TODAY'S RENEWABLE ENERGY TECHNOLOGIES

The renewable energy technologies receiving the most attention in Uzbekistan today are those that use solar, wind and biomass energy and small hydro power plants and geothermal plants.

3.1. Uses of solar energy

Solar energy can be used to produce both heat and electricity. To produce heat, flat non-focusing solar panels containing water, air or antifreeze, are used (Boxes 3.1 and 3.2). To produce electricity, the energy in a stream of light is converted directly into electrical power in photovoltaic converters, or indirectly by heating a heat-transfer agent at a solar electric power plant the same way heat-transfer agents are heated at traditional thermal power plants.

Box 3.1

ISLANDS OF MAURITIUS

Using solar energy to desalinate water for seaside villages

Blue water, stretching for as far as the eye can see, separates the island of Rodriguez from Mauritius 320 miles away. A rural community of 21 families on the island, experiencing an acute shortage of drinking water, collects rainwater from infrequent rains in special tanks. When the tanks run dry, the women have to spend between three and five hours bringing water from a natural source that does not always meet hygiene standards.

The island's abundant natural resources – solar energy and sea water – can be used to solve the problem of providing drinking water. Water desalination equipment manufactured locally whose technology was designed by a renewable energy expert at the University of Mauritius was installed in this remote community.

The equipment enabled the 21 families to use energy from the sun's rays to convert sea water into drinking water. The equipment consists of a fiberglass coated tank 1 m x 2 m in size. The sun is used to evaporate sea water poured into the tank Evaporated water condenses on the inside surface of a transparent cover positioned at an angle chosen so that water that condenses on it can trickle out of the tank into another tank for drinking water. The amount of drinking water obtained is roughly half the amount of sea water used, so that for every 10 liters of sea water three to seven liters of drinking water are obtained per day. Minerals must be added to the water before it can be drunk. The families contributed to the project, supported by the Small Grants Program of GEF/UNDP by building conduits to provide easier access to the sea water.

The desalination technology is efficient and low cost. The equipment can be built using the resources of local workshops and companies. Consequently, once the university expert had built a prototype of the distiller, another 20 were built under the supervision of a small local boatbuilding company.

Source: Small Grants Program GEF/UNDP

Box 3.2

PALESTINE

Using solar energy to dry crops and medicinal herbs

Palestine is one of the most densely settled areas in the Middle East. Approximately 15% of the West Bank and the Gaza Strip have no electricity. Solar energy and other renewable sources of energy could potentially provide the population of the region with electricity and thermal energy, which in turn could be a major opportunity to link renewable energy with efforts to raise the income of the local population.

In these communes women traditionally dry medicinal herbs in the sun which takes up a considerable amount of time and produces herbs that lose their color and freshness and that are of inferior quality. Solar dryers can produce higher quality dried herbs in a shorter amount of time.

A total of 17 small women's cooperatives (65 women) took part in a project financed by the GEF/UNDP Small Grants Program in which solar driers were installed for drying fruits and medicinal herbs and other products to be sold on the local market. The solar dryers were installed in the back yards of homes. The women, who formed small cooperatives of three to five members, pooled their fruits and medicinal herbs, dried them in the solar dryers, packaged them, sold them and shared the profits.

A solar dryer has solar panels on the outside and trays on the inside for fruits and herbs. Fruits and herbs are loaded on the trays and left to dry. Drying takes just a few days.

Because using solar dryers produces additional income, there is the distinct possibility of developing a loan program whereby loans would be repaid within a certain period of time covered by receipts from sales of dried fruits and medicinal herbs. Another important outcome of the project is that the women who participated in the project acquired new technical and business skills.

Source: Small Grants Program GEF/UNDP

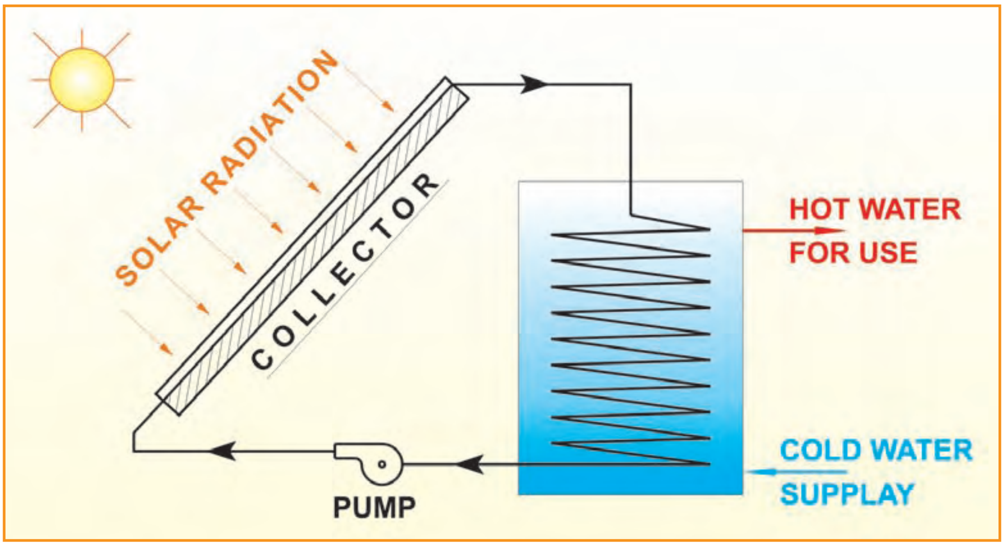
Solar water heating

Solar water heating facilities use solar radiant energy to raise the temperature of water by means of solar panels. The most widely used solar panels are flat and air-tight, have a transparent coating painted a dark color, and an absorbent metallic plate containing water pipes and insulation to reduce heat loss from the back and sides of the plate.

In regions where frost is a possibility, frost proof panels are used (Figure 3.1). In the majority of instances, frost proofing is provided by a closed cir-

Figure 3.1

Frost proof solar water heater with heat exchanger



Source: UNDP Project Report: Review Studies for National Strategy on Renewable Energy in Uzbekistan.

culation system in which a heat transfer liquid (with a freezing point lower than that of water) circulates through the solar panel and uses a heat exchanger to transfer the accumulated heat to water in an accumulator tank.

Two kinds of accumulator tank systems are used in solar water heaters - passive and active (Figure 3.2).

In passive systems the accumulator tank is located above the solar panels so that cold heat-transfer liquid can drain through an outlet pipe into the lower part of the solar panel where it passes through a heat exchanger on the bottom of the accumulator tank. The heat transfer liquid is then heated by the sun, rises back up through the solar panel and returns to the heat exchanger through an intake pipe in the upper part of the panel. This creates a steady flow of heat transfer liquid through the panel, obviating the need for a forced circulation pump.

There are two types of passive systems: closed-double and gravity fed. In closed-double systems a horizontal accumulator tank is mounted directly on top of the panel on the building roof. This system is the most economical in terms of installation costs, but its performance degrades during cool and cold weather due to heat losses in the accumulator tank. Insulation can be added to the accumulator tank to reduce such heat losses or the tank can be enclosed in a dormer-like structure.

In a gravity fed system the accumulator tank is installed under the recesses of the roof. Such systems are the least costly but the building's water pipe system must meet requirements for gravity fed liquid delivery, including wide gauge pipes between the water heater and faucets.

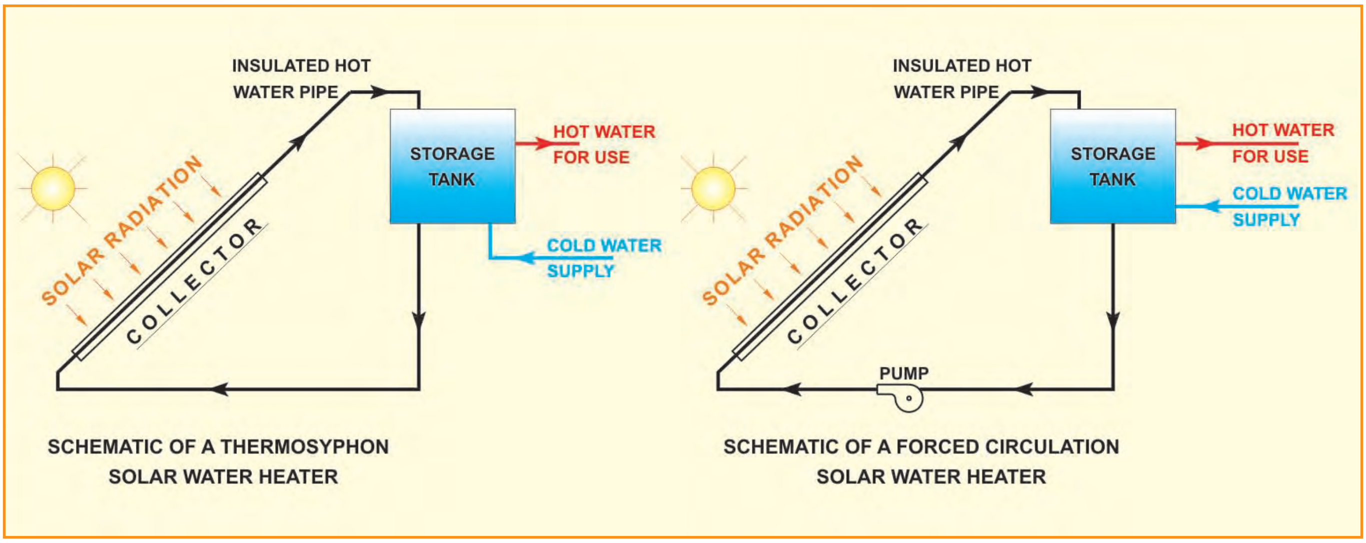
In active systems the solar panel is located on the roof while the accumulator tank can be located on the ground or any other convenient place. Water or heat transfer liquid is pumped through the panel by a small electric pump that provides forced circulation. Active systems are usually more expensive and require more serious maintenance than passive systems do. However, active systems are efficient in cases when the accumulator tank can not be installed on the roof, for example, due to weight-bearing restrictions.

Accumulator tanks are made of stainless steel or soft steel coated with vitreous enamel. Accumulator tanks that are installed out-of-doors in cold regions can break down in freezing temperatures and experience large heat losses. In such conditions it is recommended that accumulator tanks be installed indoors.

Solar water heaters can be provided with booster (backup) sources to finish heating the water when there is not enough solar radiation to heat the water fully. This can be done by using boosters running on natural gas (gas boilers) to heat the water either in an accumulator tank or in individual auxiliary devices. Electrical boosters (thermal electrical heaters) consisting of an electrical element inside an accumulator tank can be used to do so as well. The main consideration is that the booster be designed to maximize

Figure 3.2

Schematic diagrams of passive and active solar water heater systems



Source: UNDP Project Report: Review Studies for National Strategy on Renewable Energy in Uzbekistan.

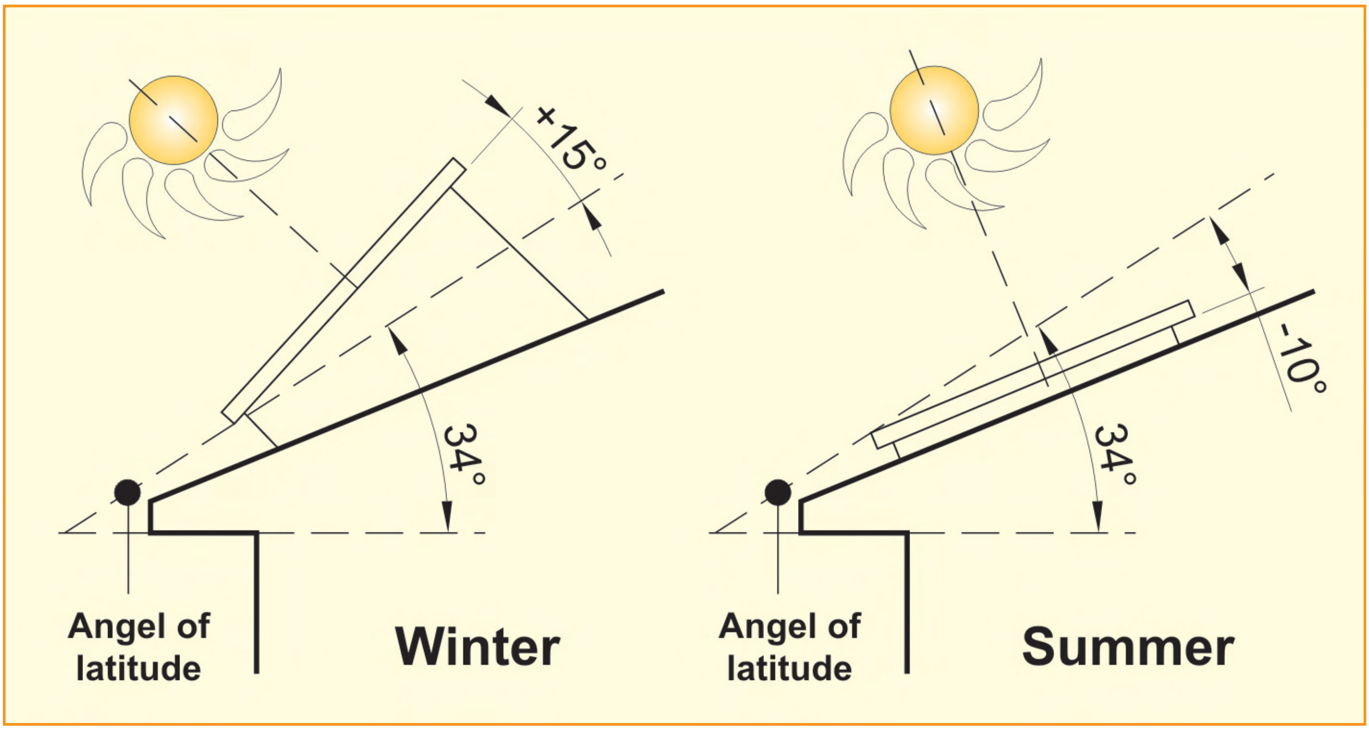
the solar energy component in heating the water.

Solar heater panels have to be positioned to accommodate the sun's daily trajectory so as to make maximum use of the sun's rays. Generally, high efficiency is achieved by orienting the panels toward the horizon since that maximizes exposure of the solar panels to the sun's rays (Figure 3.3). How solar panels are oriented is determined case by case, based on the installation site and must be planned beforehand. As a rule, optimal performance is achieved by orienting a solar panel toward the horizon, adjusting for the latitude where it is installed.

The cost (Table 3.1) of a solar water heater can vary widely depending on which company manufactures it and the capacity of the heater [23]. Installation of an active solar water heating system with forced circulation (using an electric pump) usually costs an additional 500 USD [24].

Figure 3.3

Positioning of solar panels to heat water on the latitude of Sydney, Australia



Source: UNDP Project Report: Review Studies for National Strategy on Renewable Energy in Uzbekistan.

Table 3.1

Approximate solar panel cost factors (2004)

Output (liters of water)	Panel surface area (m^2)	Cost (USD)
100	1.5	1,000
200	3.0	1,.350
300	4.5	1,900
450	6.0	2,400

Solar photovoltaic systems

Photovoltaic cells convert the energy in light rays into electrical energy (Box 3.3). Photovoltaic cells have undergone three generations of technological development:

- First generation photovoltaic cells were based on the use of mono- and polycrystalline silicon. First generation photovoltaic cells make up as much as 80% of all photovoltaic systems

Box 3.3

UGANDA

Lake Victoria wind and solar energy demonstration project

What do you do when your only source of energy is also the biggest threat to your health and your habitat? Countless numbers of rural communes all over the world face this dilemma. Clustered together off Lake Victoria's west bank are 84 small islands of which 70 are uninhabited. Fishing is the chief source of income on the inhabited islands. The basic energy needs of the local population are provided by disposable dry cell batteries, kerosene, paraffin and firewood. The improper use of so many batteries produces water and soil pollution. Kerosene, paraffin, and firewood contribute to environmental pollution and are harmful to human health.

As part of a GEF/UNDP Small Grants Program project, wind and solar energy were used to recharge non-disposable batteries thereby reducing pollution and the dangers associated with the use of disposable batteries. For similar reasons, a hybrid solar-wind device was built on the island of Musoni consisting of three 400 kW wind-driven generators and six photovoltaic panels. On the small island of Bufumira the island's partner development association's office was provided with electricity by installing seven photovoltaic systems, an inverter, three capacity regulators and two batteries charged with solar energy. The office was also equipped with seven energy-saving light bulbs. The local elementary school was likewise provided with a solar battery and energy-saving light bulbs. The high school on the small island of Bukasa was provided with electricity and the local commune with a battery recharging service. Eight photovoltaic systems, three capacity regulators, one inverter and 10 energy-saving light bulbs were also installed there.

The development association for the islands established a commission under a local commune to provide for the operation of a hybrid solar-wind station used chiefly to recharge non-disposable batteries and meet household energy needs and those of fishermen working at night. By using non-disposable solar batteries instead of disposable dry batteries, dumping of used batteries and concomitant water and soil pollution were eliminated.

In addition, members of the commune established a battery recharging payment system. Under the system, recharging a battery costs approximately one USD and each customer is issued a receipt for each payment made for recharging a battery. The island development association established a small line of credit to assist people to buy photovoltaic systems and batteries. Receipts from recharging batteries are distributed as follows: 30% for station maintenance personnel wages, 50% for the bank and 20% for operating expenditures.

Source: Small Grants Program GEF/UNDP

installed worldwide. The first generation found the widest application and was considered cutting edge technology. In the foreseeable near-term, first generation photovoltaic cells will dominate the photovoltaic cell market. Their efficiency coefficient is usually 11-16%;

- Second generation photovoltaic cells are thin films made of amorphous silicon, cadmium-telluride or copper-indium-selenide. Second generation photovoltaic cells have an efficiency coefficient of only 8% more or less but are cheaper to manufacture than first generation photovoltaic cells;

- Third generation photovoltaic cells can be installed on top of each other to produce a coefficient of efficiency of nearly 30% to 60%. Third generation photovoltaic cells, which are usually photovoltaic-chemical, organic or plastic, are in the development stage and as such are not fully developed. Their coefficient of efficiency is about 7%. Presumably, in the future, they will realize savings in manufacturing costs thanks to their simplicity and the inexpensiveness of the materials they are made of.

PV systems can operate on a stand-alone basis or can be connected to a power grid. When functioning as part of a power grid, a photovoltaic system is made up of a large number of cells to increase its capacity and reduce its cost. When functioning as part of a grid, a photovoltaic system must have, in addition to photovoltaic cells, an inverter and mechanical and electrical hardware components. A photovoltaic system generates direct current which can be converted to alternating current with the use of an inverter.

The amount of electricity a photovoltaic system produces depends on the following factors:

- Solar radiation intensity;

- Installed capacity - Wp (peak capacity during maximum solar activity);
- Orientation of photovoltaic panel; and
- Panel temperature, which though minimal, does nevertheless have an effect on photovoltaic cell electrical capacity.

The photovoltaic systems, connected to an energy grid, are grouped into modules of 30-80 cells with standard per module voltage of 15–30 V of direct current. Higher voltages can be obtained by connecting a large number of modules in series. The most widely used photovoltaic cells have an installed capacity of 5 to 150 Wp, but cells with up to 300 Wp do exist.

The photovoltaic system performance is subject to diurnal fluctuations. So long as a photovoltaic system and a grid are compatible, the photovoltaic system can be used to cover the grid's peak electric loads.

The advantages of using solar photovoltaic systems are:

- Minimal operating expenditures;
- No harmful emissions;
- Lengthy (30 years minimum) service life of photovoltaic modules;
- Ease of installation and operation; and
- Higher quality electricity when electricity is supplied locally.

The disadvantages of using solar photovoltaic systems are:

- High upfront capital investments;
- Dependence on solar radiation; and
- High ratio of useful area to unit of output.

In recent years the world solar photovoltaic cell market has been growing at a rate of approximately 30% per year, while the average price of a solar photovoltaic cell has dropped 4%.

At present, solar photovoltaic cells cost USD 4.5 per W. The total cost of installing a solar photovoltaic system with an inverter, including construction costs, is approximately USD 5.7 per W. It is expected that between 2010 and 2015 that price will drop rather quickly to between USD 2.5 and 3 per W and between 2020 and 2030 it will drop to between USD 1.3 and 2.1 per W.

The technical service life of a photovoltaic system, assuming replacement of inverters every 10 years, is 25-30 years.

The photovoltaic systems and individual photovoltaic cells can operate off-grid as stand-alone sources of electricity for individual private households and for public institutional users, such as hospitals. Use of stand-alone PV systems is limited to those regions where solar radiation is abundant, where electricity demand is low, and where load conditions do not fluctuate. Generally, it is inexpedient to use individual photovoltaic cells when energy demand exceeds 5 kWh per day [24]. Photovoltaic cells are suitable for lighting homes, operating radios and television sets and operating smaller-scale refrigeration equipment such as that used in hospitals. When photovoltaic cells are used in a stand-alone mode, a backup power source (batteries, diesel generator) is also required, and to realize efficiencies, renewable energy technologies, e.g., micro hydro power plants or wind-driven generators (hybrid or non-traditional renewable energy sources), should be used together, where possible.

Costs for installing individual photovoltaic cells vary from USD 0.04 and 3.5 per kWh, depending on where they are installed and on manufacturing company [24].

Solar electricity plants

Concentrating solar electricity plants use various configurations of mirrors to convert energy from high-temperature carriers of solar radiation into heat which is then conveyed to an ordinary steam turbine which converts it into electricity. Such technology used at average capacity plants is what makes long term use of solar energy feasible. Such plants usually consist of two parts: the first collects solar energy and converts it into thermal energy, while the second converts that thermal energy into electricity. There are two types of large-scale solar energy concentrating systems. The first uses power tower systems, the second uses parabolic-cylindrical concentrator-based systems.

The power tower system concentrates solar energy in a receiver atop a tower (Figure 3.4).

To do so the system uses the energy from hundreds, or even thousands, of heliostats to heat molten salt flowing through the receiver. Thermal energy from the salt is then used to produce electricity in a regular steam generator. Because salt retains heat efficiently, it can stay molten for several hours, even days, and at any time while it is molten, it can be used to produce electricity. The molten salt is returned from the steam generator to a cold storage tank. Next the molten salt is pumped from a "cold" accumulator tank at a temperature of about 270^{0}C through the receiver where it is heated to a temperature of 550^{0}C, whereupon it is transferred to a "hot" storage tank.

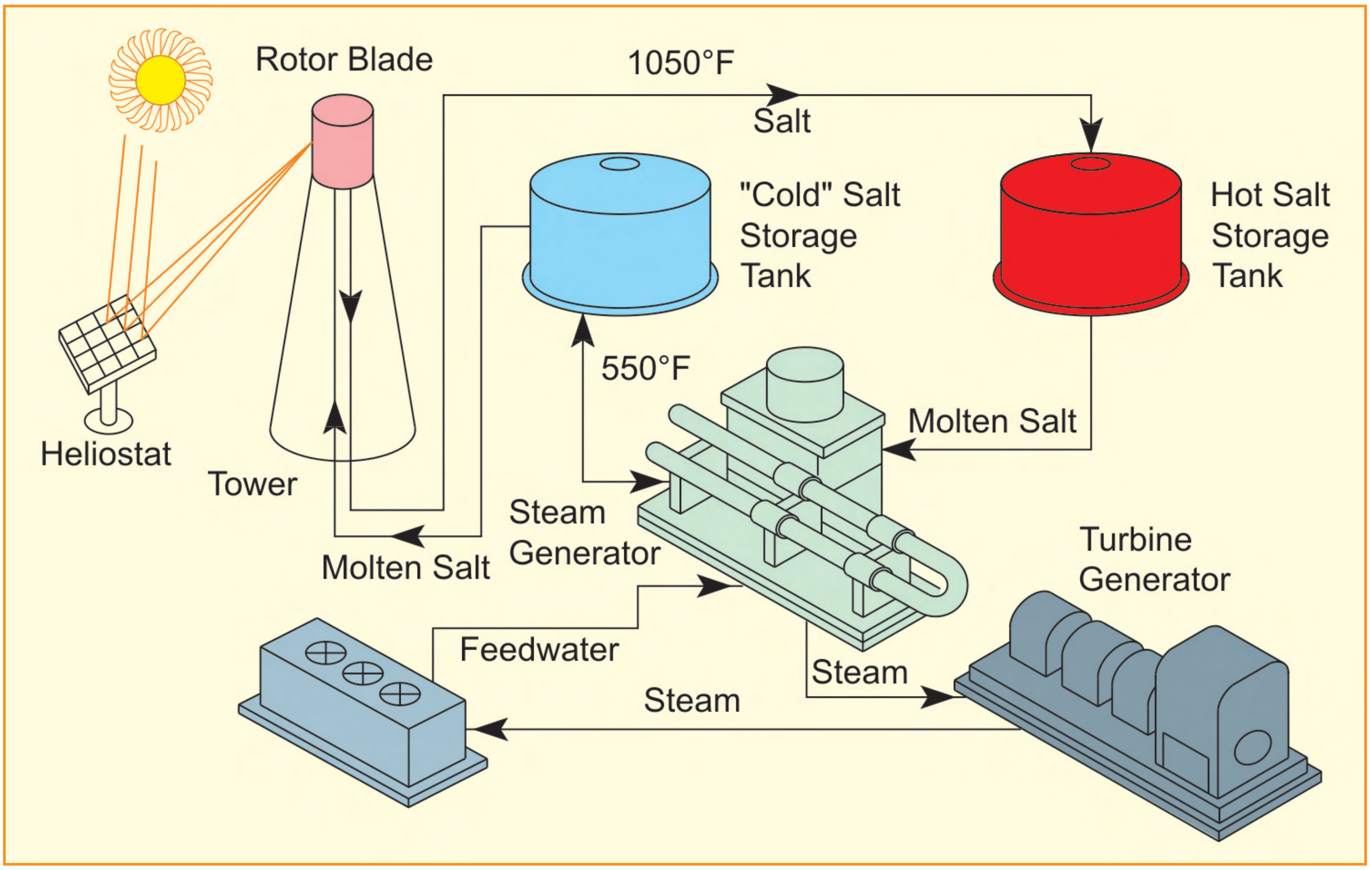
When electricity is needed from the tower, heated molten salt is pumped into the steam generation system to produce superheated steam to activate a steam turbine after which the molten salt is returned from the steam generator to the cold storage tank.

Parabolic-cylindrical systems are used to concentrate solar energy using reflectors bent into the shape of a parabola in a pipe-shaped receiver surrounding the inner surface of the bent reflector. The solar energy is used to heat oil flowing through the pipe and the energy from the heated oil is then used to produce electricity in a regular steam generator. Parabolic-cylindrical systems are grouped together in parallel rows aligned along a north-south axis allowing them to follow the Earth's motion from east to west so that the sun is constantly focused on the pipes of the receiver. At present, parabolic-cylindrical systems can achieve a capacity of 80 MW. The design of parabolic-cylindrical systems can include a heat accumulator making it possible to generate electricity for several hours, even after sundown.

Experience in operating experimental plants with solar energy concentrators shows that it costs between USD 0.1 and 0.13 for them to produce one kWh of electricity [24]. Technological advances and the use of low-cost heat accumulators will make it possible for future generations of solar energy concentrator plants to remain in operation for a greater number of hours during the day and to extend electricity production into nighttime hours. Forecasters predict that costs of solar energy concentrator technology will drop to approximately USD 0.04–0.05 per kWh [24].

Figure 3.4

Solar power tower



3.2. Wind-driven generators

How much mechanical power or electricity **wind energy** can produce depends entirely on the wind's velocity. A typical turbine for a wind-driven generator consists of a three-blade propeller-type rotor emplaced on a hollow steel support (Figure 3.5). A tilt gear keeps the rotor pointed in the direction the wind is blowing from. The rotor drives a reduction gear and an asynchronous generator. Small wind-driven generators function with wind velocities above over 3-4 m/s and reach maximum nominal output at velocities of 8–25 m/s, depending on the type of turbine and wind speed map. Their maximum operating velocity is generally 25-30 m/s.

Wind-driven generators can be remote controlled and can be set up individually in small groups or as an entire wind farm with a large number of generator units (Box 3.4). A large wind farm of wind-driven generators can be used to regulate the load of an electricity grid for the top level of an energy system. The advantages of using wind-driven generators are:

- Cost of electric power produced is not subject to fuel price fluctuations;
- Operating expenditures are low; and
- There are no harmful emissions.

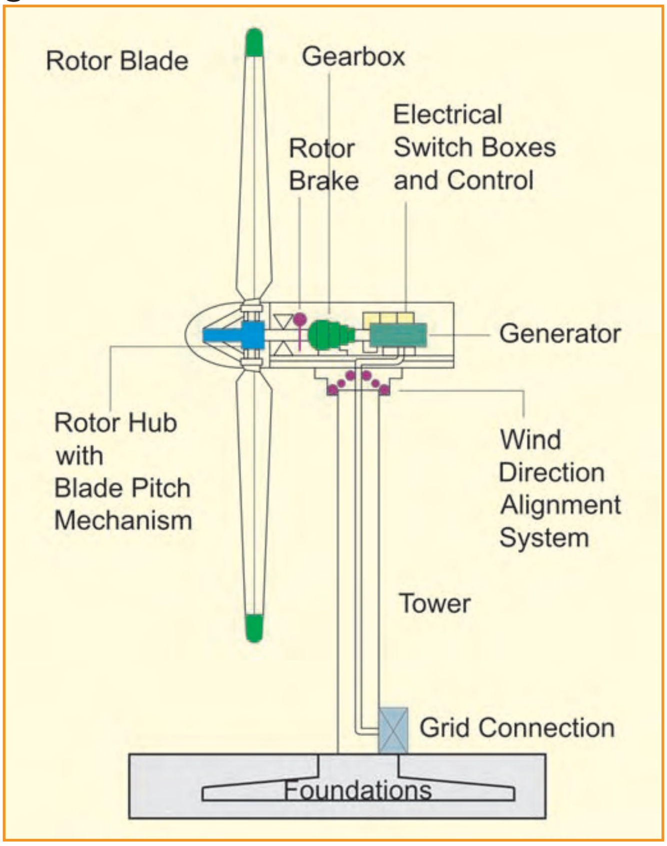
The disadvantages of using wind-driven generators are:

- Stand-alone generators require a backup power source since how much power wind-driven generators produce depends on wind characteristics;
- Upfront capital investments are high; and
- They are noisy and unsightly.

Turbines with capacities ranging between 0.5 and 3 MW dominate the market in wind-driven generators. It is anticipated that by 2020 the average capacity of wind-driven generators will have increased to 5 MW. At present wind-driven generators have a service life of 30 years and generally cost between USD 0.93 and 1 per W of installed capacity. It is anticipated that by 2020 that price will have dropped to USD 0.8 per W and to USD 0.65 per W between 2020 and 2030.

Figure 3.5

Design of a Typical wind-driven generator



Source: UNDP Project Report, Review Studies for National Strategy on Renewable Energy for Uzbekistan

Small wind-driven generators can be used in regions far removed from electric power supply systems (Box 3.5) to provide for stand-alone production of electricity for households and agricultural purposes. There are reliable wind-driven generators with a capacity of 100 W and above. Winds with average velocities above 4-5 m/s are needed to operate small wind-driven electricity generators. Wind-driven generators must have well designed towers, monitoring systems and, as a rule, a backup power source. Batteries can be used as a backup power source, but hybrid systems can be used too, if the requisite power sources are available, e.g., diesel generators, solar photovoltaic systems, micro hydro power plants or small biogas reactors. Small capacity wind-driven generators are generally well suited for providing electricity for lighting and for running small capacity refrigerators, radios, TV sets and electric pumps.

The price of wind-driven generators with a capacity of less than 1 kVA ranges between USD 0.6 and 2 per kWh, and for those with a capacity above 1 kVA, it ranges between USD 0.4 and 1.6 per kWh [24].

Box 3.4

GREAT BRITAIN

Corrour Station - 2.5 kW battery charging wind turbine

Corrour Station at Fort William in Inverness Shire is an unmanned railway station and one of the most remote in the United Kingdom. The complete lack of electricity, including electric lighting, made it difficult for passengers to board and disembark on dark mornings and evenings. In early 1993 Scotrail invested in a small 2.5 kW battery charging wind turbine that incorporated a sensor to measure light levels and a timer programmed with train schedules. At dusk the sensor determines how much light is needed and the timer ensures that lights are switched on a half hour before a train's scheduled arrival and switch off a half hour after its scheduled departure. The planning application for the scheme received approval without difficulty.

Berkshire Housing Association – Three 1.5 kW rooftop turbines

The Berwickshire Housing Association (BHA) installed renewable devices - 'Swift' domestic wind turbines - on two houses in Whitsome, and another in Ayton (Berwickshire, Scotland). BHA recognizes that affordable housing is not just about the cost of rent but also about the costs of heating and running a property. By installing small scale wind energy devices on tenants' houses, BHA aims to lower tenants' fuel costs and reduce their reliance on fossil fuel based energy sources. Director of Operations at BHA, Alastair Brown, says, "One aspect of our approach to addressing the fuel shortage has been to focus on the use of renewable energy systems. These innovations provide energy saving features at a more manageable cost to tenants." BHA is hopeful the devices will prove successful and has plans to install another seven of the devices at other houses it owns.

Ladygrove Elementary School – 2.5 kW wind-driven generator

The Ladygrove Primary School is one of many schools to have installed their own small capacity wind-driven generators to produce electricity to use directly for its own needs. Any electricity generated in excess of school needs is sent to the national grid for local use.

The school is also piloting a child-friendly Web browser-based system for monitoring the conversion of wind energy into electricity.

The school received funding for the 12,000 pound sterling project from the Energy Agency and the State Ecological Fund. One wind-driven generator produces enough electricity to supply the school with 400 pounds sterling worth of energy annually and reduces annual fossil fuel CO_2 emissions by 3.5 tons. That is equivalent to planting 17.5 trees a year. "The generator is a highly visible statement of our commitment to sustainable development," said Paul Sanderson, Ladygrove Primary's Head Teacher. "This project is providing an invaluable educational opportunity for the children and will act as a focus for pupils, parents and the local community to do all they can to protect the environment."

Source: BWEA (The British Wind Energy Association)

Box 3.5

CHILE

Wind energy technologies bring down cost of electricity in rural regions

The cost of electricity on Chile's island of Isla Tak fell by 75-90% after a new wind-diesel electricity plant went into operation. Prior to that islanders used to pay nearly 2,500 pesos per kWh equivalent of electricity provided by small batteries, wax candles for lighting, small motor generators and kerosene lamps. Today they pay between 211 and 650 pesos for kWh of electricity.

Source: UNDP

3.3. Uses of biomass

Biomass represents a rather broad class of renewable energy sources and includes firewood as well as industrial, agricultural and domestic wastes. The energy in biomass can be released through the processes of combustion, gasification, pyrolysis, and biochemical treatment to produce alcohol and biogas. Each of these processes has its own applications and purposes.

Biogas reactors

Biogas is usually produced from livestock manure and organic food industry wastes (Box 3.6). During their anaerobic treatment in a biogas reactor (Figure 3.6), gas is produced, which can be used directly in homes, replacing natural gas, liquefied petroleum gas (LPG) or can be converted into thermal energy and/or electricity.

Biogas produced from manure contains 60-70% methane (CH_4), 30-40% carbon dioxide (CO_2) and less than 500 ppm of hydrogen sulfide (H_2S). With 65% methane content, the lower end of biogas's heat producing capacity is 0.55 kg o.e./nm^3.

Biomass used in biogas reactors is usually 80-90% manure and 20-10% organic dairy farm and slaughterhouse wastes, which substantially increase the amount of biogas produced and the economic efficiency of the biogas reactors. Biogas output depends primarily on the quality of industrial wastes used and, as far as manure is concerned, output also varies with the animal species. One ton of livestock manure will usually yield about 25 m^3 of biogas, poultry manure about 190 m^3, whereas industrial wastes yield approximately 130 m^3. To collect manure for biogas, livestock must be kept in stanchions.

After the biogas has been extracted, the fermented biomass can be separated into liquid and dry fractions which can either be sold or kept for one's own use as fertilizer which is often what helps make biogas reactors economically feasible.

Total capital investment required to create a biogas plant with a 300 ton per day capacity is approximately USD 6.4 million. It is anticipated that within the next 15 years that cost will drop to between USD 5.8 and 5 million. Design output for such a plant is 30-40 nm^3/m^3 of biogas which will give the plant a generating capacity of 1 MW. The cost of such a plant is approximately USD 240,000 [24].

Box 3.6

RUSSIA

Biomass plant on livestock farm in Moscow oblast

According to data from the Russian Academy of Sciences, the Russian livestock sector produces nearly 350 million tons of organic waste per year. That is enough waste to produce 95 billion m^3 of biogas with an energy content of as much as 66.5 million t.o.e., or nearly double the amount of all the electricity Russia's nuclear power plants produced.

In 1994-95 a group of biogas promoters invested their own money in a small livestock farm on which they built a BIOEN-1 biogas plant.

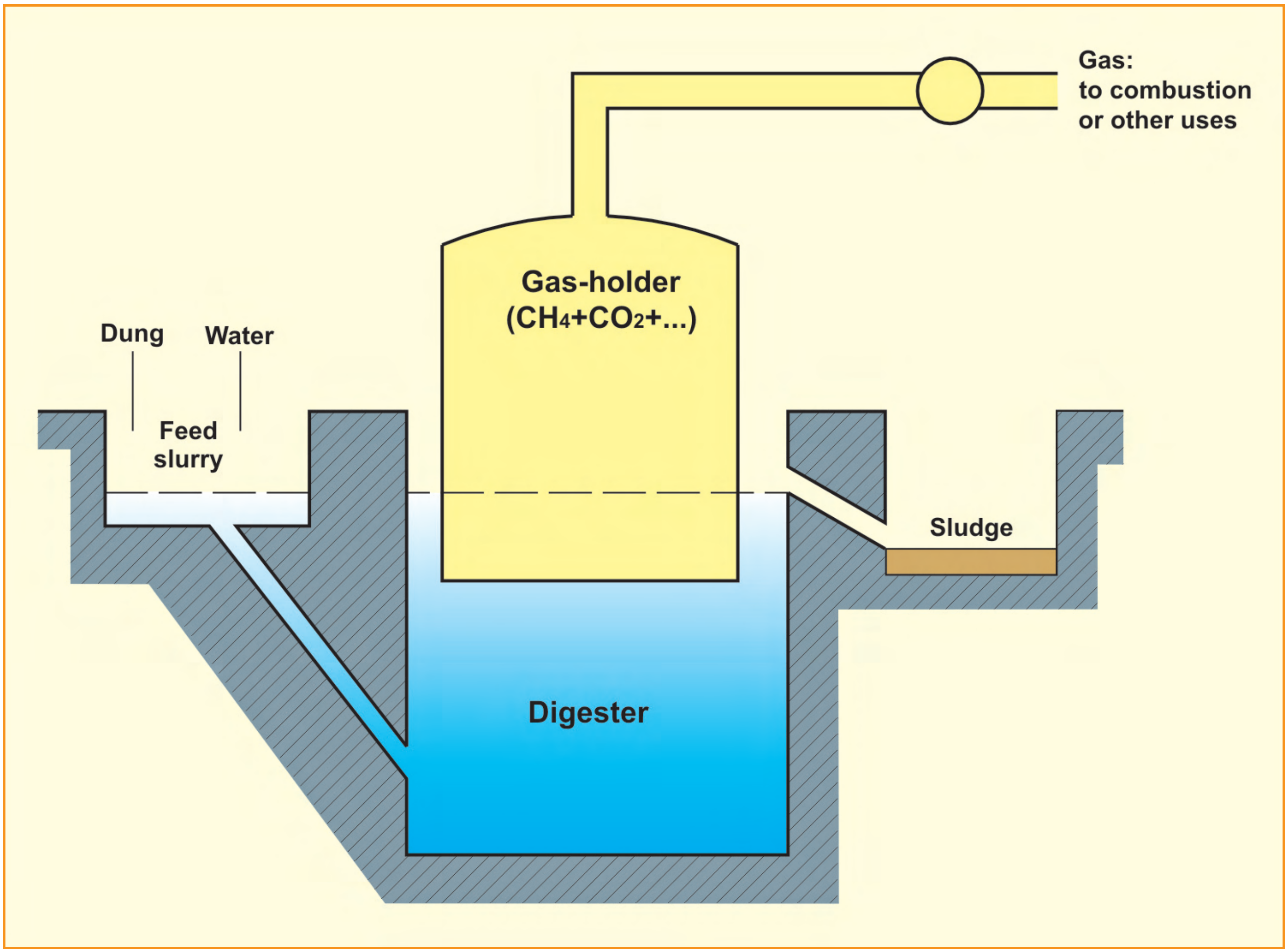
The plant's four biogas reactors can treat manure from the farm's 20-25 head of cattle to produce energy and fertilizer. The module processes one ton of biomass a day producing 40 m^3 of biogas which is enough to produce 80 kWh of electricity, almost 800 MJ of thermal energy, and one ton of fertilizer. That is enough energy to supply 10 four-person families living in Russia's climatic conditions.

The cost of the plant was USD 10,000-12,000 and the plant paid for itself in only six months because in this case the fertilizer it produced was sold. If only the methane were sold, it would take from 5 to 7 years for the plant to pay for itself. The plant has a service life of about 10 years.

Source: The EkoRos Center

Figure 3.6

Schematic diagram of a biogas generator



Source: UNDP Project Report, Review Studies for National Strategy on Renewable Energy in Uzbekistan.

The advantages of using biogas plants are:

- Biogas is a CO_2 neutral fuel and unlike fermentation of organic wastes it does not produce great amounts of atmospheric methane emissions;
- The value of the fertilizer obtained from fermented biomass is higher than that of the original raw material; and
- They use biogas fermentation to reprocess ingested food substances on farms in an environmentally safe and economically sound way.

The disadvantages of using biomass are:

- Capital investments in plants using biomass are relatively high;
- Vegetable biomass availability is seasonal;
- Gathering biomass requires organization and planning (because biomass is so widely scattered);
- Livestock must be kept in stanchions;
- A required minimum amount of biomass must be delivered on a regular basis; and
- There are technical problems with biomass combustion furnaces (grates slag up, fine particles are removed, heating surfaces become encrusted, etc.).

Of course, biogas plants are used more often for agricultural purposes than they are for producing energy. Nevertheless, the biogas produced is a useful supplementary product.

For economic reasons biogas plants (for example, in Denmark) are becoming larger. But in many countries the prospects are also good for small and micro biogas reactors on individual farms and in small rural communities.

Small biogas digesters have been installed in remote mountain regions of Nepal and Kyrgyzstan. They produce approximately 6–8 m^3 of biogas a day and 100-120 liters of fertilizer. The digesters are filled with manure and household wastes. Other biogas digesters (being introduced in Nepal) exist that are filled with human excrement as well as manure and household wastes. Using human excrement improves digester efficiency while improving surrounding sanitation conditions.

If a micro hydro power plant is in the vicinity, bioreactors can be hooked up to a hydro power plant to obtain electricity to use for heating them during cold weather months.

The digesters are usually manufactured locally. In Kyrgyzstan, for example, they cost about USD 250 per piece. Using biogas digesters to produce fertilizer for small family farm users helps make family farms financially more viable since the market price of fertilizer in these areas is quite high. Such biogas digesters can be supplemented, if need be, with small capacity hydro (Box 3.7), solar and micro wind-driven devices [24] .

Box 3.7

KYRGYZSTAN

A hybrid system with a biogas plant and a micro hydro power plant

In the Talas region of northern Kyrgyzstan the electricity supply is acutely unreliable, particularly during the winter when electric heaters are in use. In many regions where there is no electricity infrastructure local inhabitants use kerosene lamps for lighting and use firewood to cook with and to heat their houses.

In 2002, as part of a GEF Small Grants Program project, an innovative combination of renewable energy sources, adapted to local conditions and designed to raise the local population's standard of living, went into use. The hybrid system combining four locally manufactured biogas plants with an output capacity of 6-8 m^3 of biogas per day apiece with a micro hydro power plant with a 5 kW capacity provides 22 households with electricity and produces organic fertilizer as a byproduct. Moreover, basalt fiber based insulation materials were used in order to save energy and reduce heat losses.

The electricity the micro hydro power plant generates, used for heating and running home appliances, is also used during the winter to keep the biogas digesters warm to ensure they operate trouble-free. The biogas plants use a mixture of manure and river bottom silt as raw materials. A 4.5 m^3 capacity gas-holder (tank) produces on average 6-8 m^3 of biogas per day replacing firewood and fossil fuel for cooking and for lighting and heating living quarters. The system also produces 100-120 liters of fertilizer a day. The fertilizer in turn is used to grow three groves of saplings to meet the needs of the local population for construction lumber and increase the number of trees planted in the river basin. In addition, using manure to produce biogas improves sanitation conditions, reduces the amount of waste dumped in the river thus reducing river pollution and improving water quality, while the manure fertilizes the soil. Replacing fossil fuel with biogas and with electricity generated by a micro hydro power plant results in a pronounced reduction in greenhouse gas emissions.

Source: Small Grants Program GEF/UNDP

Landfill gas from household garbage

When solid household waste is buried in a dump, landfill gases are produced as the organic components in the waste decompose in anaerobic conditions. The estimated length of time it takes for landfill gas to be produced varies between 50 and 100 years, although landfill gas can be produced in as little as 10-15 years, given a very high rate of decomposition. Using a biogas reactor (Figure 3.7) and adding water and other substances to the mass of solid wastes makes it possible to control the formation of landfill gases and increase their production.

The composition of landfill gas varies depending on the kind of wastes buried, how long the wastes have been in the dump, weather conditions, and other factors. Landfill gas usually contains 50% methane, 45% carbon dioxide and tiny quantities of nitrogen, oxygen, hydrogen sulfide, water vapor and solid particles.

Before landfill gas can be used, the solid particles and water it contains must be removed and it must be chilled and compressed (pressurized).

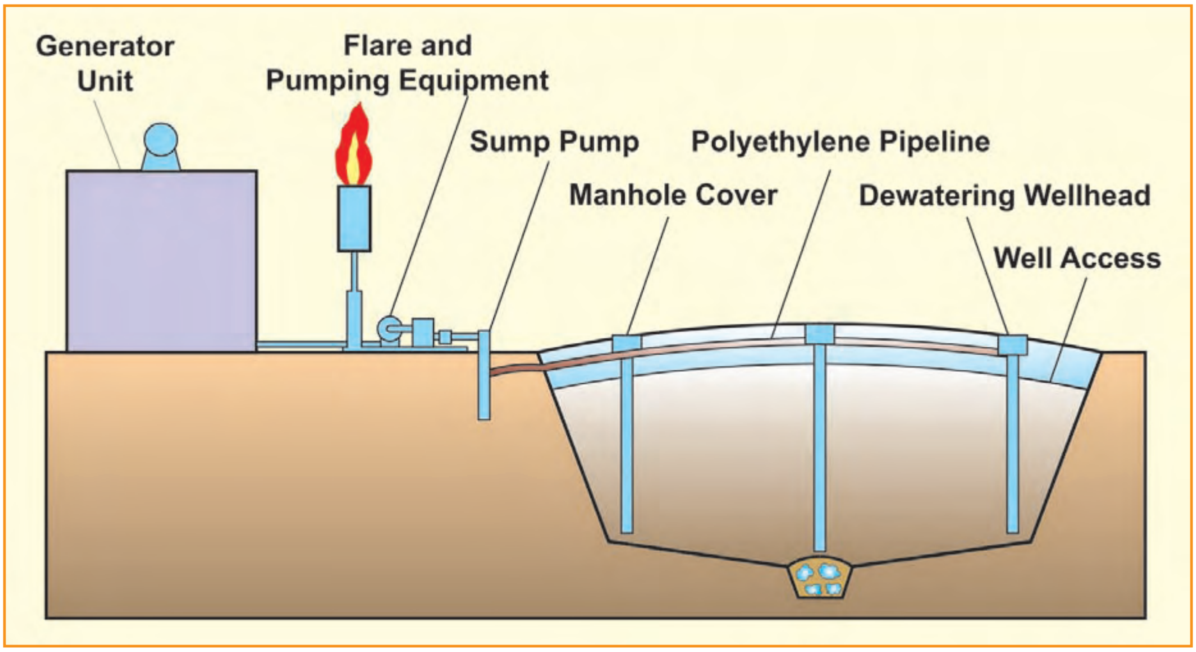
Depending on how much purification, enrichment and pressurization have to be done and the costs they incur, landfill gas can be used to fuel boilers and burners, generate steam and/or electricity and can be put into the supply distributed through the general gas transport system (Box 3.8).

To use landfill gas with burners designed to burn natural gas, only a minor modification must be made to the burners since landfill gas has a lower heat production capacity. For steam production, the steam consumer must be situated near the plant because installation of insulated high pressure steel pipes to deliver the gas is costly and the longer the pipe the more heat is lost in delivering steam to the consumer.

Air-injection piston engines, gas and steam turbines, micro turbines and fuel cells, which are now undergoing major development, can be used to produce electricity.

Figure 3.7

Typical landfill gas extraction system



Source: UNDP Project Report: Review Studies for National Strategy on Renewable Energy in Uzbekistan

Box 3.8

ESTONIA

Biogas from landfill in Tallinn

Tallinn - Estonia's capital and biggest city – has a population of 411,594 and produces 350-400 thousand tons of organic waste annually disposed of at a garbage dump occupying nearly 35 hectares in Paaskula where it is piled up in piles averaging 35 meters high. As the garbage decomposes, landfill gas made up mainly (up to 65%) of methane is produced.

In 1994 the gas company Esti Gaaz, Ltd. and several private investors started a landfill gas disposal project in Paaskula. A new company TERTS Ltd. was founded and with consultative assistance from Scandinavian experts performed preliminary studies of the quantitative and qualitative features of biogas.

In 1995 a collector container installed at the Paaskula dump was hooked up to 5,200 meters of gas filters and 2,000 meters of pipes. The biogas extracted from each individual filter passes through a collector pipe into a compressor station where it is pressurized and purified. Next, it passes through distribution networks and from there into a boiler where it is used to produce thermal energy as an alternative to fuel oil.

Implementation of the project made major improvements in sanitation conditions in the area surrounding the Paaskula dump. Based on the experience of Scandinavian countries, the project can be expected to turn a profit.

Source: www.opet.dk/baltic

Biogas boilers

Firewood is the biomass fuel of choice because it produces so little ash and contains so little nitrogen, although cotton wastes and straw are other biomass fuels with low ash and nitrogen content.

Biogas boilers are used to produce heat only (Box 3.9). Their centralized heat supply capacity is generally between 1 and 50 MW, their operational readiness coefficient is 96-98%, and the service life of biogas technology is around 20 years. Typical exhausts from such boilers contain 3.4 kg of NOx per t.o.e. of fuel, 40 mg of particles/nm^3 and 41.9 kg of dry ash per t.o.e. of fuel.

Installing a biogas boiler requires an investment of between USD 0.3 and 0.7 per W. Operating expenditures are approximately 3% of the initial investment. Various technologies can be used to burn biomass in boilers, e.g., furnace grate combustion, suspension combustion, and combustion in a pseudo-liquefied film. Furnace grate combustion is the most widely used technology for burning the various types of biomass.

Cogeneration boilers producing both thermal and electrical power using furnace grate combustion for burning biomass can have a capacity of 5 to 15 MW. Such boilers use straw or waste from wood as biomass raw material to produce electricity or heat in the form of steam or hot water. The demand for thermal energy in the immediate vicinity of a cogeneration plant is what usually determines its capacity.

Steam turbines using furnace grate combustion to burn forestry product wastes have a service life of about 20 years and an efficiency rating of 90%. Exhausts from such systems yield 41.9 kg of ash, 2.99 kg of NOx and 0.8 mg of particulate matter per t.o.e. of fuel. The cost of a furnace grate combustion boiler that burns wood chips is approximately USD 3.56 per W of electricity, but the expectation is that in the next 15 years the cost will come down to USD 3–3.4 per W of electricity. Total operating expenditures are about USD 70,000 a year per MW.

The service life and efficiency rating of systems with furnace grate combustion of straw are the same as those for steam turbines with furnace grate combus-

Box 3.9

LATVIA

Biogas boilers in Brotseny

Brotseny is a small town southwest of Riga with a population of 3,500. The main industrial enterprise there is a cement factory outside the city limits. The town's old steam plant was re-equipped with a heat exchanger to replace the two pipes from the cement factory that were used to supply the town with steam. In the winter time the factory's own thermal energy needs increased sharply making it very difficult to meet the town's thermal energy needs. There were large steam losses in the old thermal grid. All of which meant that the residents of Brotseny paid high prices for inferior thermal energy services. Soon after the collapse of the Soviet Union, the cement factory lost all of its customers and went out of business.

The municipality of Brotseny took stock of the situation and made the decision to begin overhauling its centralized thermal heating system with priority emphasis on using RES and energy efficient technologies.

Choosing biofuel as the technological solution, Brotseny became one of the first places biofuel was used in Latvia. Fuel oil was replaced by biofuel from forestry products industry waste -- straw and sawmill waste. The overhaul took all of eight months

During the project the heat exchanger in the old boiler was removed and replaced with two new boilers. One boiler had a furnace that burned biofuel to cover the basic thermal energy load, and the other operated on natural gas to cover peak loads. In addition to the boilers, the system, delivered by a Swedish manufacturer, included burners, an automated biofuel storage receptacle, a fuel management system as well as furnace gas purification equipment. As a result, biofuel is providing consumers with hot water year round while the problem of how to dispose of forestry industry waste has been solved.

Source: www.opet.dk/balti

tion of wood wastes but produce more exhaust: 2.0 kg of SO_2, 5.5 kg of NOx, 1.675 g of particulate matter and 83.8 - 167.5 kg of ash for every t.o.e. of fuel. The cost of a furnace grate combustion boiler for burning straw is approximately USD 2.86 per W of electricity. The expectation is that the price will remain the same for the next 15 years. Fixed operating expenditures are approximately USD 105,000 to 140,000 per year/MW [24].

Biomass cook stoves

Typical stoves (ovens) used for cooking and baking (Box 3.10) that operate on biomass have an efficiency rating of between 6% and 25%. Biomass stove efficiency can be increased significantly by: modifying stove design region by region; reducing the distance between pots and pans and stove burners; using fireproof burners; using oven grates to regulate air intake; and insulating stove walls.

Whatever stove design modifications might need to be made and how much they would cost can be determined only after local conditions and needs have been studied.

Box 3.10

NEPAL

Biogas cook stoves

Of what use to a country can cook stoves that operate on biogas be? In Nepal they made it possible to improve household sanitation and people's health by reducing the use of firewood which in turn reduced the number of trees cut down.

Nepal's households consume up to 95% of Nepal's total energy demand, which is mainly for food preparation and heating. This energy demand is satisfied by burning firewood (75%) and agricultural and livestock wastes (20%). Such high demand for firewood led to deforestation which resulted in land degradation, soil erosion, landslides and floods.

Today 140,000 people in rural areas of Nepal prepare their food using biogas stoves. Their stoves have already helped save 400,000 tons of firewood and 800,000 liters of kerosene, as well as prevent 700,000 tons of greenhouse gases from being emitted into the atmosphere.

Biogas stoves are technologically very simple: farm animal manure is the raw material and biogas is the end product. Some systems are hooked up to toilets as well which improves sanitation conditions while contributing to biogas production. Nepalese design includes an air-tight underground tank (methane tank) where manure is kept and later mixed with a certain amount of water. Bacteria in the manure decompose the raw material underneath the tank's cupola thereby generating methane. The reaction takes place in the absence of oxygen and the gas produced contains up to 70% methane and 30% carbon dioxide. A pipe connects the outlet in the biogas digester cupola to the stove. Residue (the liquid fraction), produced in proportion to the amount of gas produced, is removed and can be used as organic fertilizer.

This design has much to recommend itself. It operates reliably and safely, is inexpensive to operate, and has a relatively long service life. Such a stove costs local residents USD 300. Government subsidies for rural users bring the cost down to USD 200, making the stoves more affordable for them. Plus, by using biogas instead of fossil fuel, in three years time they save themselves the price (USD 200) of the stove.

Source: Ashden Awards

3.4. Small and micro hydro power plants

At the present time there is no single definition of small and micro energy all countries agree upon. In Uzbekistan an hydro power plants (HPP) with an installed capacity of less than 30 MW is considered a small HPP. In Norway hydroelectric power is subdivided into the following categories: micro (<100 kW), mini (between 100 and 1000 kW), and small (between 1 and 10 MW). The World Bank classifies hydro power plants with a capacity under 10 MW as small hydro power plants.

The following small hydro power plant classifications are now gaining recognition worldwide: micro small hydro power plants are plants with a capacity of up to 1000 kW; small hydro power plants are plants with a capacity of up to 10 MW (Figure 3.8).

Mechanical energy (water-lifts, water mills, etc.) is used directly or is converted to electricity to supply small industrial, agricultural, and household users with power (Box 3.11).

The electricity thus generated can either be distributed with a small distribution network to individual household users or be used to charge batteries which are brought in to be recharged periodically. When users are located a great distance from a micro small hydro power plants, the battery option is preferable.

Two types of turbines are used for micro hydropower. Impulse (active) turbines convert kinetic energy in flowing water falling onto turbine blades, and jet hydro-turbines which are completely immersed in a stream of water to make use of both the angular energy and the linear energy of the water on the turbine blades. A hydrogenerator that is driven by a hydroturbine is equipped with an electronic load controller (ELC) to regulate rotation speed as changes in load occur.

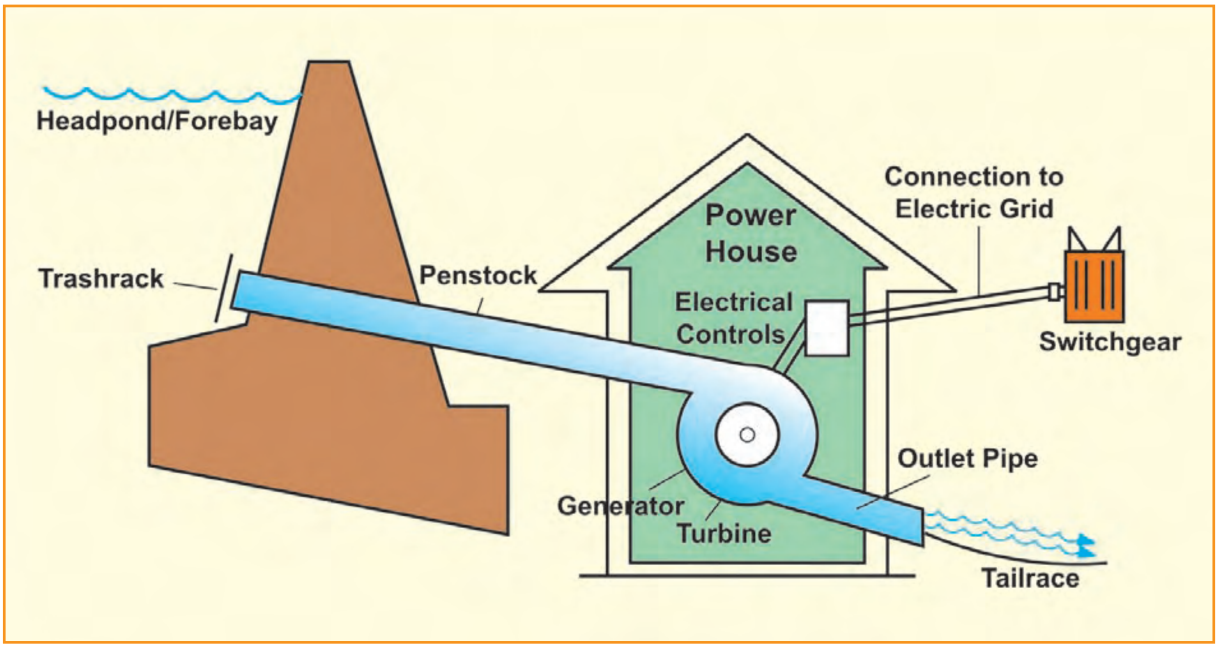
Basic costs for a micro hydropower facility go for construction-installation work and equipment. Hydropower fixed costs usually go down as capacity (i.e., water flow and pressure) goes up. The cost of an hydro power plant can be reduced by using existing irrigation canals, by locating the hydro power plant as close as possible to consumers, and by using a self-cleaning trash trap and drainage system to protect turbines from damage.

The cost of a micro hydro power plant depends on the specifics of each facility and can change significantly with the relative remoteness of the micro hydro power plant and the physical details of its main components: construction work (including penstock, dams, etc.), generating equipment, and transmission/distribution lines. Whereas the specific cost of producing electricity is basically a function of hydro power plant capacity, capital expenditures depend on the cost of hydrotechnical structures and electrotechnical equipment. That makes estimating beforehand the total cost of a micro hydro power plant fairly difficult. As a rule, USD 2,000 per kW of installed capacity works out to be the top end estimate [24]. The Non-Grid Energy Consumer's Handbook prepared by the World Bank lists USD 0.2 – 2.5 as the price range for a kWh of electricity produced by a micro hydro power plant.

The list of renewable energy sources with potential for developing small power is extraordinarily broad. It includes rivers, streams, as well as water draining down into lakes and irrigation canal systems below.

Figure 3.8

Schematic diagram of a typical small hydro power plant



Source: UNDP Project Report: Review Studies for National Strategy on Renewable Energy in Uzbekistan

Box 3.11

AUSTRALIA

Micro hydro power plant supplies house with electricity

Leon Trembath's house is located in a mountainous region of eastern Australia on the banks of a mountain stream known as the Jack River. Leon installed two micro-turbines in the house to supply the house with electricity year round. In designing and building the house, he applied passive solar energy principles to obviate the need to heat or air condition it.

Water drawn from a 2 meter by 1 meter pond fed by the Jack River is released and flows down through a 25 mm sluice into the turbines. The sluice is equipped with a grate to trap leaves, twigs and other trash to keep it from clogging the sluice and interfering with the system's operation. Each micro hydropower unit generates about 450 W of direct current used to charge a 24 volt 850 ampere-hour battery. There are two inverters. One uses energy left over from heating water to monitor the charge on the battery. The other inverter supplies alternating current for all the household appliances in the house (refrigerator (240 volts), computer, microwave oven, electric tea kettle, washing machine, vacuum cleaner, television set and video cassette recorder). A micro hydro power plant also powers Leon's two large woodworking machines.

The turbines have worked flawlessly, producing more than enough electricity for the needs of the house for the entire time since they were installed in 1994. The battery requires some technical maintenance and the sluice leaf trap has to be cleaned out daily. To reduce technical maintenance on the leaf trap to practically zero, Leon plans to reconfigure it so that it is self-cleaning

The cost of the system - less than USD 18,000 - is a big bargain, compared with how much the connection to the electricity grid costs plus how much electricity the grid supplies costs.

Source: Australian Department of the Environment and Natural Heritage, Office of Greenhouse Gas Effect

Generally, small hydroelectric power systems make use of the same technologies as micro hydropower systems do to force a stream of water through a turbine conduit.

Small hydro power plants require a rather large flow of water to achieve the desired pressure, preferably without having to build expensive structures. This can be done by making use of existing dams, water level control systems, and irrigation infrastructure. Using existing structures significantly lowers the cost of small hydro power plants.

The creation of efficient, reliable and inexpensive equipment for micro and small hydro power plants is a high priority. Experience gained in designing and engineering large hydro power plants is not automatically transferable to small hydro power plant design and engineering. Different approaches must be taken in designing equipment for micro and small hydro power plants.

The development of high volume flow-type cross-jet or double hydroturbines is a highly promising solution to the problem. Their maximum efficiency coefficient (EC), achieved anywhere in the world to date, is on the order of 90%. Because of the simplicity of their design, low cost, reliability and rather high energy efficiency flow-type cross-jet turbines are justifiably considered the turbine of choice for outfitting micro and small hydro power plants.

Flow-type cross-jet hydroturbines have a rather wide range of uses. The type designated for use in micro and small hydro power plants can be used at pressures of 1.5 to 180 meters.

As international experience demonstrates, harnessing the potential of small rivers using small and micro hydro power plant helps solve the problem of improving power supplies. Small hydro power plants, based on already existing hydrotechnical structures, are the most efficient. According to the U.S. firm Ellims-Chalmers, unit capital investment for refitting a 10 MW capacity hydro power plant equals USD 1,100-1,400 per kW [24].

Cost of construction of a small hydro power plant with 1 MW capacity ranges between USD 0.5 and 2 million. A small hydro power plant with 1 MW capacity makes a profit of USD 300,000 per year and the payback period for recouping the capital investment in it is in the 2-6 year range.

3.5. Uses of thermal energy

Strictly speaking, **geothermal energy** is not renewable since it is not a matter of using a steady stream of heat welling up to the surface from the bowels of the Earth but rather a matter of using heat stored up in liquid or solid media situated at particular depths below the surface (Figure 3.9).

But this kind of energy may have a role to play in the future. Devices using geothermal energy are generally well suited to large plants running on a single electrical system or on a centralized heating system.

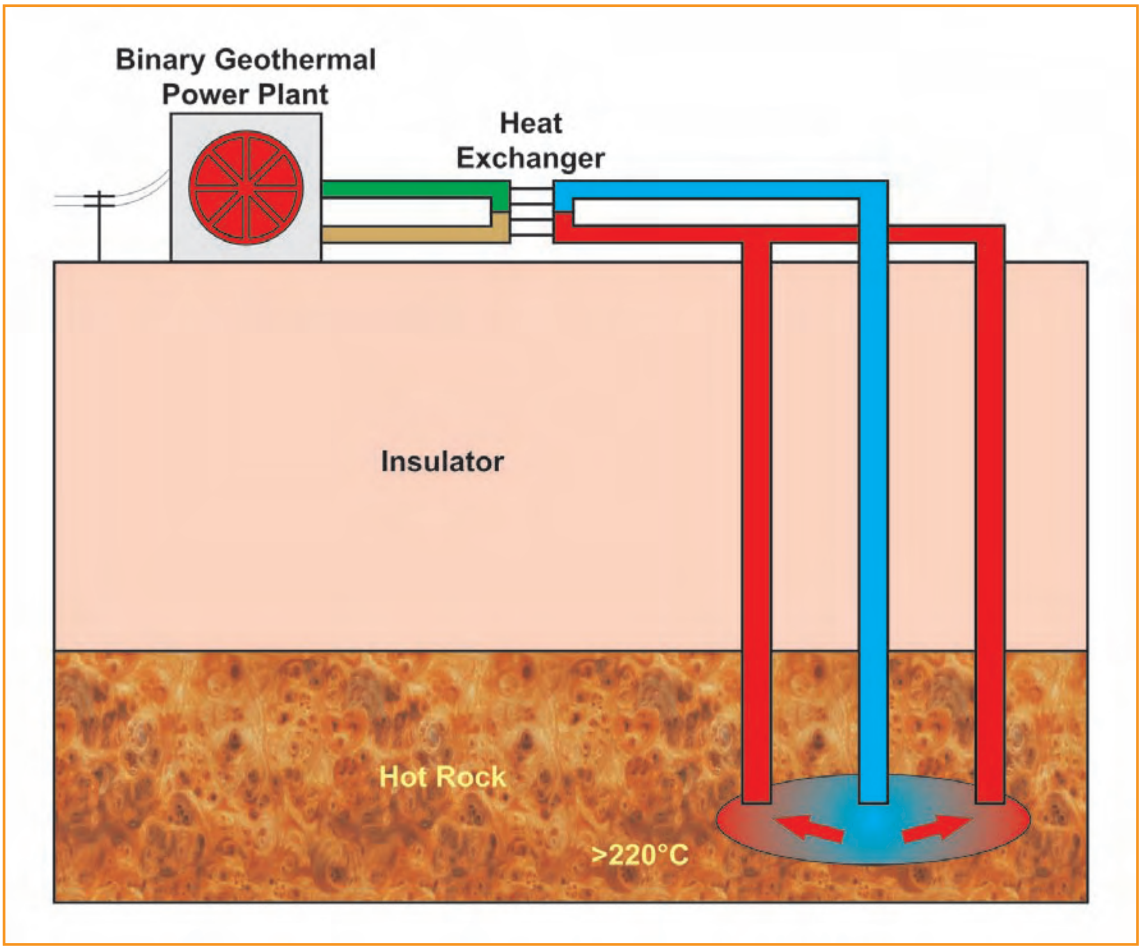
Sources of high-pressure steam for driving turbines can be accessed by drilling into natural underground reservoirs containing circulating hot water. The large amounts of thermal energy remaining in the water after it has been forced through a turbine can be used in centralized heating systems before being pumped back into the underground reservoir. There are two categories of sources of geothermal energy: high temperature and medium/low temperature. High temperature sources are usually used to produce electricity, whereas low temperature sources can be used for centralized water supply systems and for agriculture. The temperature of the source must be at least 90^0C so that the water can be supplied immediately without intermediate use of heat pumps to raise the temperature of the heat carrier (Box 3.12).

The cost of electricity produced using geothermal sources varies significantly depending on the nature of the source and on the size of the plant. Per unit energy costs range between USD 0.10 and 0.25 (10 cents and 25 cents) per kWh, whereas steam, at a minimum, costs on the order of USD 3.5 per ton.

The chief factors affecting costs are source temperature, source output, plant infrastructure, and

Figure 3.9

Fundamental principle of thermal energy use



Source: UNDP Project Report: Review Studies for National Strategy on Renewable Energy in Uzbekistan plant capacity. Generally, geothermal generation of electricity requires a relatively high level of investment to cover costs of prospecting for geothermal sources, drilling holes and plant construction. But operating expenditures are not high.

Direct capital investments in a geothermal power plant are given below (Table 3.2, [24]).

Carbon dioxide and hydrogen sulfide emissions associated with the use of thermal energy are significantly lower than those associated with the combustion of fossil fuel.

Box 3.12

USA

Geothermal water used on college campus for heating and air conditioning

Since 1964 geothermal energy has been used directly to heat dormitories at Oregon Technical Institute. Three geothermal springs meet the thermal energy needs of 11 campus buildings with a total floor space of 60,400 m^2. Besides thermal energy, the geothermal springs provide energy during the summer for some ablation air conditioning systems on campus. The output of the ablation cooling unit, which works on the same principle as a refrigerator, is 540 kW (154 tons).

Annual operating expenditures for the system are about USD 35,000 (5 cents per square foot per year), including maintenance personnel salaries, equipment replacement and repair costs, and pumping system cost. For purposes of comparison, annual operating expenditures for an analogous boiler plant running on natural gas range between USD 250,000 and 300,000.

Source: RESP (Renewable Energy Strategy Project)

Table 3.2

Capital investments in geothermal plants

Purpose	Expenditures (USD/kW) per unit of installed capacity for plants with a rated capacity of:	
	5-30 MW	Over 30 MW
Prospecting	250-600	100-400
Steam field	400-700	400-700
Power plant	950-1,200	850-1,100
Total:	**1,600-2,500**	**1,350-2,200**