Energy and Sustainable Tourism

Energy Supply and Use in Off-grid Ecotourism Facilities

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Table of Contents

1. Introduction

Energy is vital to the hotel industry as it is used to power the engineering systems, equipment, appliances and devices that provide the services and the level of comfort expected by its customers. In most cases, hotels are located in areas served by adequate utility grids and road networks and, thus, have access to what often appears to be an endless source of energy. These hotels are able to delegate to their suppliers the responsibility of generating and delivering energy, and assure their energy needs simply by paying their bills on time. They tend to operate with few restrictions on energy consumption since their actions have little or no effect on the immediate availability and reliability of their energy sources. Energy concerns in the design phase of these properties focus primarily on end-use issues, such as the type, number, capacity and cost of the equipment needed to deliver the required services, and, only for the more progressive developers, on the energy efficiency, maintenance requirements and operating costs of the selected equipment.

For off-grid facilities that are located in remote areas, with no convenient access to fuel supplies (diesel, gasoline, kerosene, propane), energy supply and use are much more pressing problems. These properties must become their own electric utility, producing all the electricity they consume and assuming full responsibility for operating and maintaining their power generating systems. They generally have to pay premium prices for the fossil fuels they use, and must carefully watch their energy use to avoid shortages and control their high energy costs (this is also true for hotels connected to the grid but relying on auto-generation for a significant portion of their energy supply).

If necessary, developers can rely on a wide range of renewable and non-renewable energy technologies to overcome power supply problems in off-grid sites, and can build conventional full-service hotels even in the most isolated locations. However, these technological solutions come at a steep price, which can often severely affect the market access, competitiveness and financial viability of the project.

Energy and Sustainable Tourism

Sustainable tourism principles are applicable to all forms of tourism -- from traditional mass tourism to niche tourism segments, such as ecotourism -- and call for the optimal use of natural resources, environmental protection, respect for the socio-cultural aspects of host communities, long-term economic viability of the tourism businesses, and the fair distribution of socio-economic benefits to all stakeholders. Management of energy supply and consumption, therefore, is a critical component of any sustainable tourism project.

Ecotourism, which involves nature-based tourism activities in remote areas chosen for their unique natural and possibly cultural attributes, must apply the principles above to the fullest extent because of the beliefs of its customer base and the sensitive environments in which it generally operates. Although there are no universally accepted guidelines for the design and operation of ecotourism lodging facilities, most agree on a common set of characteristics that clearly differentiate ecolodges from conventional hotels. These characteristics include:

- <u>Size</u> - Ecolodges are small and typically accommodate less than 30 guests.
- <u>Guest type</u> - Ecotourism generally attracts individuals who seek a rich experience based on a close interaction with the natural and cultural elements of the site. They expect operators

to demonstrate sensitivity to environmental and cultural issues in their operations, activities, and in the design and management of their facilities.

- Facilities - The facilities should be unique in character, but designed to be in harmony with the local natural and cultural environment. Emphasis should be placed on simplicity, minimal pollution and disruption to the site, and the elimination of all unnecessary demands on natural resources.
- Services and level of comfort - Although there are exceptions, ecolodges generally are not meant to provide accommodations typical of conventional hotels. Their facilities are usually more basic, though the level of customer service may be very high.
- Guest activities - The activities offered in ecolodges are centered on the surrounding environment rather than on the facility itself (e.g., hiking, safari, bird watching, diving), which typically eliminates the need to provide and operate the energy-intensive amenities that are generally expected in conventional tourist hotels (e.g., heated swimming pools and jacuzzis).

These characteristics have a profound impact on the planning, design and operation of the ecolodges' energy systems, and provide the developers a unique opportunity to create viable lodging projects in remote and off-grid locations.[1]

2. Energy End-uses in Lodging Facilities

Hotels basically use two types of energy: electricity and thermal energy. Electricity, whether purchased from the grid or produced on site from renewable or non-renewable energy sources, is mainly used for illumination and to power motor-driven equipment and electronic devices. On the other hand, thermal energy, whether obtained from fossil fuels or renewable energy sources, is used as a source of energy in heating applications. The typical end-uses for these two types of energy in the hotel industry include:

- Electricity - air conditioning units, fans and air-handlers, lighting fixtures, refrigeration equipment, water pumps, large appliances (e.g., clothes and dish washing machines), small appliances (e.g., toasters, microwave ovens, hair dryers), electronic devices (e.g., television sets, stereos, computers), and communications equipment (e.g., cellular telephones, computers).
- Thermal energy - space heaters, water heaters, cooking equipment (e.g., stoves and ovens), and laundry dryers.

The distribution of total energy use among the various energy applications in hotels depends on many factors and thus varies widely in the hotel industry. Some of the key factors that affect energy use distribution in conventional hotels include the local climate, star rating and type of accommodations (e.g., business or beach hotel), range of guest amenities, efficiency of the facilities and equipment, and quality of the maintenance operations.

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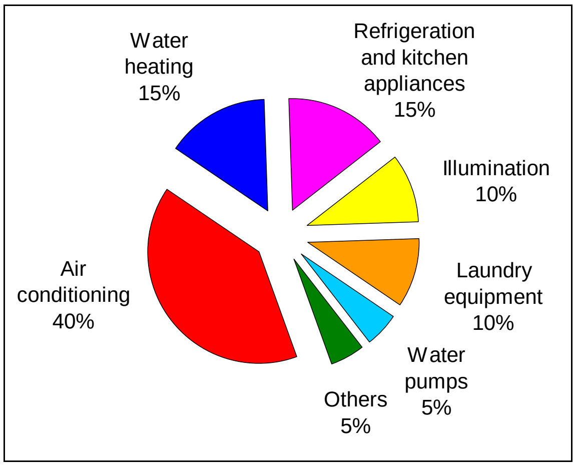
[1] Although this document focuses on energy supply and use in ecolodges, the design principles, concerns, energy supply systems, and end-use technologies that are applicable to ecolodges are generally also applicable to other small off-grid facilities (e.g., visitor centers, homes for park employees and rangers).

The following figure shows the typical distribution of energy use in a Caribbean beach hotel equipped with guestroom air conditioners, gas-fired water heaters, and a pumping station that supplies the facility with pressurized water. Although the percentages shown in this figure change from property to property, the relative importance of the principal energy-using applications remains the same in hotels offering these basic services. Thus, in most conventional hotels operating in tropical regions, more than 50% of the total energy consumption is used in two specific applications: air conditioning and water heating.

In more temperate climates, where both space heating and air conditioning are required, the operation of space heating and cooling equipment typically accounts for 40 to 50% of the hotels' total energy consumption.

Figure 1: Typical distribution of energy in a Caribbean beach hotel



Source: Jamaica EAST project

The distribution of energy use in off-grid facilities is very different from that in conventional hotels (see Figures 3 and 4). This is mainly due to the fact that ecolodges generally avoid air conditioning and rely on renewable sources of energy to meet their water heating needs and, therefore, are able to eliminate the two applications that account for more than half of total energy use in conventional hotels.

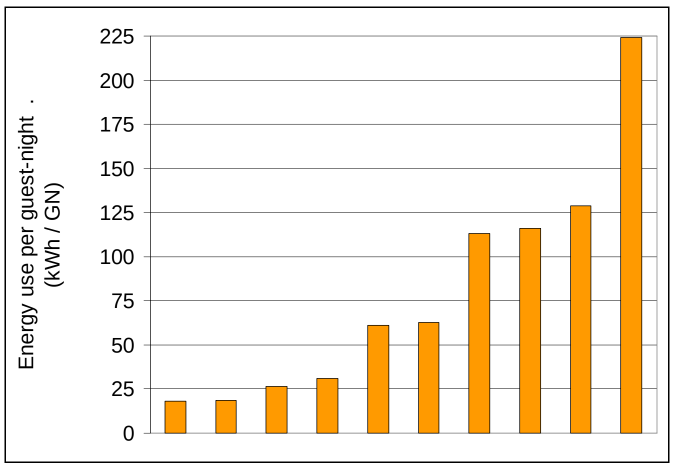
The main electricity-consuming applications in energy-efficient ecolodges are refrigeration, electric lighting, forced ventilation (fans) and water pumping. Other electric loads such as stereos, computers and communications equipment typically account for only a small fraction of their total electricity consumption. However, the use of electricity in ecolodges is highly variable because different facilities will utilize different tactics to minimize their electricity consumption and generation.

3. Energy Consumption in Lodging Facilities

Given the heterogeneous nature of the hotel industry, it is not surprising that the energy consumption per unit of "output" (i.e., the energy consumption per guest-night) varies widely from one location or from one property to the next. What is more surprising, however, is that the energy consumption performance of hotels remains equally varied even when considering a fairly narrow segment of the industry, such as hotels of approximately comparable class, type and size, operating in the same geographical area.

This fact is clearly exemplified in the following figure, generated by USAID's EAST project in Jamaica. The chart shows the energy use per guest-night of 10 medium to high-end tourist hotels, with less than 50 rooms, operating in Jamaica's main tourist destinations. The four most efficient hotels in this group managed to consume on average only 24 kWh per guest-night, or approximately five times less energy per guest-night than the six least efficient hotels (118 kWh per guest-night).

Figure 2: Energy use per guest-night in 10 Jamaican tourist hotels



Based on this data, the project determined that the total consumption of energy in an efficient three to four-star tourist hotel in a tropical climate should not exceed 25 kWh per guest-night, 50% of which is typically used as electrical energy and 50% as thermal energy.

This energy efficiency benchmark, however, corresponds to that of a conventional beach hotel offering the comforts and features normally expected in mass tourism operations, such as air-conditioned rooms, continuous hot water supply, linen service, swimming pool, and full-service restaurants.

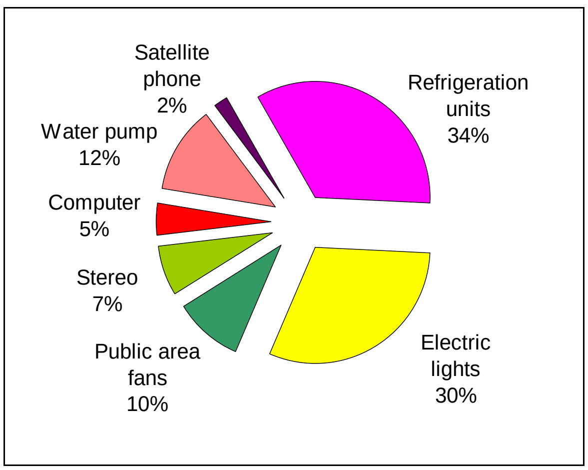
This energy efficiency benchmark is also applicable to the many off-grid hotels that have a sufficiently large power-generating capacity to provide these comforts and amenities to its guests. However, energy efficiency in off-grid ecolodges must be measured on an entirely different scale, especially when it comes to their use of electrical energy, which is generally more difficult and costly to generate in remote locations.

For example, an ecolodge with 10 double-occupancy rooms and designed to provide basic comforts and services (i.e., electric lights, ceiling fans and music in public areas, pressurized water supply, communications equipment, and refrigerated food storage) could consume as little as 6.5 kWh of electrical energy per day when operating at full occupancy. Such a facility would use as little as 0.32 kWh of electricity per guest-night, or nearly 40 times less than an energy-efficient conventional hotel.

Table 1: Electricity needs of a 10-room ecolodge operating at full occupancy (20 guests)

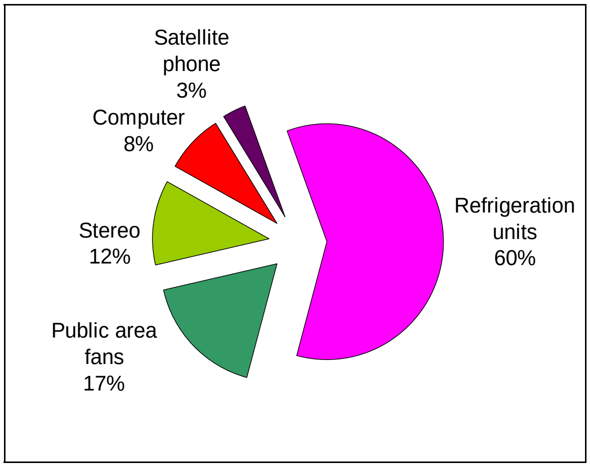
Type of device and average operating time	Number of units	Energy consumption per unit (in Wh/day)	Total energy consumption (in kWh/day)
High-efficiency refrigerator (24 h/day)	1	630	0.63
High-efficiency freezer (24 h/day)	1	1,600	1.60
DC submersible pumps (8 h/day)	2	400	0.80
Public area ceiling fans (8 h/day)	2	320	0.64
Stereo (8 h/day)	1	440	0.44
Notebook computer (6 h/day)	1	300	0.30
Satellite phone (24 h/day)	1	120	0.12
Guestroom lights (3 h/day)	2 per room, 20 total	45	0.90
Staff room lights (3 h/day)	2 per room, 4 total	45	0.18
Public and work area lights (6 h/day)	10	90	0.90
Total			6.51

Figure 3: Distribution of electricity use in the 10-room ecolodge



If this ecolodge was able to eliminate the need to operate its electric pump and electric lights (for example, by obtaining water by gravity from a spring and using oil lamps), its electricity consumption would drop to 0.19 kWh per guest-night, or 1.5% of the electricity consumption of an energy-efficient hotel. (All figures used in the above tables are for illustrative purposes only; actual energy usage in any given facility may differ)

Figure 4: Distribution of electricity use in the 10-room ecolodge without its electric pump and electric lights



The principal factors that affect energy consumption in ecolodges are presented and discussed below.

Capacity: The capacity or maximum occupancy of the ecolodge has a direct impact on its total energy needs. Regardless of the type of facility, the capacity and energy consumption of the equipment, appliances and devices that are needed to support its operations increases as the number of guests increases.

Staff housing: The number of employees housed at the facility also has a direct impact on its energy needs. In ecolodges with basic services (i.e., electric lights, pressurized water supply, water heaters, meal service and refrigerated food storage), the electricity and thermal energy consumption of an employee is similar to that of a guest.

Climate: The average annual and monthly temperatures, as well as the differences between daytime and nighttime temperatures, have an important impact on the energy needs of a facility.

In hot climates (e.g., desert, semi-arid and tropical regions), the need for space cooling is an important concern as it can seriously affect guest comfort. Air conditioning is generally not an option as it is prohibitively expensive in remote off-grid locations and also contradicts basic principles of ecotourism, such as the efficient use of resources and living in harmony with the local environment. Instead, ecolodges must rely on building design features (e.g., cross ventilation, heat reflecting surfaces, shading and insulation) or less energy-intensive cooling systems (e.g., evaporative coolers in dry climates, fans) in order to maintain their living spaces at a reasonable temperature or provide some respite from the heat.

Hot climates also affect the efficiency of refrigeration equipment. For example, a rise in temperature from 70°F to 90°F increases the electricity consumption of a high-efficiency refrigerator by 30 to 60%. This rise in energy consumption is very significant, especially since refrigerators and freezers may constitute the largest electricity loads in an off-grid facility.

From an energy use standpoint, one of the few benefits of high ambient temperatures is the reduction in the energy consumption of water heating systems, which results from the higher temperature of the feed water and the lower demand for hot water in guest and staff showers.

In colder climates, space heating is a major energy use concern. However, given that renewable energy heating systems are simpler, cheaper and more readily applicable in off-grid locations than space cooling systems, lower temperatures generally create fewer guest comfort problems in ecolodges. Nevertheless, even when located in areas where biomass is cheap and plentiful, the ecolodge's buildings should be properly designed and rely on passive solar features to minimize the capacity and fuel consumption of the supplemental space heating systems.

Lower ambient temperatures also affect the energy consumption of refrigeration systems and water heaters. Refrigeration units operate more efficiently and consume less energy in colder climates, while water heaters use more energy to raise the temperature of colder feed water and meet the greater demand for hot water in guest and staff showers.

Operating cycle of the facility: Facilities that operate for only part of the year may be able to avoid the higher energy needs and, in some cases, the energy systems that would be necessary to sustain their operations during periods of more extreme weather conditions. The seasonality of the operations in response to weather conditions is generally market driven: few tourists would be willing to brave the humidity and heavy rains which characterize the monsoon in parts of South-East Asia, or the bitter cold that grips the steppes of Mongolia eight months of the year.

Type of operation and guests: Generally speaking, the higher the level of luxury and the more services provided by a facility, the greater its energy consumption. This level of service comes at a price, as the facility's higher energy consumption increases the capacity and cost of both the energy supply system and the backup generator that is needed to prevent interruptions in power supply.

Water needs of the facility and location and quality of the water source: Water pumps can use a lot of energy and can be among the highest energy consumers in an off-grid facility. The amount of energy consumed by a pump depends mainly on its flow output and operating pressure: the greater the flow and height to which the pump must lift the water, the greater the amount of energy needed by the pump.

The location of the source as well as the water needs of the facility must, therefore, be taken into account to determine the capacity of the pumping system and estimate its energy needs. Ideally, the facility should be located at a lower elevation than the source so that the water can be conveyed to the point of use simply by gravity. Such a gravity water supply system requires no external energy input to reliably deliver pressurized water to the facility.

Water quality can also have an impact on pumping requirements and, thereby, on the facility's energy consumption. For example, driving water through a filter requires energy, which should ideally be provided by gravity. However, if the water source is located lower than the point of use, the filtration process will have to be driven by a pump and will increase the facility's pumping load and energy needs.

Most other small-scale water treatment technologies, such as ultraviolet lamps and reverse osmosis cartridges, also require a source of energy and will add to the facility's energy consumption.

Energy efficiency: Energy efficiency is a fundamental requirement of sustainable and ecotourism as it allows tourism businesses to preserve natural resources and reduce the impact of their operations on the environment. However, in the particular case of remote off-grid facilities, energy efficiency is also a basic requirement for their economic survival.

Energy-efficient facilities are able to provide a greater level of comfort to their guests and staff, lower their reliance on non-renewable sources of energy, reduce the complexity and cost of their energy supply and backup systems, and lower their maintenance requirements and operating costs. As discussed below, energy efficiency should be integrated into every aspect of the design and operation of ecolodges.

- Building design: Buildings should be properly sited, oriented and designed to minimize their heating and cooling requirements, and downsize or even eliminate the need for heating and cooling systems. Well-designed buildings can maintain a comfortable indoor temperature with minimal supplemental heating and cooling in temperate climates, and operate without air conditioning in tropical climates.

  Passive cooling building features in hot climates include cross ventilation; the use of high reflectance roofs and walls, which can reduce the heat load into a building up to by 40%; and the proper insulation and shading of the roofs and walls that are exposed to the sun.

  Passive heating strategies for colder climates include maintaining a proper balance between floor space and the total window area on exterior walls that face the winter sun; using stone, masonry and other high-thermal mass materials in walls and floors to absorb and store the heat of the sun during the day and gradually release it into the living space during the night; insulating roofs, attics and exterior walls; and sealing of the building envelope to minimize the infiltration of cold outside air.

  As a general rule, buildings should also be designed to use sunlight rather than artificial light during daytime hours.

- Selection of equipment and appliances: Off-grid facilities should make every effort to use high-efficiency equipment and appliances for all applications that require electrical energy. Given the typically high cost of generating electricity in remote locations, every additional kilowatt-hour (kWh) used has a significant impact on the capital and/or operating cost of the energy supply system. For example, even though a 60-watt incandescent bulb produces the same amount of light as a 15-watt energy-efficient compact fluorescent lamp, a solar array would need to generate four times the energy to power the incandescent bulb.

  Energy-efficient equipment and appliances typically are more expensive than standard-efficiency models. However, this higher cost is generally largely compensated by the reduced capital and operating costs of a smaller electricity generation system.

Table 2: Energy consumption of high-efficiency vs standard appliances and devices

Description	**Power requirement or energy consumption of a high-efficiency model**	**Power requirement or energy consumption of a standard-efficiency model**
Computer	15 to 20 W (notebook computer)	40 to 80 W (desktop computer without monitor)
Computer monitor	30 W (15" LCD monitor)	65 to 120 W (15" to 21" CRT monitor)
Electric lamp	15 W (compact fluorescent lamp)	60 W (incandescent lamp with a comparable light output)
Refrigerator/freezer	800 Wh per day	1,800 to 2,500 Wh/day

Efficiency is typically less of a concern for non-electrical applications that can be powered with renewable sources of energy that are widely available at the project site. For example, it may not be necessary to use costly high-efficiency solar water heaters in tropical areas with plenty of sunshine, since even home-made water heaters can provide plenty of hot water in such locations.

- Staff and guest participation in energy conservation: Employees should know the importance of energy conservation for the survival of the facility, and be trained and encouraged to use energy efficiently in their daily activities. Their performance should be monitored and assessed by management to ensure they do not waste energy.

  The guests should be informed of what it takes to meet the facility's energy needs, and invited to help conserve energy. Guests who understand the facility's energy situation generally participate better in energy conservation efforts and accept more easily the limitations and discomforts of living on a tight energy budget.

4. Energy Supply Options for Off-grid Facilities

The energy supply options for off-grid facilities typically include a range of renewable and non-renewable energy sources.

Renewable energy is defined a source of energy that is replenished at least as fast as it is used, or that is available in such sufficient quantities that its use does not significantly deplete its supply. The renewable energy sources generally used in ecotourism facilities include solar and wind energy, hydropower and biomass (e.g., wood and crop residues). It is important to note, however, that these energy sources cannot be considered to be renewable if their use has an unacceptable environmental impact. For example, the falling water of a mountain stream is not a renewable source of energy if diverting water from this stream for power generation significantly affects its aquatic and riparian ecosystems.

Non-renewable energy is defined as a source of energy that is used more quickly than it is replaced. The non-renewable energy sources commonly used in ecotourism facilities are diesel, gasoline, kerosene and propane.

Both renewable and non-renewable energy sources can be readily converted into the forms of energy that are needed to meet the needs of the facility. In off-grid facilities, wind and solar energy, hydropower and fossil fuels are typically used to generate the electricity needed to power electrical appliances and devices. Solar energy, biomass and fossil fuels are used to generate the heat needed for cooking, as well as water and space heating. Biomass can also be transformed into biofuels, which can then be used in thermal applications or to power electricity generators. However, the use of biofuels is generally limited in tourism facilities, with the possible exception of the use of biogas (i.e., methane produced from the decomposition of wastes/manure) in cooking stoves.

As renewable energies are generally the cleanest sources of energy available and eliminate the net emission of greenhouse gases, they are the preferred energy sources for ecotourism facilities. Besides these environmental benefits, other important advantages of using renewable energy systems include:

- Renewable energy sources are generally available, in one form or another, in most parts of the world.
- Most renewable energy technologies are proven and reliable.
- Generating electricity with solar, wind and hydropower systems does not require the constant input of consumables that is needed by fuel-powered generators (e.g., fuel, motor oil and oil filters). Supplying such consumables to remote locations is often difficult and costly.
- In areas with ample wind and hydropower resources, the life-cycle cost of wind and hydroelectric systems yields a unit electricity cost that is generally much lower than that of conventional fuel-powered generators.

***Table 3:** Typical life-cycle cost of electricity generation systems in off-grid locations

Electricity generation system	Life cycle cost of the energy (US$ per kWh)
Small-scale hydroelectric system[2]	0.05 to 0.15
Wind turbine[3]	0.04 to 0.15
Diesel generator[4]	~0.25

* Cost figures may vary with time and location and therefore are indicative only

- Simple solar thermal devices, such as batch solar water heaters and solar cookers, can be built on site, at low cost, and with readily available materials. Although these home-made systems may not be the most energy efficient, they perform well in areas with good solar resources.
- Most renewable energy systems have a long service life (15 to 25 years).

The use of renewable energy systems also has some important drawbacks, including:

- High initial equipment and system costs, especially for photovoltaic (solar) systems.
- High life-cycle costs for photovoltaic systems.
- The technical complexity of some components of renewable electricity generation systems, which requires specialized technical skills in case of a breakdown.
- The inability to generate enough energy to power large electrical loads, except in areas with abundant wind and hydropower resources.
- The higher cost and possible unavailability in the local market of the efficient appliances that are generally needed to operate a facility on renewable electricity.

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[2] Source: Switched On - Renewable Energy Opportunities in the Tourism Industry, UNEP, 2003.

[3] Source: Switched On - Renewable Energy Opportunities in the Tourism Industry, UNEP, 2003.

[4] Source: Guide to Energy Options for Small-Scale Rural ICT Projects, Winrock International, 2004.

Although renewable energy sources are the preferred energy supply options, many ecolodges are unable to meet all of their thermal and electricity needs with renewable energies, and must rely to some extent on fossil fuels to fill this energy gap (e.g., a backup diesel generator). In some cases, however, the choice between renewable and non-renewable energy sources is guided by convenience. For example, propane-fueled thermal appliances are cleaner and require less operator attention than wood-fueled appliances, and are often preferred, especially for small or intermittent energy applications. Common examples of fossil fuel applications in ecolodges include:

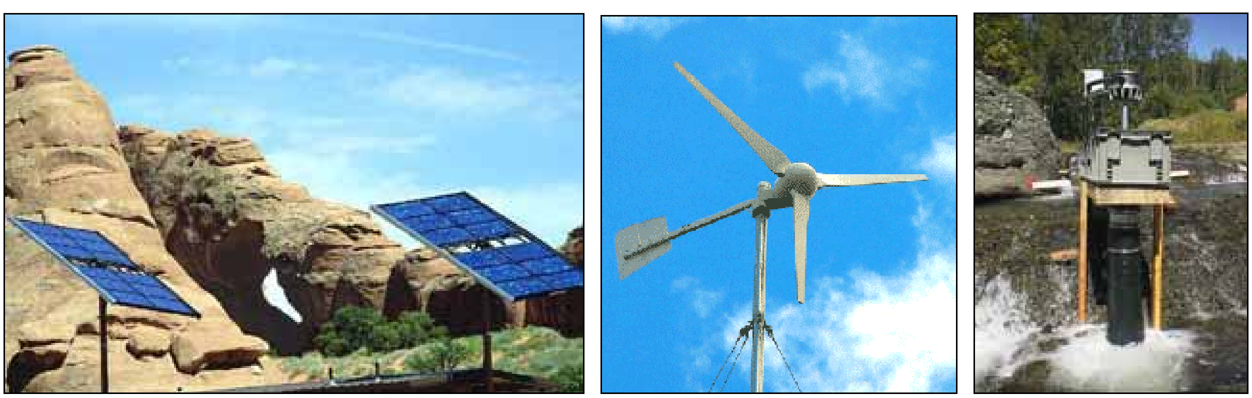
- diesel, gasoline or propane backup generators to provide electricity during periods of high energy demand or low supply of renewable energy (cloudy or windless days);
- propane cooking stoves and space heaters;
- propane backup water heaters; and
- kerosene or propane lamps.

5. Renewable Energy Systems and Technologies for Off-grid Facilities

Electricity generation: The renewable energy electricity generation options that are typically applicable to ecolodges include photovoltaic panels, wind turbines and small-scale hydroelectric turbines. Photovoltaic panels, or modules, have no moving parts and rely on semiconductor technology to convert sunlight directly into electricity. Wind and hydroelectric turbines are mechanical devices that use the energy of the wind or falling water to spin a generator, which then converts this energy into electricity.

When necessary (e.g., if a single source of renewable energy is unable to provide enough electricity), two or more of these electricity generation systems can be used side-by-side to create a hybrid electricity generation system.

Figure 5: Photovoltaic panels, wind turbine, and small-scale hydroelectric turbine



Most electricity generation systems are equipped with a bank of high-capacity batteries to provide power when the renewable energy source is temporarily unavailable and, thereby, allow the continuous operation of equipment and appliances (e.g., nighttime for photovoltaic systems, and periods of low winds for wind generators). These storage batteries also allow the facility to operate for short periods of time electrical loads that require more power than that produced by the electricity generation system. For example, a 200-watt solar array could not power a 1,000-watt coffee maker even for an instant unless it was equipped with storage batteries.

Off-grid electricity supply systems must use special deep-cycle batteries, which can survive the deep discharge cycles experienced in renewable electricity generation systems. Standard automotive "starting" batteries are designed to use only 10% of their capacity and will rapidly fail if cycled deeper than that; deep-cycle batteries are able to provide 50 to 80% of their capacity without problems.

Figure 6: Bank of deep cycle batteries

Other standard components in off-grid electricity supply systems include controllers, which manage the charging process and prevent damage to the batteries resulting from excessive overcharging; monitoring devices, which allow the operator to verify the batteries' state of charge and the system's energy consumption; and inverters, which convert the DC current supplied by the batteries or electricity generation system into AC current (i.e., standard household current).

Water heating: Renewable energy water heating systems include solar thermal water heaters and biomass water heaters.

Solar thermal water heaters, which are probably the most well-known and widespread of all renewable energy technologies, use the energy of the sun to directly heat water contained in a glass-covered collector. In most solar water heater configurations, the heated water flows by natural convection from the collector to an insulated tank, which is designed to store enough hot water to meet the end-use needs. Solar water heaters are simple and rugged and, typically, have no motors or other moving parts. However, if the supply of hot water cannot be interrupted during cloudy days or periods of peak hot water demand, solar water heaters must be backed-up by a supplemental fossil fuel or biomass heating system. In tropical climates, solar water heaters can generally meet from 80 to nearly 100% of domestic hot water requirements.

In areas with ample sunshine, home-made solar water heaters (e.g., drum water heaters) can be used as an inexpensive source of hot water.

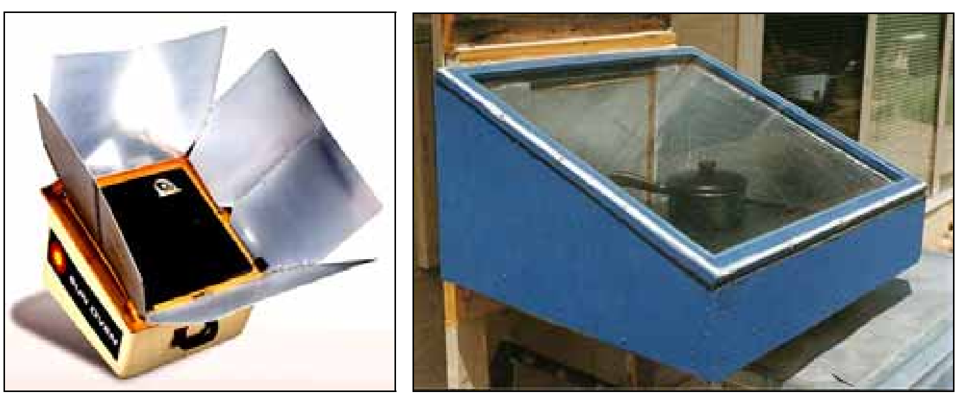
Figure 7: Drum water heater (left) and commercial solar water heaters (right)

Biomass water heaters are similar in principle and design to standard household gas water heaters, except that they use biomass as a source of energy. Efficient biomass water heaters are available on the market, but lower-efficiency models can be readily manufactured locally at low cost. Biomass water heaters are rugged and simple to operate, but generally require a fair amount of attention to load the fuel and remove the ashes.

<u>Cooking</u>: Renewable energy cooking options include solar cookers, biomass cooking stoves, and biogas ranges.

A solar cooker typically consists of a glass-covered and insulated box (or oven), which is designed to trap the heat of the sun and maintain the high temperatures needed to cook foods or even boil water. The sides of the oven are often equipped with deflectors to increase the amount of sunlight entering the oven. Solar cookers are simple devices and are highly effective in areas with abundant sunshine, but they cook more slowly than most other methods and typically are not suitable for institutional applications, which require preparation of large quantities of food. They can be purchased from various suppliers, or can be built on site at low cost (though home-made models are generally less energy efficient).

Figure 8: Commercial and home-made solar cookers



Biomass cooking stoves are widely used in developing countries and can burn various renewable fuels, such as firewood, crop residues and animal dung. Although most traditional stoves are relatively inefficient, locally-built improved cooking stoves can lower fuel consumption by 50% or more, reduce smoke generation and improve indoor air quality.

Biogas ranges are similar to standard gas ranges but, instead of using natural gas or bottled propane, they use gas generated on site by the anaerobic decomposition of animal and, sometimes, human wastes. Although both the biogas range and the anaerobic digester are relatively simple devices, the operation of the digester requires a fair amount of care and experience, in addition to an ample supply of waste. An ecolodge that plans to meet its cooking gas needs with biogas will need to have a convenient access to a source of animal (or human) manure.

Fireless cookers (or hayboxes) can be used to significantly reduce the amount of energy used for cooking. A fireless cooker is a closed and well-insulated box in which the cooking pot is placed after its contents have been brought to a boil. The insulated box prevents the loss of heat and thus allows the food to finish cooking with its own heat. Fireless cookers can reduce by up to 75% the amount of energy needed for cooking and are ideally suited for foods that have a high water content (e.g., soups, stews, rice, grains, beans).

Refrigeration: The only practical renewable energy refrigeration option for ecolodges consists of electric refrigerators and freezers powered with the energy obtained from renewable electricity generation systems (solar, wind and hydropower). However, given that refrigeration units may be the highest single energy users in off-grid facilities that operate on a tight electricity budget, the equipment selected should be as efficient as possible. Energy-efficient refrigerators and freezers are costly but, as they typically consume 50% less electricity than standard models, are worthwhile investments.

Space heating and cooling: Regardless of the climate conditions, ecolodges should primarily rely on passive building design features to maintain the living spaces at a comfortable temperature. As mentioned earlier, such design features include correct building siting and orientation, wall and roof insulation, high reflectance roofs, cross ventilation, shading, thermal mass, and the sealing of the building envelope.

Proper building design is especially important in hot and tropical climates because the most effective cooling technology (air conditioning) has prohibitively high electricity requirements. For example, air conditioning a single standard guestroom during eight hours per day can consume as much electricity as the fully-booked 10-room ecolodge presented in Table 1.

Less energy-intensive cooling systems include fans and, in dry climates, evaporative coolers. Evaporative coolers are typically fan-driven appliances that rely on water evaporation to cool and humidify the ambient air.

Renewable energy space heating systems include solar heaters, which operate on the same principle as solar water heaters but use the generated hot water to heat indoor spaces, and biomass heaters, which can burn firewood, agricultural crop residues or other renewable fuels. The design of the biomass heater is important. For example, energy-efficient wood-burning stoves can consume less than half the fuel for the same heat output and significantly reduce air emissions compared to standard-efficiency models.

Lighting: Renewable lighting options include high-efficiency electric lamps powered with the energy obtained from renewable electricity generation systems, oil lamps and biogas lamps.

Off-grid facilities that operate electric lights typically use fluorescent tube lamps or compact fluorescent lamps to minimize their electricity consumption. Fluorescent lamps generally consume four times less energy for the same light output and last eight times longer than standard incandescent bulbs.

Stand-alone "solar lamps", which are basically miniature photovoltaic systems designed to power a single high-efficiency LED lamp, can also be used for outdoor lighting.[5] However, given the low light output of the LED lamps, these solar lamps are typically used only for path lighting or for decorative purposes.

Oil lamps are simple and inexpensive lighting systems which offer the additional advantage of being able to burn easily available, and often locally produced, vegetable oils or animal fats. Since electric lights can account for a significant fraction of the total amount of electricity used in an ecolodge, replacing electric lamps with low-tech oil lamps can greatly reduce the capacity and cost of the planned electricity generation system.

Biogas can also be used in gas lamps that have been specially adapted to operate at the low gas pressure generated by biogas digesters.

Figure 9: Compact fluorescent and oil lamp

Water pumping: Renewable energy water pumping options include high-efficiency electric pumps powered with renewable electricity, hand pumps and ram pumps. Ram pumps are simple hydraulic devices that use the energy of a flow of water falling from a short height to lift a small fraction of this flow (2 to 10%) to a much greater height. They can work with as little as a 2 gallon per minute supply flow and lift water to a considerable height (up to 500 feet).

[5] A "solar lamp" incorporates in the body of the lamp all of the basic elements of a photovoltaic power system (i.e., a photovoltaic panel, a storage battery and the energy consuming load or lamp).

Figure 10: Hand pump (left) and ram pump (right)

In order to reduce the required capacity of the pumping system and/or the energy needs of the pumps, the facility should practice water conservation and use efficient plumbing fixtures. Examples of water conservation measures applicable to ecolodges include: operating the water supply system at the lowest acceptable pressure; using efficient faucets, low-flow showerheads, and composting or water-saving toilets; eliminating the need for irrigation or relying on graywater irrigation; and minimizing the amount of linens and dishes that must be washed.

In addition to reducing the workload on the pumps, water conservation can also reduce the required capacity and the energy needs of hot water supply systems.

Case study - Energy supply in an off-grid lodging facility[6]

The Tortoise Head Guest House on French Island, Australia generates most of its power from a wind and photovoltaic hybrid system that has been in operation since 1995. The Guest House consists of six large bedrooms (for 2 to 6 people each), five double bed cabins and meeting/conference facilities. It is located 500 feet from the seashore, which makes it an ideal site for a wind turbine.

The Guest House's electricity supply system includes a 10 kW wind turbine, an 840 W photovoltaic array, two diesel generators (15 and 25 kW) and battery storage.

The principal energy uses at the facility include:

- electricity for lighting, water pumping, refrigeration, dish washer, domestic appliances, and communications equipment;
- propane for water heating and cooking;
- solar water heaters for water heating;
- wood from fallen trees for space heating; and
- diesel for the backup generators.

About 68% of the electricity consumed by the Guest House is produced by the wind turbine, 11% by the photovoltaic array, and 21% by the backup diesel generators.

The Guest House is in the process of installing additional solar water heaters and implementing energy efficiency measures to further reduce its reliance on fossil fuels (i.e., propane and diesel).

6. Non-renewable Energy Systems and Technologies for Off-grid Facilities

Electricity generation: In remote locations, motor-driven generators are the only non-renewable energy alternative for producing electricity. Generators can run on various types of fossil fuels, including gasoline, diesel, propane and kerosene. They come in a wide range of capacities and can fully meet the electricity needs of any type of facility, from small, energy-efficient ecolodges to large conventional hotels.

[6] Source: Switched On - Renewable Energy Opportunities in the Tourism Industry, UNEP, 2003.

Figure 11: Small capacity diesel generator (3 kW)

Generators can also run on biofuels (e.g., biodiesel) and fossil/biofuel mixtures (e.g., diesel/ biodiesel and gasoline/ethanol blends) and, thereby, generate electricity totally or partially from renewable sources of energy. However, the use of biofuels for electricity generation in ecolodges in generally greatly restricted by the limited availability of biofuels in many parts of the world, and by warranty restrictions on the use of biofuels imposed by equipment suppliers. For example, equipment manufacturers typically specify the maximum biofuel/fossil fuel ratio that can be used in their equipment.

Generators can be used as the primary source of energy in off-grid facilities, or as backup power supply in ecolodges that operate renewable electricity generation systems.

When used as the primary source of energy, generators are normally operated intermittently to recharge the battery banks that provide an uninterrupted source of electricity to the facilities. Alternatively, generators can be operated only for a few hours per day (e.g., evening) to directly provide the electricity needed during that period of time.

Tourism facilities that are equipped with generators and have convenient access to reasonably priced fuels have fewer restrictions in the manner in which they use electricity and the type of equipment they operate. Nevertheless, to remain true to the principles of sustainable tourism and control operating costs, such facilities should strive to minimize their energy consumption by using energy-efficient equipment, such as the electric appliances and devices presented in the previous section.

Water heating: In areas with a limited availability of sunshine and renewable biomass, fossil fuels such as propane and diesel can be used to heat water. If available, propane is generally the preferred fuel for this application because propane water heaters do not require the pumps or blowers that are generally needed for diesel water heaters.

Cooking: Propane or kerosene stoves are commonly used in ecolodges that cannot rely on biomass and constant sunshine to meet their cooking needs. Propane is generally the preferred fuel for cooking applications because it burns more cleanly than kerosene and minimizes indoor air pollution. Propane stoves rely on the pressure of the bottled gas to feed the fuel to the burners and condition it for combustion and, therefore, are easier to operate and maintain.

Refrigeration: Various manufacturers produce refrigerators and freezers that use the energy of an open flame, slightly more intense than a pilot light in a gas range, to drive an "absorption cycle", instead of the more conventional compressor-driven refrigeration cycle. These appliances typically run on propane or kerosene.

Although less energy efficient than high-efficiency electric refrigerators/freezers, fuel-driven refrigeration units are often used in facilities where fuel is readily available and electricity generation is costly or difficult. As refrigeration can account for 50 to 75% of the total electricity demand in energy-efficient ecolodges, the use of a propane or kerosene refrigerator/freezer can significantly reduce the size and cost of the required electricity generation system.

Space heating and cooling: The non-renewable options for space heating and cooling include fossil fuel heaters and air conditioners.

Fossil fuel space heating systems can operate on a wide range of fuels, including propane, kerosene and diesel. As with other fossil fuel thermal applications, propane is often the preferred option as it burns cleanly and generates less air emissions. In addition, propane space heaters require minimal maintenance and are generally easier to operate.

Besides the fans and evaporative cooling systems discussed earlier, the principal active space cooling system is air conditioning. Unfortunately, air conditioners consume vast amounts of electricity compared to the electric appliances that are normally used in ecolodges: operating a single air conditioning unit can easily double the electricity needs of a small facility. Air conditioners are therefore rarely used in ecolodges, unless they have an abundant source of inexpensive and preferably renewable energy (e.g., large wind or hydropower resources). When used, air conditioning units should be energy efficient and used to cool only properly insulated and sealed buildings and rooms.

Lighting: Lighting options include electric lamps powered by electricity generated from fossil fuels, kerosene lamps and candles. Most commercial candles are made of paraffin derived from fossil fuels and are thus a non-renewable source of energy (natural wax candles would, of course, not fall in this category).

Water pumping: Water pumps can be driven by electric motors as well as by internal-combustion engines fueled with gasoline, diesel or propane. Engine-driven water pumps have a water delivery capacity significantly greater than that of renewable electricity pumps. Therefore, they are often the only alternative for meeting large water needs in off-grid locations that operate on a tight electricity budget.

7. Selection of Energy Supply Options

Given the wide range of renewable and non-renewable energy supply options available, selecting the right energy source, or combination of energy sources, for an off-grid facility is not an easy task. This selection process is also critical to the sustainability of the facility because the choices made in the planning stage will have a significant impact on the initial equipment and installation costs, the long-term operating costs and reliability of the energy supply systems, as well as guest comfort.

Although the initial system cost is an important concern, project designers should refrain from giving it too much weight. Technical decisions largely based on minimum up-front cost criteria often turn out to be extremely costly in the long-run.

The energy supply system of an ecolodge should ideally rely on renewable energy sources, produce enough energy to reliably meet the needs of the facility, need no or a minimal fossil fuel backup capacity, and require a moderate investment. However, as discussed below, there are many factors that affect the energy supply choices and the possibility of achieving this ideal scenario.

Energy needs and end-uses: The amount of energy and the end-uses of the energy consumed by the facility affect the energy supply decisions. For example, photovoltaic systems are very expensive and are cost effective mainly when used to meet relatively small loads (solar array with a peak capacity of 1 kW or less). Facilities with high energy needs, such as large or more comfortable high-end ecolodges, must generally obtain their electricity either from less costly renewable energy sources (wind or hydropower), if available, or fossil fuel-powered generators.

As most renewable energy thermal technologies are relatively simple, require low to moderate investments and can be built locally (e.g., solar water heaters, solar cookers, improved cooking stoves, passive solar buildings), it is generally easier to rely on renewable sources of energy to meet a facility's thermal energy needs than its electricity needs. Thus facilities with low electricity requirements are generally those that are able to meet most of their energy needs from renewable sources, and require the smallest investment in energy systems and equipment.

Location and features of the site: The location of the site plays an important role in determining the balance between renewable and non-renewable energy options. For example, facilities located in isolated or hard to access sites will generally not be able to use fossil fuels to meet their energy needs, and will need to rely more heavily on the renewable energy sources available locally.

Site features can also have a profound impact on the use of some technologies. For instance, tall trees and other sheltering features can severely restrict the use of solar technologies and wind turbines, even in locations with ample sunshine and wind.

Availability of renewable energy sources: Sunshine is available all over the world even though the amount of energy provided by the sun varies with location. Insolation is generally higher in tropical and arid regions but, even in such locations, it can be affected by local factors such as cloud cover and haze. Wind, hydropower and biomass resources are much more site-specific, and can range from plentiful (e.g., the hydroelectric resources of a large mountain stream) to nonexistent (e.g., sustainable biomass in arid regions).

The quantity of renewable energy resources at a site -- that is, insolation, wind speed, stream flow, and sustainable biomass -- is the primary factor affecting the applicability of renewable energy systems. However, the reliability and annual distribution of these resources are also important considerations for the selection and design of renewable energy systems. Low wind speeds or stream flows during the summer, or low insolation during the winter, may restrict the applicability of these resources or affect the composition of the energy system that is needed to meet the facility's year-round energy requirements. For example, wind-solar hybrid systems must often be used in areas where the season of high winds coincides with the season of lowest insolation (winter) and vice versa.

Availability of information on renewable energy resources: It is necessary to know with a certain degree of precision the amount of renewable energy available at a site not only to ascertain if the supply is sufficient to meet the energy needs, but also to determine, in the case of renewable electricity generation systems, the required size and capacity of the solar array, wind generator or hydroelectric turbine.

Although insolation data is available for many parts of the world, the same cannot be said for information on wind speeds and small stream flows. Collecting reliable wind and small stream flow data at a project site is a slow process and could involve a monitoring period of one to two years.

The quality of wind speed data is particularly important. Since wind power varies with the cube of the wind speed, errors in the estimated wind speeds can result in significantly over or under-sized wind generators.

<u>Availability of fossil fuels</u>: The availability and cost of fossil fuels at the project site has a large impact on the energy supply decisions. Ecolodges that have an easy access to reasonably priced fossil fuels may be hard pressed to justify investments in renewable energy systems with high life-cycle costs, unless their commitment to renewable energy gives them a competitive advantage (e.g., green marketing).

<u>Laws and regulations</u>: Laws and regulations governing the use of natural resources (e.g., the use of streams and rivers for power generation), the use of natural resources in protected areas (e.g., firewood), and the generation of electricity by an independent operator, among others, may affect the energy supply options available at a project site.

<u>Environmental concerns</u>: The negative impacts of the possible energy system options must also be taken into account in the decision making process over energy sources. The environmental concerns related to the typical energy systems used in ecolodges are summarized in the following table.

Table 4: Typical environmental impacts of the energy systems used in ecolodges

Energy system	**Environmental concerns**
Motor-driven generators	• Noise • Air pollution and greenhouse gas emissions • Soil, groundwater or surface water pollution resulting from fuel and oil spills • Disposal of used motor oil, oil filters and batteries
Photovoltaic systems	• Proper disposal of used batteries
Wind systems	• Disruption to bird nesting sites • Disposal of used batteries
Hydroelectric systems	• Soil erosion • Impact to the aquatic or riparian ecosystems • Disposal of used batteries
Solar thermal (solar water heaters, cookers and space heaters)	• None
Biomass energy systems (water heaters, cooking stoves and space heaters)	• Sustainability of the source of biomass • Air pollution, possible greenhouse gas emissions

Diesel or kerosene energy systems (water and space heaters, cooking stoves, lamps, refrigeration units)	• Soil, groundwater or surface water pollution from fuel spills • Air pollution and greenhouse gas emissions
Propane energy systems (water and space heaters, cooling stoves, lamps, refrigeration units)	• Greenhouse gas emissions

Figure 12: Used motor oil storage area (left) and fuel spills around a storage tank (right) in off-grid hotels

Financial assistance: Tax breaks, grants and other economic incentives designed to promote the use of renewable energy will facilitate the application of renewable energy technologies in ecotourism facilities by making them more cost-effective compared to non-renewable energy options.

Applicability of the technology to the site: The performance, operating and maintenance requirements, local experience and support, and cost of the energy supply technologies may all limit their application in certain ecolodge projects. These factors are discussed in greater detail in the following section.

8. Applicability of Energy Technologies

The factors that may affect the applicability of the technologies that are needed to take advantage of the energy resources available at the project site include track record, availability of technical support, operating and maintenance requirements, and costs.

Track record: Ecolodges are obligated to cater to the needs and comfort of their guests. If they plan to remain in business, they cannot assume the role of energy pioneers, especially when dealing with systems that provide essential services. The energy technologies chosen by a facility should have a proven performance and track record--ideally, in the local market as certain site-specific conditions may affect their viability (e.g., effect of constant humidity on electronic components or of wind-borne sand on wind turbines).

Technical support: The manufacturers or suppliers of the energy technologies used by the facility ideally should have local or regional representatives, who could provide reliable and reasonably prompt technical support in case of a breakdown. The availability of this assistance is particularly important for the more sophisticated systems, which require specialized technical skills to troubleshoot and repair (e.g., photovoltaics and wind turbines, charge controllers and inverters).

Simpler or widely used technologies, such as diesel generators, can generally be repaired without much trouble by qualified local technicians.

Operating and maintenance requirements: Since small tourism facilities may not be able to maintain the full-time services of an engineer or qualified technician, the operation and maintenance of the facility's equipment is often in the hands of individuals with limited to moderate technical skills. The energy technologies used in such lodges should, therefore, have relatively simple operating and maintenance requirements.

Fortunately, most renewable energy technologies fit this description. For example, the operating and maintenance needs of a photovoltaic system are typically limited to monitoring the level of charge of the battery bank, and periodically cleaning the solar panels and adding distilled water to the batteries. As a general rule, the operating and maintenance requirements of all common renewable energy electricity generation systems (photovoltaic, wind and hydropower systems) are simpler than those of a conventional fuel-powered generator.

Regardless the simplicity or complexity of the equipment, the facility's operator should always obtain from the supplier detailed instructions and, when necessary, hands-on training on the equipment's operating and maintenance needs.

Costs: High initial equipment costs are an important concern for facilities seeking to utilize renewable energy technologies. This is particularly the case for photovoltaic systems, which are often the only renewable electricity generation systems applicable to many project sites, but have a very high initial cost compared to the amount of power they deliver. However, all possible factors should be taken into consideration when performing a cost-benefit analysis comparison of the various energy supply alternatives applicable to the site. These factors include equipment, shipping and installation costs; the service life of the equipment and of its major components; and its operating and maintenance costs.

Although renewable electricity generation systems almost always have a higher up-front cost than conventional fuel-powered generators, they often yield favorably lower life-cycle costs when used to provide power in remote off-grid locations.

Table 5: Sample capital cost, and operating and maintenance costs of various energy supply options[7]

Energy supply option	Capital cost (US$ per peak kW)	Operating and maintenance costs (US$ per 1,000 kWh)
Grid electricity[8]		80 to 120
Photovoltaic system	12,000 - 20,000	5
Small wind turbine system	2,000 - 8,000	10

[7] Source: Guide to Energy Options for Small-Scale Rural ICT Projects, Winrock International, 2004. Figures accurate at time of publication but subject to variability.

[8] The cost figures shown for grid electricity correspond to the prices charged by utilities for grid-supplied electricity.

Small-scale hydroelectric system	1,000 - 4,000	20
Diesel generator	1,000	250

9. Impact of the Energy Systems on the Local Environment and Communities

The sources of energy and the energy systems used by an ecolodge often have an effect, which may be negative or positive, on the local environment and surrounding communities. These possible impacts must be taken into consideration in the planning and design stages and, later on, during the operation of the facility, and efforts should be made at all phases of the project to mitigate the negative impacts while maximizing the positive impacts.

The possible negative impacts of the energy source and systems of an ecolodge include:

- Competition for resources: The ecolodge's use of renewable energy sources, in particular its use of watercourses for power generation and biomass (e.g., firewood), may compete directly with the local community's needs and traditional uses of these resources. For example, diverting water from a stream to run a hydroelectric turbine will reduce its flow and could affect the community's ability to use this stream for irrigation or water supply.

- Air emissions: The combustion of both biomass and fossil fuels generates air pollutants. The use of renewable biomass may also result in the net emission of greenhouse gasses when not combusted efficiently.

- Soil and water pollution: Both renewable and non-renewable energy systems can be a source of soil and water pollution.

  The main concern with renewable energy systems is the disposal of the batteries, which typically must be replaced every three to five years. These batteries contain lead and sulfuric acid, and can become a source of soil, groundwater or surface water contamination if disposed improperly. Used batteries should be recycled but, unfortunately, this service is not available in many parts of the world.

  Pollution concerns with non-renewable energy systems include soil, groundwater or surface water contamination resulting from fuel leaks and spills, and the improper disposal of used batteries and motor oil.

- Damage to ecosystems: Examples of the impact of energy systems on ecosystems include the pollution of surface waters due to oil or fuel spills, the reduction in stream flow caused by the diversion of water for hydropower projects, and the disturbance of bird nesting sites by larger wind turbines.

The possible positive impacts of the energy sources and systems of an ecolodge include:

- Source of income to local communities: The ecolodge's energy systems can become a source of income for the residents of local communities. Examples include the sale of firewood and other sources of biomass by local providers, the employment of local craftsmen for the construction of renewable energy systems, and the purchase of fresh food products from local farmers by facilities that have no or minimal-capacity refrigeration systems.

- Technology demonstration and transfer: An ecolodge can be a valuable demonstration platform for home-made energy systems that could be beneficial to local communities (e.g., solar cookers, improved biomass cooking stoves, batch solar water heaters, passive heating or cooling building features).
- Essential energy services: Part of the ecolodge's electricity generation capacity could be used to provide essential energy services to the local community. For example, the refrigeration of temperature-sensitive drugs in hot climates; the supply of electricity to a clinic or school (e.g., to operate computers); or the provision of basic or emergency communication services (e.g., cellular or satellite phones).

10. Conclusions

Energy supply and use are important concerns for lodging facilities that are located in remote areas with no access to power grids. These properties must produce all of the electricity they consume, take responsibility for operating their own electricity generation systems, and often pay high prices for the fossil fuels they use. Although technically feasible, operating energy-intensive conventional hotels in such locations requires high-capacity energy supply systems that are typically powered with fossil fuels and are costly to run and maintain.

From an energy as well as from a global standpoint, sustainable tourism (particularly ecotourism) offers a more economically and environmentally sound alternative to conventional hotels for lodging projects in remote and off-grid locations. By focusing on the unique qualities of their surrounding natural environment and practicing to the fullest extent the principles of sustainable tourism, ecolodges are able to attract a growing number of visitors without having to provide the amenities and services expected from conventional hotels. Such facilities are thus able to minimize their energy consumption, rely on renewable energy sources to meet part or most of their energy needs, reduce the capacity and cost of their energy supply systems and, as a result, lower their operating costs and improve their profitability.

There is a wide range of renewable and non-renewable energy options and technologies available that can be used to meet the specific needs and characteristics of off-grid facilities. However, the applicability of these energy options and technologies is affected by many factors, which must be taken into account in the **design** phase of any tourism project in order to ensure its long-term viability.

Photos courtesy of Patricio Gonzalez Morel

Additional Resources

- USAID Energy Team

  (contact Pam Baldinger pbaldinger@usaid.gov or Jeff Haeni jhaeni@usaid.gov)
- USAID/Winrock International

  "Guide to Energy Options for Small-Scale Rural ICT Projects"

  (Renewable and non-renewable energy supply options for small off-grid facilities)

  http://www.winrock.org/what/energy.cfm
- Danish Wind Industry Association

  (Wind energy and wind turbines, see "guided tour" under the "know how" tab)

  www.windpower.org/en/core.htm
- Natural Resources Canada - Clean Energy Decision Support Center

  (Clean energy project analysis software and case studies on technology applications)

  www.retscreen.gc.ca
- Sustainable Sources

  (Energy and water conservation, passive solar building design)

  www.greenbuilder.com/sourcebook
- UNEP

  "Switched On: Renewable Energy Opportunities in the Tourism Industry"

  (Renewable energy options for lodging facilities)

  www.uneptie.org/pc/tourism/library/energy.htm
- US Department of Energy - Energy Efficiency and Renewable Energy

  (Renewable energy, energy conservation and energy-efficient buildings)

  www.eere.energy.gov
- World Bank/ESMAP

  (RE ToolKit - Tools to improve the design and implementation of renewable energy projects)

  http://wbln0018.worldbank.org/esmap/site.nsf/files/marj.pdf/$FILE/marj.pdf
- PA Consulting

  (Information on the USAID Jamaica EAST project – energy and environmental management systems for hotels)

  www.paconsulting.com/industries/travel_tourism/projects/americas/Jamaica.htm