer or manufacturer expresses these costs.

The worksheet does not take into account the discount rate, a financial phenomenon that makes a future payment more burdensome than a present payment of the same cash value.

The white boxes in the "Value" column are to be filled in using the station's own data; the grey boxes can be filled in using the suggested equation in the "Calculations" column. An online version, containing equations and ready for use, is available for downloading from www.cameco.org/publications.

PARAMETERS	Unit	A	B	C	#	Calculations
Daily energy output averaged over a year	kWh/day				A1	
Annual energy output(1)	kWh				A	= A1 x 365
Initial cost	$				B1	
Lifetime	yr				B2	
Annualised initial cost	$/yr				Ba	= B1 / B2
Levelised initial cost	$/kWh				Bl	= Ba / A
Annualised fuel cost	$/yr				Ca	
Levelised fuel cost(2)	$/kWh				Cl	= Ca / A
Percentage maintenance cost	% initial cost/yr				D1	
Initial cost	$				D2	
Annualised % maintenance cost	$/yr				Da	= D1 x D2 / 100
Levelised % maintenance cost(3)	$/kWh				Dl	= Da / A
Replacement part cost	$				E1	
Frequency of replacement	yr				E2	
Annualised replacement cost 1	$/yr				Ea	= E1 / E2
Levelised replacement cost 1(4)	$/kWh				El	= Ea / A
Replacement part 2	$				F1	
Frequency of replacement	yr				F2	
Annualised replacement cost 2	$/yr				Fa	= F1 / F2
Levelised replacement cost 2	$/kWh				Fl	= Fa / A
Other levelised costs(5)	$/kWh				Gl	
Annualised "other levelised costs"	$/yr				Ga	= Gl x A
TOTAL LEVELISED COST	$/kWh					= Bl + Cl + Dl + El + Fl + Gl
TOTAL ANNUALISED COST	$/yr					= Ba + Ca + Da + Ea + Fa + Ga

Chapter 4 contains more information on evaluating the costs of energy generating technology.

(1) The annual energy output of the technology is used to calculate the levelised cost of the option.
(2) The annualised and levelised fuel cost can be estimated using the worksheet in **Appendix A.3**.
(3) Maintenance costs of renewable energy technologies are often expressed (including in this guide) in terms of the percentage of the initial cost of the technology per year e.g. solar panels might have maintenance costs of 2% of the initial cost of the panels, each year.
(4) A replacement cost is the cost of a part such as a wind turbine blade, batteries, or a sun-tracking system for solar panels. It does not refer to the cost of replacing the entire system (replacing a set of solar panels, for example). As there may be different components to replace, at different times, and with different costs, this worksheet gives room for the replacement costs of two components ("Replacement cost 1" and "Replacement cost 2").
(5) This category is for costs that are already expressed as levelised costs e.g. utility companies often express the cost of the public power supply in dollars per kWh.

A.5 Payback period

More efficient equipment (such as an LCD computer screen or high-efficiency light) often has a higher initial cost than inefficient equipment – yet the extra initial cost is often cancelled out by savings in the cost of energy. The worksheet below can be used to find the payback period (in days, months and years) for a more efficient electrical device. The payback period is the amount of time the efficient device must operate before the money saved in reduced energy costs cancels out the extra initial cost of the more efficient device.

PARAMETERS	Values	#	Calculations
Initial cost of inefficient consumer ($)		A1	
Initial cost of efficient consumer ($)		A2	
Cost difference ($)		A	= A1 - A2
Average power draw of efficient consumer (kW)		B1	
Daily usage of efficient consumer (hours)		B2	
Daily energy draw of efficient consumer (kWh)		B	= B2 x B1
Average power draw of inefficient consumer (kW)		C1	
Daily usage of inefficient consumer (hours)		C2	
Daily energy draw of efficient consumer (kWh)		C	= C2 x C1
Daily difference in energy draw (kWh)		D1	= C – B
Cost of energy ($/kWh)		D2	
Cost saving per day ($)		D	= D1 x D2
PAYBACK PERIOD (DAYS)		E1	= A / D
PAYBACK PERIOD (MONTHS)		E2	= E1 / 30
PAYBACK PERIOD (YEARS)		E3	= E1 / 365

The worksheet assumes that the efficient and inefficient consumers do their job equally well and last for the same length of time.

The white boxes in the "Value" column are to be filled in using the station's own data; the grey boxes can be filled in using the suggested equation in the "Calculations" column. An online version, containing equations and ready for use, is available for downloading from www.cameco.org/publications.

Approximate costs of energy sources (in US cents/kWh) [4]:

Public power supply:	4 – 8
Solar panels:	50 – 60
Wind turbine:	25 – 35
Diesel generator:	50 – 65
Pico/micro hydro:	10 – 15

Notes:

The given costs of energy sources are approximations only, and costs vary widely in different conditions. The cost listed for the public power supply (4-8 cents/kWh) does not take into account the cost of storing or regulating the power supply. The use of batteries and regulation equipment can greatly increase the cost of public power.

Chapter 2 contains more information on energy saving at a radio station, including energy saving through the use of more efficient equipment.

Appendix B

B.1 Power consumption of key equipment

The table below shows typical ranges of the power and energy consumption of radio station equipment and appliances. These figures are approximations only – a more accurate estimate of a station's power and energy consumption can be attained by using the manufacturer's ratings of equipment or by direct measurement

CONSUMER	Power (W)	On-time (hr/day)	Energy per day (Wh)
Transmitter*	300—8000	5—24	**1500—190000**
Air conditioners	500—1500	5—15	**2500—25000**
Computer (desktop)	200—300	5—20	**1000—6000**
Computer (laptop)	50	5—20	**250—1000**
Fans (ceiling or standing)	20—200	5—20	**100—4000**
Lights (incandescent)	20—100	2—12	**40—1200**
Lights (CFL)	5—30	2—12	**10—360**
Lights (tube flourescent)	20—40	2—12	**40—480**
Mixer	15—80	5—20	**75—1600**
CD player	10—25	5—20	**50—500**
Cassette Deck	10—20	5—20	**50—400**
TV 12" B&W	15	1—4	**15—60**
TV 19" Colour	60	1—4	**60—240**
TV 25" Colour	130	1—4	**130—520**
Refrigerator/freezer	variable	variable	**1100—3000**
Freezer	variable	variable	**700—3000**
Electric kettle	500—1500	variable	**500—3000**
Hand power tools		1—3	**100—800**

Fig. B.1
Typical daily power and energy consumption of key consumers at a radio station.
*Transmission power consumption is two to three times greater than the output power of a transmitter.
Data: used with permission of the National Renewable Energy Laboratory, originally published in Renewable Energy for Rural Schools, November 2000; www.nrel.gov/docs/fy01osti/26222.pdf, accessed March 2010.

of the equipment's power draw. **Chapter 2** contains more information on the energy consumption of radio station equipment, and on ways to save energy on such equipment.

B.2 Solar map for Africa

Below is a map of the average annual solar irradiation (or "insolation") across Africa. The map was generated using NASA's "Surface meteorology and solar energy" tool (http://eosweb.larc.nasa.gov/sse). This online tool is free to use and can give detailed numerical and graphical data for specific locations in Africa.

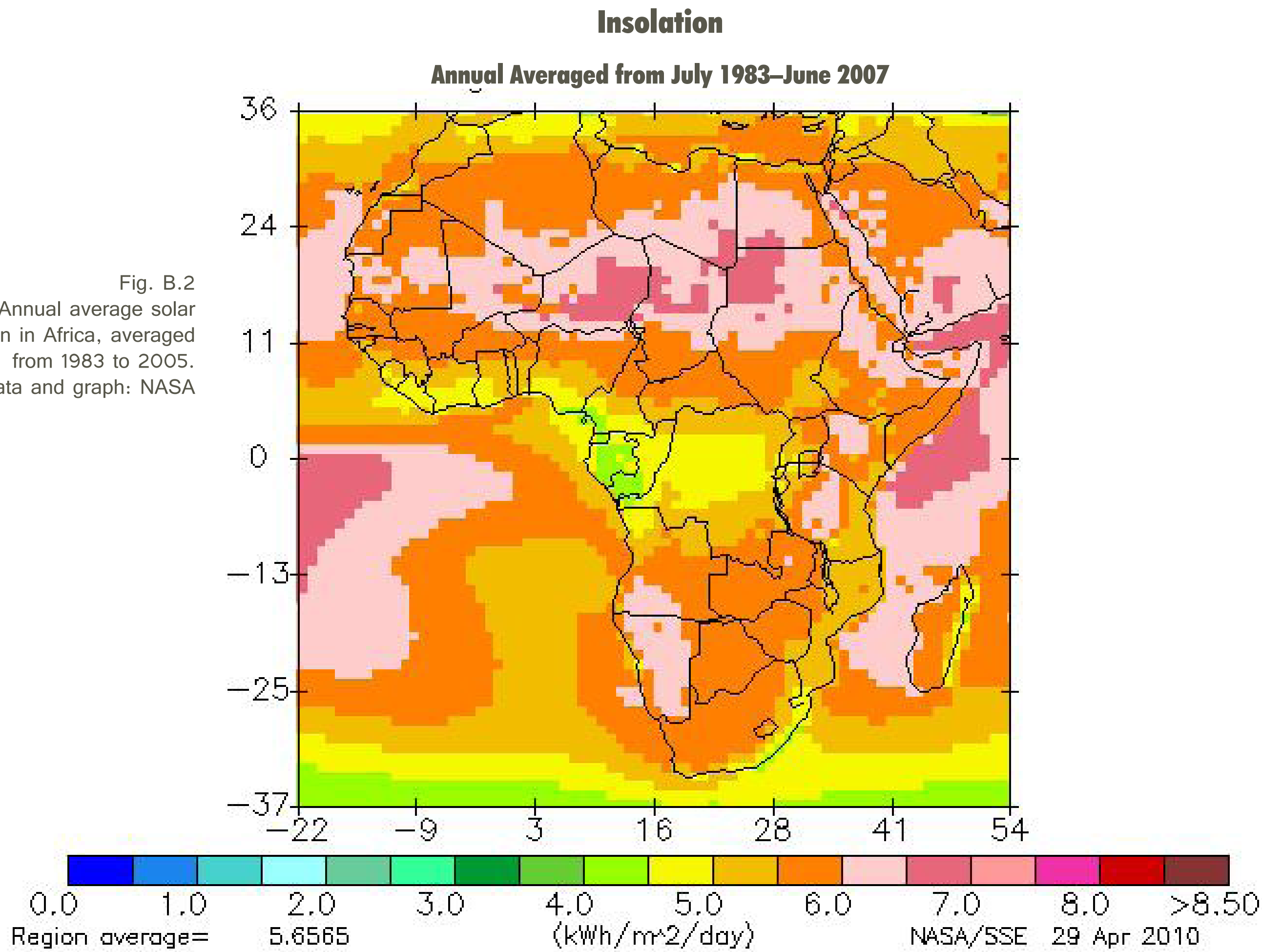


Fig. B.2
Annual average solar insolation in Africa, averaged from 1983 to 2005.
Data and graph: NASA

As the map shows, most regions in Africa have solar irradiation of between 4 and 6 kWh/m^2/day. By global standards, 4 is a medium amount of sun, 5 is high, 6 is very high, and anything over 6 is rare.

Notes:

1 kWh/m2 per day is the same as 1 sun-hour per day, or 1 hour of full sun. Solar modules are rated according to their output in full sun. A module rated at 100 Wp, for example, will produce 100 Wp in full sun. If such a module receives 5 sun hours per day, it will generate 500 Wh or 0.5 kWh of energy per day, before de-rating factors are considered (100Wp x 5 sun hours = 500Wh). Losses due to high temperatures, wiring, batteries, and inverter mean that this value is usually de-rated by 50-60% to give the usable electrical energy per day for the module.

The map shows solar potential only. It takes the average cloud cover into account, but does not consider any local obstructions such as trees and buildings. It also ignores variation on solar irradiation over the course of a typical day and year.

Annual variation is averaged out in the graph. Even in areas with high irradiation on the map, there may be extended periods during the year when irradiation is low due to cloud cover (during the rainy season, for example).

Chapter 5 contains more information on solar panels. **Chapter 4** includes an analysis of the performance and cost of a sample energy system based on solar panels.

B.3 Wind map for Africa

Below is a map of the average annual wind speed across Africa. The map was generated using NASA's "Surface meteorology and solar energy" tool (http://eosweb.larc.nasa.gov/sse). This online tool is free to use and can give detailed numerical and graphical data for specific locations in Africa.

50m Wind Speed

Annual Averaged from July 1983–June 1993

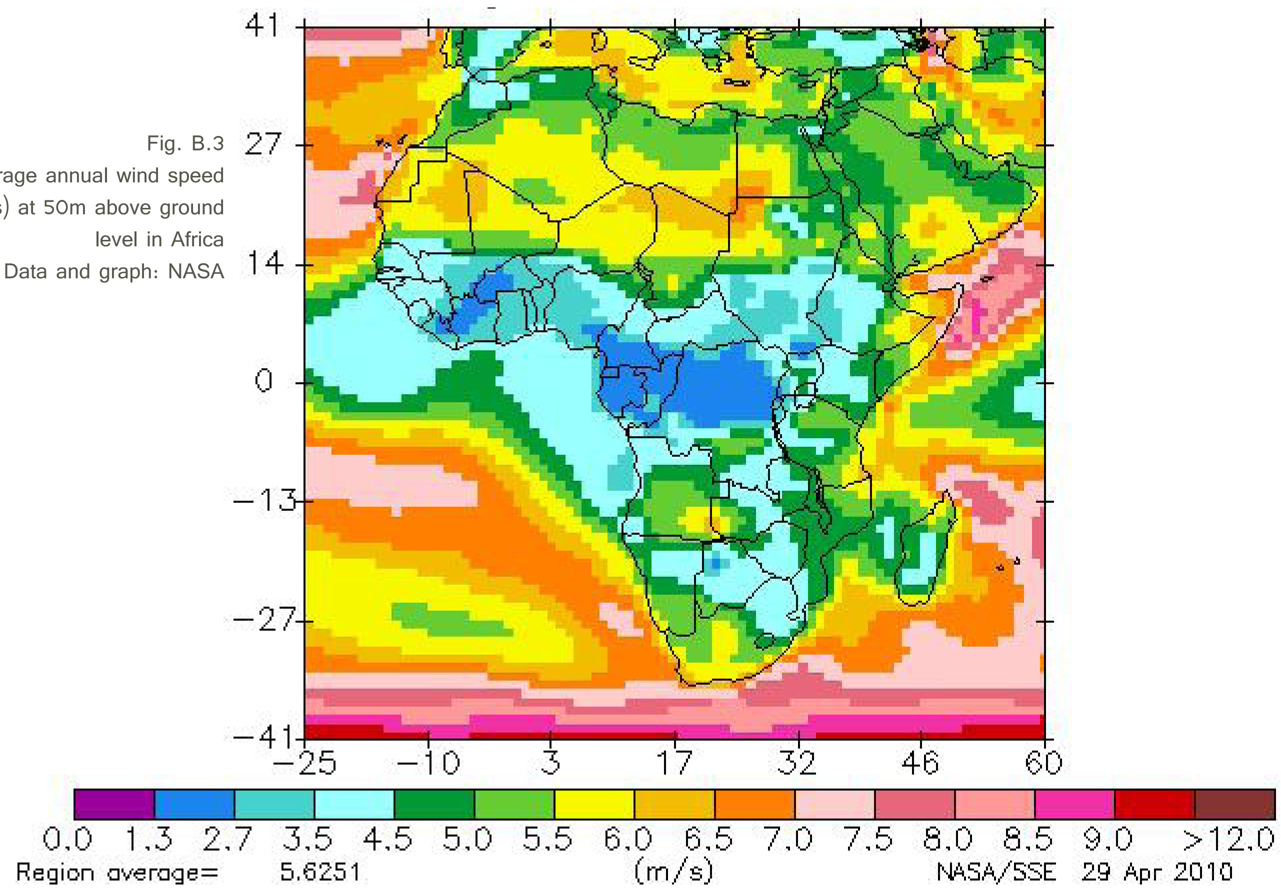


Fig. B.3
Average annual wind speed (m/s) at 50m above ground level in Africa
Data and graph: NASA

How to use this map. The map shows annual wind speeds at 50m above ground level across the African continent, averaged over a 20-year period. Since wind turbines are usually located below 50m, the map is not an accurate guide to the winds available to turbines in Africa. It can be used to identify regions that are **almost certainly unsuitable** for wind energy use (since the wind available to a turbine is rarely greater than the wind at 50m). It can also be used to identify regions that **might be suitable** for turbines. However, regions that show high winds on the map may in fact have low wind availability, and a local wind assessment is needed to get an accurate measure of the resource. The key below can be used to estimate the potential for wind power on areas of the map:

Little or no potential for wind power: less than 3.5 m/s.

Some potential for wind power: between 3.5 and 5.0 m/s.

Strong potential for wind power: 5.0 m/s and above.

Chapter 5 contains more information on wind turbines. **Chapter 4** includes an analysis of the performance and cost of a sample energy system based on a wind turbine. **Appendix B.4** presents some data that may be useful when estimating the daily energy output of a wind turbine.

B.4 Theoretical energy output of a wind turbine

The table below gives the theoretical energy output (in kWh per day) of a wind turbine for four typical wind speeds and a range of rotor diameters. When interpreting this data, note that:

The values in the table are averages, and in practice there will be considerable day-to-day fluctuations about this average.

The values are also **theoretical**: a very efficient small wind turbine may be able to convert half of the theoretical output into usable energy; an inefficient turbine may only convert a quarter. This is before electrical losses in the wires, rectifier and inverter are taken into account.

Technically, the values in the table assume a conversion efficiency of 59% (Betz's limit) and 1.89 as the factor by which the energy is increased due to the distribution of the wind speeds.

Fig. B.4
Theoretical average energy output (kWh per day) for four typical wind speeds and a range of turbine diameters.

The wind speed in the table is the average speed of the wind that is available to the turbine. This can be found using a local wind assessment.

The diameter of a turbine (not to be confused with its radius) is usually given by the manufacturer.

kWh/day		Blade diameter (m)												
		1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	7	8
Wind speed (m/s)	3	0.35	0.78	1.4	2.2	3.1	4.3	5.6	7.1	8.7	11	13	17	22
	4	0.83	1.9	3.3	5.2	7.4	10	13	17	21	25	30	40	53
	5	1.6	3.6	6.5	10	15	20	26	33	40	49	58	79	103
	6	2.8	6.3	11	17	25	34	45	56	70	84	100	137	178

For example, a turbine of diameter 3.5 m has a theoretical output of 20 kWh per day in winds averaging 5 m/s. A very efficient small wind turbine may convert half of this into usable energy to give roughly 10 kWh a day on average (before electrical losses in the wires, rectifier and inverter are taken into account). An inefficient turbine may give as little as 5 kWh a day in these conditions, before electrical losses.

Source: Hugh Piggott, author's analysis

The values in Fig. B.4 can also be calculated for arbitrary wind speeds and rotor diameters using the formula:

E = 0.0129 x D ^ 2 x v ^ 3

Where E is energy per day (in kWh), D is the turbine diameter (in m), and v is the wind speed (in m/s). The energy values found using this formula are, like the values in Fig. B.4, theoretical averages.

Appendix C

C.1 Photo Voltaic (PV) module data sheet

Below are explanations of some key information regularly displayed on sample data sheets for a range of PV modules. These are the cells found in modern solar panels. The modules here used as an example are the Schott ASI 87, 90, 95, and 100 models.

1. Cell type

The majority of PV modules are amorphous silicon, mono-crystalline silicon, or poly-crystalline silicon.

Characteristic data

Solar cells per module	56
Cell type	a-Si/a-Si tandem (amorphous silicon)
Connection	Junction box IP65 with bypass diode, 4 mm^2-solar cable with Tyco-Connectors, length of pole 1.2 m each
Dimensions junction box [mm]	138 x 90 x 22
Front panel	thermally treated float glass 4mm
Frame material	aluminium - black

2. System voltage

The maximum allowed voltage across the PV module.

Limits

System voltage [V_{DC}]	1000
Maximum reverse current I_R [A]*	15
Operating module temperature [K]	-40... +85
Maximum load (to IEC 61646)	Pressure: 2,400 N/m^2 or 245 kg/m^2 Suction: 2,400 N/m^2 or 245 kg/m^2
Fire classification (to IEC 61730)	A
Application classification (to IEC 61730)	C

* *No external current in excess of U_{OC} shall be applied to the module.*

3. Permissions and certificates

This module has met the international quality standards for PV modules, administered by the International Electrotechnical Commission.

Permission and certificates

The modules are certified to IEC 61646 ed. 2 and IEC 61730, Electrical Protection Class II and the CE-guidelines.

4. Nominal power under standard test conditions (STC)

The power that the module delivers under standard (i.e. ideal) conditions. Nominal power does not take into account electrical losses in wires and an inverter, or losses due to non-ideal sun conditions (such as on heavily overcast days). It also assumes that the module faces the sun directly at all times (an unrealistic assumption, especially for PV arrays without a tracking mount).

The output of amorphous cells declines over the first few months of use before stabilising; hence the two values ("stabilised" and "initial") for the module's nominal power. The "initial" power value is *not* an accurate guide to the long-term output of the module. Use the stabilised figure instead for calculations.

5. Modular efficiency level

This is the proportion of the available solar energy that the module converts into usable electrical energy. A modular efficiency of 6% means that for every 1000 W of available solar energy the module delivers 60 W of electrical energy.

Electrical data

Electrical data refer to Standard Test Conditions (STC):
Irradiance 1000 W/m², spectrum Air Mass 1.5 and cell temperature 25°C

Product name		SCHOTT ASI™ 87		SCHOTT ASI™ 90		SCHOTT ASI™ 95		SCHOTT ASI™ 100	
		stabilised value	initial value	stabilised value	initial value	stabilised value	initial value	stabilised value	initial value
Nominal power [Wp]	P_{Nom}	87	106	90	110	95	116	100	122
Voltage at nominal power [V]	U_{mpp}	17.2	19.0	17.3	19.0	17.4	19.0	17.5	19.0
Current at nominal power [A]	I_{mpp}	5.07	5.60	5.21	5.70	5.47	6.00	5.71	6.30
Open-circuit voltage [V]	U_{oc}	23.3	24.3	23.4	24.4	23.6	24.6	23.8	24.8
Short-circuit current [A]	I_{sc}	6.50	6.70	6.60	6.80	6.69	6.90	6.79	7.00
Modular efficiency level (%)	η	6.0		6.2		6.6		6.9	

Rating tolerance for power output is ± 5 % and rating tolerance for all other parameters is ± 10 %.

6. Data at normal operating cell temperature (NOCT)

The data in this table applies for less-than-ideal sun conditions i.e. at irradiance of 800 W/m^2, not 1,000 W/m^2. This makes the data in this table more realistic than the data in the standard test conditions (STC) table. For the modules described on this datasheet, the power rating under NOCT is about 20% lower than the nominal power under STC (for example, 87 Wp compared to 68 Wp, for the Schott ASI 87 model).

Data at normal operating cell temperature (NOCT)

Irradiance 800 W/m², spectrum Air Mass 1.5, windspeed 1m/s and cell temperature 20°C

Nominal power [Wp]	P_{nom}	68	70	74	78
Voltage at nominal power [V]	U_{mpp}	16.2	16.3	16.3	16.4
Open-circuit voltage [V]	U_{oc}	21.3	21.4	21.6	21.7
Short-circuit current [A]	I_{sc}	5.22	5.30	5.37	5.45
Temperature [°C]	T_{NOCT}	49	49	49	49

Rating tolerance for power output is ± 5 % and rating tolerance for all other parameters is ± 10 %.

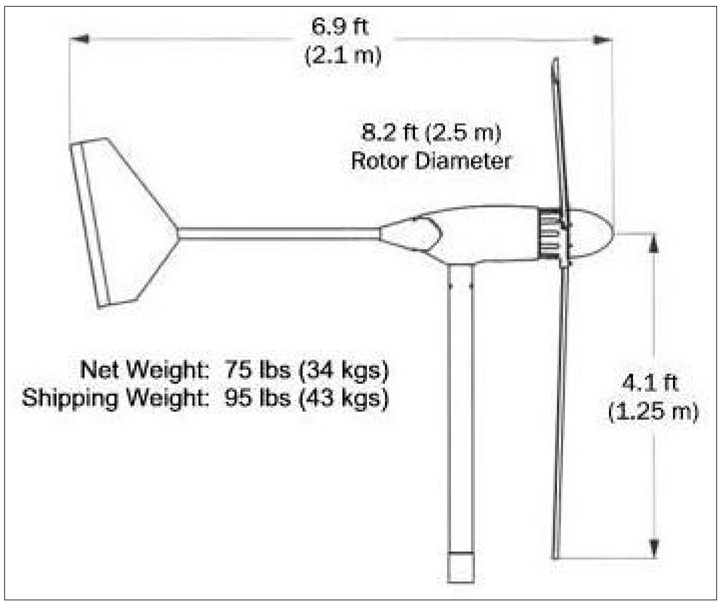
Fig. C.1
All Images: Schott solar

C.2 Wind turbine data sheet

Below are explanations of some key information for a wind turbine. The turbine is the Bergey XL.1. Each image is part of the respective data sheet.

1. Rotor diameter

The rotor diameter (2.5m) is the best indicator of the potential power of the turbine.



2. Single-figure power rating

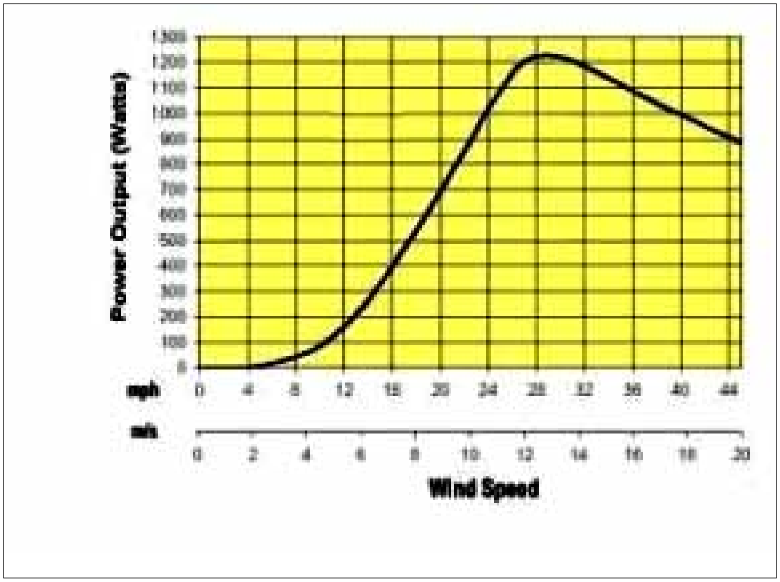
This turbine is rated at 1,000 W at a wind speed of 11m/s – a rare wind speed in practice.


Performance

Start-up Wind Speed ... 6.7 mph (3 m/s)
Cut-In Wind Speed ... 5.6 mph (2.5 m/s)
Rated Power ... 1,000 Watts
Rated Wind Speed ... 24.6 mph (11 m/s)
Rated Rotor Speed ... 490 RPM
Furling Wind Speed ... 29 mph (13 m/s)
Max. Design Wind Speed ... 120 mph (54 m/s)

3. Power curve

Gives the power output for a range of constant wind speeds. For realistic wind speeds (4 to 8 m/s) the output is under 500 W, much less than the single-figure power rating of 1,000 W.



4. Long-term energy output, top of tower

A table showing the daily, monthly and annual energy output (in kWh) of the turbine, for different wind speeds *measured at the top of the tower*. The energy figures apply to towers of any height; the user might measure wind speed at the top of a tower with an anemometer. The figures in this table (unlike the power curve) take into account variations in the wind speed around its average speed.

Predicted Energy Production

Wind Speeds Taken at Top of Tower

Annual Average Wind Speed (m/s)		3.5	4	4.5	5	5.5	6	6.5
Annual Average Wind Speed (mph)		7.8	8.9	10.1	11.2	12.3	13.4	14.5
Production in kWh (24 VDC)	Daily	1.9	2.8	3.9	5.1	6.4	7.7	8.9
	Monthly	55	85	115	155	195	235	270
	Annually	680	1,010	1,410	1,850	2,320	2,790	3,260

5. Long-term energy output, at 10m

A table showing the energy output of the turbine for different wind speeds measured 10m above ground level. Energy output depends on the height of the tower used, so the table includes energy figures for three different tower heights (9m, 20m, and 32m).

Wind Speeds Taken at 10 meters (per standard wind resource maps)

		US-DOE Wind Power Class	1	2	3	4	5	6	7
		Annual Average Wind Speed (mph)	~ 8.9	~ 10.7	~ 12.1	~ 13.0	~ 13.9	~ 15.0	~ 18.8
		Annual Average Wind Speed (m/s)	~ 4.0	~ 4.8	~ 5.4	~ 5.8	~ 6.2	~ 6.7	~ 8.4
Production in kWh (24 VDC)	30 ft (9m) Tower	Daily	2.6	4.3	5.8	6.8	7.8	9.1	12.7
		Monthly	80	130	175	205	240	275	385
	64 ft (20m) Tower	Daily	4.1	6.4	8.2	9.3	10.4	11.7	14.7
		Monthly	125	195	250	285	320	355	445
	104 ft (32m) Tower	Daily	5.2	7.8	9.7	10.9	12.0	13.1	15.4
		Monthly	160	235	295	330	365	400	465

Assumptions. Inland site, Rayliegh Wind Distrubution, Shear Exponent = 0.20, Altitude = 1000ft (300m)
Note. Battery charge regulation (batteries full) and wire run losses will reduce actual XL.1 performance.
Your Performance May Vary.

Fig C.2
Data sheets for a wind turbine. All Images: Bergey Windpower

6. De-rating advice

The data sheet ratings do not take into account losses in transmission wires, battery charging, or an inverter.

Appendix D

D.1 Key resources

The following is a list of organisations and websites which may assist radio stations in different parts of Africa to find information, consultants, suppliers, and training opportunities related to energy management (especially those related to renewable energy technology).

Websites

ENergy Focus (ENF)
An dedicated directory of solar businesses around the world, including a number in Africa.
www.enf.cn

Global Village Energy Partnership (GVEP International)
An NGO working to reduce poverty by accelerating access to affordable and sustainable energy services. GVEP's website includes a database of energy-based projects, funding opportunities, organisations and an online forum.
www.gvepinternational.org

NASA Solar and Wind Resource Data
Free source of data on worldwide sun and wind resources. Includes plain text data and coloured maps for a wide range of parameters, from daily cloud cover to precipitation.
http://eosweb.larc.nasa.gov/sse

Practical Action Technical Enquiry Service
An online enquiry service giving free technical information to development workers, community-based organisations, NGOs and other groups using technology (including energy technology) to aid sustainable development.
www.practicalaction.org/practicalanswers/technical_enquiry_service.php

Renewables 4 Africa

Umbrella site for the Wind 4 Africa, Solar 4 Africa, and Hydro 4 Africa websites, all run by the South African energy consultant Wim Jonket Klunne. The websites contain forums, directories, case studies, and other resources on key renewable energy technologies.

http://renewables4africa.net/index.php

Renewable Energy Toolkit (REToolkit)

A World Bank website including a number of resources on renewable energy technology, for end-users as well as development workers.

http://www.worldbank.org/retoolkit

Organisations

African Centre for Renewable Energy and Sustainable Technology (ACREST)

A Cameroon-based organisation that supports information, training, and equipment for RETs and STs in Africa.

http://www.acrest.org

E-Mail info@acrest.org

Centre for Energy, Environment and Engineering Zambia (CEEZ)

A Zambia-based NGO that conducts policy research on energy, as well as carrying out studies, research and development, consultancy and training in energy.

http://cdmsusac.energyprojects.net/viewcategory.asp?ID=4

Contact: Prof. Francis D: Yamba,

E-Mail: f.d.yamba@eng.unza.zm

East African Energy Technology Development Network Uganda (EAETDN-U)

A networking organisation that aims at increasing energy access for households and enterprises through promoting energy for productive use as well as wellbeing. The network is based in Uganda but has members in Kenya and Tanzania.

http://www.energynetworkuganda.org

E-Mail: sengendo@infocom.co.ug

ENDA Energy, Environment and Development

A Senegal-based branch of the organisation Enda Tiers Monde. Their work focuses on energy use and management in the African context, with an emphasis on the linkages between energy and development.

http://energie.enda.sn/index.html

E-Mail: enda.energy@orange.sn

International Solar Energy Society (ISES)

The global association for solar energy manufacturers, suppliers, enterpreneurs, consultants, policy-makers, and users. The society has an African branch based in South Africa.

http://www.ises.org

ISES Africa contact: Prof Dieter Holm

E-Mail: dieterholm@worldonline.co.za

Kenya Green Energy Foundation

A registered charity that aims to help people and businesses throughout Kenya to reduce their carbon emissions through the use of energy efficiency measures and renewable energy sources.

http://www.kengef.org

E-Mail: info@kengef.org

Kumasi Institute of Technology and Environment (KITE)

A Ghana-based group that contributes towards sustainable energy and industrial development based on technological capabilities, implements action research projects and undertakes feasibility studies and project management and evaluation.

http://kiteonline.net

E-Mail: info@kiteonline.net

Mali Folkecentre (MFC)

An NGO that aims to promote sustainable management of natural resources and the use of these resources to catalyse local economic growth and sustainable development, by working in partnership with rural populations and local entrepreneurs.

http://www.malifolkecenter.org

E-Mail: specific contacts see website

Practical Action

A UK-based organisation that aids people around the world to choose and use simple but useful technologies. Their main African offices are in Sudan, Zimbabwe, and Kenya. The Zimbabwe and Kenya offices of PA include “Resource Centres” that hold thousands of print resources on technologies (including energy technologies) which can improve the lives of people in poor regions of the world.

Pratical Action UK contacts: http://www.practicalaction.org

E-Mail: practicalaction@practicalaction.org.uk

Regional contacts see: http://www.practicalaction.org/about-us/contact_us

Sustainable Community Development Services (SCODE)

An NGO and company based in Kenya that provides improved stoves and solar lanterns to businesses, communities, and government groups. SCODE has working relationships with a host of other organisations in Africa working with communities in renewable energy.

http://www.pciaonline.org

E-Mail: scode@africaonline.co.ke

Tanzania Traditional Energy Development and Environment Organization (TaTEDO)

An NGO responsible for developing and promoting renewable energy technologies in Tanzania. TaTEDO is a coalition of individuals, professionals, artisans, farmers, community-based organisations and micro enterprises.

http://www.tatedo.org

E-Mail: energy@tatedo.org

D.2 Resources by chapter

Chapter 3: Types of energy system

Below are some online or downloadable tools that can be used to analyse the cost and feasibility of different energy systems.

Note: These programmes are only as good as the data they use, so a station needs to have a realistic idea of its energy needs and potential solutions before consulting this software.

These tools are a supplement to, but not a replacement for, advice from experienced energy professionals.

Hybrid Optimization Modeling Software (HOMER)

Software developed at the US National Renewable Energy Laboratory as an easy-to-use tool for analysing renewable power systems, distributed power systems, and hybrid power systems. It is available for free download on the HOMER website (the free version expires after six months, however). An excellent decision-making tool that also makes use of NASA data on solar irradiation around the globe.
http://www.homerenergy.com/index.asp
HOMER online users group: http://homerusersgroup.ning.com

RETScreen Clean Energy Project Analysis Software
Excel-based software that can be used worldwide to evaluate the energy production, life cycle costs and greenhouse gas emission reductions for various types of proposed renewable energy technologies compared to conventional energy projects. Available in 35 languages, and has over 200,000 users in over 200 countries (as of February 2010).
Available for free download. http://www.retscreen.net

Hybrid2
The Hybrid2 software package is a user-friendly tool for performing detailed long-term performance and economic analysis of a wide variety of hybrid power systems. Hybrid2 is a probabilistic/time series computer model, using time series data for loads, wind speed, solar irradiation, temperature and the power system designed or selected by the user, to predict the performance of the system. Available for free download. Developed by a team at the University of Massachusetts.
http://www.umass.edu/windenergy

Village Power Optimization Model for Renewables (VIPOR)
A free downloadable application that calculates the best way of distributing RETs in a village. Only for villages, not individual households (or individual radio stations).
http://analysis.nrel.gov/vipor/default.asp

GSM World "Decision Tree"

GSM World is a mobile phone network website, and features a set of pages on "Green power for mobile" i.e. the use of renewable technologies (especially solar and wind power) to power base stations for mobile networks. These pages include a useful "decision tree" that is designed to inform network operators about the benefits and challenges of RETs, and to suggest solutions to potential barriers to using such technologies.

http://gsmworld.com/our-work/mobile_planet/green_power_for_mobile/decision_tree/index.htm

Chapter 5: Renewable energy technologies

Solar power:

PVWatts Version 1 (Performance Calculator for Grid-Connected PV Systems)

A calculator that estimates the electrical energy produced by a solar panel with specifications entered by the user. Users enter their location, the rated output of a proposed panel, and other data. The tool uses irradiation data and the user's latitude to calculate the energy output of the panel for each month of the year. Data are only provided for particular stations within some African countries: Kenya, Senegal, Zimbabwe, Ghana, Ethiopia, Egypt, Tunisia, and Morocco.

http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/

Solar Energy Directory

A recently established, US-based directory covering a broad range of topics from suppliers and manufacturers to news and research. However, the results are not ordered by country, the directory is not yet large, and the site has a strong US-focus.

http://solarenergydirectory.com/news/

Solar Expo

Global list of solar energy providers that includes a good number of sales and wholesale dealers in African countries. Some of the listings may be out of date, since the site is not regularly maintained.

http://www.solarbuzz.com/solarindex/expo.asp

ENergy Focus (ENF) business directory

An up-to-date directory of solar businesses around the world, including a number in Africa (serving South Africa, Malawi, Kenya, Ghana, Nigeria, Zambia, Senegal, Namibia, Mozambique, Cameroon, Botswana, Ethiopia, Uganda).

http://www.enf.cn

NASA solar and wind resource data

Free resource for worldwide data on wind and solar resources. Includes plain text data and coloured maps for a wide range of parameters from daily cloud cover to precipitation. The site provides yearly, monthly, daily, and even hourly data for regions as small as 100 square kilometres. The site also includes a list of units and definitions related to solar energy. Users need to sign on with an email address and password, but the service is free.

http://eosweb.larc.nasa.gov/sse/

PV Estimation Utility

A simple online tool for viewing maps of solar irradiation in Africa. Users can also input the location, power, inclination and orientation of an installed solar panel, and estimate how much energy it will generate on their site.

http://sunbird.jrc.it/pvgis/apps/pvest.php?lang=en&map=africa

Underwriters Laboratories (UL) Certification Directory

Online directory of solar products certified by the US-based certification authority UL.

http://database.ul.com/cgi-bin/XYV/cgifind.new/LISEXT/1FRAME/quickguide.html

Technischer Überwachungsverein (TÜV) Certification Directory

Online directory of solar products certified by the German-based certification authority TÜV.

http://www.tuvdotcom.com

Build It Solar

A popular site devoted to plans, information and tools for do-it-yourself renewable energy projects. Includes a set of useful tools for solar resource assessment and analysis.

http://www.builditsolar.com

Build It Solar Forums

A list of online forums related to renewable energy, especially solar, compiled by the author of the "Build It Solar" site.

http://www.builditsolar.com/References/Forums.htm

International Energy Agency (IEA) Case Studies

A report on 16 case studies of solar power projects in developing countries, compiled by the International Energy Agency (available for download under their "Publications" section).

http://www.iea-pvps.org

Florida Solar Energy Center (FSCE) Solar Glossary

A quick introduction to solar technology, including a substantial glossary of solar power terms.

http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics

International Solar Energy Society (ISES)

African representative (as of March 2010): Professor Dieter Holm,
E-Mail: dieterholm@worldonline.co.za

The global umbrella group for solar consultants, dealers, installers, and consumers.

http://www.ises.org

Some companies that can maintain and service solar power systems in Africa

Kenya

Mr. Mark Hankins (Renewable Energy Consultant)
P. O. Box 18092, 00100 G. P. O., Nairobi, Kenya
Tel.: 00254-20-2725297
Mobile: 00254(0)722 527710
E-Mail: mhankins@africaonline.co.ke

Ghana, Togo, Ivory Coast

Energiebau Sunergy Ghana Ltd.
Springfield Road 3, Peduase E.R.
P.O. Box 23, Aburi, Ghana
Tel.: 00233 28913114 or 00233 2446849 48
E-Mail: vermeerghana@hotmail.com

Nigeria

Nayotroptech

Mr. Okenwa Anayo Nas,
No. 250 Ogui Road, Enugu / Nigeria
Tel.: 00234 80 331 35657
Fax: 00234 42 300461
E-Mail: nayotroptech@yahoo.com

Tanzania, Kenya, Rwanda and Zambia

Renerg Tanzania

Mr. Livinus Manyanga
P.O. Box 13954, TASO Agricultural show ground Njiro,
Arusha, Tanzania
Tel.: 00255-754-662646 or 00255-713-511719
E-Mail: l_manyanga@yahoo.com or kakute@tz2000.com

Wind power:

Africa Wind Energy Association (AfriWEA)

Trade association for wind energy in Africa. Mainly interested in large scale wind energy i.e. wind farms, but the site contains a good link list. The current website includes country by country information on wind resources, contacts, and organisations. The quality of this information varies from country to country. http://www.afriwea.org

All small wind turbines

Website claiming to list all the world's small wind turbines, and giving technical data and price (in Euros) for most of them.
http://www.allsmallwindturbines.com

Scoraig Wind Electric

Website by Hugh Piggott, UK-based expert on small wind power, including small wind power in Africa. Includes information on home-built wind turbines, and on small scale wind projects in Cameroon, Madagascar, and Tanzania. http://www.scoraigwind.com

Wind Energy Businesses in Africa (Source Guide)

Listing of wind turbine manufacturers and dealers around the world, sorted by country.

http://energy.sourceguides.com/businesses/byP/wRP/byGeo/byC/byC.shtml

African Wind Power

South Africa-based manufacturers of "Heavy Metal" wind turbines. These are long lasting heavily built machines with large diameter, designed to operate well at low wind speeds. African wind power distributors serve Kenya, Uganda, Namibia and South Africa.

http://www.africanwindpower.com

Wind Power Terms Glossary

A long and relatively technical glossary of wind power terms.

http://www.otherpower.com/glossary.html

National Renewable Energy Laboratory (NREL) Wind Energy Payback Period Workbook

An excel spreadsheet tool that can help to analyse the economics of a small wind electric system and decide whether wind energy will work for a station. It asks the user for information about how the system will be financed, the characteristics of the site, and the properties of the wind turbine being considered. It then estimates a payback time in years.

http://ww.nrel.gov/wind/docs/spread_sheet_Final.xls

NASA Solar and Wind Resource Data

Free source of data on worldwide wind resources. Includes plain text data and coloured maps for a wide range of parameters from daily cloud cover to precipitation. This data can give an idea of the wind resource in a location, but it is not a substitute for a professional wind assessment.

http://eosweb.larc.nasa.gov/sse/

The World of Wind Atlases

A source of information on wind atlases around the world with two examples from sub-Saharan Africa: Mali and South Africa.

http://www.windatlas.dk

Logic Energy

A UK-based company specialising in live monitoring of weather and energy data at a site; the data can be uploaded automatically to the web using GSM mobile phone networks. Their products include a data logger for conducting wind assessments.

http://www.logicenergy.com

Better Generation

A UK-based company that sells the Power Predictor, a combined anemometer and solar detector that automatically uploads and analyses wind and sun data once the device is installed at a site.

http://www.bettergeneration.com

Wind Survey UK

A company specialising in anemometers and other wind assessment products.

http://www.windsurvey.co.uk

Hydro power:

Micro Hydropower Web Portal

A useful all-purpose website on micro-hydro power in developing countries, run by an Africa-based expert. Includes lists of consultants, suppliers experts and organisations involved in micro-hydro power, an active discussion forum, case studies, and detailed technical information about the different components of hydropower and different kinds of turbine.

http://microhydropower.net/index.php

Pico Hydro Resources (Nottingham Trent University, UK)

A useful set of resources relating to the work by a now disbanded research group on pico-hydro at Nottingham Trent University in the UK. The site includes an introduction to the main types of pico-hydro system, publications by the research unit, technical and non-technical manuals on pico-hydro systems, reports on pico-hydro case studies (including some in Africa), and information about where the unit's researchers are and how they can be contacted.

http://www.eee.nottingham.ac.uk/picohydro

Hydropower Glossary

A short glossary of hydro-power terms produced by the US Department of Energy

http://www1.eere.energy.gov/windandhydro/hydro_glossary.html

River Turbine Summary (Practical Action)

An online summary of the principles behind river turbines drawing directly on the kinetic energy of a natural stream or river. The document includes some further references on the topic of river turbines.

http://practicalaction.org/practicalanswers/product_info.php?products_id=362

Motors as Generators for Micro-Hydro Power
(Nigel Smith, ITGD Publishing, 2001)

A thorough (92 pages) introduction to the use of motors as generators in micro-hydro systems. It is intended to help local manufacturers and rural development engineers select a motor and convert it for use as a generator for a micro-hydro scheme.

http://www.cd3wd.com/cd3wd_40/JF/JF_OTHER/BIG/Motors%20as%20Generators%20-%20N.%20Smith,%20%20ITDG%20UK%201994.pdf

International Network on Small Hydro Power (IN-SHP)

Since its establishment in 1994, the IN-SHP has worked to promote small hydro-power development with the aim of rural electrification.

http://www.inshp.org

Best Practices for Sustainable Development of Micro Hydropower in Developing Countries
(Khennas, Smail and Andrew Barnett, World Bank/ESMAP, 2000)

An in-depth report on the experience of micro-hydro developments in Sri Lanka, Peru, Nepal, Zimbabwe and Mozambique. The report gives a comparative economic analysis of the cost and financial returns of a sample of plants across the five countries. It focuses on large micro hydro plants, between 10 kW and 200 kW in power output, and on mini-grid applications of the power.

http://www.microhydropower.net/download/bestpractsynthe.pdf

Pico-Hydro for Village Power: A Practical Manual for Schemes up to 5 kW in Hilly Areas (Nottingham Trent University, 2001)

A 21-page online guide giving clear instructions on the design and installation of pico-hydro schemes on a local level. Designs are recommended which emphasise simplicity, low maintenance, and long life expectancy. A valuable and readable introduction to the topic, written by pico-hydro experts at Nottingham Trent University in the UK.

http://www.eee.nottingham.ac.uk/picohydro/docs/impman(ch1-6).pdf

Animal power:

Production d'Electricité par Traction Animal (PETRA) technology (RFI Planète Radio, 1997)

A short introduction (in French) to the PETRA system. RFI Planète Radio developed the PETRA system. Contact RFI Planète Radio for further information about the system.

http://hippotese.free.fr/blogdocs3/rfi-planete-radio-boeuf.pdf

http://www.rfiplaneteradio.org, E-Mail: contact@rfiplaneteradio.org

Biogas:

Biofuels in Africa: Growing small-scale opportunities (IIED, 2009)

Summary of recent biofuel enterprise in Africa, mainly initiated by European companies and working with local farmers. Produced by the International Institute for Environment and Development (IIED).

http://www.iied.org/pubs/pdfs/17059IIED.pdf

Below are some biogas projects in Africa (as of 2010). All of the following are carried out by the SNV (Netherlands Development Organisation).

Rwanda

The Rwandan National Domestic Biogas Programme targets 15,000 biogas installations by 2011, serving an estimated 90,000 people. The project includes technical advice on biogas, development of biogas enterprises, and lobbying the Rwandan government for policies in favour of renewable energy (e.g. tax

reduction measures).
www.snvworld.org/en/countries/rwanda/ourwork/Pages/energy.aspx

Ethiopia
The National Biogas Programme in Ethiopia began in 2008 with the construction of 100 plants in four regions (Tigray, Oromia, Southern region and Amhara). The programme aims to construct another 14,000 plants in Ethiopia by 2013.
www.snvworld.org/en/countries/ethiopia/ourwork/Pages/energy.aspx

Tanzania
In the first phase of the Tanzania biogas programme, SNV and the Tanzania Biogas Stakeholders Group (TBSG) plan to construct 12,000 new biogas plants. This is expected to directly affect around 72,000 people by eliminating the need to collect firewood. According to SNV, Kilimanjaro, Mbeya, Iringa, and Ruvuma are the areas in Tanzania with the most biogas potential.
www.snvworld.org/en/Documents/SNV%20-%20Domestic%20Biogas%20Brochure%20Tanzania.pdf

Chapter 6: Gensets

Reducing Rural Poverty Through Increased Access to Energy Services: A Review of the Multifunctional Platform Project in Mali (UNDP, 2004)
Report (81 pages) available in French and English on the use of the multifunctional platform in programmes in Mali up to 2001. Includes details about the planning, financing, and institutional background to the technology. Produced by the UN Development Programme.
http://www.undp.org/environment/sustainable-energy-library.shtml

Chapter 7: Electrical storage and regulation

Batteries and Charge Control in Stand-Alone Photovoltaic Systems: Fundamentals and Application (Sandia National Laboratories, 1997)
71-page guide to batteries in off-grid systems. Includes types of battery, selection of battery, charge control issues, and matching battery size to solar panels. Designed for batteries used in solar power systems, but suitable for other off-grid

battery applications.
http://www.fsec.ucf.edu/pvt/resources/publications/pdf/FSEC-CR-1292-2001-1.pdf

Lead-Acid Battery Guide for Stand-Alone Photovoltaic Systems (IEA, 1999)
33-page guide for users of lead-acid batteries, including maintenance, installation, and safety. Produced by the International Energy Agency.
http://www.iea-pvps.org/products/download/rep3_06.pdf

Chapter 8:
Planning for long-term management of energy technology

Training:

The following is not an exhaustive list of training sources in Africa. Most of the sources below do not run regular training courses suitable for radio station staff, but they have the expertise to do so. If station staff needs training in energy technology, it is always worth consulting the local university to find out whether they have the expertise to offer a course.

University of Dar es Salaam, Centre of Engineering and Technology
A research centre in Tanzania with a strong outreach programme. The university also runs a Masters programme in renewable energy that is part of the "Promoting Renewable Energy Project" supported by the EU and the International Solar Energy Society (ISES). Masters course (MA) details online at
http://prea.ises.org/Documents/MSc_Tanzania.pdf
Centre of Engineering and Technology, E-Mail: principalcoet@udsm.ac.tz

Bethel Business and Community Development Centre, Lesotho
A private agency in Lesotho whose main goal is to develop the human, economic and technical potential of the area through practical education.
http://www.bbcdc.org.ls
Managing Director and Principal: Ivan Yaholnitsky, Tel: 266-5874-2991,
E-Mail: bbcdc@ilesotho.com

Uganda Martyrs University

University that runs a Masters programme in Environmental Design as part of the ISES "Promoting Renewable Energy in Africa" project.

Online at http://prea.ises.org/Documents/MSc_Uganda.pdf

Administrator, Faculty of the Built Environment: Tel: +256 38 241 0611,

E-Mail: fbe@umu.ac.ug

Energy, Environment and Climate Research Group at the University Eduardo Mondlane, Mozambique

University in Mozambique that runs a Masters programme in renewable technology and has been involved in wind power in Mozambique through The Clean Energy Company.

http://www.uem.mz

The Energy Centre, Kwame Nkrumah University of Science and Technology (KNUST), Ghana

The Energy Centre runs annual short courses (one to two weeks long) to help build local and sub-regional capacity in the development and utilisation of renewable energy technologies. The 2010 courses covered solar panel sizing and installation, grid connection, and biogas technology.

http://energycenter.knust.edu.gh

Energy course contacts: Tel: 233 (026) 6755479 / (024) 7590828,

E-Mail: reep_tec@knust.ed.gh or david.ato.quansah@gmail.com

International Institute for Water and Environmental Engineering (2iE), Burkina Faso

The Institute has a strong focus on energy issues.

http://www.2ie-edu.org

DENG Solar Training Centre (DSTC), Ghana

DENG is a Ghana-based engineering firm that runs training courses in the design, installation and maintenance of solar power systems. The DSTC also organises Solar Awareness Workshops at selected rural townships.

http://www.dengltd.com

Tel: +233 21 257099, +233 21 257100,

E-Mail: fbosteen@dengltd.com or info@dengltd.com

Online forums:

A short list of online forums devoted to renewable energy technology, in Africa and elsewhere.

Global Village Energy Partnership (GVEP)

GVEP is an international non-profit organisation working to reduce poverty by accelerating access to affordable and sustainable energy services. It has links to over 2000 organisations worldwide working on sustainable energy in developing countries. It is free to register for the website, which includes access to GVEP's database of energy-based projects, funding opportunities, organisations and an online forum.
www.gvepinternational.org

Household Energy Network (HEDON)

An online network of people, organisations and projects interested in household energy solutions in developing countries. HEDON focuses mainly on non-electrical energy, such as improved stoves and biomass.
http://www.hedon.info

Knowledge and Information Base for Energy Solutions in Africa (Kibesa)

An online forum for information and discussion about energy in Africa, set up by the Capacity Enhancement and Mobilisation Action for Energy in Africa (CEMA), as part of the EU-Africa Energy Partnership. It is free and relatively easy to become a member of the wiki.
http://kibesa.wikispaces.com

Solar Power Forum

An active, US-based forum on solar power, with a list of posts running well into the thousands. Free to register and to ask questions.
http://www.solarpowerforum.net

List of Renewable Energy Forums

A list of online forums related to renewable energy, compiled by the author of the popular "Build It Solar" site.
http://www.builditsolar.com/References/Forums.htm

Micro Hydropower Discussion Forum

An online discussion forum on micro hydropower set up by the South Africa-based expert on hydropower, Wim Jonker Klunne. The purpose of the forum is to exchange information on technical as well as non-technical issues concerning micro hydro.

http://microhydropower.net/mhp_group

Chapter 10: Case studies

Below are contact details for the stations that featured as case studies in **Chapter 10**.

Radio Voice of Life (Uganda)

Voice of Life station: E-Mail: arua@diguna.de, Mr. Frank Knuepfer, technician and head of station: E-Mail: frank.knuepfer@diguna.de.

DIGUNA mission society: http://www.diguna.de, Mr. Kurt Zander,

E-Mail: kurt.zander@diguna.de,

Radio Pacis (Uganda)

http://www.radiopacis.org,

Fr. Tonino Pasolini, director: E-Mail: tonino.p.arua@sat.signis.net and/or media.centre@sat.signis.net

Radio Voice of Peace (Sudan)

Sudan Catholic Radio Network (SCRN)

http://www.sudancatholicradio.net.

Directress: Sr. Paola Moggi: E-Mail: scrn.director@gmail.com

Radio Voice of Peace Directress: Sr. Mary Carmen Galicia Alfaro,

E-Mail: voiceofpeace2008@gmail.com

Fadeco Community Radio (Tanzania)

Joseph Sekiku, station director and technical manager:

E-Mail: sekiku@satconet.net

Devotha Martine, station manager: E-Mail: devomart@yahoo.com

Réseau Étoile stations (Haiti)
Pierre Bélanger, International Co-ordinator of Réseau International:
E-Mail: pierre.belanger@jesuites.org

Radio Pikon Ane (Indonesia)
Tessa Piper, Indonesia Media Loan Development Fund:
E-Mail: tessa@minihub.org

The following case study may also be of interest. The UK branch of the cell-phone company Motorola produced a report on genset, solar and wind power in Africa. The report is based on a series of trials of energy options for the company's GSM base stations in Africa. They found that various combinations of wind and solar were the most practical, since the site did not have continuous sunshine – but on cloudy days it was usually windy. The report also concludes that wind turbines smaller than 3 kW were not cost effective, being more unreliable than solar power for only a slightly smaller investment.
http://www.motorola.com/mot/doc/6/6682_MotDoc.pdf

Chapter 11: Energy policy and enterprise

Energy and policy:

The following websites contain information on current and recent initiatives related to renewable energy technology and carried out by African governments.

Renewable Energy Policy Network (REPN) Global Status Report
A comprehensive global report on the state of renewable energy technology, investment, and policy.
http://ren21.net/publications/default.asp

International Energy Agency (IEA), Global Renewable Energy: Policies and Measures
International Energy Agency database of policies and measures adopted by national governments around the world to increase energy efficiency and the use of renewable energy in their countries.
http://www.iea.org/Textbase/pm/grindex.aspx

Global Network on Energy for Sustainable Development (GNESD)

GNESD is a UNEP facilitated knowledge network of developing world Centers of Excellence and network partners. The main objective of GNESD is to carry out policy analysis on thematic energy issues which can facilitate towards reaching the Millennium Development Goals (MDG). http://www.gnesd.org

Renewable Energy and Energy Efficiency (Reegle)

Website produced by Renewable Energy and Energy Efficiency Partnership (REEP) and Renewable Energy Policy Network (REN21) that collects information on events, groups, people, policies, and publications related to energy efficiency and renewable energy worldwide.
http://www.reegle.info

Energy Interventions in Africa (Kibesa)

A list of projects, policies and programmes related to renewable energy in Africa. The list appears on the Kibesa wiki, an online hub for renewable energy in Africa set up as part of a joint Africa-EU project.
http://kibesa.wikispaces.com

African Energy Policy Research Network (AFREPREN)

A group of nearly 100 energy policy experts in Africa. AFREPREN was formed in 1987 to bring together government policy and energy research, and since then has (among other things) published 14 books on energy policy, covering many countries in Sub-Saharan Africa. The AFREPREN website includes a list of working papers on energy policy. AFREPREN is a key source on energy policy in Africa.
http://www.afrepren.org,
E-Mail: stephenk@africaonline.co.ke or afrepren@africaonline.co.ke

End notes

[1] Oil price history and projections taken from the website of the Energy Information Administration, of the U.S. Department of Energy. Data originally published as International Energy Outlook 2010; www.eia.doe.gov/oiaf/ieo/pdf/liquid_fuels.pdf, accessed July 20 2010.

[2] Light bulb data used with permission of National Renewable Energy Laboratory, originally published in *Renewable Energy for Rural Schools*, November 2000; www.nrel.gov/docs/fy01osti/26222.pdf, accessed March 2010. Energy cost data from World Bank and Energy Sector Management Assistance Programme, *Technical and Economic Assessment of Off-Grid, Mini-Grid and Grid-Connected Electrification Technologies*. Washington, D.C.: World Bank and ESMAP, 2007: ESMAP Technical Paper 121/07, pp. 54-57.

[3] Genset data applies to the 2007 Yamaha Premium EF4000DE (note: the maximum AC output of this model is 4 kW, but the rated AC output [the value given in the text] is 3.5 kW). Data originally published as *2007 Yamaha Premium EF4000DE Data sheet*.
www.yamaha-motor.com/outdoor/products/modelspecs_pdf.aspx?ls=outdoor&mid=447&showprevmodel=0, accessed July 21 2010.

[4] Energy cost data from World Bank and ESMAP, *Technical and Economic Assessment of Off-Grid, Mini-Grid and Grid-Connected Electrification Technologies*, pp. 54-57.

Bibliography

Bale, M., and Launay, G., *PETRA: Production d'Electricité par Traction Animal*. Planète Radio, 2007

Barnes, F. (ed.), *The Challenge of Rural Electrification: Strategies for Developing Companies*. Washington, D.C.: Resources for the Future, 2007

Cabraal, A., Cosgrove-Davies, M., and Schaeffer, L., *Best Practices for Photovoltaic Household Electrification Programs*. Washington, D.C.: World Bank, 1996: World Bank Technical Paper #324

Dunlop, J. and Farhi, B., *Recommendations for Maximising Battery Life in Photovoltaic Systems: A Review of Lessons Learned*. University of Central Florida: Florida Solar Energy Centre, 2001

Dunlop, J., *Batteries and Charge Control in Stand-Alone Photovoltaic Systems: Fundamentals and Applications*. University of Central Florida: Florida Solar Energy Centre, 1997

Florida Solar Energy Centre, *Glossary of Solar Power Terms* www.fsec.ucf.edu/en/consumer/solar_electricity/basics/index.htm, accessed May 2010

Foley, G., *Photovoltaic Applications in Rural Areas of the Developing World: World Bank Technical Paper 304*. World Bank

Geerts, A., Appendix 1: Basic Technical Data, in *World Bank Community Radio Training Manual*. Washington, D.C.: World Bank, 2006 - unpublished

Grimshaw, D., *Solar Power: Coming Out From Behind a Cloud?* Warwickshire: Practical Action UK, 2006: Practical Action New Technology Briefing Paper No. 4

International Energy Agency, *Renewables in Global Energy Supply*. Paris: IEA, 2007

International Institute for Environment and Development, *Biofuels in Africa: Growing Small-Scale Opportunities*. London: IIED, 2009

Jimenez, J., and Lawand, T., Originally published as *Renewable Energy for Rural Schools*. Golden, Colorado: US National Renewable Energy Laboratory, 2000: www.nrel.gov/docs/fy01osti/26222.pdf, accessed March 2010

Kemp, W., *The Renewable Energy Handbook: A Guide to Rural Independence, Off-Grid and Sustainable Living*. Gazelle Drake Publishing, 2006

Mapako, M. and Mbewe, A (eds.), *Renewables and Energy for Rural Development in Sub-Saharan Africa*. Zed Books, 2004

McKay, D., *Sustainable Energy Without the Hot Air.* Cambridge: UIT Cambridge, 2009

NASA Surface Meteorology and Solar Energy data. http://eosweb.larc.nasa.gov/sse/, accessed March 2010

NASA, *Glossary for Surface Meteorology and Solar Energy.* http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s07#s07, accessed May 2010

National Renewable Energy Laboratory, *Small Wind Electric Systems: A U.S. Consumer's Guide*. US Department of Energy, 2007

Otherpower, *Glossary of Windpower Terms.* www.otherpower.com/glossary.html, accessed May 2010

Practical Action UK, *Energy from the Wind.* Warwickshire: Practical Action UK, 2008

Practical Action UK, *Micro-Hydro Power: Technical Briefing*. Warwickshire: Practical Action UK, undated

Practical Action UK, *Wind for Electricity Generation: Technical Briefing*. Warwickshire: Practical Action UK, undated

Reducing Rural Poverty Through Increased Access to Energy Services: A Review of the Multifunctional Platform Project in Mali. United Nations Development Programme, 2001

Solari, G. and Stevens, E., *River Turbines: Technical Brief.* Warwickshire: Practical Action UK, 200?

US Department of Energy, *Get Your Power From the Sun: A PV Consumer's Guide*. USA DOE, 2003

Wilson, E. and Zersky, L., *Power to the Poor: Sustainable Energy at the Base of the Pyramid.* London: International Institute for Environment and Development, 2009: IIED Briefing Paper

World Bank and Energy Sector Management Assistance Programme, *Technical and Economic Assessment of Off-Grid, Mini-Grid and Grid-Connected Electrification Technologies*. Washington, D.C.: World Bank and ESMAP, 2007: ESMAP Technical Paper 121/07

World Bank, "Technology module," in *REToolkit: A Resource for Renewable Energy Development: Issues Note*. Washington, D.C.: World Bank, 2008

Glossary

Words that are bold in the definitions are defined elsewhere in the glossary.

Alternating current (AC): Electric current in which the direction of the flow oscillates at frequent, regular intervals.

Alternator: A device that produces **alternating current** from the rotation of a shaft.

Amorphous (thin film) silicon: A form of silicon that has no crystal structure and can be applied in thin layers.

Anemometer: A device for measuring the speed and direction of the wind at a site.

Angle of incidence: The angle at which the sun's radiation strikes a surface. A "normal" angle of incidence is 90° i.e. the sun strikes the surface at right angles.

Annualised cost: The average cost per year of an energy source over its lifetime.

Autonomy, days of: The number of days that a full battery bank can power a load or loads without drawing on other energy sources. This is important during, for example, rainy or cloudy periods.

Battery bank: An array of batteries connected in **series**, **parallel**, or both.

Battery cell: A device that releases electrical energy as a result of chemical reactions in the cell.

Betz Coefficient: 59.3%. This is the theoretical maximum efficiency at which a wind turbine can operate. If the turbine slows the wind down too much, air piles up in front of the blades and is not used for extracting energy.

Biogas: Gas produced by the breakdown of biological matter, such as manure, sewage, or plant matter, in the absence of oxygen.

Biogas digester: A machine that digests organic matter to produce methane gas.

Blade: The part of a wind turbine rotor that catches the wind.

Bonded earthing: An **earthing system** in which all connections to earth are earthed at the same point.

Briquettes: Compact fuel sources made out of charcoal, agricultural waste, straw, hay, coconut husks, wood chips, or other flammable matter.

Bulk charge: Charges a battery up to a **state of charge** when **gassing** starts and the voltage rises; the battery is then 80–90% charged. Also called the main charge or full charge.

Capacity (Amp-hours): The amount of charge stored in a battery. A battery with 2,000 Ah will deliver 20 A for 100 hours, 50 A for 40 hours, and so on.

Carbon credits: Credits earned by companies for reducing carbon emissions. Carbon credits can be bought and sold.

Ceramic jiko: A portable charcoal stove with an hourglass shape, consisting in a ceramic basin supported by a metal lining. The stove is thought to reduce charcoal use by 30–50% compared to ordinary cooking stoves in use in Africa.

Channel: The man-made structure that carries water from a river to a **penstock** in a hydro scheme.

Charge controller: A device that controls the rate at which current from an energy source charges a battery.

Compact fluorescent light bulb (CFL): An energy efficient light bulb that uses a vacuum, rather than heat, to produce light.

Consumer: Any device or appliance that consumes electricity.

Credit union: An organisation that works to help its members save money and draw loans.

Critical load: A device or appliance that has a high priority as an energy consumer.

Current (I): 1. A flow of **electrons**, usually in a conducting wire.
2. The rate at which electrons flow through a wire, measured in **Amps (A).**

Customs tax: Taxes levied by a government on goods entering the country.

Cut-in wind speed: The wind speed at which a wind turbine will start producing **power**.

Data sheet: A summary of the technical specifications of a technology.

Deep-cycle lead-acid battery: A standard class of battery for electricity storage with **RETs**. "Lead-acid" means the battery has lead plates and acidic **electrolyte**. "Deep-cycle" means that (unlike a car or truck battery) it can be regularly discharged to around 50% of its **capacity**.

Depth of discharge: The amount of charge that has been removed from a battery, as a percentage of the battery's **capacity**.

De-rating factor: The amount by which the **rated** performance of a technology needs to be revised to give the actual performance, usually expressed as a percentage of the rated performance.

Design month: The month with the lowest ratio of energy production to energy consumption. If an **RET** is sized for the design month, energy will be sufficiently, or even amply, available every month.

Direct current (DC): Electrical current flowing in one direction only.

Dump load: A **load** that absorbs the excess electricity from an **RET**; often a water or space heater.

Earthing system: A system for conveying excess electricity to the earth, guarding people against electric shock and shielding electrical devices from current surges (during lightning, for example).

Efficiency: The ratio of the output power of a technology to its input power, expressed as a percentage.

Electrical generator: A device that converts the energy of a rotating shaft into electrical energy. Electrical generators are built into some energy generating technologies, including wind turbines, hydro turbines, and gensets.

Electrolyte: The substance in a battery that reacts with the plates to produce electrical current.

Electron: A sub-atomic particle with a negative charge.

Energy : The capacity to do physical work. The standard unit of energy is the Joule (J). Energy is also measured in kilowatt-hours (kWh).

Energy assessment: A study of the energy needs of a person, physical site, or organisation.

Energy generating technology: Any technology that converts chemical, mechanical, solar or other energy into electrical energy. Includes solar panels, wind turbines, hydro turbines, gensets, etc. (often abbreviated to **generating technology** in this guide).

Energy source: Any device or material that can deliver useful energy to a radio station.

Equilisation charge: Delivers a high **voltage** to a battery when it is at or near a full **state of charge**, resulting in overcharging and **gassing**. Used periodically for flooded batteries to remove charge differences between cells and to mix the **electrolyte**.

Feed-in tariff: Charges levied on utility companies for the electricity they receive from renewable sources. The charges are paid to suppliers of renewable energy, to encourage **RET** enterprise.

Float charge: Holds a battery at a full **state of charge** when it is fully charged but not frequently used. Also called the maintenance charge.

Float life: The lifetime of a battery if it is unused but kept fully charged by a **float charge**.

Flow rate: The amount of water that enters the **intake weir** of a hydro scheme, in m^3 per second.

Fossil fuels: Fuels derived from ancient deposits of carbon. Fossil fuels such as diesel or gasoline are contrasted with vegetable- or animal-based fuels such as **jatropha oil**.

Furling wind speed: The wind speed at which a wind turbine is turned out of the wind to prevent damage.

Gassing: The process of a battery releasing gasses when it is overcharged.

Generating technology: Abbreviation of **energy generating technology.** Any technology that converts chemical, mechanical, solar or other energy into electrical energy. Includes solar panels, wind turbines, hydro turbines, gensets, etc.

Generator: A device that converts the energy of a rotating shaft into electrical energy. Generators are built into some energy generating technologies, including wind turbines, hydro turbines, and gensets.

Genset: A device (such as a diesel generator) that converts the chemical energy of fuel into electricity, using a combustion engine and an electrical generator.

Grid: The network of transmission lines, distribution lines, and transformers used in central power systems. "Grid power" is used interchangeably with "public power supply" in this guide.

Grid-connected system: An energy system that draws on the public power supply, and/or feeds power to the public power supply.

Guy ropes: Ropes or cables used to support the pole or tower of a wind turbine.

Head: For a hydro power scheme, the vertical height of the top of the **penstock** above the turbine.

Hertz (Hz): A unit of frequency, used to measure the rate at which **alternating current** changes direction. One Hz is one cycle per second.

Hub: The forward-facing part of a wind turbine where the **blades** meet.

Hybrid system: An energy system that uses both a **genset** and one or more **RET**s. Sometimes used to refer to energy systems that use both the public power supply and other energy sources.

Hydrometer: A device for measuring the **specific gravity**, or density, of a liquid.

Impulse turbine: A hydro turbine design where water hits blades that spin freely in air.

Initial cost: The total cost of installing an energy technology, including transport, material, and labour costs.

Insolation: The solar energy that strikes a surface, usually expressed in W/m^2

Intake weir: The point at which water from a river is diverted to the **channel** in a hydro scheme.

Inverter: A device that converts **direct current** into **alternating current**.

Jatropha oil: Vegetable oil produced from the seeds of the jatropha plant.

Joule (J): The standard unit of **energy**. About 4 J are required to heat 1 gramme of water by 10° Celsius.

Levelised cost: The average cost per kWh of an energy source over its lifetime.

Life cycle cost: The total cost of a system over the period of its useful life, including **initial** and **running** costs.

Light emitting diode (LED): An energy efficient light form, often used as a light source in electronic displays.

Load: The amount of electrical power being consumed at any given moment. Also, any device or appliance that is drawing **power**.

Low voltage disconnect (LVD): The battery **voltage** at which a **charge controller** disconnects **loads** to protect the battery from excessive discharging.

Low-load efficiency: The **efficiency** of a **genset** when it delivers energy to small loads.

Maintenance-free battery: A class of battery that has a solid or gelled **electrolyte** and sealed vents. Also called a voltage regulated lead-acid (VLRA) battery, sealed battery, or captive electrolyte battery.

Maximum design wind speed: The wind speed above which damage could occur to a wind turbine.

Maximum power point tracker (MMPT): A feature of a **charge controller** that holds the electricity from a solar panel at a **current** and **voltage** that result in the maximum possible **power** being delivered to the batteries.

Micro-hydro: A class of hydro schemes ranging from 5 kW to 100 kW.

Mini grid: A small **grid**, usually linking houses and businesses in a village to a small power source.

Modified sine wave: A form of **alternating current** where the **current** varies in small steps.

Mono-crystalline silicon: A material formed from a single silicon crystal.

Multifunctional Platform: A genset designed to serve multiple tasks, e.g. milling, pumping, and battery charging.

Nacelle: The part of a wind turbine that encloses the electrical generator, wiring and (for larger turbines) gears.

Nickel-cadmium battery: Expensive, low-maintenance batteries that use nickel and cadmium rather than lead and acid.

Off-grid energy system: An energy system that does not draw on a public power supply – otherwise known as an island system or stand-alone system.

Overcharge protection: A feature of a **charge controller** that stops charge flow to a battery once it is fully charged.

Payback period: The time it takes for the earnings from an investment to cancel out the cost of the investment. In the context of energy efficiency, it is the time it takes for the savings due to energy efficient equipment to cancel out the extra initial cost of the efficient equipment.

Peak load: The maximum **load** or electrical power consumption occurring in a period of time.

Peak Watts (Wp): The amount of **power** a photovoltaic device will produce under ideal sun conditions.

Penstock: The pipe through which water is conveyed, under pressure, to the turbine of a hydro scheme.

PETRA: Production d'Electricité Par Traction Animal (Electricity Production by Animal Power). A system for generating electricity from the guided movement of large animals.

Pico-hydro: A class of hydro schemes ranging from a few hundred watts to 5 kW.

Poly-crystalline silicon: A material formed from multiple silicon crystals.

Power: The rate at which energy is converted from one form to another. One Watt of power is one Joule of energy per second.

Power curve: A graph showing the **power** of a wind or hydro turbine in different wind and water conditions.

Power draw: The **power** that a device draws from a power supply.

Power factor: An electrical phenomenon that means the actual **power** of some electrical currents is smaller than the **voltage** of the current multiplied by its **current**.

Power strip: A strip of sockets at the end of a flexible cable that allows multiple devices to be plugged in. Can save energy by making it easy to switch off multiple devices; some strips switch off automatically when the connected devices go into standby mode.

Power surge: A sudden increase in **voltage**, **current**, or **frequency**, usually from the public power supply.

PV cell: A photo-electric cell that generates electrical energy when sunlight falls on it.

PV module: A collection of **PV cells** wired together and mounted in a frame.

Rating: The official performance characteristics of a technology, usually only valid in ideal conditions.

Reaction turbine: A hydro turbine design where the blades are fully immersed in moving water.

Rectifier: A device that converts **alternating current (AC)** into **direct current (DC)**.

Renewable energy technology (RET): A technology that converts the energy of natural resources into usable energy, often electrical energy.

River turbine: A hydro turbine that is immersed directly in a naturally occurring river or stream.

Rocket stove: An improved stove that cooks efficiently by ensuring a good air draft to the fire, controlled use of fuel, complete combustion of volatiles, and efficient use of the resulting heat.

Rotor: The part of a wind turbine that rotates, usually comprising the **hub** and **blades**.

Running cost: The costs of operating an energy technology e.g. fuel and maintenance costs.

Self-discharge rate: The rate at which a battery loses charge without any active charging or discharging.

Sine wave AC: A form of **alternating current** where the **current** varies smoothly in a wave pattern.

SLI (starting, lighting, ignition) battery: SLI batteries, such as car batteries, are designed to give a high **current** for a short period and have poor deep-cycle performance. They are cheaper than deep-cycle batteries, but have short lifetimes in off-grid systems.

Specific gravity (SG): A unit for measuring the density of a liquid. A liquid with an SG of 1.2 is 1.2 times denser than water.

Square wave: A form of **alternating current** where the direction of the **current** alternates abruptly.

Start-up wind speed: The wind speed that will turn an unloaded **rotor**; that is, a rotor not connected to an **electrical generator**.

State of charge: The amount of charge present in a battery, as a percentage of its total **capacity**.

Stationary battery: Often found in **UPS** systems, these batteries are designed for infrequent use and low maintenance.

Stratification: The process of **electrolyte** becoming concentrated at the bottom of a battery.

Sulphation: The process of sulphate hardening on the plates of a battery, weakening the battery.

Sun-hour: The amount of **energy** per area delivered to the earth's surface during one hour of full, direct sun. One sun-hour is equivalent to 1,000 W/m^2.

Tail: The part at the back of a wind turbine that orients the turbine to face the wind.

Temperature compensation: An allowance made by a charge controller for changes in the battery temperature.

Tilt angle: The angle of a solar panel (or other collector of solar energy) as measured in degrees from the horizontal.

Tip-speed ratio: The ratio of the speed of the tips of a wind turbine's blades to the speed of the wind.

Top-up charge: Carefully brings a battery to full charge, after a **bulk charge** has brought the battery to a state of charge of about 90%. Also called the tapering charge or absorption charge.

Tracking mount: A mount for solar panels that rotates and/or tilts the panels to track the sun.

Undercharge protection: A feature of a **charge controller** that disconnects loads from a battery once the battery has reached its lowest desirable **state of charge**.

Uninterruptible power supply (UPS): A device that monitors an incoming power supply and provides back-up power when the supply fails.

User manual: A booklet describing the construction, operation, and maintenance of a technology.

Ventilation: The process of changing or replacing air in an indoor space to improve the air quality. Includes the expulsion of hot air (from a transmitter room, for example) and toxic fumes (from a battery room, for example).

Voltage (V): The amount of **energy** given to electrons in an electrical circuit.

Voltage monitor: A device that monitors the **current**, **voltage**, and **frequency** of a power supply and shuts off the supply if one or more of those quantities becomes too high or too low.

Voltage regulator: A device that smoothes out the **voltage** of an incoming power supply, protecting electronic equipment connected to the supply.

Watt (W): The standard unit of **power**. One Watt is one Joule of energy per second.

Yaw bearing: The mount of a wind turbine that allows the turbine to rotate on its pole or tower.

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Elmar Dimpl is a freelance energy consultant frequently working for GTZ, a federally owned German development organisation. For this guide Mr. Dimpl gave advice on biogas plants and conducted a thorough review of the text.

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Jason Morenikeji is founder and director of **The Clean Energy Company** (www.thecleanenergycompany.com), a company that works with local NGOs, businesses, and a university to manufacture wind turbines in Mozambique (www.thecleanenergycompany.com). Mr. Morenikeji advised on wind energy and on the role of local enterprises in delivering renewable energy. The Clean Energy Initiative is the development branch of the Clean Energy Company.

Neil Noble is a technical adviser for **Practical Action** (http.//practicalaction.org), a development charity that aims to improve the lives of people in developing countries through the application of simple technologies. The UK-based organisation has regional offices in Sudan, Kenya and Zimbabwe, and makes technical information accessible through its resource centres (in Nairobi and Harare, for example) and an online inquiry service. Mr. Noble advised on pico- and micro-hydro schemes.

Hugh Piggott, of **Scoraig Wind Electric** (www.scoraigwind.com), is a Scotland-based wind expert with three decades' experience in the field of small wind power. As well as writing books and leading workshops on small wind turbines, he has advised renewable energy NGOs and enterprises in Africa and other areas of the developing world. He advised on the wind power section of the guide.

Simon Willans is Director of **Energy for Opportunity** (www.energyforopportunity.org), an NGO based in Sierra Leone that provides equipment, installation, and vocational training in solar power systems. He advised on solar power systems for this guide.

Bernd Wolff is Director of Off-grid Systems at **Energiebau** (www.energiebau.de), a German wholesaler of solar panels, batteries, inverters, and all other components for the construction of solar power systems. Energiebau's projects in Africa include the development of jatropha gensets, the distribution of simple solar-powered lighting systems, servicing of existing solar systems, and training technicians to install and maintain solar systems. Mr. Wolff advised on solar power systems for this guide.

Gerd Zeitter is a consultant for **BEGECA** (www.begeca.de), a German company that offers planning, consultancy, procurement and logistics services for projects in countries of the South and the East, including energy projects. Mr. Zeitter's areas of expertise include solar power systems and renewable energy. He gave extensive advice for the guide, especially on solar systems, gensets, and planning an energy system.

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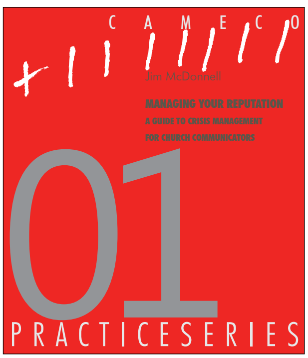

Managing Your Reputation
A Guide to Crisis Management for Church Communicators
By Jim McDonnell

On 48 pages, “Managing Your Reputation” provides guidelines for media communications, and offers concrete advice on how to prepare for a crisis, establish a Crisis Management Team and develop a respective plan of action. In addition, checklist templates for setting up a Crisis Management Plan of Action and for establishing a Crisis Management Team are available for downloading.

The author: Jim McDonnell was Director of the Catholic Communications Centre. Since 2002, he runs McDonnell Communications, an independent communications and public relations advisory service. He is also the Director of Development and Advocacy for SIGNIS, the World Catholic Association for Communication.
Spanish and French translations are in progress and will be available in the near future.

Coming Soon:

Le Public! Quel(s) public(s)?
Guide de l’etude d’auditoire pour les radios locales en Afrique
Par Martin Faye et alii

Knowing the audience is a constant concern for any radio station. Who is listening to the programme? Why and when are people tuning in? Is the actual listenership the expected audience? This guide describes simple and efficient quantitative and qualitative methods, which have been applied and tested by local stations and community radios in francophone Africa. Tips, tools and examples are offered.

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