Switched On

Renewable Energy Opportunities in the Tourism Industry

UNEP

United Nations Environment Programme

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Foreword

Today alternative forms of energy are being generated or delivered in new ways: electric utilities are buying clean electricity from modern wind turbines; automobile companies are replacing the internal combustion engine with electric/petrol hybrids and fuel cell power; and oil companies are repositioning themselves as energy companies. These developments, considered by many to be impossible just a few decades ago, are part of the response to increasing environmental damage, climate change, resource depletion and global competition.

Technologies that produce clean and renewable energy are now a focus of both multinational companies and hundreds of small entrepreneurs who are creating and servicing expanding markets with innovative products. In developing countries one of the challenges in implementing cleaner energies is access to the appropriate technology. With this in mind, UNEP pioneered the Rural Energy Enterprise Development (REED) initiative in partnership with the US-based non-profit clean energy investor E+Co. Co-funded by the United Nations Foundation, the projects apply a new development model to support entrepreneurs providing energy efficiency and renewable energy in five African countries, in Brazil and in China.

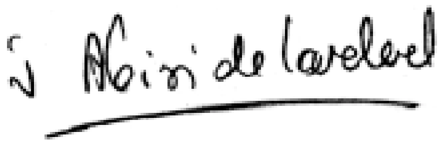
The World Summit on Sustainable Development in Johannesburg 2002 acknowledged tourism as one of the major energy-consuming sectors and requested states to integrate energy efficiency into tourism related polices. Other sections in the WSSD plan of implementation are dedicated to sustainable tourism, energy conservation and emission control, and the special need for effective conservation and management of natural resources in Small Island Developing States.

The tourism industry has grown rapidly to become one of the largest business sectors in the world economy, employing in excess 200 million people worldwide in 2002, generating an estimated $3.6 trillion in economic activity and accounting for one in every 12 jobs worldwide. Tourism has shown remarkable resilience in times of crisis, and is expected to continue to grow in the long term. The industry's rapid growth, however, has placed a heavy burden on local economies, cultures, and environments. Uncontrolled tourism is stressing many of the planet's sensitive locations, especially in Small Island Developing States where low-impact energy sources such as hydroelectricity are often available only in restricted quantities, and where seawater desalination can consume significant amounts of fuel. Compounding the problem, 90% of energy consumption in tourism today is spent on transportation. With current energy sources, carbon emissions are quite high – tourism is responsible for 5-7% of total emissions in Europe according to the European Environment Agency (EEA), and climate change actually threatens some of the most prized tourism destinations such as beaches, island paradises and coral reefs.

Using renewable energy sources, on the other hand, can significantly decrease the environmental footprint of tourism. According to the Institut Français de l'Environnement (IFEN) the Olympic swimming pool in Castres, France, is heated by a 400 m^2 system of solar panels, saving the energy and carbon emissions equivalent of 100 private cars.

As a major global economic sector with substantial environmental impact, the tourism industry provides many opportunities to use and benefit from clean and renewable energy systems. For some tourism businesses, renewable energy offers an opportunity to demonstrate an environmental credential that their customers desire. For others, it may simply be a bottom line decision. Whichever may be the case, renewable energy offers a particularly attractive solution to the challenge of energy supply in tourism.

This handbook is a guide for tourism businesses to learn what the opportunities and benefits of renewable energy are, what questions to ask suppliers on system configuration and design, and how to select reliable suppliers. It contains information on a wide range of renewable energy technologies that can be used by tourism businesses, and I hope it will help increase commitment from the industry to protect our environment as one of our most valuable tourism assets.



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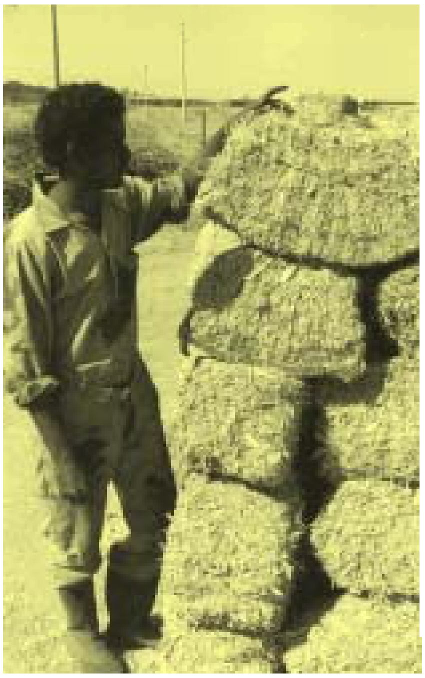
Part 1: Energy for Tourism

Virtually every business has a balance sheet expense called 'energy'. For some, the amount is only a few percent of the total operating expense, but for many businesses – particularly in the tourism sector - it is a major item that heavily influences 'bottom line' profits. Yet, many businesses do not understand the way they use – and often pay for – energy, which is often inefficient and results in both waste and unnecessary expense (see box on page 10: 'Starting with Energy Efficiency').



Crop and animal wastes such as sugar cane waste (bagasse) above are an important source of renew - able energy

But the cost of energy is not just a business expense – its generation and use can also be a significant expense to the environment and to the community, although this cost is rarely paid.[1] For a tourism business that relies on the fossil fuels of coal oil and gas to run their operations, this environmental expense shows up as air and water pollution, toxic waste and climate change. Although tourism businesses and their customers may not pay these costs directly, they are all impacts that can have a direct effect on a tourism business by reducing the desirability of tourism destinations.

The mounting environmental debt from fossil fuel energy use is cause for great concern, which is beginning to drive actions to reduce these environmental impacts. Further, as customers become more aware of these impacts, they increasingly demand action to reduce them through their purchases of cleaner goods and services. In the tourism sector, this awareness is driving an expanding 'ecotourism' movement, but it is also having a general impact on the sector.[2]

Governments, business and individuals are responding through a wide range of actions, beginning with energy efficiency and continuing through investments in renewable energy. In this response, many tourism businesses are discovering that it is possible to reduce their energy expenses, increase profit and meet increasing customer expectations of environmental responsibility.

Renewable forms of energy (see box) thus offer an exciting opportunity to the tourism sector. Renewable energy is abundant, clean, and inexhaustible. It is also the most cost-effective energy source for a variety of applications, meeting between 15 and 20 percent of total world energy demand and 24 percent of the world's total electricity supply.[3] Renewable energy in the form of traditional biomass fuels, such as wood and crop residues, represents about 14 percent of the world's total energy consumption—a larger share than coal (12 percent).

Energy needs in tourism: the size of the problem

Of all energy expenditures related to tourism in Europe and the US, 90% is spent in travel to and return from destination (EEA, EPA). In the US, this meant a total of 76.2 billion kWh used up in 2000 in direct tourism and recreation activities (of which 73% is spent in lodging services), plus 791.3 billion kWh in getting there and back (EPA). Most of the energy in lodging is spent on refrigerating and/or heating rooms, water for consumption and pools, and food – lighting responds for only 5 to 10% of totals (IFEN, France). Even if an average tourist (international and domestic – a conservative ratio of 1:6 is used) requires only half of an American domestic tourist, this would mean that energy consumption in global tourism could be in the order to magnitude of 5,000 million kWh per year, or 80% of Japan's yearly primary energy supply.

Consumption levels in lodging are geometrically linked to the level of luxury of hotels. One-star Accor hotels consume 157 kWh per m^2 per year, two star hotels show an increase of 46%, and four star hotels get up to 380 kWH per m^2/year, an increase of 142% over one-star facilities (IFEN).

Defining Renewable Energy (RE)

Sources of renewable energy exist in the form of direct and indirect solar radiation, the heat of the Earth ("geothermal energy"), and the gravitational effects of the moon that create the tides. Direct solar radiation striking the Earth also drives the global weather system and photosynthesis. This, in turn, creates the wind and waves, as well as biomass (plant and animal matter). The energy in falling water may also be considered a renewable energy source but only if the local environmental impacts are sustainable. Generally, new large-scale hydropower schemes are not considered a source of renewable energy due to their substantial environmental impacts.

Renewable energy can be converted to many other energy forms. Electricity can be generated from solar, wind, biomass, geothermal, hydropower, and ocean resources. Heat can be generated from solar thermal, biomass and geothermal sources, while biofuels such as ethanol and hydrogen can be obtained from combinations of renewable sources.

However, the contribution of newer renewable energy technologies is increasing rapidly. Biomass, geothermal, solar, small-scale hydropower, and wind technologies have grown proportionally faster than any other electricity supply technology, and now supply about two percent of total global energy demand.

In just two decades, the wind energy industry has grown from a producer of small machines for remote power applications into a modern, multi-billion dollar industry supplying grid-connected power. At the beginning of the 21st century, more than 30,000 megawatts (MW) of wind turbines generate clean electricity in more than 30 countries. Consequently, the cost of wind-generated electricity has dropped seven-fold, which makes windpower competitive with most fossil fuel technologies in locations with a good wind resource.

Advantages of Renewable Energy

Renewable energy is generally the cleanest option for producing energy, particularly to eliminate greenhouse gas emissions. But there are many other advantages for both individual tourism businesses and their regions or nations. These include:

Energy Security

RE can diversify the energy supply, thereby promoting energy security and price stability. Renewable energy technologies can be used in conjunction with national utility grids, local "mini-grid" systems or as 'stand-alone" systems. For some applications, RE can reduce dependence on imported fuels, an issue that is particularly important for the tourism sector in developing countries where petroleum imports can account for 50 to 60% of the trade deficit. The use of RE can help countries reduce their payments for oil imports and allow scarce hard currency resources to be used for national priorities.

RE can also enhance energy security by decentralising energy supplies with smaller, modular, and rapidly deployable projects that are particularly suited to the electrification of remote communities and businesses in developing countries. For isolated groups with small power requirements, connections to national utility grids are generally expensive and often not cost-effective. Renewable energy-based "mini-grids" or "stand-alone" systems are, in many cases, better options to provide electric power.

Modern wind generators such as these can produce clean electricity for electricity grids or remote areas (photo courtesy Nordex)

Economic Security

RE is often the most economical choice because of its scale. The modular nature of many RE systems means they can be built (and paid for) as the demand for

The energy in falling water can generate electricity.

energy grows, and embedded within the existing energy network, if there is one. By contrast, large, centralised energy systems take much longer to build and are normally designed to supply a future power demand that may not eventuate. Central power plants and transmission lines are also vulnerable to power interruptions. For the tourism sector, increasing the reliability of power supplies and minimising power outages can be a key element of customer satisfaction.

Environmental Security

For most tourism businesses, maintaining environmental quality is a prerequisite for continued business. RE can offer direct environmental benefits, particularly for developing countries, by improving air quality as a result of reduced airborne emissions of pollutants compared to traditional fossil fuels.

This is particularly important in cities where carbon monoxide, nitrous oxides and hydrocarbons from petroleum-fuelled transport create ground level ozone and other forms of air pollution. Many of these centres are tourism hubs and transit destinations losing business from the environmental concerns of tourists. The 1999 European Union 'Eurobarometer' survey showed that good air quality was a key criterion for selecting holiday destinations.

Burning fossil fuels also emits carbon dioxide, the key greenhouse gas linked to global climate change. The resulting impacts from increased concentration of greenhouse gases includes altered rainfall patterns, floods and droughts, an increase in the frequency and intensity of storms, shifts in climate zones, and sea level rise – all of which can dramatically affect the tourism industry.

Small renewable energy systems can often be a better option than extending cen - tralised electricity grids.

The areas most at risk - small islands, coastal zones, flatlands and wetlands - are primary tourism destinations. A shift in climatic zones and subsequent changes to fauna and flora may mean that many countries will loose their key tourism sites. Increased flood and storm events can also destroy basic infrastructure and increase the incidence of vector borne diseases such as malaria. These impacts will continue to lower visitor numbers to the effected regions. Although tourism businesses may only be very small contributors to greenhouse gases in these areas and unable to affect the overall global emissions, their participation in efforts to reduce greenhouse gases should not be underestimated. Indeed, it is these regions that can demonstrate the effectiveness of clean energy options to other areas of the world.

A Positive Image, A Better Business Environment

Renewable energy systems can offer tourism businesses a positive community image that can be actively promoted to clients. This positive image can also be important to employees who can not only feel a sense of pride in the environmental leadership of their employer, but also benefit from a better working environment. Several studies have shown, for example, that buildings designed to heat and cool themselves using solar design are more comfortable and lower worker absenteeism.

Success Stories: Bucuti Beach Resort

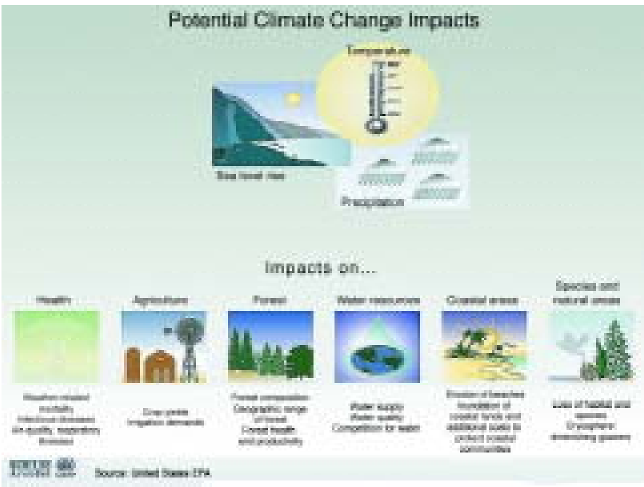
Bucuti Beach Resort in Eagle Beach, Aruba of the Dutch Caribbean, was a runner up for the Environmental Award 2002 of the International Hotel and Restaurant Association (IH&RA). The 63-room resort utilizes light bulbs that help save energy, solar panels to heat water and a treatment facility that recycles water for garden use. Apart from using solar energy sources, Bucuti also promotes strict water saving measures as an energy saving strategy. "Saving water is the single most efficient way of saving energy, since water used in our resort is partially produced by desalination" says Mr. Ewald Biemans, Owner Manager of the Bucuti Beach Resort. (http://www.bucuti.com/english/newsletter/releases/281002.htm)

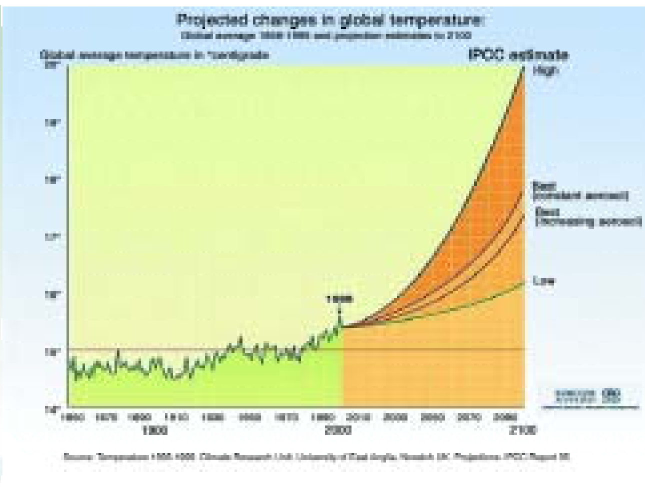
Employment

Developing and expanding markets will create employment in areas related to the design, development, sale, application, manufacture, installation, and servicing of renewable energy-based systems. Although this may not be a direct benefit to tourism operators, it can be a useful element in government discussions that may benefit the tourism sector, such as creating policies to invest in renewable energy projects.

Other Benefits

Creating a strategy to employ energy efficiency and renewable energy can also produce other benefits if used as a basis for sustainable development. Taking a resource efficiency approach to water and sewage, for example, can multiply the benefits obtained through energy efficiency improvements. For example, using efficient shower roses can reduce water and energy use by up to 70 percent without sacrificing shower "comfort". The saved water alone can be used in other areas, while the lower hot water demand can enable the use of solar water heaters (see next chapter 'Generating Heat').





Courtesy UNEP GRID

Limitations of Renewable Energy

The major limitation in renewable energy systems lies in the intermittent and site-specific nature of the energy source. Solar cells, for example, generate electricity only when light is available and wind generators operate only when there is sufficient wind. However, even though such resources are intermittent, they are often highly predictable.

In terms of electricity, most modern grid systems can absorb up to twenty percent of their total capacity from intermittent generating sources such as wind. Even this limitation can often be overcome with a mix of technologies. For example, wind

Starting with Energy Efficiency

Most of the energy used in your business is wasted before it does any productive work. Please read that sentence again. It is a fundamental point.

Consider this: for two devices – the automobile and the incandescent light bulb - the overall efficiency (measured as the percent of energy that actually does the work) is less than two percent. Just two (2) percent.

Consequently, most of our energy devices are simply “leaking” money. Capturing this wasted energy is both economically and environmentally desirable.

In 2001, a major power break forced all of the 19 million inhabitants of the city of Sao Paulo, Brazil, to save 20% of their daily energy consumption. The overwhelming majority reported that this was very easy, just by turning off unnecessary devices and controlling consumption.

For renewable energy systems, however, improving energy efficiency is often the “enabling path” to economic competitiveness. For example, a modern compact fluorescent light globe (CFL), such as the ones pictured here, is four times more efficient than an incandescent bulb, and much cheaper to run over its useful life. However, it is the reduced electricity demand needed to power the bulb that actually enables the compact fluorescent light to be an cost-effective component of a photovoltaic (PV) system (see Solar Photovoltaic Electricity).

For example, a small PV panel can supply sufficient energy to run a 20 watt CFL, but this same panel would run a standard 75 watt incandescent lamp (which produces the same amount of light) for only a fifth as long. Five PV panels would therefore be needed to run the incandescent for the same amount of time as the CFL. The PV-CFL combination offers the benefit of electric lighting with a much lower capital cost than most other options, including a transmission grid. For a tourism business in a remote area of a developing country, for example, the PV-CFL system is five times more efficient than PV with incandescent bulbs, 100 times more efficient than a kerosene lamp, and 500,000 times more efficient than candles—without creating indoor pollution. Consequently, it is a superior alternative to both capital-intensive and low-tech options.

For more information on conducting an energy efficiency audit, see Part 3.

energy and photovoltaic systems combined with another generating source such as hydropower can provide a much higher percentage of electricity in a grid system. Crops harvested on a continuous basis can often fuel biomass energy systems and solar water heaters can store heated water in a tank for later use.

RE systems can also be capital intensive as most of their cost is incurred when they are built. However, their zero or low fuel cost means the cost of energy over the life of the system (life-cycle cost) is often competitive with other energy options.

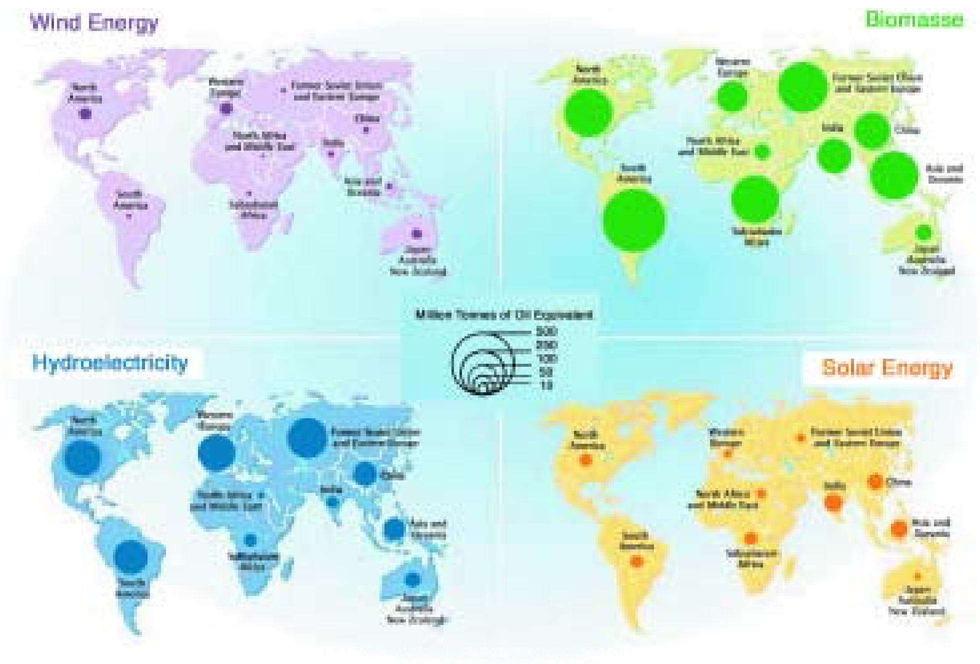
Another key issue that can limit RE development is the need to establish trained support. Past experience has shown that many failures have resulted from lack of maintenance or inappropriate operation. RE technologies are also at different stages of development and therefore may have technical limitations.

Part 2: A Tour of Renewable Energy Applications

There are many different renewable energy technologies, but the most appropriate technology depends on both the available renewable energy resource and the particular application, such as providing electricity for lighting or heat for cooking. There are basically three types of renewable energy applications described in this publication:

- Heat Energy
- Electrical Energy
- Transport Fuels

For many tourism businesses, the majority of energy demand – 60-70 percent – is for hot water and space heating. About 20 percent of total demand is for electricity and the rest powers transport. Of course, these percentages can vary greatly, but they illustrate that heating applications are often the first place to look for opportunities to utilise renewable energy or energy efficiency.



World renewable energy potential (courtesy of UNEP GRID)

Generating Heat

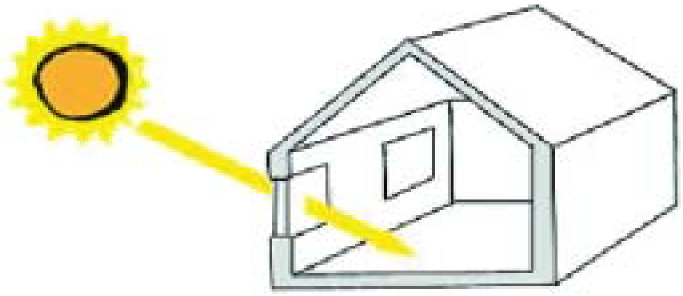
For the tourism sector, renewable energy technologies can provide thermal (heat) energy via solar, geothermal and biomass energy resources to heat buildings, provide hot water and cook food. Buildings and water can be heated using a number of renewable energy technologies. These include:

- Passive solar design;
- Solar thermal systems, (including domestic and commercial hot water systems and pool heating);
- Geothermal systems (including ground-source heat pumps);
- Biofuel systems.

Often, several technologies can be used together. A solar hot water system, for example, can be used together with a wood-fired boiler to heat water.

Passive Solar Design

One of the simplest and most cost-effective means to heat and cool buildings is to use passive solar design. Using a few basic principles, a building can take advantage of the daily and seasonal variation of the sun's path across the sky. In temperate climates, the combination of south-facing windows (in the Northern Hemisphere), adequate insulation and the use of heavy materials such as bricks and concrete, can trap winter sun to heat buildings.



Passive solar design uses a buildings orientation and materials to heat the building in hotter months and keep the building cooler in winter months. (courtesy CASE)

The same buildings can be cooled in hotter months through the use of strategically planted deciduous trees and roof overhangs to shade. These passive solar measures can reduce heating costs by 40 percent or more. In hotter climates, wider roof overhangs, verandas, insulation, light roof colours and materials/designs that do not readily absorb heat and promote cross-ventilation can avoid or reduce the need for expensive air conditioning systems.

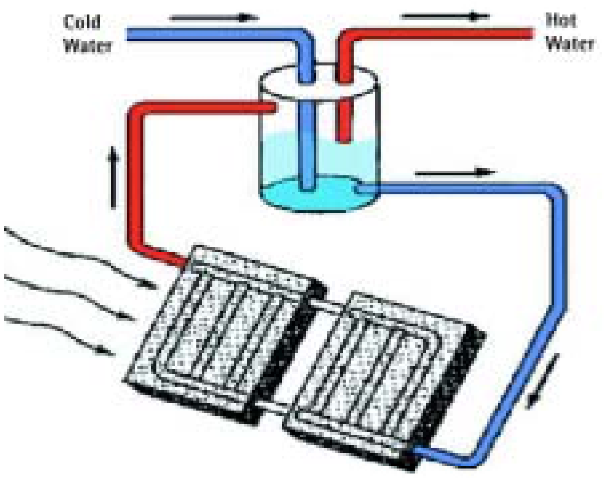
For new buildings, passive systems entail very low or no additional cost because they simply take advantage of the orientation and design of a building to capture and use solar radiation. Passive solar buildings can look like any other building, but are generally more comfortable to live in and less costly to run.

Solar Thermal Systems

Solar energy can cost-effectively provide heat or hot water for applications where temperatures of less than 100°C are needed, including small domestic applications and larger industrial systems. These systems vary in design, but are usually based on a number of solar collectors, a pump/controller, and storage.

Solar Hot Water

A solar hot water system (also called a 'solar water heater') is a mature and commercial renewable energy application. The technology is already widely used in hospitality businesses requiring a constant supply of hot water. As water heating in an average hospitality businesses accounts for approximately 12% of total energy costs (20% of energy use), solar water heaters can lower fuel and electricity bills, provide a buffer against rising energy prices and compensate for unreliable power grids. Solar water heaters can work for up to 20 years with relatively little maintenance. Consequently, they can be very cost-effective.



Natural convection pumps heater water rising from the solar collector into the storage tank in a process called 'thermosiphoning' (see additional diagram below).

In temperate climates, a standard solar water heater can generally meet between 50–65 percent of domestic hot water requirements, while in subtropical climates, the percentage can be 80–100 percent. Domestic solar water heaters range in price from about $500 to $2,500,[4] depending on their tank volumes, which have nominal capacities of 180litres and 300 litres. The cost of a commercial system will vary greatly depending on its size.

In equatorial, tropical and Mediterranean regions where solar energy is plentiful throughout the year, solar water heating can be particularly cost-effective as the reduced energy costs can "pay" for any additional system costs in as little as 2 to 4 years. In equatorial regions, 2 hours of bright sunlight on a collector panel approximately 2 square meters will maintain the water in a 225 litre tank between 40°C to 60°C when it is used at a continuous withdrawal rate of 8.8 litres a minute.

Success Stories - Sea View guest house, Sri Lanka

The solar water heating system at the 20 room Sea View guest house, in Mt. Lavinia, Sri Lanka, consists of 3 collector panels of 2 square metres each, and a 450 litres stainless steel water tank, 2.6 metres in length and 0.5 metres in diameter. The system is closed-coupled and direct; i.e. water circulates through the collector and flows from a natural thermo syphoning action into the water tank located above the collector panel. The system cost around US$ 1,500 (Rs.115,000).

Apart from the availability of solar energy, the viability of solar water heaters depends on the price of the fuel used to augment the solar heated water. Most solar water heating systems include some type of auxiliary heating to provide hot water when there is insufficient solar energy (at night or during cloudy periods) or to raise the temperature of the solar heated water. (Hot water is generally used at 45°C to 55°C and in times of low solar energy, additional heating is needed). In many systems, the auxiliary heating can be gas or electric and incorporated directly into the hot water tank.

Solar hot water systems can often be retrofitted to existing buildings with few modifications. In new buildings, integrating the design and the development stage offers several advantages, including lower pipe runs and easier plumbing access – both of which can reduce costs.

Several manufacturers offer a range of products for different regions, roof types and even colours for the tank and trim. Tourism facilities with a number of residential buildings or units can often benefit from small solar hot water systems placed on individual rooftops, while larger solar hot water systems can be used as larger central hot water systems. Solar water heaters can also be used to “pre-heat” water for certain applications.

Components of Solar Water Heaters

The Collector

Absorber plates are made of a stainless steel or copper plates tubes painted with a special black paint to maximise heat absorption and bonded to copper tubes. The absorbers are covered with a single or double sheet of glass (called ‘glazing’) and placed in an insulated metal casing. Some collectors are double glazed where the additional glazing is made of UV resistant plastic. Evacuated tube collectors are made of a number of heat-pipes, which are each soldered to a copper plate and placed in an evacuated tube.

Water tank

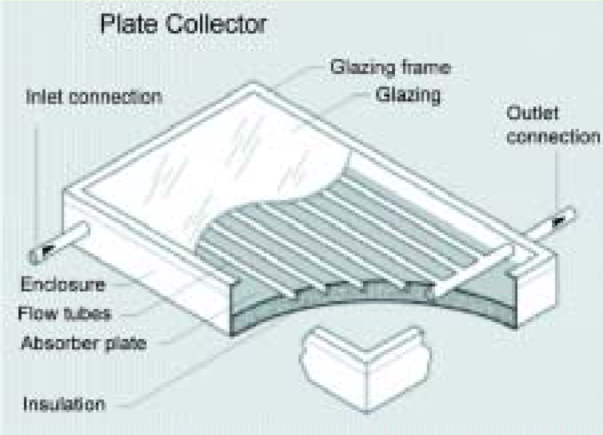
Tanks are made of stainless steel or mild steel with an enamel lining and are insulated to keep the water warm at night and during periods of low solar energy.

Heat exchanger

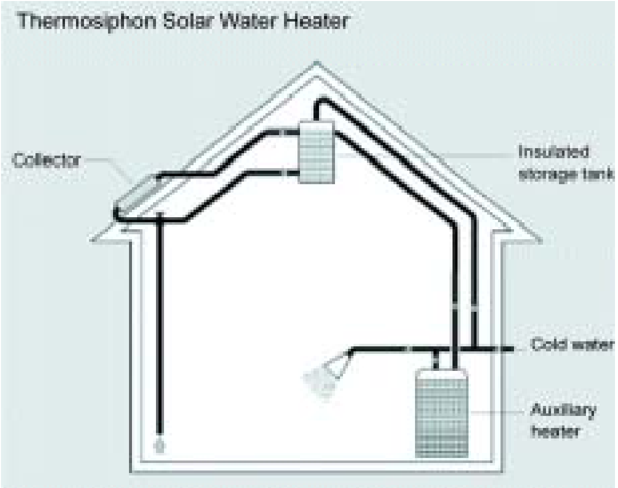
Some systems include a heat exchanger, which is usually located in the hot water storage tank.

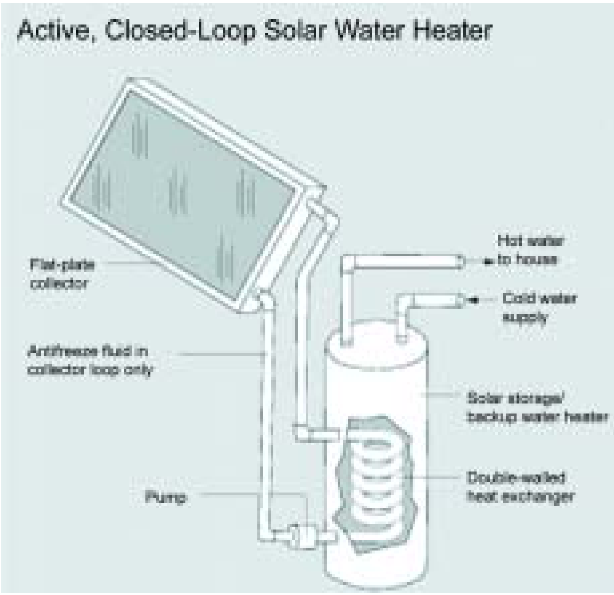
A backup electric or gas water heater

This is often needed to heat water at times when there is no sunlight or to raise the temperature of the water heated by the solar water heater. In some tropical climates, electric or gas backup heaters are not needed.



Solar heated water can also be used for space heating. In such a system, the solar heated water is circulated throughout a building via radiators or through special collectors embedded in a cement slab. Solar space heating systems generally require much larger areas of solar collectors and hot water storage, but their operating principles are the same.





Solar water heating manufacturers and distributors verify their products through several methods. In the U.S., for example, the Solar Rating and Certification Corporation (SRCC) and the Florida Solar Energy Center (FSEC) offer independent performance testing and certification for solar water heating systems. SRCC is an independent, nonprofit trade organization that creates and implements solar equipment certification programs and rating standards. FSEC is a state-supported solar energy research facility. Similar rating programs exist in Europe and other countries where solar water heating systems are widely used.

A solar water heater works by collecting solar energy in solar collectors (see box), which are usually mounted on the roof facing the sun (south in the northern hemisphere and north in the southern hemisphere). Collectors can be mounted directly on the roof at the roof angle or on a frame titled to maximise solar exposure and match hot water demand, which is often the greatest in winter.

When solar energy falls on the surface of the collector it is absorbed as heat and transferred to the water or a heat transfer liquid continuously circulating through the copper tubes of the collector (in frost-prone areas, an antifreeze solution is used to prevent freezing). The flow of water or liquid continues uninterrupted as long as the sun is shinning and the collector plate is heated. Each time the water or liquid flows through the plates, the temperature of the water or liquid increases.

In *passive systems*, the heat transfer fluid is circulated naturally via the natural convection process called thermosiphoning,[5] while in active systems, electric pumps, valves, and controllers are used to circulate water or other heat-transfer fluids through the collectors. In close-coupled systems, the tank is located above the panel.

In a *direct close-coupled system*, potable water is circulated through the collector and stored in the storage tank. For an indirect system, an antifreeze liquid is circulated through the collector, storage tank and the heat exchanger (located in the tank). Indirect systems are most used in temperate climates where water could freeze and break the pipes or where the water contains a high level of dissolved minerals that can build-up mineral deposits and block collector pipes.

In a *split collector and storage system*, the water storage tank is located some distance from the collector panel. In ‘passive’ systems, the tank is located at some distance but above the collector, which then allows the heated water/liquid to circulate naturally to and from the tank. In ‘active’ systems, the storage tank is located below the collector and uses an electric pump to circulate water/liquid to the collector. Some systems utilize a small low voltage solar electric panel to drive the electric pump, which negates the need for an external electricity source. Passive and active systems can be designed as direct or indirect systems.

Drainback systems are a type of indirect system using pumps to circulate water through the collectors. Because the water in the collector loop drains into a reservoir tank when the pumps stop, this system is appropriate for colder climates.

Success Stories - Solar water heating in Denmark

The 800 m^2 Glamsbjerg outdoor swimming-pool in Glamsbjerg, Denmark has used solar pool heating since 1989. The solar collector consists of a simple network of plastic tubes placed in the valleys of the corrugated roof on a sports hall adjacent to the swimming pool. The roof faces south and is slanted at a horizontal angle of 26°C. The solar collector covers 560 m, including the spaces between the plastic tubes and is directly linked to the pool's water treatment system in a way that some of the water being pumped into the pool passes through the collector. An electronic sensor starts the pump when the water in the collector reaches a temperature higher than that of the pool.

Solar Pool Heating

Heating the water in a swimming pool is one of the most cost-effective and simplest applications of solar energy. In such a system, the pool water is pumped through a solar collector that is usually mounted on a building rooftop facing south (in the Northern Hemisphere) or north (in the Southern Hemisphere). Because solar pool-heating collectors operate just slightly warmer than the surrounding air temperature, these systems typically use inexpensive, unglazed, low-temperature collectors made from specially formulated plastic materials. Glazed (glass-covered) solar collectors usually are not used in pool-heating applications, except for indoor pools, hot tubs, or spas in colder climates. In some cases, unglazed copper or copper-aluminum solar collectors are used for solar pool heating.

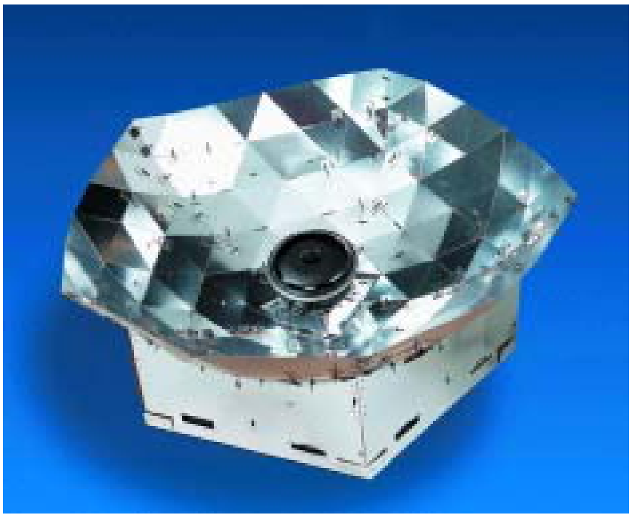
A solar pool heating collector is generally much larger than a solar water heater for domestic water heating and 50% to 100% of the area of the pool, depending on local climate conditions. Such systems often incorporate an insulating plastic "blanket" placed over the pool to prevent heat loss when it is not in use.

The system requires no heat exchanger as the water circulating through the tubes comes directly from the pool. However, since the system is not protected against frost it has to be drained every winter.

The solar system annually displaces 120 megawatt-hours (MWh) of electricity or 12,000 m^3 of gas; reducing annual heating costs by DKK 42,000. With a capital outlay of DKK188,000 and annual operating costs of DKK 3,000, the simple payback period was less than five years. The solar heating system also reduces nitrous oxide emissions by 65 kg and carbon dioxide emissions by 32,000 kg per year.

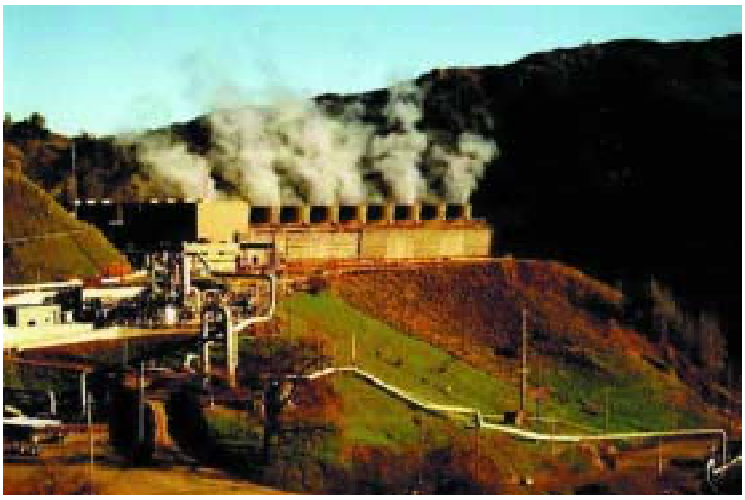
Other Solar Thermal Applications

Renewable energy can be used for range of additional thermal applications, though few are directly relevant to the tourism sector. Cooking with solar energy is one application that can be used, particularly in developing countries with significant solar energy potential. Solar cookers are relatively simple devices - either an insulated box with a glass lid or a parabolic dish that focuses solar energy onto a cooking surface.



Tourist hiking camps and rural lodges in Nepal are using solar cookers such as the one above.

Solar cookers are widely used by tourist hiking camps and rural lodges in the Himalayan region in Nepal. The cookers are used to boil water for drinking and hot beverages, boil vegetables and rice, and heat dried and tinned food. The Nepalese Alternative Energy Promotion Centre reports an increasing number of tourism businesses using these cookers and not only in the Himalayas but also in Kathmandu. They are suitable for cooking most Nepalese dishes (which the tourists want to taste) and for boiling water. In addition, ghee and oil shops are using these cookers to melt ghee. The cookers lower both fuel use and the need to cut trees while improving hygiene and overall sanitation. Tourists are also pleased and often find them an attraction.



A geothermal energy field.
(Courtesy NREL)

Geothermal Heating Systems

Geothermal energy – the heat of the Earth - can be recovered at temperatures ranging from 35°C to 150°C and used to heat buildings, greenhouses, aquaculture facilities and to provide industrial process heat. Higher temperature geothermal energy can also be used to generate electricity.

Using geothermal energy directly is 50 to 70 percent efficient compared to the 5–20 percent efficiency when it is used indirectly to generate electricity (although the waste heat from generating electricity can also be used and thus boost the overall efficiency). Direct applications can also draw from both high and low temperature geothermal energy sources and produce useful energy for as low as US$0.02/kilowatt-hour (kWh). Industrial quantities of geothermal energy are retrieved via wells drilled into a geothermal field as pictured above.

One of the most commercially accepted geothermal technologies is the geothermal heat pump (GHP), also described as geoexchange and the ground source heat pump.[6] A GHP takes advantage of the natural and nearly constant heat of the Earth, which can be used as a heat resource in the winter and a heat sink in the summer.

GHPs can be used for heating and cooling buildings, water heating, snow melting and swimming pool heating. It is not a new technology but their use is growing in the building heating/cooling sector. Although they can have higher initial costs, when designed and installed properly a GHP system can quickly pay for itself through energy cost savings.

GHPs are one of the most energy efficient and cost effective cooling and heating systems available; using much less energy than conventional heating/cooling systems and delivering 3 to 4 times the energy they consume. This is because a GHP moves heat to or from the ground instead of generating it from heating coils or electrically operated compressors. GHP operating costs are significantly lower than conventional heating and cooling systems and they operate for 20 years or more with minimal maintenance. Hotels using GHPs in North America report energy savings of 40%-70% in the winter and 30%-60% in the summer.

GHPs are most often used for space cooling and are usually designed to meet the entire space-conditioning load of a building. When used for heating, they are usually designed to provide approximately 80% of the heating demand. A backup heating system is usually necessary for installations operating year round in temperate regions.

Other advantages of GHPs for tourism businesses include:

- Silent operation;
- Improved indoor air quality, including comfortable humidity levels and reduced pollutants; and allergens from the lack of combustion;
- Absence of reliance on air from outside the building;
- Absence of aboveground equipment (such as cooling towers and air coils) that might jeopardize exterior aesthetics.

GHP design is based on soil characteristics, the type of ground material, moisture content and ground temperature. GHPs can be used in most regions except desert areas where dry and sandy soils do not efficiently transfer heat. The technology is founded on the principle that the Earth's interior temperature remains relatively constant during most of the year (see box for a description of different GHP systems.)

When the GHP system operates in the heating mode, the heat from the ground-water is absorbed by the circulating refrigerant. The heated refrigerant is then pumped toward a heat pump that transfers the heat from the refrigerant to water. This heated water can then be used directly as hot water or circulated through radiators for space heating. Such installations are called refrigerant (or water)-to-water systems. Alternatively, air can be blown over the heated pipes and the heat delivered to interior spaces through a system of air ducts, which is referred to as a water-to-air system. When GHPs are operated in the cooling mode, the process is reversed. The refrigerant absorbs the heat from interior spaces of the building and transfers it to the ground.

One of the most important aspects of heat pumps in relation to the heating/cooling of buildings is the direct relationship between the efficiency of the unit (and the energy required to operate it) and the difference in temperatures. In heat pump terminology, the difference between the temperature where the heat is absorbed (the "source") and the temperature where the heat is delivered (the "sink") is called the "lift." The larger the lift, the greater the electric power input required by the heat pump.

This is the basis for the efficiency advantage of the geothermal heat pumps over air-source heat pumps. An air-source heat pump must remove heat from cold

Geothermal Heat Pump Systems

GHP systems include three principal components:

1. Earth connection;
2. Heat pump;
3. Heat distribution subsystem.

Earth Connection Subsystem
The earth connection subsystem consists of geothermal wells or trenches, (or, for open loop systems, ponds, lakes, rivers, or irrigation ditches where clean water can be recycled), pipes (loops) through which the refrigerant (or ground water) is circulated.

Using the earth as a heat source/sink, a series of pipes knows as a "loop," is buried in the ground near the building to be conditioned. The loop can be buried either vertically or horizontally and contains a circulating fluid (water, or a mixture of water and antifreeze) that absorbs heat from (or relinquishes heat to) the surrounding soil, depending on whether the ambient air is colder or warmer than the soil. Currently, horizontal systems constitute about half of the installations, vertical systems 35%, and pond or other systems approximately 15%.

Geothermal Heat Pump Unit
The foundation of any GHP system is the heat pump unit itself. The most commonly used unit is a single package water-to-air heat pump. Such a unit consists of a single enclosure, about the size of a small gas furnace, housing a refrigerant-to-water heat exchanger, refrigerant piping, control value, compressor, air coil (heats in winter; cools and dehumidifies in summer), fan and controls refrigerant piping and control valves.

Most GHP units use an R-22 refrigerant gas, which is considered a transition gas with an ODP (ozone depletion value) of 0.05, i.e. only 5% of the most damaging refrigerants R-11 and R-12. R-22 is scheduled to be phased out by 2030.

The capability to heat water can be added to most equipment using components consisting of a refrigerant-to-water heat exchanger and a small circulating pump. Field installed piping connects this unit to the existing domestic hot water heater. Because geothermal heat pumps are so much more efficient than other water heating systems, manufacturers are beginning to offer "full demand" systems using a GHP specifically to heat hot water in climates where the GHP can be operated most of the year.

Heat Distribution Subsystem
As GHP systems are usually sized to meet cooling requirements, backup heating systems are usually required. Conventional ductwork is generally used to distribute heated or cooled air from the geothermal heat pump throughout the building when a water-to-air system in used.

outside air in the winter and deliver heat to hot outside air in the summer. By contrast, the GHP retrieves heat from relatively warm soil (or groundwater) in the winter and delivers heat to the same relatively cool soil (or groundwater) in the summer. As a result, geothermal heat pumps are always pumping the heat over a smaller temperature difference than the air-source heat pump, regardless of the season. This leads to higher efficiency and lower energy use.

The heat removed from the indoor air during the summer can also provide a low cost source of hot water. In cold weather, however, a part of the GHP's heating capacity must be diverted for water heating, which lowers the heat available for space heating. Also, water heating can only be done when the GHP is in operation. During periods of the year when neither space neither heating nor cooling is required, an alternative water heating method is required. GHP systems are most cost effective when space cooling is required for significant periods during the year.

GHP Designs

The most cost-effective GHP depends entirely on local ground conditions. An inspection of the site and ground conditions is therefore mandatory before the best method can be selected.

There are two basic types of GHP systems: ground-coupled systems and ground/surface water heat pumps.

Ground-coupled systems use vertical loops in boreholes or horizontal pipe loops installed in trenches in direct contact with the earth. There are two types of these systems, including:

Vertical loops in boreholes - Placing the loops vertically in the ground requires more expensive drilling for a borehole than digging a trench. However, as the pipes are buried deeper in the ground (46 to 152 metres), they are in a more stable thermal zone and thus more efficient. The temperature in the ground at 30 metres does not vary during seasons as much as surface soils at 1 –2 metres. Vertical systems can therefore be a better option in areas of extreme temperatures. They are also easier to install when the exterior spaces have already been landscaped and site disruptions need to be minimised.

Horizontal loops in trenches - Horizontal installations are cheaper to install than vertical designs as the loops are laid out in a trench (1 to 2 metres below the ground), and trenching is cheaper than drilling. They are also a better option when the soil includes hard rocks. On the downside, trenches need large surface areas and longer pipes, which are often coiled to maximise heat transfer capacity.

Ground and Surface Water Heat Pumps have been used since the early 1970s. Ground water and surface water systems can be used when there is an adequate supply of water either in wells, lakes or rivers. The well, lake or river water is pumped through supply pipes into the building and returned to the source through a discharge pipe. This method of ground coupling should be considered by tourism businesses situated near lakes and large ponds, where the loops can be submerged or where the ground water supply is relatively close to the surface. As water provides a stable thermal zone, this technology can be easily installed and is highly cost effective where temperatures are not extreme.

Open loops - Open loop systems can be used when there is an adequate supply of useable groundwater. The water is pumped through supply pipes into the building and returned to ground through a discharge well. An additional heat exchanger is often installed between the building water piping systems and the ground water piping system. However, when the water has a high content of dissolved minerals (>100ppm) and/or contains hydrogen sulphide (that gives the odour of rotten eggs), closed loop systems need to be used.

Closed loops - For a closed loop system, a closed heat exchanger can be placed within a lake and the working fluid pumped through it and into the dwelling being heated or cooled.

Designing and retrofitting GHP for tourism properties

Importantly for small tourism projects, GHP can often be easily retrofitted to existing buildings. All components (including compressors, heat exchangers, fans, filters and controls) are 'packaged' into a single cabinet installed in a small indoor space.

As with all renewable energy choices, the scope for GSP should be considered at the onset of the building or project design process. This can facilitate better use of space and lower costs, particularly because a GHP system:

- Requires very little mechanical space;
- Eliminates the need for a boiler room;
- Lowers the size of air distribution ducts, which can allow higher ceilings that can be an asset for accommodation properties, museums, galleries and visitor centres;
- Allows for greater individual temperature control, an important requirement for accommodation business;
- Eliminates exterior equipment such as cooling towers and split systems.

Dual-fuel heating systems - These systems use GHP as the primary resource and fossil fuel boilers/furnaces as backup. Duel-fuel systems can be easily retrofitted into existing fossil fuel systems.

Success Stories - Fox Chase Club House, West Philadelphia, USA

The 150-acre, Fox Chase Golf Club in Lancaster, Pennsylvania (USA) has been using a GHP system since 1999. The 3,000 square metre clubhouse, which remains open all year round, is heated and cooled with 6 GSHP units that provide hot water for the bathrooms and kitchen.

The GHP system consists of:

- 6 GHP units connected to one vertical well with a total installed capacity of 25.5 tons;
- 4 units of 5-ton capacities each connected to four 200 metre wells;
- 2 units of 2.5 and 3 tons respectively are each connected to two 100 metre wells;
- One of the 5-ton units equipped with an additional heat recovery/exchange unit to provide hot water;
- 2 circulating pumps for all 6 GHP units, which alternate service and cycle-on when compressor action is required;
- A single wall thermostat that controls each GHP;
- Heat exchanger pipe composed of 4cm diameter of polybutylene;
- A secondary heat transfer fluid composed of water and 20% propylene glycol.

A cost comparison of the GSHP System to a conventional system is given below:

	GHP System (US$)	Conventional System (US$)
System purchase costs	40,000	38,600
Heat pumps	14,200	-
Air distribution ducts	16,800	11,900
Pumps and circulating loops	2,000	-
Vertical drilling	7,000	-
Roof top equipment	-	26,700
TOTAL	$77,200	$80,000
Club house energy costs per annum	$13,500	$14,700

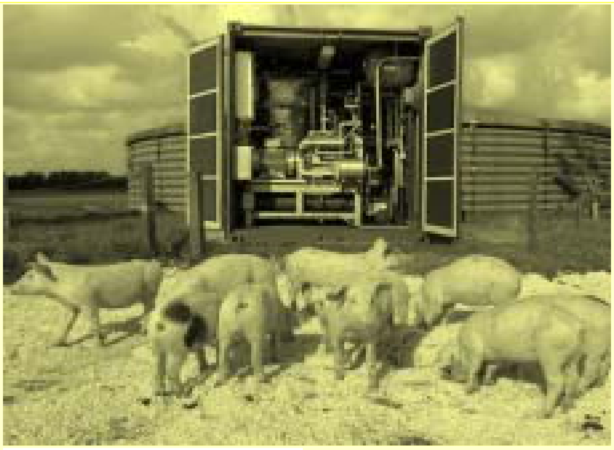
The above figures show that the GHP system is around US$1,400 more expensive than a conventional system with electric air conditioning and propane fuelled heating. The annual operating costs, however, are $1,200 less than conventional systems. The only maintenance required is the cleaning and replacing of filters. The total energy costs of the clubhouse, including heating, cooling and hot water are around US$2.7 per square metre. Energy efficiency is enhanced with ceiling and wall insulation and double glazed windows. The payback period for the GSHP is less than 2 years.

Heating swimming pools - As with water heating, swimming pools can be heated by GSHP systems that recover and reuse the waste heat rejected to the ground during the reverse space cooling operation.

Biomass Systems

Biomass can be used in a variety of heating applications, depending on the type and availability of the biomass resource. The main sources of sustainable biomass include:

- *Industrial and agricultural wastes and residues*, such as sugar cane waste (bagasse), wood waste from forestry operations, and residues from other short rotation crops;
- *Organic wastes* from animal husbandry, straw and husks;
- *Energy crops*, such as sugar cane, corn, and trees grown in short-rotation plantations;
- *Domestic and municipal wastes*, such as sewage and garbage.[9]



A biogas plant converts animal manure into biogas

About Digesters

Digesters are especially built units, which allow for the decomposition of wet waste by bacteria in the absence of air (anaerobic digestion). In this process, bacteria first digest biomass into sugars and then into various acids, which then decompose to produce an inert residue and biogas. Digesters can be built in virtually any size, from as small as $1m^3$, producing just enough biogas for cooking for one household, to as large as 20,000 m^3, which can produce sufficient gas to generate 1MW of electricity.

Animal (chicken, pig, cow) excrement is a rich fuel source and is usually a combination of bedding material and droppings that is excellent feedstock for biogas production. While the animal waste is relatively easy to handle, it does have an odour and is often produced in modest quantities at dispersed locations. Biogas production is most viable when considerable quantities of animal waste are available at a central location.

The main processes for utilising these sources of biomass include:

- *Direct combustion*, usually of solids, in boilers or as a fuel in engines or turbines;
- *Gasification*, via a physical or chemical conversion process to a secondary gaseous fuel, followed by combustion in an engine, boiler or turbine;
- *Biological conversion*, via bacterial anaerobic digestion to methane-rich biogas that is used as a gaseous fuel (see box ‘About Digesters’);
- *Chemical or biochemical conversion*, to produce methanol, ethanol, or other liquid fuels.

Many combinations of source, processes, and technology are possible, but direct combustion is the most commercially developed process.

One of the principal biomass fuels is wood. Wood burning appliances have improved notably in efficiency, cleanliness and convenience in recent years. Room heaters as well central furnaces for heating water or air are sold commercially in many regions.

In many rural areas where forest degradation is not an issue, firewood is often cheaper than oil, gas, or electricity, even when labour costs for cutting, collecting and refuelling is accounted for. Tourists also appreciate the aesthetics of a flame, especially in cabins or rooms - even though they may require refuelling every 4 to 8 hours.

Some central heating units are semi-automatic and require attention only once a day and fully automated units burning woodchips or wood pellets are also available. For tourism businesses located near saw mills or other wood processing plants, the use of sawdust and other wood waste for heating and/or cooking purposes can be particularly attractive. In many cases, the low cost of wood fuel makes it well suited to water heating. Wood-based water heaters can be used in conjunction with solar water heaters; providing additional hot water in winter (and other times when solar radiation is low).

Biofuel Boilers

New model boilers fuelled by biomass can automatically switch to an existing oil or gas boiler if the biofuel supply runs out. Other options include boilers that operate on biofuels as well as oil or gas, and gasification boilers where the biofuel is first converted into a burnable gas.

Biogas

A methane-rich gas called biogas can be produced in purpose built digesters ranging from 1 to 10 cubic metres from the digestion of plant and animal wastes, sludge and wastewater (see box above ‘About Digesters’). The gas can be used in a combined heat and power (CHP) plant or co-generation unit to produce heat and electricity (see next section), or fuel cooking stoves as well as boilers for space and water heating. The input of wastes into the digester can be continuous or in batches, and the digestion process can take several days to several weeks, depending on the types of biomass and the local climate. Generally, each dry kilogram of input will produce 8 megajoules of energy – an amount required to boil 250 litres of water.

Success Stories: Dunstall Court, Worcestershire, UK

Space heating and hot water at the holiday rental cottage (with indoor swimming pool) at Dunstall Court, Redditch, Worcestershire, UK, is provided through a wood-fired boiler. The cottage is a refurbished farmhouse and barn, owned by the agri-tourism business A F Hill & Son, who have been managing 10 hectares of willow and poplar coppice plantations[7] since 1995. The plantation cuttings are used to provide heat and hot water for the present farmhouse and holiday cottage and also sold to other industries.

Wood harvested from coppicing, together with waste wood produced in the preparation of the cuttings, is chipped, spread over the ground and allowed to dry. The dried chips are then stored and fed into a 150kW boiler. One initial difficulty was the inconsistent size of the wood chips, but this was rectified through the use of a tractor-mounted chipper. Hot water is fed via a network of pipes for direct use, heating the swimming pool and for space heating radiators. Except for a manual ignition, the entire system is fully automated and cost approximately $34,000. Around 1.3 cubic metres of chips are required to provide heating and hot water for 24 hours.

Generating Electricity

There are basically two applications for renewable energy electricity: as electricity fed into central power distribution facilities – also called the transmission grid or simply ‘grid’ – and electricity for remote areas where a grid is either weak or not available, such as small islands. In both cases, renewable energy can often (though not always) be used in conjunction with other generating options, such as diesel generators.

Grid-based Electricity

Although electricity generated for centralised power grids tends to come from larger size units, usually tens or hundreds of megawatts (one megawatt can power about 200 average homes), the trend in the last decade of the twentieth century has been to smaller units and down to the size of a one-kilowatt rooftop system of solar cells (see PV electricity below). This approach, referred to as 'distributed generation', has derived and benefited from competition and new regulations allowing access to the power grid for smaller generators.

A tourism business can also decide to generate electricity from a renewable resource and sell excess power not used by the business to the local power authority, if it is allowed. This will involve the use of special equipment such as power electronics and special meters. In this type of system, the business buys electricity from the utility when their system is not generating electricity, thus using the local power grid as a form of battery.

The price that a utility will pay for this cleaner electricity varies greatly, but can often be economically advantageous. In some US states, for example, systems less than one megawatt in size can be 'net metered' – meaning the customer pays the same for the electricity fed into the power grid as the power that is taken from the grid. In essence, this means the customer is selling electricity at the retail rate and buying it at the wholesale rate.

Greenpower

One outcome of competition and new market regulations is an electricity product based on renewable energy called 'greenpower'. In Australia, Europe and the US, there is a growing market for greenpower, which has also increased demand for renewable energy systems. If available, greenpower is one of the simplest ways to power your business with renewable energy.

In most greenpower programmes, customers agree to buy a certain percentage of their power from a renewable energy resource, usually (but again not always) at a rate that is usually about ten percent more than the cost of conventional power on a per unit basis.

However, it is important to remember that your business does not pay a rate for electricity, you pay a bill. Smart businesses can combine their purchase of greenpower with energy efficiency to maintain, and even lower, their existing electricity bills. Thus, running your operation on greenpower can be a valuable, cost-effective distinction for marketing purposes.

Off-Grid Remote Area Power Supplies (RAPS)

Although renewable energy options such as windpower (see below) are an increasingly attractive option for generating electricity into centralised power grids, renewable energy systems are particularly cost-effective in areas where there is no electricity supply or where the supply is erratic. As most forms of renewable energy are intermittent (hydropower can be an exception), they require some form of energy storage, usually batteries.

A RAPS system generally consists of:

- One or more generators, including solar, wind, hydro, petrol and diesel options;
- Energy storage;
- Controllers;
- Electronic devices to convert the electricity to the voltage required for applications (such as 230 or 240 volts AC).

Some RAPS systems rely on renewable energy generators alone, while others incorporate a back-up generator fuelled by petrol or diesel (including biodiesel – see following section on 'Liquid Fuels'). Per unit of electricity generated, RAPS systems are generally more expensive to build and maintain than grid-connected systems.

Several technologies can often be used together in a RAPS system, such as this PV-diesel hybrid.

However, RAPS technology has advanced rapidly in the past two decades and is generally available in a wide range of configurations and from a number of international dealers. The systems generally range in size from one to 50 kilowatts. A properly designed and maintained RAPS system can provide a reliable, safe and cost-effective electricity supply. A version of RAPS – called an uninterruptible power supply or UPS - is also frequently used in larger businesses with access to a conventional power grid but need higher power reliability. RAPS systems can also be the basis for a village power system with the use of a local electricity distribution system, which is referred to as a 'mini-grid'.

One critically important design element for RAPS systems is the choice of appliances. For systems without an auxiliary power supply, such as a diesel or petrol generator, using an appliance that draws large amounts of power, such as washing machines and power tools, is often not possible. Such systems are better at running lights and electronic equipment, such as radios and televisions. As mentioned in the first section, it is critically important to choose the most efficient appliances for even small systems. In a small solar photovoltaic system, for example, the same system that powers one 75-watt incandescent light bulb can power four energy efficient compact fluorescent bulbs.

In larger RAPS systems, the choice of power electronics to convert direct current into alternating current, (called an 'inverter'), is also crucial. Motor driven appliances, such as washing machines, often consume a large amount of electricity – several times the motor rating - for a fraction of a second when starting. Inverters vary in their ability to handle this peak load and also in their efficiency of converting the DC power into AC power. The best inverters on the market today have an efficiency of 90-95% and cost about $1/watt or $2000 for a 2 kW inverter.

In smaller systems, the decision on whether or not to use an inverter depends on the type and frequency of appliances to be used. An inverter allows the use of conventional (and often cheaper) appliances and wiring. In addition, the choice of using AC or DC appliances will depend on their availability (DC appliances can be more difficult to source and more expensive) and their suitability to the application. DC appliances are usually available in low voltages of 12 or 24 volts. This means that the electric cabling must carry more current and is therefore more expensive than AC wiring.

Some systems use both DC and AC circuits; the DC circuits powering lights while the AC circuits power points AC appliances. The use of a split system means that even if the inverter fails, lights (and other DC appliances) can still be run.

Following is a guide to using different appliances in RAPS systems:

Lighting

Lights may be powered by either low voltage direct current (DC) or conventional alternating current (AC). In a small home, tourist cottage, RV, or boat, low voltage DC lighting is usually preferable as DC wire runs can be kept short and allow the use of smaller gauge wire. System costs are lower because an inverter is not required.   Although incandescent bulbs can be used, DC fluorescent lights are often preferable because they produce 3 to 4 times the light of incandescent bulbs for the same amount of energy.

Halogen bulbs are 30% more efficient and actually seem almost twice as bright as similar wattage incandescent because of the spectrum of light they produce. Twelve and 24-volt replacement ballasts are available to convert AC fluorescent lights for use with DC. For large installations with many lights, the use of an inverter to supply AC power for conventional lighting may be the most cost effective approach.

Refrigeration

Refrigerators are major users of electricity and should therefore be as efficient as possible for use in a RAPS system. The most efficient models use DC motor and compressors that consume 300 to 400 watt-hours of electricity per day compared to conventional AC refrigerators that use 3000 to 4000 watt hours per day (at a 70 degree F average air temperature). Although the cost of more efficient DC refrigerators can be higher, the lower energy demand can reduce the overall system cost by reducing the required number of batteries and the size of the generator(s).

Major Appliances

Appliances such as washing machines, larger shop machinery, power tools and pumps normally use standard AC electric motors (250-750 watts) and require significant amounts of power, which may not be cost-effective in systems without an auxiliary petrol or diesel generator. AC motors can also be difficult to start with an inverter power and can use 50% to 75% more electricity than efficient models.

A standard washing machine, for example, uses between 300 and 500 watt-hours per load. If the washing machine is used more than a few hours per week, it may be more cost-effective to purchase a high-efficiency washing machine rather than increase the size of the system to power a low-efficiency machine. For many belt-driven appliances (washers, drill press, etc.), standard electric motors may be replaced with high-efficiency motors (either AC or DC) that can be purchased as separate units or as motor-replacement kits.

Small Appliances

Irons, toasters and hair dryers consume large amounts of power but are usually operated only during short or infrequent intervals. For tourist cottages, a stand alone system with a large enough inverter and battery storage will allow these appliances to be used, although such systems will be more costly.

Electronic equipment, such as stereos, televisions, VCR's and computers are well suited to stand alone systems as they have relatively modest power requirements and are available in low voltage DC as well as conventional AC models. Generally, DC models use less power than their AC counterparts and battery-powered devices, such as portable stereos that run on "D-cell" batteries, will operate on a 12-volt DC system.

Renewable Energy Electricity Options

For businesses that would like to generate their own power, either in a stand-alone system or to feed into a power grid, the following section gives some guidance on different options.

Windpower

Generating electricity from the wind is a mature technology and economically competitive with most fossil fuel applications, depending on the location. Wind turbines offer an attractive energy option for tourism businesses situated in coastal areas, flat open plains and mountain passes exposed to consistent winds. Once a wind turbine is properly installed, it requires little maintenance and does not emit greenhouse gasses or other airborne pollutants.

The most common wind turbines for generating electricity today use two or three blades revolving around a horizontal axis connected to a generator. They are mounted on concrete or steel towers and usually include a gearbox, generator, and other supporting mechanical and electrical equipment.

The power that can be generated from a modern wind turbine is practically related to the square of the wind speed, although theoretically it is related to the cube of the wind speed. This means that a site with twice the wind speed of another site will generate four times as much energy. Consequently, the availability of good wind speed data is critical to the feasibility of any wind project. Most commercial wind turbines operating today are placed at sites with average wind speeds greater than 6 metres/second (m/s) or 22 km/h, although annual wind speeds over 5.5 metres per second can also be viable. A high-quality wind site will have an annual average wind speed in excess of 7.5 m/s (27 km/h). Although the wind resource for any site is intermittent, it can be highly predictable and thus the output from wind turbines can be integrated into existing electrical grids with a high degree of confidence.

Wind energy systems are available in sizes ranging from less than one kilowatt (small scale) to 100-700 kW (medium scale) and large scale (greater than 700 kW) For commercial utility-sized projects, the most common turbines sold are in the range of 750 kW-2000 kW (2.0 megawatts), although the newest commercial turbines are rated at 2.5 megawatts. A typical 750 kW turbine has a blade diameter of 35 metres and is mounted on a 50-metre concrete or steel tower. The minimum height for a tower supporting a small-scale turbine is generally 10m.

Wind projects can vary in size from a one-turbine installation to a large number of turbines erected at an individual site, which is often referred to as a windfarm. Utility-sized commercial wind projects are usually constructed as windfarms and wind projects have been successfully built to power a wide range of applications in diverse and often extreme environments.

Costs - Wind Energy

Capital cost equipment:	$600 - 2000/kW
Capital costs project:	$800 - 2500/kW
Maintenance costs:	< $0.01/ kWh
Life-cycle Cost:	$0.04 - 0.15/kWh
Operating Life:	up to 20 years

Small clusters of wind turbines, called a windfarm, can not only generate large amounts of electricity, they can also allow for other land uses and are often a tourism destination.

For most tourism businesses, small and medium scale wind turbines are the most suitable. Although a large-scale turbine or windfarm is generally outside the scope of a tourism or hospitality business, directly purchasing the electricity – or even owning part or all of a turbine – can be an economically attractive option for a large organization or consortium of smaller organizations.

Wind projects can be constructed as either “build-own-operate” facilities under long-term power purchase contracts or as turnkey facilities. For large grid-connected turbines, the wind energy industry is competitive and mature and there are many choices of project developer and manufacture, depending on location. Ten major international manufacturers currently produce 97 percent of all wind turbines in power outputs ranging from a few hundred watts to several megawatts

At the beginning of 2003, 25,000 MW of wind power have been installed in more than 30 countries. Since the current phase of development began in the 1980’s, the price for wind-generated electricity fed into major grids has reduced by an average of 3 percent per annum.

Wind turbines produce no pollution when they are operating but care must be taken in siting turbines to account for local environmental impacts, including visual amenity, noise and avian impacts. With properly designed and sited modern turbines, these impacts can be mitigated. In areas of very high visual amenity – such as coastal national parks – wind development may not be compatible with community values.

For tourism businesses in remote areas that remain open year round, a hybrid system combining windpower and solar photovoltaic (PV) (see following section) or other generating option offers several advantages over a single generator system. In many areas, wind speeds are lowest when there is excess solar energy (for example in the summer), and highest when solar energy is minimal (eg, winter). As the peak operating periods for wind and PV occur at different times of the year, hybrid systems can be designed to provide higher reliability. For those times when neither the PV modules nor the wind turbine are working (at night and during low winds), most systems include battery storage and/or a diesel or petrol generator that can recharge batteries.

For hospitality businesses, wind turbines can also be used to power electric water pumps. The turbines can be placed at some distance from the well (or other water source) and often require much less maintenance. Although standard centrifugal and volumetric pumps can be used, the manner in which they are selected and installed is different from water pumping systems powered by the grid. Of course, windmills that directly drive the water pump can also be used.

Wind Turbine Systems

A wind turbine system contains a number of components, including:

- *Rotors and blades* - The rotor usually consists of 2 or 3 blades and a hub attached to a shaft. The blades are designed with an airfoil section to extract the maximum energy from the wind.
- *Wind sensor and recorder* - Wind sensors monitor and record wind speed and direction.
- *Gearbox* - The gearbox transfers the energy from the rotating shaft to the generator drive shaft.
- *Generator* - The rotating drive shaft is connected to an electrical generator.
- *Housing or Nacelle* - The gearbox, generator, and rotor (to which the blades are attached) are contained in a housing called the nacelle, which is located on the top of the tower.
- *Turbine Tower* - The blades and nacelle are mounted on the top of a tower to maximise exposure to the wind. The speed of the wind increases with height so the higher the turbine tower, the more electricity the turbine is able to generate.
- *Power Electronics* - Power electronics, also commonly called an inverter, is required to convert direct current (DC) electricity that is produced by the turbine to alternating current (AC), which is required for use by most commercial appliances and for connection to the grid.
- *Electrical cables* - Electrical cables connect the turbine, batteries, meters and end-use points (and possibly the grid).
- *Deep Cycle Batteries* - Stand-alone and hybrid wind turbines are connected to high capacity batteries that store excess electricity for use during times of low wind speeds.
- *Back up power system* - Stand-alone wind turbine systems may require back up power systems, such as diesel, gasoline or propane generators or PV systems, to ensure the supply of electricity to critical loads.
- *Electric meters* - The voltage and current generated by wind turbines can be monitored through the use of meters and serve as a check on the performance of the system. Meters can be used to monitor the battery charge level and separate metering systems may also measure voltage, current and energy supplied to the grid.

Internal view of a large grid-connected wind turbine

Geothermal

The technology to convert geothermal energy into electricity is well proven, relatively uncomplicated, and involves extracting energy via conventional wells, pumps and/or heat exchangers. Steam extracted from geothermal wells is used to drive an electrical turbine and generator to produce electricity. Generally, the generating capacity of geothermal systems is in the megawatt range. As with windpower, installing a geothermal electricity system will be restricted to larger tourism operations (or a consortia of businesses) and to areas with a significant geothermal resource.

Costs - Electricity from Geothermal Steam

(US$/kW installed capacity)

Plant Size	High Quality Resource	Low Quality Resource
<5 MW	$1600-2300	$1800-3000
5-30 MW	$1300-2100	$1600-2500
>30 MW	$1150-1750	$1350-2200

Exploring and developing a steam field for electricity generation represents a significant portion of the overall investment and can amount to 30 percent of the overall cost for a project, depending on the quality of the geothermal resource.

Geothermal steam can be used to generate electricity

Extracting geothermal energy can have adverse environmental impacts, particularly air pollution from radon gas, hydrogen sulfide, carbon dioxide, methane, and ammonia emissions. Using geothermal resources can also create substantial thermal pollution from waste heat.

Many of these impacts can be controlled with technology that re-injects waste gases or fluids back into the geothermal well. Generally, the carbon dioxide emissions of a geothermal power plant are only five percent of the emissions from equivalent fossil fuel power plants. The area of land impacted by a geothermal development is relatively small and such developments can usually co-exist successfully with other land uses.

Other drawbacks include mineral deposits on components and the need to drill new wells after a few years of use. It is also important to note that geothermal energy is renewable only if the rate of extraction is less than the recharge rate. Currently, few geothermal projects for generating electricity meet this requirement.

Small-Scale Hydro (SSH)

The energy in falling water can be converted into electrical energy or into mechanical energy by hydraulic turbines. In the past, hydropower stations were often built as a part of large dam projects. Due to the size, cost, and environmental impacts of these dams (and the reservoirs they create), hydro developments today are increasingly focused on smaller-scale projects.

Although the definition of small-scale varies, only projects that have less than 10 MW of generating capacity are considered here and are abbreviated by ‘SSH’. This definition also includes mini-hydro) (less than1 MW), micro-hydro (less than 100 kW and pico-hydro (less than 1 kW). Small-scale hydro technology is efficient and commercially proven. Many companies supply small-scale hydro equipment in areas of the world where hydro resources are located.

Success Stories - Tortoise Head, Guest House, Victoria, Australia

The Tortoise Head Guest House on French Island, Victoria, Australia generates its power from a remote power wind and PV hybrid system that has been operating since 1995. The Guest House is located 150 metres from the seashore, which makes it an ideal site for a wind turbine.

The system includes:

- 10 kW wind turbine;
- 840W PV array;
- 2 diesel generators of 15 kW and 25 kW
- Battery storage (wired to produce a system voltage of 120 Volts DC);
- 10 kW inverter to convert the DC into the Australian standard of 240 Volts AC and 50 cycles per second.

> *"Guests can experience renewable energy – in their hot drinks, lights, music, and pumped water".*
> - Tortoise Head Guest House.

The energy uses of the Guest House include:

- Electricity for lighting, water pumping, cold room, freezer, dish washer, domestic appliances, communication equipment and some heating];
- LPG for water heating and cooking;
- Wood from fallen trees for space heating;
- Solar water heaters to pre-heat water;
- Diesel for back up electric generator.

The Guest House consists of 6 large bedrooms (for 2 – 6 people each), 5 double bed cabins and meeting/conference facilities. About 68% of the energy comes from wind, 11% PV and 21% diesel. The Guest House continues to reduce diesel and LPG consumption by through the use of additional solar water heaters and energy efficiency measures.

Success Stories - Reliable power in Sarawak

A wind/PV hybrid system is being used at the Samunsan Forest and Wildlife Sanctuary, 60 KM North of Kuching, in Sarawak, Malaysia. The population of the community fluctuates between 20-70 people, including children who return to the community on weekends, tourists, and scientists. The facilities of the Sanctuary include a dormitory, bungalow, guestrooms, office, amenities block, store rooms, boat shed and power shed.

The objectives of installing the system were to:

- Provide reliable 'grid quality' power supply 24 hours a day;
- Power refrigerators and freezers for tourist services, health, and preserving scientific specimens;
- Reduce environment impacts;
- Reduce costs;
- Reduce dependence on fossil fuels;
- Minimise potential supply disruptions;
- Enable and community and its children, tourists, and researchers to work and study at night;
- Reduce the risk of fire associated with the use of candles or kerosene lamps.

The system includes:

- 2.5 kW wind turbines mounted on a 26 m tower;
- 900 W PV array;
- 2 lead acid batteries storing 2 kWhs;
- 5 kW inverter;
- 30 kW diesel generator;
- Remote monitoring equipment.

> *"There is a much higher level of comfort with renew - able energy than a year ago. We hope that projects like this will take off all over Malaysia".*
> - Samunsan Forest and Wildlife Sanctuary

The community has been trained to perform all maintenance activities through training sessions that include an overall education of renewable technologies, which has increased the community's appreciation of the system.

The wind turbine generates the largest proportion of electricity over the year while in the summer the PV output is at its maximum. The diesel generator is most used in the summer, due to periods of low wind and an increase in electricity demand arising from tourism, research and community activities. Installed in 1997, the system cost US$60,000.

Success Stories - RAPS in Victoria, Australia

Point Hick is a lighthouse converted to a tourist resort in Southeast Victoria, Australia. The resort consists of several accommodation cottages, a manager's cottages and a low-cost bunkhouse for low budget tourists. The resort is situated in the Cann River national park.

In 1998, a wind/PV hybrid system was installed to:

- Meet all the electricity demands of the managers and tourist cottages;
- Reduce the use of diesel operation to 600 hours a year while maintaining a 24 hour power supply;
- Reduce the costs of diesel fuel;
- Reduce the environment impacts from using fossil fuels.

The systems includes:

- A 10 kW wind turbine on an 18 m tower;
- 550 W PV array;
- 20 kW diesel generator;
- 10 kW inverter;
- 120 kWh lead acid battery storage.

The wind turbine provides an average of 42kWh a day at a wind speed of 5-6 metres per second while the PV array generates a daily average of 2.8 kWh under 5 hours of direct sun. The system cost US$ 65,000 with an estimated payback period of 4 years.

"There is electricity with no greenhouse gas emissions, noise, or any damage to the pristine tourist area. Such systems should be duplicated in numerous tourist resorts with similar loads and natural resources".

- Parks Victoria

Success Stories - Wind power in a UK national park

Holwell Farm within the Dartmoor National Park, in Devon, UK, is using a 20 kW RAPS system incorporating a wind turbine system, 20kWh battery storage and a backup 25 kW diesel generator. The system provides electricity for agricultural activities, bed and breakfast tourist accommodation and other domestic uses. The farm is located 2.5 km from the nearest electricity grid.

"The (wind) turbine provides a great alternative to the 3 diesel generators we were using earlier – which were noisy and needed a lot of maintenance. It causes no disturbance to livestock. It has also been good for PR in the local community and amongst visitors to the park".

- Holwell Farm

The three-blade wind turbine has a rotor diameter of 8.8 metres, a hub height of 24.4m and is mounted on a lattice tower. An automated control system ensures AC power is always available and switches to the diesel generator when batteries are 80% discharged or when electrical demands are high.

Success Stories - Costa de Cocos, Xcalak, Quintana Roo, Mexico

Costa de Cocos is small scuba diving and fishing resort in Southern Quintana Roo, Mexico consisting of 12 residence 'banas', restaurant/bar, dive shop, and workshop. The resort was previously powered by a succession of small (5-20 kW) diesel generators operating just four hours each evening. However, in 1996, a RAPS system consisting of a 7.5 kW wind turbine, battery storage, and two 5.5 kW inverters were installed to provide the resort with electricity 24 hours a day. The wind turbine sits on a 24 m tower with protection against salt corrosion. The batteries are located in a specially designed integrated rack assembly.

The wind system has operated without any problems, although one inverter did fail temporarily. However, the system continued to operate because the second inverter was able to carry the load while the first one was being repaired. The system cost approximately US$35,000 and has a payback period of 8 -10 years.

Hydro potential is very site specific but can be a viable option for tourism businesses in mountainous areas where there are streams that flow with a sharp downward gradient. Any small river or large stream with a reasonably constant water flow throughout the year can be considered. Small-scale hydro systems are modular and can generally be sized to meet individual or community needs. However, the financial viability of a project is subject to the available water resource and the distance the generated electricity must be transmitted.

The two critical variables that determine the viability of a hydro site are:

- The vertical drop at which the water falls (metres), referred to as the effective head;
- The total amount of water that 'falls' (cubic metres per second), called the flow rate.

The power (P) that can be generated by falling water is approximately 7 times the product of the flow rate (Q) and the effective head (H): P(kW) = 7 x Q x H.

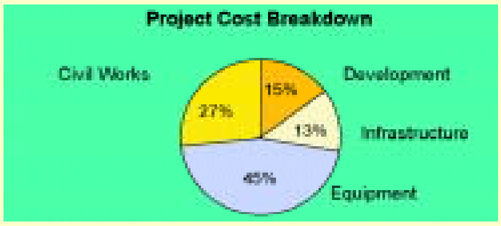
Therefore, the greater the available head, the lower the required water flow, and vice versa. For example, to generate 1 kW of electricity, a hydro system with a head of 100 metres will require 10% of the water flow that a site with a head of 10 metres requires. Low head sites are generally less than 10 metres while high head sites are greater than 30 metres.

Sites with very low head (<3m) present technical and economic challenges. Low head hydro equipment must accommodate considerably more water flow than equivalent capacity high head equipment and must be physically larger, which requires larger civil works. Also, the turbine's output shaft speed decreases with lower head. As a result, low head schemes generally need gears to drive high-speed generators. A head of one metre and a flow rate of 54 litres per minute are considered the minimum requirements to generate electricity.

Small scale hydro system in South America (courtesy NREL)

Costs - Small Scale Hydroelectric

Turbine Cost	US$450-$600/kW
Project Cost	US$1000-$5000/kW
Construction Time:	2-3 years
Life Cycle Cost	US$ 0.05-$0.15/kWhr



Different types of turbines are commercially available and the optimum choice depends on the both the head and flow rate. Generally, a high head site will require smaller, less expensive turbines and associated equipment.

For most hydro projects, water is supplied to the turbine from some type of storage reservoir, usually created by a dam or weir. The reservoir allows water to be stored for generating electricity according to demand and particularly during periods of peak electrical demand or when the electricity can be sold for a higher price if it is connected to the grid. In these systems the amount of electrical power that can be generated is determined by the amount of water stored in the reservoir and the rate at which it is released.

The most environmentally desirable hydro system does not impact the amount or pattern of water flow that normally exists in the river or stream. This "run-of-river" system may use a special turbine placed directly in the river to capture just the energy in the water flow. A conventional SSH plant may also operate as a run-of-river system if the natural variability of the river flow is maintained. However, this type of system may generate less power during times of low river flow.

For tourism businesses, a run of river system can bring additional challenges, as the demand of power is likely to be higher when it is hot and dry which is often when the tourist season reaches its peak. A dam or weir may still be required if the water needs to be diverted and if the diversion is to take advantage of existing downward gradients.

Although SSH systems have few of the environmental impacts of large-scale hydro projects, they can still create local environmental impacts (particularly if they significantly change the amount or timing or river water flows). With careful design, particularly with any civil works that could lead to erosion, many of these impacts can be avoided.

SSH systems do not create any air or water pollution when they are operating and generally offer highly reliable power. They also have very low running or maintenance costs and can be operated and maintained by locally trained staff.

Hydro systems generally have a long project life. Equipment such as turbines can last 20–30 years, while concrete civil works can last 100 years. This is often not reflected in the economic analysis of power projects, where costs are usually calculated over a shorter period of time. This is important for hydro projects, as their

Success Stories - Malborough Sounds, New Zealand

Tourist lodges situated in an isolated area in the Malborough Sound of New Zealand solved problems of high energy running costs for by installing a micro-hydro generating station that displaces power from a diesel generator. Surplus electricity from the hydro system is used to replace LPG for water heating.

A small dam was built to create a reservoir for 8 hours of full power production. The installation included a Pelton turbine, synchronous generator and an electronic voltage and frequency control system. The unit generates 5.8 kW from a head of 56 meters with a flow of 20 litres/second.

Success Stories - Leymonthyme Lodge, Tasmania Australia

A small scale hydro system powers the 90 bed Lemonthyme Lodge, consisting of a living area, restaurant, craft shop, staff accommodation and amenities, laundries and 27 self-contained cabins with spas. The lodge is located between Lemonthyme Valley and Cradle Mountain in the midst of a forest in northwest Tasmania. The nearest power lines are more than 2 km away and connection to the grid would have caused unacceptable impacts on the surrounding forest.

A small weir was constructed that provided a drop of 208 metres to the site where the turbine was installed. With an effective head of140 metres and a flow rate of 46 litres/second, the 52kW Pelton turbine generator produces an average output of 47.8kWh per day. The system provides the lodge with refrigeration, lighting, heating, hot water, other small power requirements including fire-fighting equipment.

The system costs A$ 440,000 (US$ 200,000) or A$ 2.5/watt. Compared to the cost of connecting to the grid at A$ 40,000, the system has a payback period of about 5 years, with considerable savings accumulating thereafter.

Success Stories - Mangala Oya Estate Visitor Centre, Sri Lanka

The Mangala Oya Tea Estate and Visitor Centre constructed a run of river 1,300 kW micro hydro system in November 2000. No water storage was needed to utilise the net head of 123 metres and flow rate of 1,300 litres/second. The system uses a twin jet Turgo impulse turbine and a 3 phase synchronous generator; meeting all the power requirements of the visitor centre and estate. Surplus electricity is sold to the local electricity grid.

Construction costs were Rs. 97.5 million (US$1.3 million) with annual operating costs of Rs.1.5 million, and annual turnover at present power purchasing rates of Rs 20.2 million. Power purchase rates are expected to increase significantly in the coming years.

initial capital costs tend to be comparatively high because of the need for civil engineering works.

Although significant potential exists for further SSH development, the availability of suitable new sites for larger developments is limited, particularly if dams or other structures must be built and where local land use and planning laws may limit such development. However, tourism businesses in mountainous areas can often tap a high head water resource without using a dam or weir.

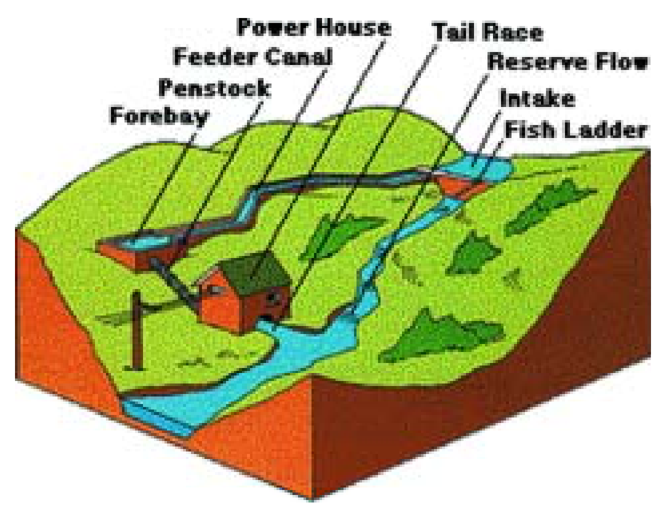
There are also existing weirs and other in-stream structures that can be retrofitted with hydro equipment. About 3000 MW of these low-cost applications are esti-

Small Scale Hydro (SSH) System

A SSH system can consist of some or all of the following components:

Dams and Weirs - A weir is a wall or line of stones built to direct water to an intake point. A dam or weir is needed to:

- Divert the water from the source river or stream;
- Create a water storage pond;
- Increase the head of the site by providing vertical distance for the water to fall.



Feeder Canals and Tunnels - A feeder canal or tunnel channels water under low pressure from an intake source to a head pond. Feeder canals are usually excavated following the contours of the terrain while tunnels are installed underground by drilling, boring or blasting.

Headponds - A headpond (also called a forebay) is a small reservoir that holds water between a feeder canal or tunnel and a penstock. A headpond should be deep enough to completely submerge the penstock inlet to prevent air from entering the turbine and generator

Penstocks - A penstock is a pipe of high-density plastic or steel that carries the falling water under pressure to a turbine usually located in a powerhouse. A penstock should be as short, straight and seamless as possible to minimize friction losses and increase system efficiency. A penstock also includes:

- A filter or trash rack to guard against debris reaching the turbines;
- Valves and steel gates to stop the flow of water to the turbines during maintenance periods.

Turbines - A turbine consists of a set of blades that rotate due to the force of flowing water to capture as much of the water's kinetic energy as possible. Water is directed toward the turbine's blades and its support structure by channels or a penstock.

Tailraces - The tailrace is an excavated canal or tunnel that carries the water from the turbine exit back to a storage pond or river.

Fish ladders - Fish ladders are a series of stepped pools with a continuous downward flow of water. They allow fish to migrate upstream and minimise the environmental impact of the hydro system.

Batteries and Back up Power Systems - Stand-alone hydro systems usually include batteries to store electricity and a backup power system (such as a diesel engine) to ensure electricity supply at times of low water flow.

Inverters - Inverters change direct current (DC) electricity into alternating current (AC). Special inverters enable DC systems to synchronize with the grid and allow excess electricity to be fed into the grid when its not needed locally.

Powerhouses - The turbines, generators, batteries, backup power systems, grid interface inverters and related power equipment are usually installed in a powerhouse, the size of which will vary with the size of the system. For very small systems, the powerhouse will consist of the turbine and generator equipment. For larger systems, space will be required for workshops and other facilities. The powerhouse may be built of concrete and other local building materials.

mated to exist globally. As the civil works already exist, the additional environmental and land use impacts of these projects are often very low.

Hydro developers wishing to construct larger systems with dams generally need to invest in de-tailed analyses before a project can proceed. Regulator authorities may require structures or systems that prevent adverse effects on flora and fauna, particularly fish. Conversely, some hydro systems may enhance local environments through, for example, the creation of wetlands.

Over one hundred companies manufacture SSH systems with the most active industries in Europe and China.

Bioenergy Electricity

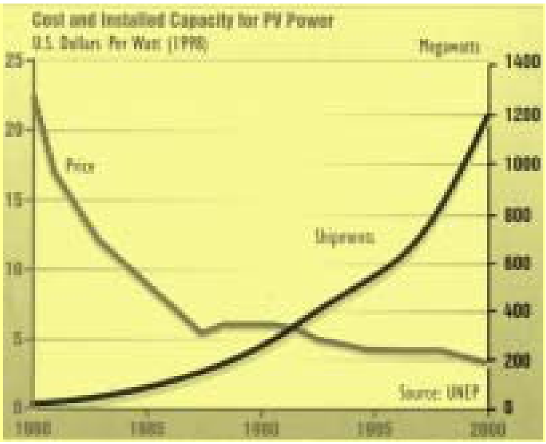
Bioenergy electricity projects generate electricity via conventional steam combustion technology and can often be designed to co-generate both heat and electricity (called ‘combined heat and power’ or CHP), which can greatly increase the overall efficiency and financial viability of a project. Such projects may also create a cost-effective solution to the disposal of agricultural or industrial wastes that may otherwise become potential environment problems. Such projects can be built in a wide range of sizes from one megawatt to as large as 100 megawatt CHP power stations.

The keys to an economically viable bioenergy project are the type, amount and cost of the biomass resource. Projects are generally more cost-effective when waste products from some production process are utilized (such as sugar bagasse or sawmill residue). For many bioenergy applications, however, big is not necessarily better as transporting the biomass fuel or feedstock over larger distances can decrease the economic viability of projects.

In addition, some agricultural wastes are available only during certain times of the year and may have to be stored if they are to be used as on a continuous basis. This can be difficult, expensive and require special equipment or storage facilities. An alternative to storing biomass is to use other fuels, such as natural gas, during these periods. This may allow a more efficient, continuous and profitable operation, but will also usually increase the project’s capital cost.

The intermittent availability of a biomass resource can be an issue for many bagasse-fired electricity plants operating only during sugar harvesting periods. However, the liberalization of electricity markets in some countries has created an economic opportunity to invest in facilities and equipment that allows such projects to generate electricity during non-harvesting periods, thus generating higher revenues.

Issues that can influence the viability of a bioenergy project, particularly larger projects, include competition for land-use, public resistance to proposed land-use changes, and the complexity of co-ordinating a range of activities and institutions (farmers, utilities, transport companies, etc). For these reasons, an intensive planning and management process is usually required and may also need to address these issues at local, regional and national levels.



The cost of PV continues to decline

Solar Photovoltaic (PV)

Photovoltaic (PV) cells, also called “solar cells,” are semiconductor devices that convert solar energy directly into electricity. In many applications, PV is a mature and commercial technology with an estimate 400,000–800,000 photovoltaic systems installed worldwide in applications ranging from large grid-connected power stations and grid-connected roof-

High purity silicon wafers are used to produce these monocrystalline solar cells.

top residential systems, to small-scale, stand-alone units for rural use and consumer products. PV is currently most economically competitive in remote sites away from electricity grids and where only relatively small amounts of power are required—typically less than 10 kW. This makes PV applications particularly attractive for tourism facilities in such areas. However, the market for residential and commercial grid-connected systems is growing rapidly as costs continue to decline.

In remote areas, PV systems offer significant advantages over petroleum-based diesel engines including:

- Silent operation;
- High reliability;
- Absence of moving parts;
- Low operating costs;
- Low maintenance;
- Modularity (can be sized to suit demand);
- Easy installation at remote sites;
- Absence of airborne pollution or CO² emissions;
- Reduction in electricity losses as the electricity is generated near the point of use.

Although there are about 30 different types of PV devices under development, there are three main technologies in commercial production: monocrystalline cells, polycrystalline cells, and thin-film cells.

Monocrystalline, (single crystal) solar cells are manufactured from wafers of high-quality silicon and are generally the most efficient cells for converting solar energy into electricity. Polycrystalline solar cells are cut from a block of lower-quality multicrystalline silicon and are less efficient, but also less expensive to produce. Thin-film solar cells, manufactured in a process similar to tinting glass, are made of semiconductor material deposited as a thin film on glass or aluminium. Thin-film solar cells are generally only half as efficient as mono and polycrystalline cells, but they are much cheaper to produce and widely used to power consumer devices such as watches and calculators.

A PV module such as this one can power efficient lights for small tourist huts

Costs - PV Systems

For a SHS, the approximate cost breakdown for a $1000 system are:

PV modules	*30%*
batteries	*22%*
lights	*13%*
installation	*11 %*

By comparison PV system costs for a $10,000 school system breakdown as:

PV modules	*31%*
installation	*22%*
management	*16%*
15 percent contingency	*15%*
TV-VCR	*9%*

of an average installed cost of $10,000.

Solar cells are encapsulated into modules that are often combined to form an array. There is, however, a growing market of “building-integrated” PV devices manufactured as part of conventional building materials, such as roof tiles or glass panelling.

A PV array is usually part of a system that may also include energy storage devices (usually batteries), support frames, and electronic controllers. These are collectively referred to as the balance-of-system (BOS) components.

Average Daily Irradiance	
North Asia	2 to 4kWH/day/m^2
South Asia	3 to 6kWH/day/m^2
North Central Africa	4 to 6.5kWH/day/m^2
South America	3 to 5kWH/day/m^2
North America	2 to 4kWH/day/m^2
Europe	2 to 4kWH/day/m^2
Australia and the Pacific	3 to 6kWH/day/m^2

The amount of power from a PV array is directly proportional to the intensity of the light hitting the array. PV panels do not need direct sun and can even generate 50-70% of their rated output under a bright overcast sky. A dark overcast day might correspond to only 5-10% of full sun intensity, so output would be diminished proportionately.

As the result of differences in solar intensity between regions, the same PV module used in an equatorial or tropical region will produce almost double the annual power output than when used in a temperate country. The amount of sunlight a PV panel receives (known as irradiance) is measured in kilowatt-hours per square meter per day (kWh/m^2/day). Equatorial and tropical regions receive an average daily irradiance of 4 to 6.5kWh/m^2/day while temperate regions receive 2 to 4kWh/m^2/day. However, summer solar irradiance in higher latitudes can be greater that 6 kWh/m^2/day, making PV a good investment for tourism facilities that operate mainly in summer months (see box 'Average Daily Irradiance').

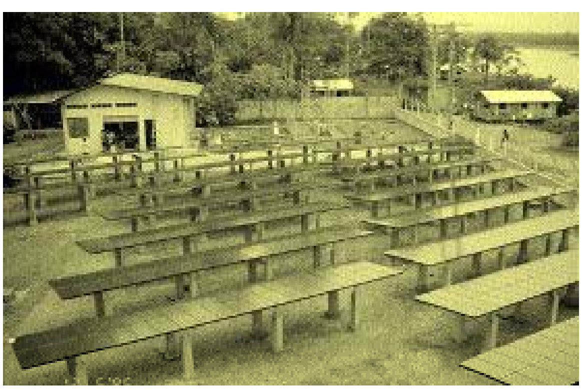
Photovoltaic arrays produce direct-current (DC) electricity, but the power can be regulated through electronic devices to produce any required combination of voltage and current—including conventional residential alternating current (AC). PV is a modular technology that can be used in most parts of the world and integrated with diesel, wind, and hydropower systems.

PV Systems

The selection and proper installation of appropriately configured and sized components directly affect PV system reliability, lifetime, and initial cost. In PV system design, trade-offs are necessary to keep costs reasonable and ensure appropriate service. PV systems can be configured as "stand-alone", "grid-connected" or as part of "hybrid" installations.

Stand-alone systems (also known as "remote" or "autonomous" systems)
Stand-alone systems are used in areas where power grids do not exist or where the cost to connect to the grid is not cost-effective. A stand-alone system channels surplus electricity generated during the day into batteries to be used at night or during cloudy periods and are designed to have sufficient PV and battery capacity to provide electricity during these times. In areas with long periods of no or low sunshine, a backup generator is often installed to ensure an uninterrupted supply of electricity.

A Solar Home System (SHS) is a common version of a stand-alone PV system and normally composed of a PV array, batteries, and an electronic controller. The system can be constructed in a range of sizes from 30 W to several hundred watts. Larger systems up to 50 kilowatts can provide power for an entire village or town. Generally a small SHS system costing between $500-1000 will power a few fluorescent lights and a radio/television but are not intended to run larger appliances such as refrigerators or washing machines.



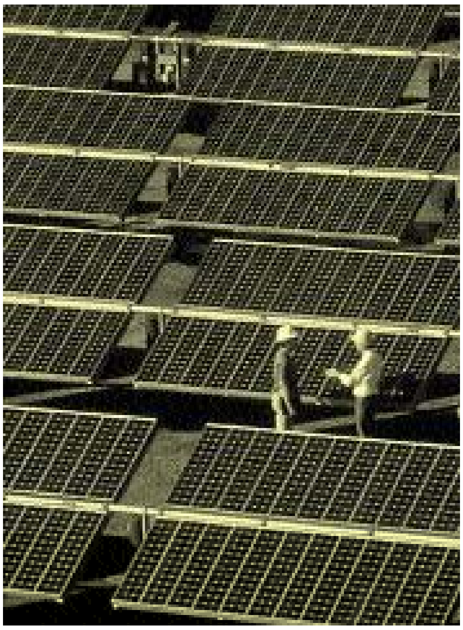
PV modules can often wired together to generate larger amounts of solar power.

Stand-alone PV systems include:
- PV arrays;
- A structure to mount the array;
- Over current protection/safety disconnects;
- Charge regulator[8] (including circuit protection and remote monitoring);
- Batteries to store energy for use when there is no sunlight, at night and during bad weather.
- An inverter to convert the stored direct current (DC) into alternative current (AC) if AC appliances are to be used;
- Electrical cables that allow electricity to be moved between cells, batteries and usage points;
- Voltage, current and state-of-charge meters;
- Optional backup power systems that operate on wind, diesel, gasoline, propane, or other energy source.

Stand-alone systems are the preferred option when:
- The power is required in an area that is far from a power grid;
- Costs of extending the power lines are higher than the capital costs of a PV system;
- Power demand levels are modest;
- The environmental impact must be minimized;
- The grid is poorly developed with regular power interruptions;
- The user would like to operate independently from the utility grid;
- There is an adequate solar resource.

Grid connected PV systems

Grid connected PV systems supply electricity to the grid when excess power is being produced by the PV panel (when the sun is shinning) and draw electricity from the grid when the PV panel is not producing sufficient electricity (i.e. at night). The interface between the PV system and the grid can be metered in two possible manners when power is being supplied by the PV system to the grid: (a) the electrical meter will turn backwards or (b) a separate electrical meter will measure the electrical energy the PV system is feeding into the grid.



A large PV array such as this one can provide power to the electricity grid. (Courtesy NREL)

Grid connected PV systems include:
- PV arrays;
- A structure on which to mount the array;
- Excess current protection/safety disconnects;
- Charge regulator /system control (including circuit protection and remote monitoring);
- An inverter to convert the direct current (DC) into alternative current (AC) and which can be synchronized to the grid;
- Electrical cables that allow electricity to be moved between cells, batteries and usage points;
- Electric metering system.

Grid-connected systems are preferable when:
- Grid access is near;
- Power demand levels are higher (>1 kW);
- Grid connection costs are economic;
- Utilities allow ‘net billing’ or favourable power purchase agreements.

Grid-connected PV systems can be integrated into individual buildings or constructed as a central power plant. On individual buildings, PV systems can be integrated into building components, such as PV roof tiles or large PV-tinted windows.

PV hybrid systems

PV hybrid systems combine PV technology with another energy technology (i.e. wind, hydro, and biomass). When properly designed, the combined availability of a hybrid system should be sufficient to provide power for all periods and conditions.

PV/wind hybrid systems may be appropriate for tourism businesses located in coastal regions or flat open plains where wind is available on a seasonal or irregular basis. Depending on climatic conditions, PV/wind hybrid systems may offer significant advantages over single systems. If peak wind periods and maximum solar periods occur at different times of the year, a hybrid system will be more reliable than either system by itself and produce electricity year round. For periods when neither sun nor wind resources are available (at night during low wind periods), battery storage and/or a diesel generator can be installed. If the batteries become discharged, the generator can be used to charge them.

Other applications

Water pumping

PV systems can also power motors to pump water. In most PV pumping systems, batteries are not necessary as the system works only when there is sufficient solar energy. Adequate water during hot seasons is often a critical issue for the tourism industry and as most hotels have water tanks with storage capacities for at least 2 to 3 days, PV-powered water pumps can be a cost-effective application.

Street and Path lighting

Pre-configured PV lighting kits are increasingly popular in theme parks, visitor centers, museums and cottages that require lighting and other small-scale energy uses. Kits may be pre-configured or designed locally and usually include one or two PV modules, mounting structure, charge controller, cabling, connectors, and light fixtures. A battery is usually added separately. If AC appliances are to be used, an inverter will be required to convert direct current from the PV module to standard AC household current. Preconfigured kits usually range from 30 – 200 Wp.

Portable PV power systems

These systems, packed in strong boxes made for travel, are of particular interest to managers of permanent and mobile campsites as they can be used to provide electricity for lighting, public address systems, etc. at outdoor events such as festivals.

Trickle chargers

These devices are used to charge batteries in motor vehicles, boats, and recreational vehicles such as caravans, snowmobiles, go-carts, golf carts, snowmobiles and lawn mowers when they are not in use. The PV panel is connected to the vehicle battery through either a cigarette lighter or accessory outlet.

Solar cells have been directly installed as part of this building's roof (courtesy NREL).

Integrating PV Systems

To cost-effectively integrate PV systems into new buildings, PV options should be considered at the outset of the architectural design process when specifications are being finalised. This allows for a better building orientation, a building shell with PV-suitable surfaces and a wide choice of PV applications.

In the past, PV applications have failed to win design approval in many cases because they required anaesthetic rooftop-mounting structures. Newer PV modules and systems, however, can now be integrated into roofing materials and replace both rack-mounted panels and traditional roofing materials such as

Success Stories - Pulau Lakei, Malaysia

Pulau Lakei is a small island and eco tourism destination 30 km north east of Kuching, Sarawak, Malaysia. The facilities consist of several accommodation cottages, the home and office of the forest ranger, kitchen, bathrooms toilets, and jetty.

A remote PV system was installed in Palau Lakei in 1999 to provide electricity for all the buildings, the electric water pump and a 24-hour jetty navigation light. The system consists of a 1.3 kW PV array mounted on the roof, 2.4 kW 48-volt inverter and 12 kWhs of battery storage.

The system produces 4.5kWh a day and provides:

- Continuous electricity supply for lighting, refrigeration and cooling for the ranger;
- The electricity (especially lighting) requirements of tourists, fishermen and yachtsmen; replacing intermittent petrol power with clean and environmentally suitable energy.

Before the PV system was installed, electricity was available for only 3 hours a day by a petrol generator. The increased electricity supply and reliability has resulted in an increased number of tourists to the island. The Department of Forests, National Parks and Wildlife Branch, Sarawak, Malaysia funded the project cost of US$22,000.

"Remote PV systems are a practical solution, capable of providing continuous power, without polluting the natural environment. They offer considerable potential for islands throughout the South East Asia".
- Department of Forests, National Parks and Wildlife Branch, Sarawak, Malaysia.

Success Stories - Manau Lani Bay, Hawaii

The Manau Lani Bay Hotel and Bungalows, Hawaii, meets all its electricity requirements through 100 m2 of PV cells incorporated into special lightweight roof tiles placed on a reinforced roof. The PV array not only improves the aesthetics of the roof, but also acts as a layer of insulation, which lowers air conditioning requirements and extends the life of the roof by protecting it from the harsh coastal climate. The 11 kW system meets all the electricity requirements of the 350-room hotel and displaces the use of 14,500 barrels of oil every year. Manau Bay is a part of the Manau Lani Resort, on the Kona Kohala Coast of the Big Island of Hawaii.

Success Stories - PV in a rain forest tourism camp

TENTativeNests is a local art and nature tourism venture with accommodation and tour operator services at Kuranda, in the Australian state of Queensland. The accommodation consists of 8 'nests' (heavy canvas tents based on wooden platforms) in the rain forest. Showers and composting toilets are located in a separate block outside the rain forest area. Lanterns with batteries recharged by PV panels are given to guests at night for moving between the building and for wildlife viewing. PV torches also light the pathways. Electricity for the main building however, is obtained from the grid as PV is not viable due to the high level of shade from the rainforest canopy.

"The PV torches and lanterns have been a great hit with many visitors talking about getting their own. They are also help to enhance the philosophy of TENTativeNESTS – appreciate the beauty and majesty of the rainforests, gain inspiration from Tjapukai art and help protect those elements that nurture, care and sustain us all."
- Joell Bacon and Tina Kennedy, TENTativeNESTS

asphalt shingles, standing seam metal roofing, and slate or concrete tiles. The result is a PV system that is difficult to notice on the roof but has many benefits. Once installed, integrated PV systems produce electricity to power some or all building functions with generally low maintenance. PV roofing systems and other building integrated PV components (such as vertical glazing) are commercially available from a number of manufacturers.

In North America, an unshaded southern-facing roof is best and, depending on the PV roofing product and the contractor's experience, can be installed by roofing professional, an electrician, or both. Most PV roofing products have undergone extensive testing and certification for fire, wind uplift, and electrical safety performance. Some have obtained evaluation reports from major building material laboratories to assure their quality. In the US, PV roofing products are tested and evaluated by testing facilities such as The Underwriters Laboratory (UL). For many applications, a UL rating is essential to comply with local building codes.

PV systems can also be easily retrofitted to existing buildings. A variety of support structures are available to suit different building designs, building materials, geographical features, and maximize exposure to sunlight.

Transport Energy

Renewable energy can be converted to liquid fuels to provide motive power. The most successful and most widely used technology is to convert crops such as sugar cane to ethanol that can be used directly or blended with petrol. The largest and most successful use of energy crops is the US program to produce ethanol from corn (4 billion litres in 1999) and the Brazilian industry to produce ethanol from sugar cane (14 billion litres in 1999). Crops and crop waste can also be used to create 'biodiesel' and biogas for use in transportation applications.

Bioethanol

Bioethanol is produced through the fermentation of high carbohydrate crops such as sugar cane potatoes, maize, sorghum and other grains, wood, cassava, and sweet potatoes. The fermentation process is essentially the same as that used to make alcoholic beverages - yeast and heat are used to break down complex sugars into more simple sugars, creating ethanol.

Sugar cane and other crops can be converted in to ethanol.

Ethanol is used as a gasoline extender for internal combustion engines including motor vehicles. In the US and other countries, a blend of ten percent ethanol and 90 percent petrol (E10) has been used for several decades. In other countries, a widely used ethanol blend, E85, contains 85% ethanol and 15% gasoline. Vehicles running on E85 blends have a good operating record and provide an 80-90% reduction in carbon dioxide and hydrocarbon emissions. Fuel economy is more than two thirds of the fuel economy mileage from similar models running on pure gasoline. (E85 has only two thirds the energy of gasoline).

In addition, ethanol models are proving to be more reliable, easier to maintain and will last longer as an E85 blend burns cleaner than pure gasoline. Most leading motor vehicle manufactures have launched several models of flexible fuel vehicles, which are able to operate on E85 and lower ethanol blends.

Success Stories - Yellowstone National Park, USA

Since mid 1998, the entire vehicle fleet of the Yellowstone National Park, USA, including shuttle busses, mini vans and 85,000 snowmobiles, are fuelled on E10. The switch was preceded by "A truck in the park'' project which involved the driving of a E10 powered vehicle 92,000 miles to produce primary research data on the performance of ethanol vehicles. The results were highly positive. No major fuel problems were encountered and toxicity, emissions, smoke and odours were lowered while safety and biodegradability were increased.

Success Stories - Zimbabwe

Zimbabwe is an example of a relatively small country tackling its oil import problem while fostering its own agro-industrial base. An independent and secure source of liquid fuel was seen as a sensible strategy because of Zimbabwe's geographical position, its politically vulnerable situation and foreign exchange limitations, and other economic reasons. Zimbabwe has no petroleum resources and must import all oil products – at a cost of $120 million per annum or 18 per cent of the country's foreign-exchange earnings. In 1980, Zimbabwe pioneered the production of ethanol fuel for blending with gasoline in Africa. Initially a 15-per cent alcohol/gasoline mix was used, but due to increased consumption, the blend is now about 12 percent. This mixture is the only fuel available in Zimbabwe for vehicles powered by spark-ignition engines. Since 1983 and until the recent economic and political crises, annual production was 40 million litres.

Soft Mobility: Making Tourism in Europe More Sustainable

"Soft mobility" describes the effort to change people's habit of using private motor vehicles to one using public transport such as non-motorized alternatives. The word "soft" suggests two important aspects: higher quality and greater sustainability.

An EU model project on "Soft Mobility in Tourism Destinations" in twelve destinations was carried out from Austria, Germany and Italy. This model project was behind the founding of NETS (the Network for Soft Mobility in European Tourism). With support from NETS, experience gained in the EU project will be disseminated and implemented within the tourism industry.

For further information see UNEP Industry and Environment January-June 2001

For sugar-producing countries, bioethanol production can diversify the sugarcane industry and displace energy imports. Bioethanol can also increase the efficiency of resource use and, indirectly, improve environmental management.

Non-Motorised Options

For many tourists and tourism facilities, walking and cycling can be the most advantageous transport options and can certainly be cost-effective. Many larger resorts operate a fleet of bicycles that can travel on dedicated pathways. Non-motorised options are often the safest transport option with the lowest environmental impacts.

Biodiesel

The seeds of many plants can be crushed to yield oils, which after simple chemical processing by 'esterifying', i.e. combining with ethanol or methanol, leads to biodiesel. This can be used alone or combined with petroleum diesel, the most common blends are B20 (20% biodiesel and 80% petroleum diesel), B30 (30% biodiesel) and B50 (50% biodiesel). The plant oils used include soybean, rapeseed (the result is called rape methyl ester or RME), sunflower oil, castor oil, palm oil, and coconut oil.

Biodiesel can be used in any conventional, unmodified diesel engine including in road and marine vehicles. It extends engine life (as it is more lubricating than petroleum diesel), and delivers similar torque, horsepower and kilometres per litre as petroleum diesels. Carbon dioxide and hydrocarbons emissions can be reduced by up to 80% and exhaust odours eliminated by using biodiesel blends.

Biofuels and Aviation

Pure ethanol is a viable, high-octane alternative fuel for small aircraft. Ethanol is cleaner and cooler in use than avgas, prolongs engine life, delivers more power and is likely to become a cheaper option as supplies become easily available.

Although ethanol has only 2/3 the energy of avgas, it has a higher thermodynamic efficiency which compensates for the loss of range. For example, an aircraft such as Cessna 152 (the world's most commonly used trainer) with a modified ethanol engine uses about 13.8 litres per 100 km on avgas and 15.7 litres per 100km on ethanol.

Engine modifications are often not technically difficult or expensive. For example, converting a Cessna 152 engine costs around US$3,000, a cost that includes a larger carburetor jet, fuel pump, fuel flow metre, a totaliser, and a small avgas tank to enable the engine to be primed in temperatures below 21°C. Not all engines are expected to need this level of modification.

The biggest benefit of ethanol use has been the reduction of exhaust emissions. When comparing with diesel exhaust emissions, nitrogen oxides are lowered from 9.0 to 3.8 grams per kWh, carbon monoxide from 5.0 to 0.05 grams per kWh and hydrocarbons from 1.2 to 0.16 grams per kWh.

Aircraft using ethanol and ethyl-tertiary-butyl-ether (ETBE) have performed at air shows all over the world since 1996. Corn and Bagasse are the most common ethanol sources, but some pilots in the US are also using ethanol from potato and orange waste and waste cheese whey.

Part 3: Getting Started

After reading the previous sections, you may already have a good idea of where renewable energy can be used in your business or operation. However, it is almost always a useful –and profitable - exercise to undertake an energy audit before embarking on a particular project. A comprehensive energy audit can identify both areas where renewable energy can provide cost-effective additional energy as well as areas where energy efficiency can reduce overall costs, including the size and cost of any renewable energy system. As stated earlier, energy efficiency is the key to developing cost-effective renewable energy systems.

Step 1: An Energy Audit: How much and what kind of energy?

A full energy audit is a detailed analysis of the way your business uses different forms of energy. An energy audit will answer questions such as:

- What does your business pay for electricity?
- How many kilowatt-hours a day do you use?
- Does the demand for electricity fluctuate greatly at differently times of the year?
- What is the cost per kilowatt-hour?
- How many kilowatt-hours are used for water heating? What is the cost of this water heating?
- How many litres of petrol or diesel does your business use? What is the annual cost?

If you are considering the construction of a new building, an energy audit can often uncover many hidden opportunities to both reduce energy use and utilise renewable energy – often with no or little cost. Implementing these improvements will then help you to design the most functional and cost-effective renewable energy system.

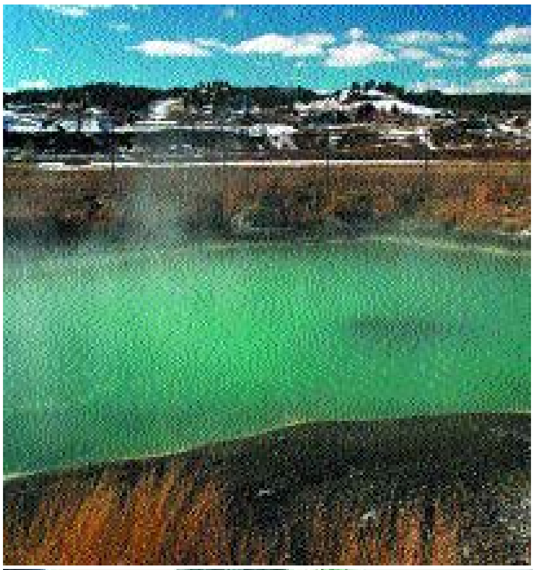
Step 2: Determining Renewable Energy Potential

One of the basic rules for designing renewable applications is “don’t fight the site”. Each site will offer varying potential for different renewable energy resources.

The first investigation is to determine the forms of renewable energy found at your site. Have there been any measurements of this potential (wind speed, for example)? Are there any constraints to the use of renewable energy, such as tall trees that could shade solar collectors? Other questions include:

- Where can renewable energy fit into my planned (or present) business and energy supply mix?
- Which renewable energy systems may be the most cost-effective for my business and where can they be best applied?
- Can I integrate new renewable energy systems into my existing energy systems and gradually transition to a complete (or majority) use of renewable energy?
- How can I find a manufacturer and system installer whose work I can trust, including their claims related to reliability, efficiency, durability, low maintenance costs and emissions?
- How can my improved treatment of the environment through the use of renewable energy be promoted and translated into increased profits for my business?

To answer the above questions requires information and consultation with one (or more) energy engineers, suppliers and/or installers. This process may require learning more about your existing energy system, which will enable you to turn



Assessing the renewable energy potential, such as the amount of biomass or geot - hermal energy, is the first step

that knowledge into environmental and economic benefits for your business and your community.

With knowledge of your energy supply and demand, you can then assess the renewable energy potential. Often, you will need specific data to determine if a renewable energy option would be appropriate.

- For a potential hydro installation: Is there a flowing body of water nearby that would make the site feasible for small hydro? Is there flow data available?
- For potential PV or solar thermal installations: Is there bright sunshine much of the time that would make the site suitable for solar photovoltaic and / or thermal systems? Is there solar data available?
- For a potential wind turbine: Are there strong winds available much of the time that would make the site suitable for a wind turbine? Is there wind data available?
- For a potential biofuel installation: What types of biofuels are locally available? Can they be supplied year round or will supply interruptions occur during certain seasons (i.e. crop wastes may be available only after harvest season)?

Other general steps include:

- Inquiring about performance, reliability and maintenance from other owners of wind, PV, solar thermal, small hydro, GHP, and biomass installations.
- Ensuring provisions are made for metering your renewable energy system so you (or an employee) can monitor the operation of key components as well as electricity consumption or sale to the grid.
- Examining the possibilities of complementing and combining renewable energy technologies as hybrid systems, particularly if energy services are needed 24 hours a day and year round. For example, PV systems are increasingly being combined with wind systems and a battery backup.
- Checking zoning issues and procedures for obtaining permission from local authorities for installation of hydro, solar, geothermal heat pump, wind or biomass-based systems. Also check for restrictions on renewable energy system installations in areas in and around protected reserves and national parks.

Once you've addressed the above issues on a preliminary basis, you may be able to identify your "most likely" renewable energy system(s).

Step 3: Evaluating the "Most Likely" Renewable Energy System in More Detail

Now that you have an idea regarding the use of one or more renewable energy technologies to provide energy for your tourism business, you can investigate the costs and benefits in more detail. This process includes a number of steps:

- Shortlist a few established companies with experience and a good track record for quality work in relation to your "most likely" renewable energy system;
- Obtain and review literature from these companies about your potential renewable energy system. Ask for and check references and if possible, identify and inquire about performance, reliability and maintenance from other renewable energy system owners who are not provided as references.

RETScreen

A software program called RETscreen can be used to assess different renewable energy technologies. The software can be downloaded free of charge from

http://retscreen.gc.ca

- Invite the short-listed companies to visit your site to assess your energy needs and resources. Obtain their assessments of the potential viability of your potential renewable energy system, possible configurations, costs and maintenance requirements.
- Enlist the services of a local engineer or consulting firm to carry out a pre-feasibility and, if encouraging, a feasibility study for the project. The pre-feasibility study could include wind, solar, biomass, stream flow, and/or geological investigations (for geothermal heat pumps), site mapping, preliminary system layout and material selection, environmental impact assessment and financial evaluation. The pre-feasibility study provides the information for confirming that the proposed site and "most likely" technology are suitable for a renewable energy installation.
- Decide between a stand-alone (remote) or grid-connected system.
  - Stand-alone systems may require additional choices on battery type and capacity and a backup power system. Backup options include hybrid PV-wind systems and biofuel generators. Diesel, gasoline and propane generators may also be considered, although they are noisier, emit greenhouse gases and can be more expensive to operate.
  - For grid connected systems, as part of the pre-feasibility study ask your supplier and utility company for information on power purchase agreements for selling renewable energy-based electricity to the grid.
- For a small renewable energy system, you may decide to proceed on the basis of the results of the pre-feasibility study. If so, move to step 4.
- For large, more complex projects such as a larger hydro power station, a detailed feasibility study is recommended that includes design and layout of the project, full environment impact assessment and financial evaluations, and installation schedule.
- The financial evaluation component of the feasibility study should include:
  - Land leasing charges;
  - Property taxes;
  - Water charges (for hydro systems) for using the water from public waterways;
  - Insurance contracts if you plan to connect to the grid with a small hydro, wind, PV or other power generation installation. Insurance may be needed for public liability, equipment failure, power supply interruption and property damage;
- Options for remote monitoring of the operation of your system via radio or satellite.

Pre-feasibility and feasibility studies should not account for more than 6-8% of the total project cost. After they are completed, carefully study the results, final design, financial evaluation and other details. Ask the developer to explain technical elements in plain language to you and your employees.

You may also need to inform neighbors and the local community of your plans. Concerns relating to environment damage (both during construction and operation), effects on water and air quality and flora and fauna land and water rights issues, noise, visual impacts etc., should be discussed at the outset.

Step 4: Identify a Company to Provide and Install Your Renewable Energy System

Upon completion of the studies, obtain bids from a number of companies (3-4 if possible) that have experience with the technology, good references, and will be in business in your area for a considerable time. Study the bids in detail in relation to the feasibility studies. Designing and installing a renewable energy system can be complex and highly specialized, although small systems can be no more complex than any other project. As one of the most frequent problems encountered with new users is maintenance tasks, these problems can be minimized through good design and careful material selection and installation.

Bids from companies should include:

- A description of the appliance and components;
- Examples of applications;
- Mechanical specifications including heat and/or electrical power output;
- Fuel consumption (biomass);
- Information on emissions;
- Safety features;
- Special features that lower noise (for wind turbines);
- Prices;
- Qualifications;
- Certificates;
- Minimum instructions for installation;
- Equipment guarantee period;
- Maintenance requirements; and
- After sale service options.

A one module solar home system is installed in Sri Lanka (courtesy SELCO)

Verify that prices quoted include both the equipment (renewable energy system plus cables, inverters, charge regulators, switches, batteries, etc.) and installation. Select a company to provide and install your system paying particular attention to reference checks, type, quality and quantity of civil engineering works, equipment quality, measures to lower environmental impact, the availability and lead-time for the system (and obtaining spare parts). Also note guarantee periods and offers of maintenance contracts. The best way to ensure quality is through a guarantee period that extends as long as possible (at least one year) and the reputation of the equipment manufacturer and installer.

You may also want to identify neighbouring companies who may have similar needs and who can cooperate in buyer groups or other ways to maximize benefits from the installation of a renewable energy application.

Step 5: Monitor the Installation and Learn About Your Renewable Energy System

Together with the selected installation company, begin authorization and licensing procedures, if required. In many cases, feasibility studies may need to be completed and findings included in the authorization / licensing request.

Ask suppliers for instruction manuals on routine maintenance, and ensure that they can be understood and used by non-specialists. If needed, ask for translations into local languages, with graphics to illustrate technical explanations. This is vital to build in-house expertise.

You may also want to have an employee of your business participate in the installation of the renewable energy system in order to learn how it is assembled and installed and how it should be maintained.

For general advice and installation tips on specific types of renewable energy systems (solar, wind, biomass, hydro, geothermal heat pump, etc.) see the corresponding section below:

In terms of the installation:

- Keep careful notes and retain all documents relating to purchase and installation of your renewable energy system.
- Have the installation company commission the system and monitor it during its break-in period.
- Ask the installation company (or the equipment manufacturer) to train one of your employees in the required operation and maintenance procedures required for your system.
- Post a maintenance schedule near the control area and require that the person responsible for maintenance sign the schedule once the maintenance operation has been carried out.
- Keep track of installation and operation expenditures so you can accurately compute the actual costs (and savings) associated with your renewable energy system.

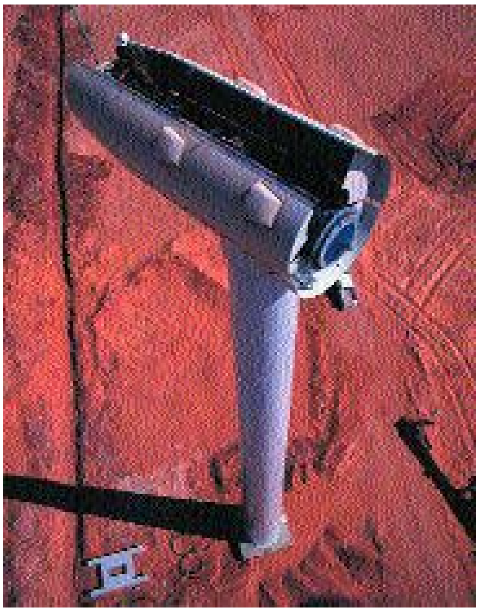
Solar Hot Water

- As solar collectors are usually mounted on roofs, adequate roof space is required. Flat roofs allow the collector to me positioned in the optimal direction and angle of exposure to the sun. Other roofs may require more complex mounting brackets. If roof space is not available, collectors can be placed at ground level (usually on a frame or stand).
- Whether mounted on rooftops or at ground level, the collectors should be free from shadows from surrounding vegetation, geographic features and buildings.
- To maximize solar exposure, collectors installed in the northern hemisphere should face south, while those in the southern hemisphere should face north.
- Collectors should be tilted towards the sun. A tilt equal to the angle of the latitude plus or minus 15° usually gives the best overall performance. Lowering the tilt will be best to optimise summer operation while increasing the tilt will optimise winter performance.
- In warmer climates, solar heated water can reach boiling temperatures. Electronic sensors and/or special 'tempering' valves (that automatically combine hot and cold water) may then be required to ensure that water temperature does not rise above the set ceiling – usually around 45°C to 65°C.[10]
- In temperate climates, plan to use a water heater storage tank with at least R-16 tank insulation. Insulate all hot water pipes in unheated areas. Install faucets with low-flow aerators and install low-flow shower roses. In addition to saving energy on their own, these measures will improve the performance of the solar water heater by maximizing heat retention and hot water use.

Wind

- Obtain site-specific data on wind speeds. While most manufacturers/contractors will help in evaluating wind speeds, it is best to get the help of an independent expert to ensure the data is accurate. Accurate wind speed measurements are critical as the output of a wind turbine varies greatly according to wind speed.[11] Even a small error in wind speed estimation can cause a large error in the power output (and cost). Wind speeds can vary greatly within short distances. Obstructions (buildings, trees, hills, etc.) can dramatically impact wind speeds.

Discuss with a professional where to find the best wind site



A modern grid connected wind generator being installed

- Wind speeds should be measured at a prospective site over a period of at least one (but preferably two) complete year(s), preferably at the 'hub height' of the proposed wind generator. There can also be large variations in wind speeds from one season to another.
- Work with a manufacturer/supplier to design and size the wind system. The key criteria are the electricity demand pattern, location, wind speed, distances to neighbouring dwellings, and the ground surface area available.
- Try to avoid microwaves towers and radio transmitters within close proximity to the wind turbine to eliminate electromagnetic interference. This may not be an issue with modern wind turbines that have flexible blades made of epoxy or plastic.
- Wind turbines are best installed at a distance equivalent to 5 times the rotor diameter from the closest neighbouring dwelling, and around 250 metres from the user's property. If space is limited, turbines may be installed at 50-100 metres away from the user's property. This distance is an important consideration for tourism businesses to minimise exposure to the aerodynamic 'swishing' sound of the blades and to ensure visitor and employee safety.
- When more than one turbine is being considered, a distance of 3-5 times the rotor diameter needs to be maintained between turbines, depending on the site characteristics.
- Each turbine requires a ground surface of between 100–225 square metres for installation.
- It is advisable to provide a road or pathway leading up to each turbine to ensure easy vehicle access for maintenance and repair. If these roads are to be constructed, care must be taken to minimize environmental impacts.
- A lead-time of 6 months is usually required for delivery of wind turbine equipment.
- Avoid planning the installation of a wind turbine near a bird breeding area, as the constant movement of the blades can disturb nesting habits. This is of particular significance for tourism businesses located in and around protected areas and migration routes.
- When designed and installed properly, the maintenance required by wind turbine systems is generally regular inspection of hydraulic parts, especially bearings. Electronic components should be inspected once a year and may require replacement at five-year intervals.

Small-Scale Hydro

- An initial assessment should be made regarding the suitability of the site(s) for small hydro. A head of one metre and a flow rate of approximately 54 litres per minute are the very minimum requirements for a low head application.
- Identify a reliable and experienced small hydro project developer who should have hydrological, civil engineering and geotechnical expertise. In most countries, hydro developers design the hydro system and outsource the civil works design to civil engineers.
- Hydro systems less than a few kilowatts (pico hydro) may not need extensive studies if there is a large water resource, a large head and where the intake and exit of the water is a small fraction of the overall volume. Developing a small hydro system, however, generally always involves several engineering studies:
  - When there are several potential sites, hydraulic and geographical studies may be conducted prior to (or as part of) pre-feasibility studies. Hydraulic and geographical studies should include the ranking of sites in terms of power potential, delineation of drainage basins, estimates of

water flow, indications of suitable excavation areas and options for system layout.
  - A pre-feasibility study involves geological investigations, site mapping, preliminary system layout and material selection, preliminary environment impact assessment and financial evaluation. It provides the information for selecting the project site or for confirming that the proposed site is suitable for a hydro project.
  - A more-detailed feasibility study may be the next step. This includes design and layout of the project, full environment impact assessment, and detailed financial evaluation.
  - Final engineering studies and planning schedules are then prepared including the design, construction drawings, installation schedule and transmission requirements. A detailed list of equipment and, possibly, steps to connect to a nearby grid point can also be prepared in detail at this stage.
- Ensure that fish ladders are included in the design to allow species to migrate upstream.
- Obtain bids from a number of developers (three if possible). Ensure their financial evaluations (and/or your overall cost calculations) include:
  - Land leasing charges;
  - Property taxes, which will depend on either the area and value of the land used by the system or revenues generated;
  - Water rental charges for using water from public waterways. This may be calculated on anticipated flow rates or energy output of the system;
  - Insurance contracts. Premiums for small hydro can be high and insurance may be important for public liability, equipment failure, power supply interruption and flood / property damage.
- Ensure that the developers have accounted for variations in flow rate at different times of the year. This is also important for sizing the backup power system (in stand alone systems).
- Remember that high effective head and low flow sites are more cost effective than low head sites with high flow rates. The latter require larger and more expensive equipment, earthworks and turbines to handle the flow.
- Depending on the location of the powerhouse and local air temperature, both ventilation and soundproofing may be needed. This is usually provided through roof insulation and double doors.
- Designing hydro developments is highly specialised. Maintenance problems can be greatly minimised through good design and careful material specification.
- It is important (often a legal requirement), to periodically monitor environmental conditions such as water quality, erosion, etc. while the hydro system is in operation. Local expertise should be enlisted to carry out these reviews.

Solar Photovoltaic

- As with other renewable energy applications, try to keep designs simply as complexity lowers reliability and increases the need for technical support.
- Understand system availability – achieving 99+ percent availability with any energy system is expensive. Providing power to some loads may not be essential at all times.
- Be thorough but realistic when estimating the system load. Many system "failures" have been the result of underestimated loads.
- Check local weather sources. Errors in solar resource estimations can cause disappointing system performance.
- Know what hardware is available and at what cost. Shop for the best deal, talk to dealers and other users.
- Visit and become acquainted with the installation site before designing the system. PV arrays need to be free from shadows from nearby buildings, vegetation and other geographical features. Although PV arrays are usually best mounted on roofs or open spaces, other mounting positions can be considered.

A solar-powered house

- PV arrays can be mounted on motor or hydraulic-driven trackers can be used to follow the angle of the sun throughout the day. In some cases, however, the investment may not be cost effective and can add additional complexity. Ask your supplier for advice.
- Temperature considerations are not as important as exposure to sunlight, although PV output decreases with higher temperatures. PV works very efficiently in cold climates with adequate solar resources.
- Good system design and installation will eliminate possible damage from severe weather conditions and (as with all electrical installations) risks of electric shock.
- Ensure the contractor you hire installs the system correctly. Connections should last up to 30 years, which is also the lifetime of many PV modules.
- Plan periodic maintenance. PV systems have excellent records for unattended operations, but will perform optimally with regular maintenance.
- Good design and installation will reduce maintenance tasks to only cleaning the panels every few months, topping up the batteries with distilled water and adding a new coat of paint to the support structures every few years.
- Batteries in remote systems have a typical nominal voltage of 12 volts. The models should therefore include a sufficient number of cells to ensure that the charging voltage will be above 13V.
- Provide a warm, dry and well-ventilated area for battery storage. Batteries should not be exposed to direct sunlight or freezing temperatures.
- Ensure that the contractor you select to install the system provides:
  - Mechanical specifications and electrical characteristics of each module;
  - A list and description of components with corresponding prices. Make sure the list includes the panels and the 'balance of system' (BOS) components. These include support structures, cables, inverters, charge regulators, switches, and batteries. 'Balance of system' components are usually 50% of the total system cost. Pay special attention to the quality of electronic charge regulators and power conditioning equipment. Though these components are generally reliable, the services of a specialist may be needed in case of a breakdown.
  - Company qualifications, previous experience with PV systems, licensing and certificates;
  - A written guarantee. Systems are usually fully guaranteed for at least one year, materials for 5 years and PV modules for 20 years or more.
  - A written offer of a maintenance contract (if needed).
  - An assurance of after-sales services.
  - Written instructions on maintenance procedures. Lead acid batteries need to be regularly checked for terminal corrosion and topped-up with distilled water. Maintenance-free lead acid batteries that require attention only every few years are available but are generally more expensive.
- Ask the PV supplier about external agencies that have tested, qualified, or otherwise approved the modules being proposed. In the US, look for a listing from Underwriters Laboratories (UL) and Factory Mutual Research (FM), both of which certify the safety and performance of PV products. In Europe, look for approval by the Commission of the European Communities (CEC). Ask if the module passed tests established by the US Jet Propulsion Laboratory (JPL Block V) to verify long-term reliability. Find out if the manufacturer regularly qualifies production units (rather than laboratory samples) to international standards.
- Enquire about the manufacturer's duration for producing PV modules. What is their reputation? Have their products proven reliable during many years of operation? Do they have a trained sales force and authorized distributor team

to back up their products in the field? Are they an organization likely to be in business in 10 years?

- Study the label on the back of the panel. Is the actual tested power of the particular module printed on the back, or is there only a generic label? Is it clear how far below nominal the manufacturer considers the power can be and the module still be considered within specifications?
- Examine the warranty and ensure it guarantees a specific level of panel and system performance over a pre-determined period.
- Check building codes that may relate to the installation of a PV system.

For systems providing power all year round with a fixed module the appropriate tilt angle **above horizontal** to maximize annual energy output can be found in the following guide:

Site Latitude	Tilt Angle (above horizontal)
0-4°	10°
5-20°	Site Latitude +5°
21-45°	Site Latitude +10°
46-65°	Site Latitude +15°
66-75°	80°

Ground Source Heat Pumps

- Contact the International Ground Source Heat Pump Association (http://www.igshpa.okstate.edu/) and relevant national bodies for information on certified contractors.
- The loops should be guaranteed for between 20 to 40 years and the heat pump unit for 5 years.
- Work with a qualified local contractor to select the ground coupling method that best suites the site conditions.
- If the GHP is being designed to provide space heating, it may be designed to economically provide only about 80% of the heating requirements. A backup heating system will therefore be needed.
- Investigate combining the use of the GHP for space heating/cooling and water heating.

Biofuels

- Investigate accessible biofuels are in your area. The lack of accessibility can limit the availability of biofuels, even if large reserves exist. For examples, businesses located in and around national parks and conservation reserves may find it difficult to obtain wood and forest residues.
- Find a reliable and experienced technology manufacturer and raw material supplier. Obtain and review literature and prices from several companies.
- Check building codes for use and installation of biofuel appliances. If needed, verify procedures to obtain planning permission from the local authority.
- Select a raw material supplier; paying special attention to raw material quality, combustion efficiency, energy values, and ease of storage and use.
- Select a technology supplier paying particular attention to product quality, fuel consumption, maintenance contracts, the availability and lead-time for obtaining spare parts and the equipment guarantee period. The best way to ensure quality is through the guarantee period and the reputation of the manufacturer.
- Investigate options to use biofuels with other renewable technologies. For example, a wood fuelled boiler can be used to backup a solar water heater, or an ethanol-fuelled generator can be used to backup a wind turbine or PV system.
- Note that biofuel appliances may need more routine maintenance (loading and ash removal for instance) than their oil or gas fuelled counterparts. Many maintenance problems can be greatly minimised through quality equipment and careful installation.

Epilogue: Further Actions

We hope this publication has demonstrated how a combination of major improvements in energy efficiency plus the introduction of a range of renewable energy can enable the tourism industry to depend less on fossil fuels and reduce the environmental impact of energy use from increasing numbers of tourists.

To date, however, the use of renewable energy technologies within the tourism sector has been limited, due, in part, to a lack of knowledge by hotel owners, architects, engineers, consultants, promoters and managers. This is changing, however, as tourists and their travel agents request accommodation and services with higher environmental standards. Consequently, a time lag often exists between tourist preferences and tour operator responses.

There is also a lack of appropriate regulatory policies, an absence of credit for renewable installations, insufficient trained technicians and maintenance personnel, poor information on successful projects, and perceptions that renewable energy is significantly more costly than fossil fuel-based energy.

One response to this challenge is to improve the communication between tourists, tour operators, hotel owners, engineers, equipment suppliers, communities, and governments. Sharing information and experiences will accelerate the acceptance of renewable energy in a diverse range of applications. Tour operators who genuinely improve their environmental performance – and communicate these improvements to their customers – are often well rewarded for their efforts in the form of continuing business and word-of-mouth referrals.

Governments must also play their part through policies that reward environmental preservation and penalize practices that damage the environment. To reflect the true environmental cost of fossil fuel energy use, energy policies with levies such as CO_2 taxes may be effective at reducing CO_2 and other polluting emissions in the short term and affecting a general shift toward increased use of renewable resources in the medium to longer term. This will be a challenge for the tourism sector that depends mainly on fossil fuels for transportation and electricity.

Finally, governments and the private sector – including the tourism sector - can work closely to establish realistic greenhouse gas emission targets and provide resources for research and demonstration projects to promote energy efficiency and the use of renewable energy sources.

The issues and case studies included in this handbook demonstrate that renewable energy can be cost-effective, reliable and environmentally sustainable for a wide range of applications. Renewable energy technologies are commercially available now and the transition to a fossil-free future has begun. Using renewable energy not only reduces CO_2 and other emissions, but can also help to ensure tourism profits for future generations of tour operators and facility owners.

Tourism businesses can also benefit from environmental accreditation and standards. Environmental accreditation is a process designed to establish and continually improve industry standards for conducting tourism businesses, including methods to safeguard the environment. It is designed to establish minimum industry standards that act as 'quality benchmarks' for tourism operators.

From an environmental perspective, most tourism businesses are currently 'self-regulated'. Although the value of tourism is generally recognized, short-term financial considerations often take precedence over long-term benefits. Although, in some cases, industry practice could be improved through effective collective action, in others, additional mechanisms to improve environmental performance must be provided by external agencies.

To date, renewable energy technologies have not been included in the efforts to establish environmental standards for the tourism business. This issue needs examination by tourism agencies and other bodies involved in the establishment of standards and accreditation procedures.

If after reading this publication you conclude that there is no current opportunity to use renewable energy in your operations, there are still several things you can do to become as energy and resource efficient as possible. You can also discuss energy issues with your industry colleagues and pass on this publication. Most importantly, tell your customers what you are doing and what you want to achieve. The experience of many tourism businesses (including those mentioned in this publication) is that customers want to be informed and participate in efforts to improve environmental performance.

You can do this through press releases, public relations material, newsletters, in-house TV channels and websites. Inform local authorities, financiers, community groups and your business contacts. You can also join and participate in additional networks focused on sustainable development.

Communicating your efforts to employees is also important. A number of tourism operations with renewable energy applications report heightened employee moral associated with awareness that the company has a greater commitment to environmental responsibility.

Clean and renewable energy is good for the tourism sector and good for the planet, but in the end, the decision to use these resources rests mainly with those who make and use tourism products and services.

Endnotes

1. Economists call this an 'externality'. An externality is a cost or benefit that is not included in the market price of a good because it's not included in the supply price or the demand price. Pollution is an example of an externality cost if producers aren't the ones who suffer from pollution damages. Education is an example of an externality benefit when members of society other than students benefit from a more educated population. Externality is one type of market failure that causes inefficiency.

2. Emissions of carbon dioxide by aircraft were about 2% of total human generated carbon dioxide emissions in 1992 or about 13% of carbon dioxide emissions from all transportation sources. This is likely to grow by 2050 to between 1.6 and 10 times the 1992 value. However, aviation is responsible for about 3.5% of the total climate change impact (called "total radiative forcing") of emissions due to the way these emissions affect the atmosphere. (Source: UNEP; see http://www.unep.org/ozone/19oewg-2-add1.shtml).

3. Natural Selection: Evolving Choices for Renewable Energy Technology and Policy, UNEP, 2000.

4. Unless noted, all monetary amounts in this publication are in US Dollars.

5. When water is heated, it expands and as a result, it rises and creates a flow of liquid. This is known as the natural convection of hot water.

6. A heat pump is a device that can move heat from one place to another. Although heat flows naturally from a point of high temperature to one of low temperature, heat pumps are used to move heat in the opposite direction.

7. Coppicing involves the planting of fast growing trees (such as Willow, Eucalyptus and Bamboo) and pruning every 2 to 5 years and allowing them to grow again. The trees are kept productive for around 30 years. Modified conventional forestry is the preferred technique in Northern Hemisphere plantations, where conifers are planted at a high density and are vigorously thinned a few years later.

8. Some PV modules are made to be self-regulating.

9. Mixed solid municipal waste contains items such as plastics that can be burned to generate heat, but these plastics are derived from fossil fuels. Municipal waste also includes glass, metals, and ceramics that cannot be combusted. Therefore, mixed municipal waste is not technically a biofuel. Hazardous waste regulations may also prohibit burning municipal solid waste.

10. Hot water at tap is generally maintained at around 55°C to 60°C.

11. The energy available from the wind is proportionate to the cube of its velocity. This means, for example, the doubling of the wind speed increases the available energy by a factor of 8. Alternatively, a site that has an average wind speed of 5.5 metres per second can generate twice as much energy as a site that has an average wind speed of 4.4 metres per second.

Additional Resources

The following section contains additional information resources on renewable energy technology and applications. For additional UNEP information on renewable energy resources, please visit our website at www.uneptie.org /energy. For additional information on tourism, please visit the UNEP Tourism website at www.uneptie.org/tourism.

General Renewable Energy Information

AGORES
Global overview of renewable energy sources
http://www.agores.org/Publications/EC_pubs.htm

Business Enterprises for Sustainable Travel
http://www.sustainabletravel.org

CADDET
Renewable energy information and project examples
http://www.caddet-re.org

Center for Energy Efficiency and Renewable Technologies (CEERT)
http://www.ceert.org/

CREST
Information on renewable energy, energy efficiency and sustainability on the Internet.
http://www.crest.org/aboutus.html

Energy Efficiency and Renewable Energy Network (a project of the US Department of Energy)
http://www.eren.doe.gov

European Business Council for a Sustainable Energy Future
http://www.e5.org

National Renewable Energy Laboratory (NREL, USA)
Substantial information resources on renewable energy
http://www.nrel.gov

Intermediate Technology Development Group
http://www.itdg.org/

International Hotel & Restaurant Association (IH&RA)
IH&RA is a global business organization representing the hospitality industry worldwide. Its members are national hotel and restaurant associations throughout the world, and international and national hotel and restaurant chains representing some 50 brands.
http://www.ih-ra.com

On-line Renewable Energy Education Module
http://solstice.crest.org/renewables/re-kiosk/index.shtml

Renewable Energy Bookstore
http://www.serve.com/commonpurpose/bookstore.html

Renewable Energy Generation Technologies
http://es.epa.gov/new/business/sba/options2.html

Renewable Energy on Small Islands
http://www.energimiljoeraadet.dk/publikationer/pdf/veoe.pdf
http://www.sidsnet.org/docshare/energy/RE_smallislands_2ed.pdf

RETScreen
Downloadable software to design renewable energy applications
http://retscreen.gc.ca

Sustainable Tourism and Renewable Energy Sources for European Islands
http://www.eurocaribbean.org/prioritytourism.htm

The European Renewable Energy EXchange
http://www.eurorex.com

The Source for Renewable Energy
A global buyers guide and business directory
http://energy.sourceguides.com/index.shtml

World-wide Information System for Renewable Energy (WIRE)
http://wire0.ises.org

Wind

American Wind Energy Association
122 C Street, NW, Suite 380
Washington, DC 20001
(202) 383-2500 | Fax: (202) 383-2505
windmail@awea.org

The European Wind Energy Association
http://www.ewea.org/src/about.htm

Danish Wind Industry Association
A guided tour on wind energy
http://www.windpower.dk/tour/

Harnessing Wind, Solar and Micro Hydro Power
http://www.wind-power.com/

PV and Solar Thermal

The International Solar Energy Society (ISES)
http://www.ises.org/

Solar Energy International (SEI)
http://www.solarenergy.org/

EL PASO Solar Energy Association
Provides practical information on solar energy and energy efficiency.
http://www.epsea.org/

European Solar Industry Federation
http://erg.ucd.ie/esif/welcome_to_esif.html

Sandia PV
http://www.sandia.gov/pv/recpract.htm

Solar Energy Nonprofit Organizations in the World (by Business Name)
http://energy.sourceguides.com/businesses/byP/solar/byB/org/byN/byName.shtml

Biofuels

European Biomass Association
http://www.ecop.ucl.ac.be/aebiom

Bioenergy Information Network
A gateway to information about fast growing trees, grasses, and residues for fuels and power
http://bioenergy.ornl.gov

American Biomass Association
http://www.biomass.org

Alternative Fuels Data Center
http://www.afdc.doe.gov

Small Hydro

International Network on Small Hydro
http://www.inshp.org/

International Small Hydro Atlas
small hydro resource, technical and regulatory issues
http://www.small-hydro.com/

European Small Hydro Association
http://profesionales.iies.es/minas/celpenc/ukindex.htm

Independent Power Producers' Society on Ontario, Canada
http://www.newenergy.org/water.html

GeoExchange

The International Ground Source Heat Pump Association (IGSHPA)
Non-profit organisation promoting geoexchange technology, training, research and development.
http://www.igshpa.okstate.edu/visitor.htm

Geothermal Heat Pump Consortium
Technical expertise on geoexchange technology
http://www.geoexchange.org/home.htm

Notes

About the UNEP Division of Technology, Industry and Economics

The mission of the UNEP Division of Technology, Industry and Economics is to help decision-makers in government, local authorities, and industry develop and adopt policies and practices that:

- are cleaner and safer;
- make efficient use of natural resources;
- ensure adequate management of chemicals;
- incorporate environmental costs;
- reduce pollution and risks for humans and the environment.

The UNEP Division of Technology, Industry and Economics (UNEP DTIE), with the Division Office in Paris, is composed of one centre and five branches:

- **The International Environmental Technology Centre (Osaka)**, which promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins, in developing countries and countries in transition.
- **Production and Consumption (Paris)**, which fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.
- **Chemicals (Geneva)**, which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety world-wide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO).
- **Energy and OzonAction (Paris)**, which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of the Unit.
- **Economics and Trade (Geneva)**, which promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.
- **Coordination of Regional Activities Branch**, which coordinates regional delivery of UNEP DTIE's activities and ensures coordination of DTIE's activities funded by the Global Environment Facility (GEF).

UNEP DTIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology cooperation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

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