Handbook for Financial and Development Professionals

Chapter 1

Introduction to Sustainable Energy Technologies

This chapter provides introductory information and sources of additional information concerning four renewable energy technologies

- ## Solar PV

PICTURE AND PAGE NUMBER

- ## Hydropower

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- ## Biomass

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- ## Wind and Hybrids

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- ## Solar Hot Water Heaters

PICTURE AND PAGE NUMBER

SUGGESTION: CREATE A SEPARATE SECTION ON HYBRIDS

Solar PV – Information and General Introduction

- Information on Solar PV can be found at:

    - http://www.shell.com
    - http://www.raps.co.za
    - http://www.fsec.ucf.edu/PVT/index.htm
    - http:// www.eren.doe.gov/pv
    - http://www.pvpower.com
    - http://www.solarpv.com
    - http://www.sunlightpower.com/upvg/pv_what.htm

- General Introduction

Solar panels collect sunlight, generate electricity and are connected to different components to form a solar system suitable for a specific application. The components connected to the solar panel are called balance of system components (BOS).

The most common application are lighting, water pumping, powering small appliances in households (e.g., TV) and powering productive use applications (e.g. sewing machine).

The direct current (DC) electricity generated by the solar panels during the day is generally stored. This allows 24-hour access to electricity. For this reason most solar systems are connected to a battery-bank.

In applications where alternating current (AC) is required to power certain appliances, an inverter is installed to transform the DC current available from the solar panel or the battery-bank to AC current.

The numerous configurations made possible by connecting different balance of system components to solar panels allows their use in many different ways.

<u>Households</u>
Solar Home Systems (SHSs) are used to power lighting, entertainment and information electronics (radio, television, cassette players, etc), and to a lesser extent productive or environment improvement appliances such as fans, sewing machines, soldering irons, hair clippers, etc.

<u>Community</u>
Solar PV Systems may be used for indoor or outdoor lighting such as streetlights or the powering of small hand tools in community centers or workshops.
Solar Water Pumping Systems provide small communities easy access to water.

<u>Health</u>

Solar PV Systems can power vaccine refrigeration, general facility and task lighting, and communication with district hospitals.

Education
The provision of solar power to rural schools allows the lighting of classrooms at night, which could aid programs providing basic adult education. Solar power systems also make the introduction of teaching aids such as computers, television, video and overhead projectors possible.

Manufacturing and Commercial
Numerous possibilities exist where solar power can be used in the manufacture or processing of product and the retailing of goods in rural communities. Examples include, refrigeration, cash registers, small machine tools or appliance powering.

Tourism
Through the installation of solar power, accommodation facilities within nature reserves can be greatly improved.

Telecommunications
Solar power is used to power two-way radios and telephones but also the infrastructure backbone of these services. Service providers use solar power to relay messages through repeater towers instead of establishing direct wire links.

Transport
The high cost of providing grid power in remote sites made the transport sector one of the first to make use of solar power for road signs, railway signals and navigational buoys.

Agriculture
Agriculture in developing countries benefits from solar power through applications such as water pumping and electric fencing.

Solar PV Systems consist of a number of interconnected components. Typically a solar system would consist of a:

Solar Array – The solar array in a typical solar system consists of one or more solar panels. The size of the solar array is determined by the load (duration, quantity and size of appliances) to be powered. A solar home system (SHS) usually consists of one or more solar panels with a combined peak wattage of between 20 and 150 watt. larger arrays, a series of multiple panels, are used to meet the higher energy demands of clinics, schools, water pumps and other greater demands.

Mounting Structure – The solar array is normally mounted on a metal or wooden structure to secure it against wind gusts, at such a height as to allow minimum obstruction of the sun's rays and in such a position as to keep it out of harms way. The mounting structure is erected in such a way that the available daily sunlight on the solar array is maximized. For this reason solar panels face the equator and are tilted at an angle that allows optimal sun during all seasons of the year.

Charge Controller – The charge controller manages the charging process of the battery-bank. Batteries must not be overcharged or discharged too deeply as this can severely affect their life expectancy. The functions of the charge controller include the optimization of the charge current received from the solar array and the protection of the battery-bank from overcharging. Many charge controllers also provide a customer interface as to inform the user of battery-bank's state of charge.

Battery Bank – The energy produced by the solar array is stored in the battery bank for use at any time. The battery-bank typically consists of one or more lead-acid rechargeable batteries similar to that found in motor vehicles. The use of ordinary automotive batteries in solar PV systems is not recommended. Use should rather be made of batteries that are better suited to delivering smaller amounts of power for longer periods of time in order to increase the battery-banks life expectancy. Generally batteries are a costly item in a solar system and need to be selected with care.

Inverter – Solar arrays and battery-banks deliver direct current (DC) electricity. To make this electricity useful for the powering of electrical appliances it needs to be changed to alternating current (AC). The device used for the purpose of transforming low voltage DC current to 110 or 220VAC is called an inverter.

Other Balance of System (BOS) Components – To get the solar system to work, the components need to be interconnected. For this purpose wire and cable of appropriate size, which minimizes resistance and a potential drop in voltage, is used. Other components needed for installation purposes, to make the system operational, include connectors, sockets, power outlets, channeling and tubing, as well as mounting hardware and terminals.

A solar PV system's size is determined by the peak wattage of the solar array. The amount of power (watts) that is available for consumption on a daily basis is however dependent on the average daily insolation (amount of sunlight measured in kWh/day/m^2) that a region receives. For example, the daily average insolation in the arid semi-desert regions of the continent is significantly higher (as much as 33%) than that in the rainforests of the equator.

In practical terms, this means that if the same 50 Watt peak Solar Home System is installed in both regions, the people in the semi-desert would be able to consume 50% more power on a daily basis than their counterparts in the rainforest.

The average daily insolation in Africa per annum varies from around 4kWh/day/m^2 to 6.5 kWh/day/m^2. This is some of the best sunshine in the world and superior to the average of 2 kWh/day/m^2 to 4 kWh/day/m^2 received in northern Europe, Canada and the northern section of the United States of America.

Not all solar panels are of good quality. The best way to distinguish between solar panels is to look at the reputation of the manufacturer, its distributors and the warranty and after sale service that they are willing to attach to their product.

- Solar Photovoltaic System Costs

Giving an indication of the cost of a solar PV system is extremely difficult, as it is dependent on the system's application and whether appliances are part of the system, such as a vaccine refrigerator in a health clinic system.

As a general rule it can be accepted that the smaller the solar PV system the higher the cost per peak watt installed. Larger solar PV systems therefore cost less per peak watt to install than the average Solar Home Systems. The installed cost of a Solar Home System of between 20 and 150 watt is typically in the region of US$10 to US$12 per peak watt. The average price of PV cells declined by one third in the past year, dropping to about $2.00 per peak watt. Module prices also declined from about $4.00 per peak watt in 1998 to approximately $3.60 in 1999.

Photovoltaics are now a proven technology that holds much promise for business. PV has the ability to bring about real change in rural unelectrified communities and create a business base for entrepreneurs in:

- Small-scale usage: Sale (cash or credit) and provision of services to homes for a fee, businesses and communities.

- Large scale uses: Water pumping, clinic and schools electrification and other productive uses.

Advantages:

- In rural markets that have no access to grid-connected electricity, life-cycle costs for photovoltaic systems are often equal to non-renewable alternatives now in use (kerosene, dry-cell batteries).

- Improved quality of life by increasing the number of productive hours, i.e. hours for education, income generation activities, etc.
- Proven technology with low operation and maintenance costs.
- Free abundant resource that is non-polluting.
- Self contained generating and distribution system.
- Modular

Disadvantages:

- Systems have high capital and transaction costs.
- Most rural families cannot afford to purchase for cash.

- Batteries contain hazardous materials and a means for careful recycling or disposal should be included in the long-term project design and funding scenario.
- Photovoltaic modules produce direct current (DC) electricity only; an inverter must be added to the system to run alternating current (AC) devices.
- Many governments have yet to realize the value of solar power and there are disincentives for its use due to high import duties, taxes, and subsidies for competing fuels.
- Information gaps exist. Updated information on the technology and availability is not readily available to all potential customers.

Hydropower – Sources of Information and General Introduction

- Information on Hydropower can be found at:

  - http://www.geocities.com/wim_klunne/hydro/
  - http://www.tamar.com.au/ (click on Hydro turbine section)
  - http://www.domme.ntu.ac.uk/microhydro
  - http://www.powerflow.co.nz/
  - http://www.inel.gov/national/hydropo wer/hydror%26d/hydror%26d.pdf

- General Introduction

Hydropower uses the energy of flowing water and variations in the altitude of the terrain to generate electricity. Typically, hydro plants include:

Dam: to accumulate water (in the case of small hydro this may be an "intake weir" that would ensure a high enough water level to keep water always entering the penstock).

Reservoir: where water is stored.

Penstock: pipes that carry water to the turbines inside the powerhouse.

Turbines: turned by the force of water in their blades.

Generators: driven by the turbines, they produce electricity. Two types of electricity are produced by generators, alternating current (AC) or Direct Current (DC). The choice between the two usually depends on the size of the system. AC is more common as DC is generally used in very small power systems of a few hundred watts.

Power House: actual building where electricity is generated and transformed to allow transmission to homes and businesses.

Transformer: Equipment that changes the AC voltage produced by the generator to a higher voltage for transmission.

Transmission lines: carry electricity local substations and to final users.

Small hydro plants usually do not require the construction of large dams. Facilities that actually require water storage will usually do little or no damming to the river's flow. This is seen as one of small-hydro's main benefits.

The power potential of water depends on the volume of water in the river (the "flow") and on the difference between the levels at which the water can flow down (the available "head").

The flow of the river is the amount of water (in cubic meters or liters) that passes from one point to another in the river, in a certain amount of time. Flows are normally given in cubic meters per second (m3/s) or in liters per second (l/s). The head can also be measured as the height from the turbines in the power plant to the water surface created by the dam.

The quantity of water available and the flow at different times in the year will produce different amounts of electricity.

Theoretical power equation:
$P = Q * H * e * 9.81$
Where:
P: power at the generator (in kilowatts)
Q: flow (in m3/sec)
H: head (in m)
e: efficiency of the plant considering losses (in decimal points, 85% efficiency level is entered as 0.85)
9.81: constant value (in kilowatts) for converting flow and head into kilowatts.

There are generally two categories of hydro power plants: run-of-river and storage plants.

Run-of-river plants generally use some or most of the flow in a stream to ensure the necessary amount of water to run the turbines. A run-of-river project normally does not have a dam, except for an intake weir. This storage facility keeps the water at a specific altitude and enables the pipes to be filled at all times.

Storage plants are usually larger hydroelectric plants that have a dam where water is stored to offset fluctuations in water flow. These fluctuations are generally caused by seasonal changes (different levels of rainfall). Storage facilities can be designed to provide daily and/or weekly storage needs. This is mainly done to satisfy energy demand in “peak” demand hours, and to conserve the water during low demand hours. “Peak” demand hours are those hours in which homes and businesses need electricity the most.

Kaplan, Francis, Pelton, Turgo Impulse and cross flow turbines are the most common turbines used in small hydroelectric facilities.

All power systems produce less power than is theoretically available because losses in energy take place as a result of changes in flow, when water enters and runs through the penstock, and also because of inefficiencies in the turbines. This is why the “e”, efficiency term is used in the above calculation.

As the head decreases, to achieve the same amount of power output the flow must increase. Generally, the cost of the turbine is determined by its diameter. The lower the head, the higher the flow and the higher the cost of the machinery and powerhouse. This cost may be offset by the cost of the civil works required to build tunnels or high dams. Overall, the technologies involved in the development of small hydro facilities are proven.

Plant capacity factor: this is a commonly used term. It is the ratio of the actual power produced in a year to the power that could be produced in a year if the equipment ran at full capacity for the whole year. Normally, the plant capacity factor is in the range of 30% (for plants that have specifically been built to supply power during "peak" hours) to 75% for stations with either large storage capacity or a very steady water flow throughout the year.

- System Costs

Estimating the average capital cost of small hydro plants is difficult because the type of plants can vary (depending on the flow and head and also depending on environmental considerations). The following average data corresponds to small hydro plants of 125kW and 32.4 MW in size.

Turbine Cost: $450 - $600/kW
Total Project Cost: $1,000 - $2,100/kW
Cost Breakdown:

Civil works	15 - 40%
Equipment	30 - 60%
Infrastructure	10 - 15%
Development Costs	10 - 15%

Average Construction Time: 2-3 years
Operating & Maintenance Cost: $0.01 - 0.02/kWhr

Advantages

The environmental and industrial advantages of small-hydro power generation are often disputed because they are grouped with the problems associated with large-scale hydroelectric plants. However, in favorable sites, small-scale hydroelectric plants remain a very valuable form of energy both in environmental as well as in financial terms when compared to other forms of energy investments.

Some of the advantages commonly linked to small-hydro power generation include:

- The fuel source is essentially "free", it can be reused (as the fuel is not consumed) and it is non-polluting.
- The system can be integrated with water flows used for irrigation and potable supply.
- Systems can have a 50-year or more useful life and provide continuous power as long as water resources are sufficient.
- Limited maintenance (compared with diesel power) is required.
- The conversion of the potential energy of water into mechanical energy is highly efficient, if compared to thermal power stations.

Disadvantages

- Flows often vary throughout the year, affecting the availability of water in certain seasons or time periods (as in the case of El Niño or Monsoon climates);
- It is a site specific technology, meaning that the necessary conditions for power generation in terms of flow and "head" need to be present for use. Locations where power can be economically exploited are limited;
- Water flow and "head" conditions limit the maximum level of power that can be generated. The level of expansion is therefore bounded.

Biomass – Sources of Information and General Introduction

- Information on Biomass can be found at::

  - http:// www.shell.com
  - http:// www.solstice.crest.org/renewables/re-kiosk/biomass/index.shtml
  - http:// www.nrel.gov/research/industrial_tech/biomass.html
  - http:// www.ott.doe.gov/biofuels/what_is.html
  - http:// www.eren.doe.gov/re/bioenergy.html
  - http:// www.nrel.gov/lab/pao/biomass_energy.html

- General Introduction

Biomass accounts for more than 10 percent of global energy use. In parts of the developing world it accounts for up to 90 percent. Biomass is an indigenous fuel source that is often readily available and inexpensive throughout much of Africa. It can also be effectively converted to electricity and heat due to recent technological developments. It is because of these two factors that biomass will most certainly play a significant role in the development of energy sectors across the world.

The two most common types of biomass resources are p*lant biomass* which includes woody and non-woody biomass and processed waste and fuels; and, a*nimal biomass* which includes animal manure as a feedstock to generate energy using biogas technologies or directly as a cooking fuel.

Each type of biomass has unique characteristics that make it more or less suitable as a fuel source:

- *Moisture content:* This is simply the amount of water found in the resource expressed as a percentage of the total resource weight. The value can range from less than 10 percent, for some straws, up to 70 percent for forest residues. The percentage can be expressed as a portion of the wet, dry, or ash-free matter. Typically, it is measured on a wet basis, however it is important to know and cite the way in which the resource was measured.
- *Ash content:* Again, the ash content can be measured on all three bases - wet, dry or ash-free matter. The type used must be reported. It is most common to see the ash content measured as a percentage of the dry matter. In wood, the ash content is around 0.5 percent, for agricultural residues the percent ranges from 5 to 10, and for husks it can be as high as 40 percent. The amount of ash affects the biomass's behavior when exposed to the high temperatures necessary to convert it to electricity.
- *Volatile matter content:* This is the measurement of the amount of the biomass that escapes when heated up to 400 and 500 degrees Celsius. When exposed to high heat, the biomass decomposes into solid char and volatile gases. The volatile content can be as high as 80 percent.

- *Elemental composition:* The elements contained in biomass are typically carbon, oxygen and hydrogen with a small amount of nitrogen.
- *Heating value:* This property measures the amount of energy that is chemically bound in a standard environment. The heating value is a measurement of the energy (Joules; J) per amount of matter (kilograms; kg). The value cannot be measured directly so it is done according to reference states such as the lower heating value (LHV), measured in a gaseous state and the higher heating value (HHV) measured in its liquid state.
- *Bulk density:* This is the weight of the resource per unit of volume. This measurement can be found when the biomass is in zero (0) moisture content state (MC=0), termed the oven-dry-weight basis, or according to its given moisture content (MC_w). This property also shows extreme variations from as low as 150 to 200 kg/m^3 straws to 600 to 900 kg/m^3 for wood. The last two properties, heating value and moisture content together determine the biomass resource's *energy density*. The energy density is defined as the potential energy per unit volume. The result is typically one-tenth that of fossil fuels.

- Technology Options

The following provides a brief introduction to the various types of biomass technologies that are available for different biomass resources.

Direct Combustion: Biomass such as wood, garbage, manure, straw, and biogas can be burned without processing to produce hot gases for heat or steam. Burning the resource by direct heat is termed direct combustion. Examples of direct combustion range include burning wood in fireplaces, burning garbage in a fluidized bed boiler, producing heat or steam to generate electric power. This is the simplest, most widely used, and often most economical biomass technology especially if the biomass resource is within close proximity.

Pyrolysis: Pyrolysis is the thermal degradation of biomass by heat in the absence of oxygen. Biomass resources, such as wood or garbage, are heated to a temperature between 800 and 1400 degrees Fahrenheit, but no oxygen is introduced to support combustion. Pyrolysis results in three products: gas, fuel oil, and charcoal.

Anaerobic digestion: Anaerobic digestion converts organic matter to a mixture of methane, the major component of natural gas, and carbon dioxide. Biomass, such as wastewater (sewage), manure, or food processing wastes, is mixed with water and fed into a digester tank without air. Use of this type of technology results in biogas.

Gasification: Biomass can be used to produce methane through heating (800 Celsius) or anaerobic digestion. During gasification, about 65% of the energy is captured and converted into combustible gases. The gases are then converted into natural gas, which can be used to fuel vehicles, generate electricity, or again converted into synthetic fuels. This technology is not as commercially viable as direct combustion because it is more costly and more state of the art. The most commonly used types of gasifiers are fixed-bed and fluidized-bed. There are many advantages that gasification technologies have over direct combustion and the other converting technologies. The advantages include increased efficiencies by as much as 50%, variety of suitable biomass resources.

Alcohol Fermentation: Fuel alcohol is produced by converting starch to sugar, fermenting the sugar to alcohol, then separating the alcohol water mixture by distillation. Feedstocks such as wheat, barley, potatoes, waste paper, sawdust, and straw contain sugar, starch, or cellulose and can be converted to alcohol by fermentation with yeast. Ethanol, also called ethyl alcohol or grain alcohol, is the alcohol product of fermentation usable for various industrial purposes including alternative fuel for internal combustion engines.

Landfill Gas: Landfill gas is generated by the decay (anaerobic digestion) of buried trash and garbage in landfills. When the organic waste decomposes, it generates gas consisting of approximately 50 percent methane, the major component of natural gas.

Cogeneration: Cogeneration is the simultaneous production of more than one form of energy using a single fuel and facility. Furnaces, boilers, or engines fueled with biogas can cogenerate electricity for on-site use or sale. Biomass cogeneration has more potential growth than biomass generation alone because cogeneration produces both heat and electricity. Cogeneration results in net fuel use efficiencies of over 60 percent compared to about 37 percent for simple combustion. Electric power generators can become cogenerators by using residual heat from electric generation for process heat, however, waste heat recovery alone is not cogeneration.

Co-firing: Co-firing is only possible if using an existing coal-fired power plant. This process is possible by mixing biomass with coal and then burning them together or in different boiler feeds. Advantages of this technology are that it can be the least-cost option and can displace up to 15% of the coal. The typical biomass resources used in this case are wood products.

Overall, one of biomass's most attractive qualities is its versatility. It can be easily converted to electricity by burning or converted to liquid or gaseous fuel by physical or biological means.

- System Costs

Due to numerous variables, it is not reasonable to provide estimate costs for biomass projects. Issues to consider in determining the cost of using a biomass resource include:

- Crop selection and rotation: Biomass properties will often affect the attractiveness of the resource. For example, the energy density, leaf cover, productivity, water and nutrient requirements, soil erosion

susceptibility to disease, effect on biodiversity may increase the cost of converting the resource;
- Cost and seasonal availability of resource;
- Storage: It may be possible that you have to collect and store the resource for a period of time, which may be costly;
- Transport: Costs to get the biomass to the conversion site; and
- Efficiency: The lower the efficiency of the biomass resource the more land is required. This cost may be a substantial percentage of the total project costs or the land may be economically suited for another activity.
- Plantation running costs: labor, fertilizer, and herbicides

Advantages
- Biomass is a renewable source as is receiving a great amount of attention as a possible fuel of the future to combat climate change. This could have a positive impact on the cost, etc.
- Biomass is often available in large supply in developing countries.
- Land requirement is not an issue because there is generally a large amount of land area in Africa that cannot be used for other productive uses, but can sustain biomass.
- A variety of conversion products are available with a wide range of uses.

Disadvantages
Biomass is often left out as a fuel for the future for the following reasons:

- Associated with health related problems in developing countries mainly from particulates released during burning and carbon monoxide. These problems lead to respiratory infections in children and complications during pregnancy;
- Biomass is often bulky and may have a high water content.
- Quantity of fuel is unpredictable and may be difficult to handle. Long-term fuel supply contracts ;
- Low energy density per unit of land, water, or per unit weight of raw product;
- Energy crops and dedicated biomass requires a large amount of dedicated land area. Unfortunately, dedicated areas may reduce the soil fertility, biodiversity, water level, landscape, displace food, and affect the leaching of nutrients.
- In developing country it is expensive as wood fuel costs 2 to 3 times higher than in Europe or the US. (Better example)

Wind and Hybrids – Sources of Information and General Introduction

- Information on Wind and Hybrids can be found at:

  - http://www.bergey.com
  - http://www.energy.ca.gov/earthtext/wind.html
  - http://www.nrel.gov/clean_energy/wind.html
  - http://www.eren.doe.gov/wind/web.html
  - http://www.britishwindenergy.co.uk/frames/index.html

- General Introduction

For many years, humans have used wind to crush grain, pump water and transport goods and people. Most recently wind machines have been developed that produce electricity. Wind is used to drive a rotor (blades) that is connected through a power shaft to an electric generator. Wind speed increases with height above the ground, so wind turbines are mounted on towers. The amount of energy a wind turbine produces depends on the wind speed and the diameter of the rotor.

Electricity produced from the wind represents the fastest growing energy sector in the world. If the 27% average annual growth rates of 1995-1998 can be sustained, wind energy could account for more than one-tenth of world electricity production by the year 2020. Improved technology and larger wind energy machines have combined to make wind energy cost competitive with fossil fuel.

While large, grid-connected systems dominate the statistics of wind energy production, the improvement in smaller wind technologies has been equally dramatic. Wind energy, alone or combined with other means of energy production – such combinations are called “hybrids” – are in position to make significant contributions to rural energy supply.

These contributions can take the form of water pumping for drinking or irrigation, electricity for income producing activities, or household, health and community services. These services can be to individual buildings or groups of buildings or to a “mini-grid” covering a village or town.

The most common wind turbines in operation today have two or three blades that revolve around a horizontal axis. These “horizontal-axis wind turbines” (HAWT) also include a gearbox and generator, a tower, and other supporting mechanical and electrical equipment.

Wind turbines are rated by their maximum power output in kilowatts (kW) or megawatts (1000 kW). For commercial utility-sized projects, the most common turbines sold are in the range of 600 kW-1000 kW (one megawatt) – large enough to supply electricity to 600-1000 homes. The newest commercial turbines are rated at 1.5 megawatts or more.

If the goal is local energy production for local use – as is the case with most rural and smaller projects -- wind machines (turbines) and a tower need to be of a size suited to the prevailing winds and electricity demand in the area. Where larger projects (wind "farms") are involved, the electricity produced is usually for sale to the electricity grid. Project interconnections make these projects far more complicated from a technical perspective. Because of the need to technically integrate two complex systems.

Long-term wind data (wind maps) of an area are *absolutely critical* to ensure the average wind speed that can be expected. Once long-term wind averages are determined site specific data are equally essential and require specific measurement over time using devices known as wind anemometer.

Since the current phase of development began in the 1980's, the price for wind-generated electricity has been reduced by an average of 3 percent per annum. This has been due in part to ever-increasing turbine capacity, increasing from an average 220kW in 1992 to 650 kW in 1998.

- System Costs

  Wind Turbine Size ranges:
  - Large units – 250kW to 1500 kW each, cost $600/kW
  - Medium sized units – 10 kW, cost $1,400/kW
  - Small units – less than 500 W, cost $1,600/kW

  Total Project Cost: $1,000 - $1,600/kW

Advantages

- Although the wind resource for any site is intermittent, it is predictable and its available power increases dramatically with an increase in available wind speed. Thus the output from a wind plant can be integrated with other energy supplies or into existing electrical grids with a high degree of confidence. A modern wind turbine's "capacity factor" (the percentage of time a wind turbine generates power) is in the range of 20-40 percent.
- Wind turbines require no fuel and operations are simple with low maintenance requirements.
- Wind turbines are rugged and reliable and the modularity of wind machines allows units to be sized to match existing energy needs and expanded as demand grows.
- A small windfarm can generally be constructed within a year.

Disadvantages

- Wind energy is very site specific with minimum wind speed requirements.
- Larger wind farms require land and may be visually unappealing and noisy. Such larger systems can not be sited close to centers of demand.

<u>Wind Hybrid Systems</u>

A hybrid system comprises components that produce, store and deliver electricity utilizing more than one energy generation technology. This could include a wind turbine, PV array and diesel generator. The most common combinations are wind and PV or a generator because wind energy production tends to be highly variable; therefore, wind turbines are often best combined with PV panels or generators to ensure energy production during times of low wind speeds.

Many sites, particularly in northern latitudes have seasonally complementary wind and solar resources (strongest wind in winter, strongest solar in summer). Therefore, establishing a system using both wind and solar PV could address the energy needs year round. In addition, combining wind and PV can shrink the battery bank requirements and further reduce diesel consumption.

Utilizing a wind-hybrid system is very common in telecommunications applications. In addition, establishing a wind/diesel battery charging stations could address the need of carrying batteries to town for charging in developing countries. Offering wind/diesel power battery charging services at the village appears to be very cost effective ($2.50 - $5.00 per month).

Advantages of Hybrid Power Systems:

- Provide dependable, utility grade power 24 hours a day.
- Not dependent on a single source of energy
- Flexible, expandable and able to meet changing loads.
- Simple, quick, low cost installation.
- Low operating costs (O&M and Diesel fuel).
- Simple operation, low maintenance and service requirements.
- Lower life cycle costs of electricity for remote applications.

Disadvantages of Hybrid Power systems:

- High capital cost compared to diesel generators.
- Diesel and Hybrids have very different cost components.
- More Complex than stand-alone power systems; requires battery storage and power conditioning.
- Not yet in full commercial production/few suppliers.

Solar Thermal – Sources of Information and General Introduction

- Information on Solar Thermal can be found at:

    - http://www.eren.doe.gov/solarbuildings/ hotwater.htm
    - http://www.natenergy.org.uk/swh.html
    - http://www.nrel.gov/
    - http://www.eren.doe.gov/
    - http://www.eren.doe.gov/consumerinfo/elecsource.html
    - http://www.epsea.org
    - http://www.eren.doe.gov/erec/factsheets/solrwatr.html
    - http://www.greenbuilder.com/sourcebook/heatcool.html#Define
    - http:// www.seia.org/sf/sfsolth.htm
    - http://infinitepower.com/fs10.html

- General Introduction

Solar thermal technologies enable us to produce hot water from the sun's energy for use in homes, factories, hotels and many other applications. Solar water heating is not only a suitable and economical alternative to water heating with electricity in towns, it can also provide hot water efficiently and reliably in rural off-grid areas.

Solar water heaters typically consist of a collector and an insulated water storage tank that is similar to a conventional electric hot water tank or geyser. The collector is a box with a see-through glass (or acrylic) cover containing a number of black coloured pipes attached to or laid on a black heat absorbing surface. Water or other liquid flows through these pipes and is warmed by the sun, and then stored in the water storage tank. This process is repeated over and over while the sun is shining; every time the fluid passes through the pipes a small amount of heat is added to it. Water typically reaches between 60°C and 80°C in solar water heating systems intended for human use.

Solar water heaters are available in various sizes, designs and for various applications. Small systems, with a hot water storage capacity of less than 500 litres, are called domestic systems. These systems are usually installed in residential homes or facilities such as visitor centres and campground showers. Larger size systems (more than a 500 litres per day) are normally referred to as industrial systems. Examples of the application of large systems are found in the agriculture, industrial, tourism and accommodation sectors of the economy.

Special systems that produce a water temperature of several hundred degrees are sometimes used in industry and for power generation. Another popular application of solar water heating is the heating of swimming pool water in less temperate climates.

Homeowners that install solar water heating systems to replace water heating by electricity could expect electricity cost saves in access of 40%. The use of solar water heating therefore not only makes environmental sense but also economical sense. Generally it is possible to recoup the capital expenditure on a solar water heater within 2 to 5 years out of the savings realised.

Solar water heating is a renewable energy technology that is well proven and reliable. Various types of Solar Water Heaters are produced in different sizes. Changes in design are required depending on the climate where the system is installed, the water quality and on the specific use for the hot water.

Systems can be very similar to traditional electric water heaters, where water is stored in a tank and then heated. The difference is basically that instead of heating the water with electricity or a gas flame, the water flows through a solar collector panel, where the sun's rays heat it.

The different designs of solar water heaters available on the market allow for their application in many sectors of a developing country's economy. Examples of these applications include:

Households
Water heater by solar is used for bathing, dish washing and laundering in numerous households. Pool heating is another popular application of solar in the houses of the more affluent in less temperate climates.

Health
Clinics and hospitals use solar heated water in ablutions and laundries. Hot water in access of 80°C can also be used for sterilisation purposes.

Education
Many dormitories at schools and universities use Solar Hot Water systems for the communal shower facilities.

Tourism and recreation
Hotels and accommodation in nature reserves use solar heated water in laundries, bathrooms and sometime for swimming pools.

Industry
Apart from the application of Solar Water Heating systems in worker ablutions, hot water is also required in many industrial processes. Solar hot water applications have been particularly popular in abattoirs due to the cost savings that it brings about. The water is used for the cleaning and sterilisation of the abattoir facility.

Agriculture
A wide range of uses is also found in agriculture. These range from heating water on crocodile farms to pasteurisation and sterilisation on dairy farms.

Solar Water Heater Components

Solar Collector: which is usually a flat metal box or frame with pipes. Collectors have:

Transparent covers that let solar energy in are either made of a special glass that resists breaking and scratching or ultra violet radiation resistant acrylics (plastic).

Absorber plates are dark surfaces that trap heat. These are generally metal sheets or containers filled with water, rocks or bricks that are painted black or another dark colour to retain the heat.

Insulation materials prevent heat from escaping to colder places.

Vents, tubes and pumps carry the heated water from the collector to the places where it can be used.

Storage tank: which stores the water to be heated. The storage tank is similar to most gas or electric water heaters. The tank is made of steel and sometimes copper or even plastic.

The amount of hot water that is produced by a solar water heater depends on the size and type of the system and on the amount of sunlight available at the site. There are many types of solar water heaters, but generally, they can be classified as direct or indirect systems that employ either active or passive fluid flows in their design.

Domestic Solar Water Heaters usually have storage tanks with a capacity of 100, 150, 200 and sometime 300 litres. The size of system selected will depend on the expected household consumption and budget available.

- System Costs

The cost of solar water heaters varies depending on their size and type. Direct *passive* solar water heaters of between 100 and 200 litres usually cost between $750 and $1,250 including installation, while indirect passive heaters are usually in the $1,000-$2,000 price range depending on their size and level of sophistication. Active systems for domestic use are usually in the $2000 to $4000 price range.

Advantages

- Lower consumption of conventional energy that would otherwise involve the use of fossil fuels and cause environmental damage.
- Systems that can operate in any climate.
- Short construction and installation times.
- Modularity.
- For households already connected to the grid, substantial savings in electricity bills.

- Solar water heating is the least cost method of heating water if life cycle costs are calculated.
- Water heating by solar energy is highly efficient.
- Long-term benefits for users as the systems isolate them from future fuel shortages and price increases.
- Opportunities for local production and job creation.
- Hot water can make a valuable contribution to personal hygiene.

Disadvantages

- Ultra violet (UV) rays damage most materials after a few years in the sun. Good quality more expensive materials that are capable of withstanding the damaging effect of UV radiation need to be used.
- Systems of appropriate design and quality must be used if a medium to long-term cost saving is to be realised.
- Solar water heaters are more cost-effective than electric water heaters but less so if compared to gas water heaters.
- In places with cold weather, the solar water heater might require a back-up device (usually electric element) to ensure hot water provision at times of low solar energy. Electrically boosted solar water heaters can actually produce more air emissions than high-efficiency gas water heaters, in climates where solar systems are largely reliant on boosting.
- The initial cost of solar water heaters is generally higher than that of conventional water heaters. However, as the fuel is free, the energy costs over the life of the system offset the initial cost.