Chapter 13

Renewable Energy Sources and Water Management

13.0 INTRODUCTION

Renewable energy sources are those sources that replenish themselves and so are essentially inexhaustible, such as solar, wind and biomass energy. While renewable energy sources are not a major percentage of energy sources currently being utilized, their usage is expected to grow substantially, since they are typically less environmentally damaging than traditional energy sources. The future is likely to see more and more utilization of these renewable sources.

In this chapter we examine a selected subset of these potential sources in the following order: solar-active, solar-passive, solar-photovoltaic, wind, and refuse. Emphasis is on applications in the industrial and commercial environment. In the last part of the chapter we discuss management of another vital and renewable resource: water. Water use will likely cause a major crisis someday soon. The energy manager skilled in water management will be prepared to meet this challenge.

13.1 RENEWABLE ENERGY TECHNOLOGY

The largest portion of the contribution by renewable energy today comes from mature technologies that make use of biomass and hydropower resources. The newer technologies developed over the past two decades are beginning to enter the market and will provide an increasing share of renewable energy supplies in coming decades [1]. The percentage utilization of renewable resources has held relatively constant over the last ten years, and is around 8% of the U.S. national energy supply. Figure 13-1 shows the contributions of the various types of renewable energy sources.

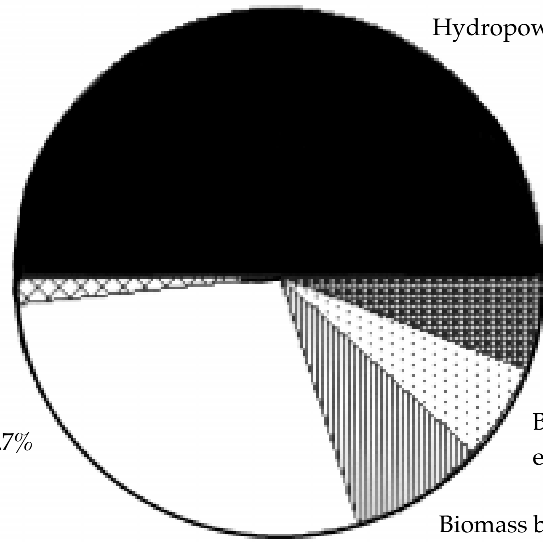

Figure 13-1. U.S. Renewable Energy Supply (1995): 6.37 quads; other includes wind, alcohol fuels, solar thermal, and photovoltaics. Source: Annual Energy Outlook for 1997, Energy Information Agency, Washington, DC, January 1997.

The contribution of renewable energy to the total energy requirements of the U.S. is expected to grow substantially over the next forty years. A broad-based study of the potential for renewable energy was conducted by five National Laboratories as part of the background for the National Energy Strategy [2]. This study projected that renewable energy sources would provide from 15% to 28% of our total energy supply in the year 2030. As concerns for the environment grow, the benefits of renewable sources in terms of reduced pollution emissions and reduced impacts from energy production will serve as positive factors in the growing use of these renewable energy technologies.

Since the focus of this chapter is on the use of renewable energy sources in commercial buildings and in industry, most of the discussion will be directed toward the use of active and passive solar systems for space heating, water heating, process heating and electricity generation. Wind energy will also be discussed as a source of electricity generation. Biomass and refuse will also be discussed, since they are sources of inexpensive fuel for many industries and some commercial buildings. Few businesses or industries directly operate hydroelectric or geothermal powered electric generation, so those sources will be covered only briefly.

13.2 SOLAR ENERGY

13.2.1 Solar Insolation

Approximately 430 Btu/h/ft^2 of solar energy hits the earth's atmosphere. Because of diffusion in the atmosphere and clouds, this is greatly reduced to somewhere around a maximum of 300 Btu/h/ft^2 on the earth's surface at 40°N latitude. This maximum, of course, only occurs at certain times of the day and year, so the average is significantly less. However, at this rate a set of collectors designed to develop 1×10^6 Btu/h of energy would have to be 3333 ft^2 in size without allowing for cloudiness, variances throughout the day, or collector efficiency. If the collector were tracking the sun throughout the day, it might be able to gather 8×10^6 Btu/day. Assuming it operates 365 days/year, the collector would be able to harvest an absolute maximum of

$$(8 \times 10^6 \text{ Btu/day})(365 \text{ days/year}) = 2920 \times 10^6 \text{ Btu/year}$$

At \$4.00/10^6 Btu, this energy would be worth \$11,680/year. The necessary collector space is 3333 ft^2, and the installed cost including controls might be around \$20/ft^2. Therefore, the cost of the proposed collectors would be around \$66,660, making the payback *under ideal conditions* somewhere around 5.7 years. Actual conditions would likely require a significantly larger collector, as will be shown below.

Detailed calculations of the amount of solar energy striking a surface located at a given latitude and tilted at a certain angle require knowledge of several angles, including the solar altitude angle, the solar azimuth angle, and the tilt angle. The values all vary with time of day, month, location, tilt of collector, etc. Tables have been developed to help a person determine the amount of solar energy available [3,4]. Table 13-1 is an example of such a table.

Example 13-1: A solar collector is to be located at Lincoln, Nebraska (approximately 40°N latitude). Find the actual energy available, the value of that energy, and the payback time for the cost of the solar collector.

Solution: Using Table 13-1, look up the data for Lincoln, NE. We find the solar radiation on a surface tilted at 40° to average about 0.6×10^6 Btu/ft^2/year. Assuming the collector is 70% efficient, the energy available is about 0.42×10^6 Btu/ft^2/year. Thus, the 3333 ft^2 collector discussed above would supply about:

Table 13-1. Average solar radiation for selected cities.

City	Slope	Average daily radiation (Btu/day•ft^2)											
		Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Albuquerque, NM	Hor.	1134	1436	1885	2319	2533	2721	2540	2342	2084	1646	1244	1034
	30	1872	2041	2295	2411	2346	2390	2289	2318	2387	2251	1994	1780
	40	2027	2144	2319	2325	2181	2182	2109	2194	2369	2341	2146	1942
	50	2127	2190	2283	2183	1972	1932	1889	2028	2291	2369	2240	2052
	Vert.	1950	1815	1599	1182	868	754	795	1011	1455	1878	2011	1927
Atlanta, GA	Hor.	839	1045	1388	1782	1970	2040	1981	1848	1517	1288	975	740
	30	1232	1359	1594	1805	1814	1801	1782	1795	1656	1638	1415	1113
	40	1308	1403	1591	1732	1689	1653	1647	1701	1627	1679	1496	1188
	50	1351	1413	1551	1622	1532	1478	1482	1571	1562	1679	1540	1233
	Vert.	1189	1130	1068	899	725	659	680	811	990	1292	1332	1107
Boston, MA	Hor.	511	729	1078	1340	1738	1837	1826	1565	1255	876	533	438
	30	830	1021	1313	1414	1677	1701	1722	1593	1449	1184	818	736
	40	900	1074	1333	1379	1592	1595	1623	1536	1450	1234	878	803
	50	947	1101	1322	1316	1477	1461	1494	1448	1417	1254	916	850
	Vert.	895	950	996	831	810	759	791	857	993	1044	842	820
Chicago, IL	Hor.	353	541	836	1220	1563	1688	1743	1485	1153	763	442	280
	30	492	693	970	1273	1502	1561	1639	1503	1311	990	626	384
	40	519	716	975	1239	1425	1563	1544	1447	1307	1024	662	403
	50	535	723	959	1180	1322	1341	1421	1363	1274	1034	682	415
	Vert.	479	602	712	746	734	707	754	806	887	846	610	373

Ft. Worth, TX	Hor.	927	1182	1565	1078	2065	2364	2253	2165	1841	1450	1097	898
	30	1368	1550	1807	1065	1891	2060	2007	2097	2029	1859	1604	1388
	40	1452	1601	1803	1020	1755	1878	1845	1979	1995	1907	1698	1488
	50	1500	1614	1758	957	1586	1663	1648	1820	1914	1908	1749	1549
	Vert.	1315	1286	1196	569	728	679	705	890	1185	1459	1509	1396
Lincoln, NE	Hor.	629	950	1340	1752	2121	2286	2268	2054	1808	1329	865	629
	30	958	1304	1605	1829	2004	2063	2088	2060	2092	1818	1351	1027
	40	1026	1363	1620	1774	1882	1909	1944	1971	2087	1894	1450	1113
	50	1068	1389	1597	1679	1724	1720	1763	1838	2030	1922	1512	1170
	Vert.	972	1162	1156	989	856	788	828	992	1350	1561	1371	1100
Los Angeles, CA	Hor.	946	1266	1690	1907	2121	2272	2389	2168	1855	1355	1078	905
	30	1434	1709	1990	1940	1952	1997	2138	2115	2066	1741	1605	1439
	40	1530	1776	1996	1862	1816	1828	1966	2002	2037	1788	1706	1550
	50	1587	1799	1953	1744	1644	1628	1758	1845	1959	1791	1762	1620
	Vert.	1411	1455	1344	958	760	692	744	918	1230	1383	1537	1479
New Orleans, LA	Hor.	788	954	1235	1518	1655	1633	1537	1533	1411	1316	1024	729
	30	1061	1162	1356	1495	1499	1428	1369	1456	1490	1604	1402	1009
	40	1106	1182	1339	1424	1389	1309	1263	1371	1451	1626	1464	1058
	50	1125	1174	1292	1324	1256	1170	1137	1259	1381	1610	1490	1082
	Vert.	944	899	847	719	599	546	548	647	843	1189	1240	929
Portland, OR	Hor.	578	872	1321	1495	1889	1992	2065	1774	1410	1005	578	508
	30	1015	1308	1684	1602	1836	1853	1959	1830	1670	1427	941	941
	40	1114	1393	1727	1569	1746	1739	1848	1771	1680	1502	1020	1042
	50	1184	1442	1727	1502	1622	1594	1702	1673	1651	1539	1073	1116
	Vert.	1149	1279	1326	953	889	824	890	989	1172	1309	1010	1109

Source: Reproduced from Reference 2.

$$\text{Solar energy} = (3333\ \text{ft}^2) \times (0.42 \times 10^6\ \text{Btu/ft}^2/\text{yr})$$

$$= \underline{1400 \times 10^6\ \text{Btu/year}}$$

At $\$4.00/10^6$ Btu, the energy value would be:

$$\text{Energy value} = (\$4.00/10^6\ \text{Btu}) \times (1400\ \text{Btu} \times 10^6/\text{yr})$$

$$= \underline{\$5600/\text{year}}$$

The time to pay back the cost of the collector—$66,660—would be:

$$\text{Simple payback period} = (\$66{,}660)/(\$5600/\text{yr})$$

$$= \underline{11.9\ \text{years}}$$

Considering the practical factors in this application lengthens the payback time substantially from the original 5.7 years determined earlier.

13.2.2 Solar Collectors

A solar collector is a device used to thermally collect, store, and move solar thermal energy. Essentially, solar collectors are heat exchangers that transfer the energy of incident solar radiation to sensible heat in a working fluid—liquid or air [5]. There are many different types of solar collectors, as shown in Figure 13-2.

13.2.2.1 Flat-Plate Collectors

A flat-plate solar collector generally consists of a shallow metal or wooden box which has a glass or plastic transparent cover, and which contains a black absorption plate that transfers heat to some fluid. The sun's shortwave radiation passes through the transparent cover, enters the collector and heats a fluid (usually water with or without antifreeze, or air). The hot fluid is then moved from the collector to the point of use or to storage for later use. A flat-plate collector almost always faces to the south (in the northern hemisphere) and is tilted at some angle. A typical flat-plate solar collector is illustrated in Figure 13-3.

A typical flat-plate solar collector application is given in Figure 13-4. Here, solar energy heats an ethylene glycol mixture that is pumped to a storage tank. The tank then heats water through a heat exchanger for alternative use as shown. In some applications, such as preheating boiler makeup water, the water itself can be pumped through the collector to a

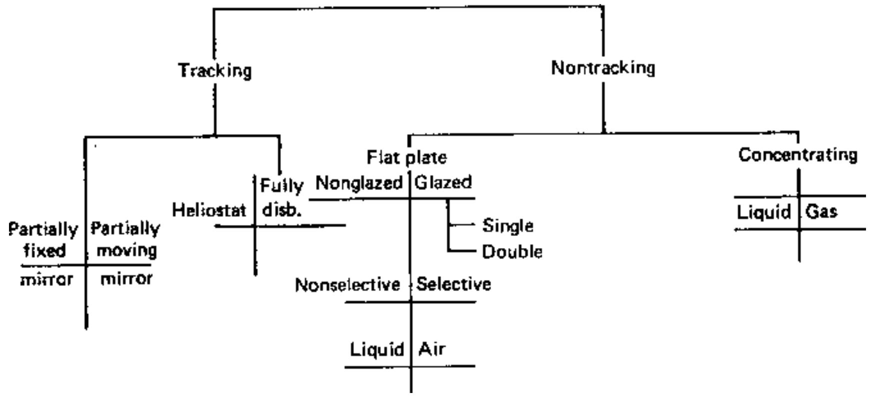

Figure 13-2. Types of solar collectors.

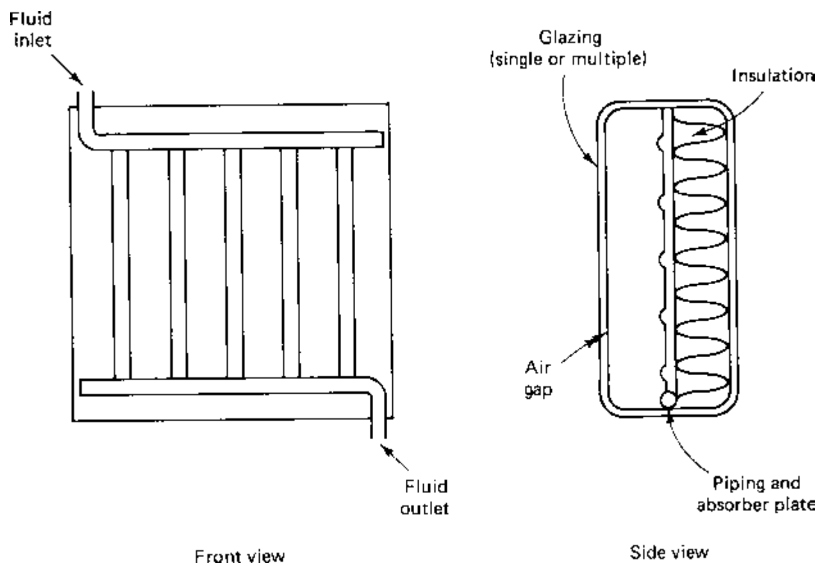

Figure 13-3. Flat-plate solar collector.

storage tank or directly to the boiler room. In such applications, care must be taken to prevent freezing; drain down provisions for the solar collector are usually employed.

Glazing:

The flat plate solar collector may be glazed or nonglazed. The most common *glazing* is tempered glass which allows the shortwave radiation

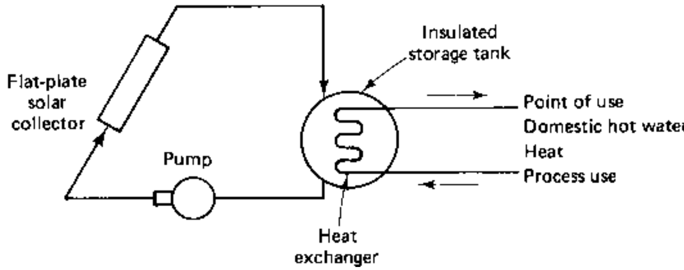

Figure 13-4. Typical flat-plate solar collector application.

of the sun to enter the collector but prevents the longer-waved reradiation from leaving. This produces a greenhouse effect and increases the efficiency of the collector but also increases the cost. Dual glazing would further cut down the heat loss while not appreciably restricting incoming solar energy, and is used for most high temperature flat plate collectors. Unglazed collectors are quite efficient at lower temperature applications such as swimming pool heaters, while glazed collectors are more efficient at higher temperatures. Typical flat-plate collector efficiencies with different glazings are given in Figure 13-5. T_{in} is the temperature of the water coming into the collector, and $T_{ambient}$ is the temperature outside the collector. The graph shows that the heating ability of the collector is greater with glazings that have higher insulating capability.

Selectivity:

The *selectivity* of the collector absorbing surface is an important property that affects a collector's efficiency. The collector must absorb shortwave radiation readily and emit long-wave radiation stingily. Surfaces with high shortwave absorption and low long-wave emittance are *selective surfaces.* Selective surfaces perform better at higher temperatures than nonselective surfaces. A single glazed selective surface collector has efficiencies very similar to a double-glazed nonselective surface collector.

Transport medium:

The *medium* chosen to move the thermal energy from the collector to the point of use or to storage can be either liquid or air. Each has advantages and disadvantages. It is much more difficult and expensive to move thermal energy with air than with liquid. In fact, the horsepower required to move the same amount of thermal energy may be 10 times higher for an air system than for a liquid system. Air systems also have lower heat transfer rates, so the system must be carefully designed to provide a

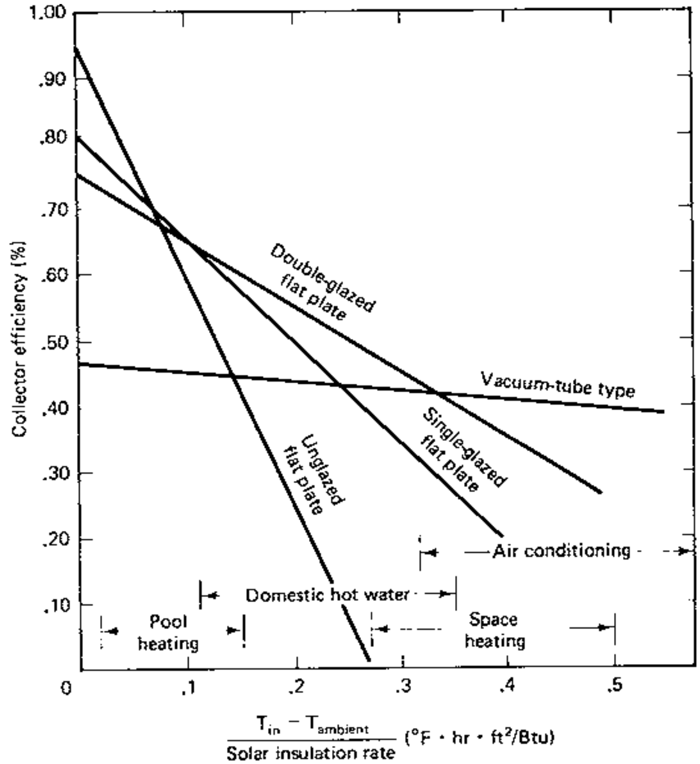

Figure 13-5. Typical flat-plate collector efficiencies

sufficiently large heat transfer surface. However, air does not freeze. In liquid systems, ethylene glycol or some other antifreeze must be used, or the system must have well-designed drain down controls. In addition, air systems do not have corrosion problems, and leaks do not present as much of a problem as with liquid systems.

The examples presented thus far have assumed the fluid is a liquid, but many applications are suitable for air. For example, an air solar collector could be used as an air preheater for an industrial furnace or boiler. Although this application is not widespread, it can be useful if the time of solar energy availability and the time of industrial heat use coincide (i.e., the energy is needed when the sun is shining).

<u>13.2.2.2 Concentrating collectors</u>

A need for temperatures of 250°F or higher usually requires a concentrating collector. The surface of a concentrating collector must be highly reflective, enabling concentration of the sun's rays on the heat absorption device. The heat transfer fluid can be a liquid or gas. A concentrating collector is usually also a tracking collector in order to keep the sun's rays focussed on a small surface. A typical design for a parabolic trough-type, tracking collector is shown in Figure 13-6. The collector can track in an east to west direction to follow the daily sun, in a north to south direction to follow the seasons, or both. Concentrating collectors that accurately track the sun's position are more efficient than those that do not track the sun's position as well.

Other types of concentrating, tracking collectors use movable mirrors that can concentrate the solar energy on a small surface that remains fixed. The *power tower* is such an application where the absorption surface or central receiver surface is located in a tower. Tracking mirrors are located on the ground around the base of the tower. These fully tracking mirrors are usually computer-controlled to concentrate the maximum amount of solar energy on the tower. Applications are mainly for steam generation used to produce electric power. This type of application takes a large amount of land area and requires careful maintenance. The most notable power tower is located in California, and is called Solar One [6]. It was operated by Southern California Edison Company up until 1989. This facility had a capacity of 10 MW, and successfully generated electric energy for almost ten years.

13.2.3 Solar Thermal Storage

One of the biggest obstacles to widespread solar utilization is that often the solar energy is not needed when it is available and it is not available when it is needed. For example, maximum heat is usually needed when the sun is not shining, especially at night. Also, solar energy flows cannot readily be regulated. When the sun shines, the collector usually delivers energy at its full capacity. Tracking collectors can be

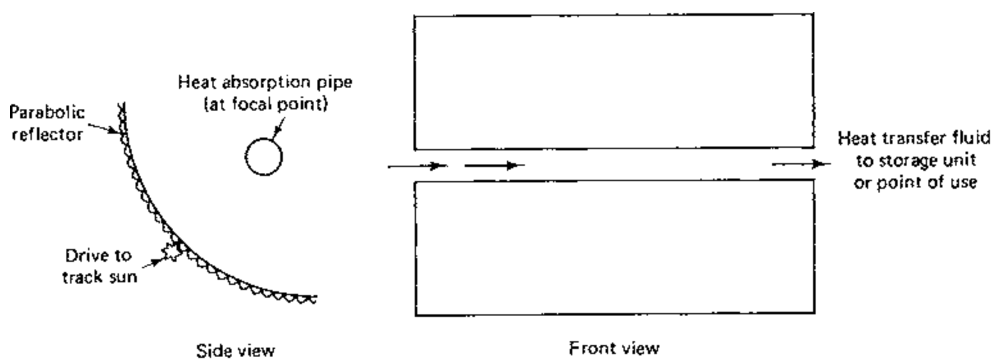

Figure 13-6. Parabolic trough solar collector

programmed to turn away from the sun, and can be regulated, but this is not generally a cost-effective mode of operation.

For these reasons, many solar applications require some type of storage system. The system must both store energy for later use and regulate energy flows. Figure 13-4 depicts one possible liquid storage system. There are three basic types of storage systems:

- *Liquid*. Liquid storage systems normally utilize water or a water-antifreeze mixture. The storage capability is determined by the sensible heat capacity of the liquid. For water it is 1 Btu/lb/°F.

- *Rocks.* Used for air systems, rock storage uses the sensible heat content of rocks for storage. Typically, airflow is top to bottom for storage and bottom to top for use as needed.

- *Phase change materials.* The preceding systems utilize sensible heat. This system utilizes the larger latent heat in phase changes such as the melting of ice. The required storage volume is smaller, but the cost is higher. Eutectic salts are often used.

13.2.4 Applications of Solar Thermal Systems

Commercial facilities and industry have not yet incorporated the use of solar thermal energy systems on a large-scale basis. There are many solar applications throughout the country, but most replace only a small quantity of the traditional energy supply. The following are some applications of solar thermal energy in business and industry.

- *Solar-heated hot water*. One of the bright spots in the application of solar thermal systems today is solar-heated or augmented hot water. The hot water tank itself is the storage system (or at least a part of it), and the hot water is usually needed the entire year. In some parts of the country, solar water heaters are very cost effective. Hotels, motels and small businesses such as laundries are using solar-heated hot water. In the industrial sector, solar-heated makeup water for boilers and cleaning tanks and solar-augmented process feeds are additional process uses for solar heating.

- *Solar space heat.* Although solar space heating is feasible, active solar collectors for space heating are very seldom cost-effective. Because they are not used all year, they do not often save enough energy to justify their cost. Passive solar applications are often cost effective for minimizing the need for traditional fuel sources in providing space heating. This is discussed in the next section.

- *Solar recuperators.* Industrial furnaces require heat year-round, so combustion air preheating is a likely candidate for solar thermal energy. In installations where outside air might already be used, the application is very simple and probably requires no storage. When the sun shines, the air is preheated; otherwise it is not. However, such systems must be designed carefully or they may cause problems with burners and excess air control.

- *Solar detoxification.* One recent application of solar thermal energy that is rapidly growing in use in commercial and industrial facilities is the detoxification of hazardous wastes. These applications make use of the thermal energy and the high energy photons from solar energy that can more thoroughly decompose and destroy toxic chemicals [7].

- *Solar-heated asphalt storage tanks*. A company which had used portable propane burners to keep asphalt in their storage tanks hot switched to solar collectors and added insulation to the tanks. The energy savings and the convenience made this application attractive.

- *Solar air conditioning.* Solar air conditioning systems use the heat from a solar collector to drive an absorption chiller, and produce cool water or air. The cost effectiveness of these active systems is generally poor at this time, and the use of passive solar features in buildings and structures is a far more successful, and cost effective technology.

13.2.5 Passive solar systems

Passive solar systems result from design strategies and related technologies that use elements of the building structure—primarily glass and thermal mass—and building orientation to heat, cool, shade, and light buildings. Passive solar technologies include direct gain heating, radiative cooling, natural ventilation and economizer cycles, natural lighting, light shelves and shading systems.

13.2.5.1 Use of passive heating

A south-facing glass window serves as a passive solar collector of heat for a building, and the interior of the building serves as the heat storage device. Windows also provide significant amounts of natural lighting. Careful attention to passive solar energy utilization in building design can reduce energy costs significantly.

Example 13.2:

Consider a building located in Fort Worth, Texas that faces south. The building has a total wall area (minus glass) of 2000 ft^2 and a roof area of 3000 ft^2. The R values of the roof and walls are 18 and 12, respectively. There is 300 ft^2 (about 40% of the south wall) of south-facing, double-pane, overhung glass (R-1.85) which permits full sunlight for the 5-month heating season. There are twenty-three 63°F heating days in Fort Worth. The glass transmits 80% of the solar energy hitting it. How much of the building's heating needs does this passive solar feature provide?

Solution: From Table 13-1, for Fort Worth, TX, we find the total solar load on a vertical surface for the months of November, December, January, February, and March to be

$$(80\%)\left(300\ \text{ft}^2\right)\left[1509(30) + 1396(31) + 1315(31) + 1286(28) + 1196(31)\right]\frac{\text{Btu}}{\text{ft}^2 \sum \text{year}}$$

$$= 48.58 \times 10^6 \text{Btu/year}$$

The heat loss (HL) (assuming no setback) is

$$\text{HL walls} = \left(\frac{1\ \text{Btu}}{12\ \text{h}\sum{}^\circ\text{F}\sum\text{ft}^2}\right)\left(2000\ \text{ft}^2\right)\left(\frac{2363\ {}^\circ\text{F days}}{\text{year}}\right)\left(\frac{24\ \text{h}}{\text{day}}\right)$$

$$= 9.45 \times 10^6 \text{Btu/year}$$

$$\text{HL roof} = \left(\frac{1\ \text{Btu}}{18\ \text{h}\sum{}^\circ\text{F}\sum\text{ft}^2}\right)\left(3000\ \text{ft}^2\right)\left(\frac{2363^\circ\text{F days}}{\text{year}}\right)\left(\frac{24\ \text{h}}{\text{day}}\right)$$

$$= 9.45 \times 10^6\ \text{Btu/year}$$

$$\text{HL glass} = \left(\frac{1\ \text{Btu}}{1.85\ \text{h}\sum{}^\circ\text{F}\sum\text{ft}^2}\right)\left(300\ \text{ft}^2\right)\left(\frac{2363^\circ\text{F days}}{\text{year}}\right)\left(\frac{24\ \text{h}}{\text{day}}\right)$$

$$= 9.20 \times 10^6 \text{Btu/year}$$

$$\text{total HL} = 28.1 \times 10^6 \text{Btu/year}$$

Percent heat supplied = 48.6/28.1 = <u>173%</u>

According to these calculations in Example 13-2, placing glass on 40% of the south-facing wall will allow solar energy to supply 170% of the total heat needed for the year. However, the following practical considerations are important:

- The heat loss by infiltration may be as large as the total heat loss through the roof and walls—especially if there is much exhaust air. Thus, the total heating load may be far greater than that initially stated.

- The sun does not shine on some days, so the heating plant will have to be designed as large as it would be without solar aid.

- On bright sunny days, the building might get too hot, so the glass area might have to be reduced or adjustable shading used.

- This building is fairly well insulated. Many manufacturing buildings have little insulation, and thus would need much larger amounts of heat to adequately warm the building.

- All glass is on the south wall. Some glass may be needed on the other walls.

- Fort Worth may not be typical of the rest of the country.

Nevertheless, passive solar energy can contribute a large percentage of the heating required in a facility. Passive solar should especially be considered in the design of manufacturing buildings whose hours of operation normally coincide well with sun hours. At night, the thermostat can be substantially reduced, whereas in homes, night setback cannot be used as readily.

13.2.6 Energy Efficiency in the Design of New Facilities

Building a new facility provides the industrial energy manager with numerous opportunities to incorporate energy efficiency into the facility design. The following sections include ways to use passive solar energy, to avoid unwanted solar loads, and to take advantage of renewable energy opportunities. For completeness, we have also included some other energy efficiency measures that should be considered in the design of a new facility.

13.2.6.1 The land.

Purchase property with good energy-efficiency characteristics. Do not choose property located in energy-intensive spots. Avoid areas that are too windy, areas on the tops of hills, and areas on north slopes. However, these spots may become attractive in the future as locations for utilizing other renewable energy sources.

Choose a location that is near energy supplies to minimize transmission losses as well as costs. Property that is near good transportation facilities will also save energy costs.

13.2.6.2 The building site.

Choose an energy-efficient building site for the facility. You should take advantage of unique spots that can use existing deciduous trees or other natural properties to provide shading from the summer sun and/or windbreaks in the winter. Hills can be utilized as berms to improve insulation instead of spending money to level them.

The building site should be close to major transportation facilities.

13.2.6.3 Facility orientation.

Orient the facility for energy conservation. The building should face south. The shorter dimension should run north to south and the longer, east to west. The manufacturing plant in Figure 13-7 below demonstrates this. This allows minimum sun exposure in the summer on the east and west walls. However, during the winter, because of the lower sun angle, the sun helps to heat the facility.

13.2.6.4 Underground construction.

Consider the use of underground structures. Use a large amount of backfill on northern and western walls. This will protect the facility from cold on the north side and heat on the west.

Partially submerge the entire structure. This will use the thermal mass of the ground to maintain a constant temperature in the facility with less energy input. Some facilities are completely submerged, such as the warehouses in the caverns under Kansas City.

13.2.6.5 Energy-conserving landscaping.

Much of the undesirable heat loss/gain can be prevented through proper landscaping [8,9]. Avoid asphalt or concrete areas around the building as much as possible; grasses, shrubs, and vines are much cooler in the summer.

Place deciduous trees strategically so they offer shade during the

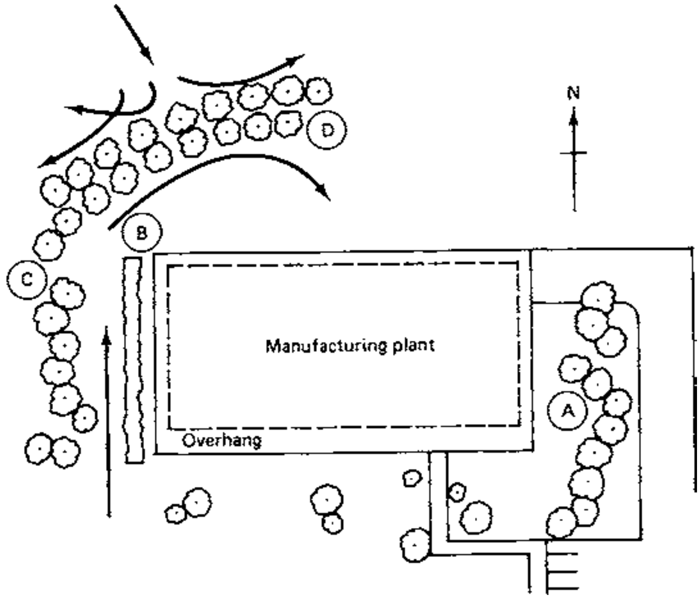

Figure 13-7. Landscaping for energy conservation. (a) Deciduous trees: In summer, allow the early morning sun to penetrate and then protect; in winter, allow the sun to penetrate. (b) Hedge: Catch the late afternoon rays. (c) Deciduous trees: Provide shade in the afternoon. (d) Shrubs or tall hedge: In winter, block northwest winds; in summer, help divert southwest winds around the building.

summer yet allow sunlight to penetrate in the winter. Use vines and shrubs to offer additional shading. In fact, thick shrubs placed close to a building effectively increase the R value of the walls.

Use trees and shrubs as windbreaks and wind diverters. For example, evergreen trees or shrubs at the northwest corner of the building can break the cold winter winds and divert the summer breezes for better utilization. (See Figure 13-7 above)

13.2.6.6 Energy-efficient building envelope.

The energy-efficiency of the building envelope will significantly affect the energy use in a facility. Energy efficiency is easy to incorporate in the initial construction of a building, but very costly to retrofit. The following suggestions should be considered in the initial design:

- **Minimize the wall perimeter area.** Use regular-shaped buildings—square or rectangular. This minimizes the wall area and thus minimizes the heat loss.

- **Insulate the building well.** Install insulation in the ceiling and the walls as well as on the slab (if appropriate). Check for local recommended levels. Figure 13-8 illustrates recommended insulation placement for an underground manufacturing facility.

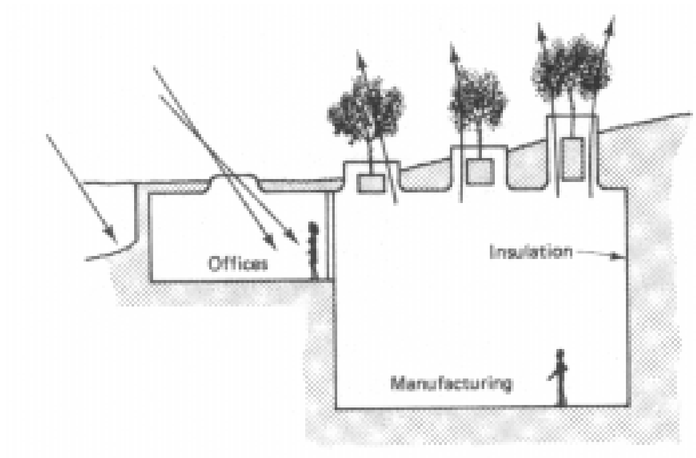

Figure 13-8. Recommended insulation placement

- **Use energy-efficiency considerations in window selection.** Use a minimum amount of glass—well placed. Avoid glass on northern and western sides. As discussed earlier, planning the southern exposure with proper solar influx is best.

  Consider installing insulating glass or storm windows. Double or triple glazed windows are cost effective in most parts of the country. Office areas are especially good candidates since they are typically heated and cooled to a greater extent than the production areas.

  With proper placement of windows, natural ventilation is also feasible. Therefore, consider the use of windows that can be opened to utilize natural ventilation.

  Consider the use of tinted window glass on all walls except the south one. The east and west walls are strong candidates for tinted glass.

Utilize drapes or outside partitions to further insulate windows and to reduce solar load when desired. Several examples of outside partitions are shown in Figure 13-9.

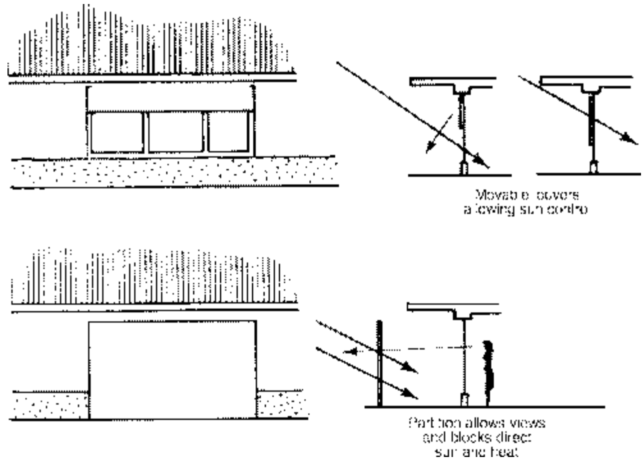

Figure 13-9. Outside partitions.

- **Utilize overhangs or awnings.** On southern exposures, overhangs block the summer sun but allow the winter sun to enter as shown in Figure 13-10. An architect can tell you the proper amount of overhang to allow for sunlight in winter months. It varies with location.

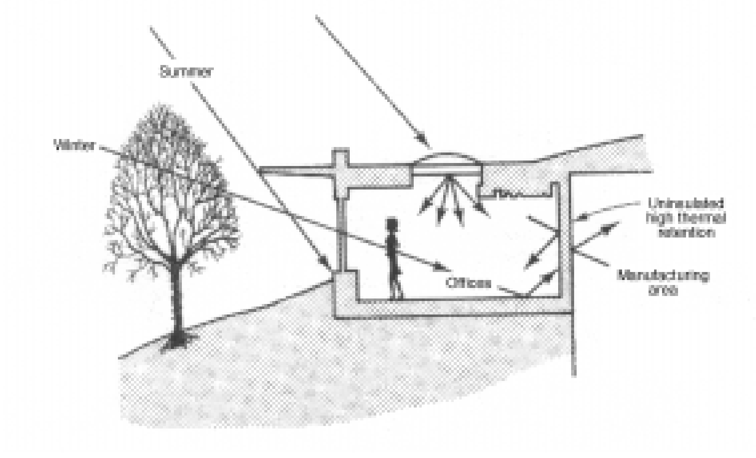

Figure 13-10. Energy conservation through the use of overhangs.

Passive solar systems (also shown in Figure 13-10) help to further reduce energy costs, and they provide attractive warm areas for personnel.

- **Design the roof carefully.** Use light colors in warm climates and dark in cold. Design the roof so it can be sprayed in the summer. Be careful not to flood the roof—it will leak eventually.

- **Engineer all wall openings for energy efficiency.** Minimize the number of openings. Caulk and weather-strip the doors and windows well.

  Design the overhead doors with two position openings to match the truck size and/or use adjustable dock seals. Utilize insulating pads on the dock doors. Consider using adjustable dock pads.

  Consider interlocking the doors and the heating units so that when the doors are open, the heat is off. Utilize automatic doors or various types of "see through" materials (plastic strips, plexiglass, etc.) for doors that must be used frequently. Air curtains are another option for minimizing heat loss.

  Use good pedestrian doors to avoid using large dock doors for pedestrian traffic. Utilize revolving doors or entrance vestibules to minimize air infiltration.

13.2.6.7 Energy-efficient facility layout.

Locate the facilities within the plant to minimize the energy required to maintain personnel comfort. Departments with high personnel density should probably be located in southern exposure areas of the plant and not in northern or western areas. Figure 13-11 demonstrates one possible layout considering energy requirements only.

Avoid or minimize northern or western exposure for dock areas (shipping and packaging). In Figure 13-11 the shipping and receiving area is oriented so that the amount of northern exposure is minimized. The entry area for shipping and receiving should be on the east side.

Consider departmental or cost center metering of utilities. By doing this, each cost center can be held accountable for its energy consumption, and energy can become a part of the budgeting process. This requires extensive preconstruction planning to lay lines and install meters as needed. Then, arrange the facilities so that energy control is easy (e.g., lights and motors can be switched off in one location).

Plan the layout so the exhaust air from one area can be used in another; e.g., the hot air at ceiling height in one area may be used as the combustion air for a large furnace.

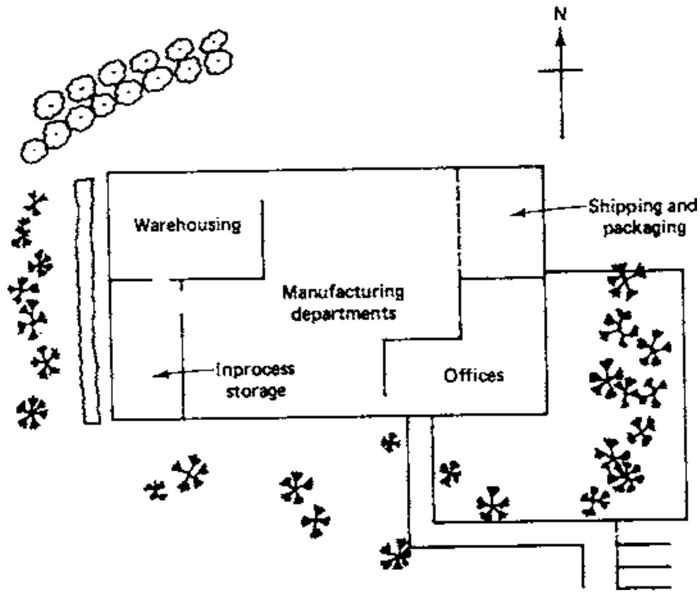

Figure 13-11. Hypothetical plant layout to minimize energy requirements for space conditioning.

13.2.6.8 Location of process equipment.

Locate all boilers, hot water tanks, and other heated tanks to minimize distribution distances and consequently energy loss in distribution. Design the boiler location and steam distribution system to facilitate return of condensate and/or reflashing or low-pressure steam.

Engineer waste heat recovery systems into the facility design. Waste heat is the one renewable energy source today whose utilization is frequently cost effective. It is much easier to incorporate feedstock preheating apparatus in the initial design rather than retrofitting. Boilers, furnaces, large motors being cooled, lighting fixtures, any cooling fluids, and compressors are just a few of the potential sources for waste heat recovery. Locate the waste heat producing equipment where it can be utilized and where the heat recovery equipment can be installed.

Locate air compressors so they can be maintained easily, they can use fresh cold air, and transmission losses are minimized. Utilize step-up air compressors to be able to reduce plant-wide pressures.

13.3 SOLAR-PHOTOVOLTAICS

Photovoltaics is the direct conversion of sunlight to direct current (dc) electricity through a photocell. Historically, photovoltaics has not been cost effective in competition with fossil fuel or electricity from a grid system, but the needs for photovoltaics in space and the subsequent research coupled with rising costs of traditional energy have pushed photovoltaics ahead. Although still not cost effective for replacing central station electric power plants, photovoltaics is cost effective for many applications where electricity is needed in remote areas. Each year, progress in research and development continually reduces the price of electricity from this source.

Photovoltaic cells are semiconductor devices which can convert the energy in photons of light into dc electrical energy. Most cells are made from single-crystal high-purity silicon and small amounts of trace elements such as boron and phosphorus. These elements are combined into a material with excess electrons (n-type semiconductor) connected to a material with insufficient electrons (p-type region). As long as the cell area is illuminated by light, electrical energy will be produced (see Figure 13-12).

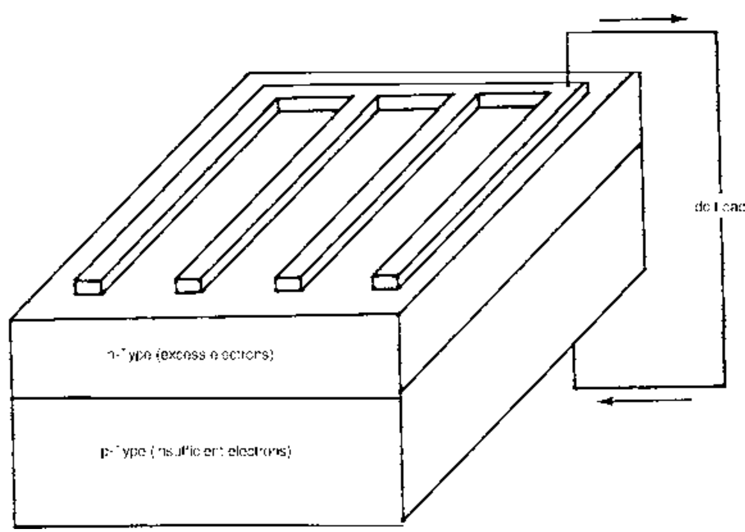

Figure 13-12. Typical photovoltaic cell

The area where the semiconductor materials are joined together can be connected to a battery, or to other cells. Cells are then put together in modules, which can be in the form of flat plates or concentrators. Most cells generate electrical energy of about 0.5 volt and a current that varies with the area of the cell and amount of light. For flat plate modules, typical wattage is about 12.5 W/ft^2 with a conversion efficiency of 5 to 15%. Higher efficiencies can be obtained from concentrator modules.

To achieve higher voltages and currents, solar cells are combined in series and parallel, like batteries. Sets of cells are usually placed in series to generate the necessary voltage, and then multiple strings are placed in parallel to develop the desired current (see Figure 13-13). Because the time of need and the solar intensity do not always match, some type of storage device and voltage regulation is necessary. Normally, a chemical battery storage system fills this need. Finally, a backup generating system is often needed to allow for consecutive cloudy days.

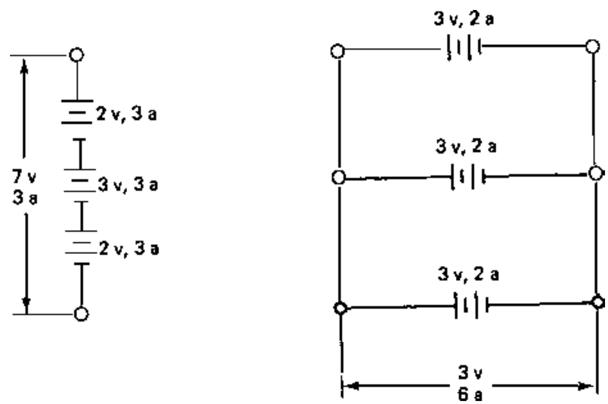

Figure 13-13. Photovoltaic hookups

Generally there are three types (sizes) of photovoltaic systems:

1. *Small* (1-10 kW). These photovoltaic systems are suitable for remote locations or other locations where conventional electricity may be costly. Examples are street lights, irrigation pumps, security lighting at construction sites, communications equipment, and field battery charging.

2. *Medium* (10-1000 kW). These photovoltaic systems could be used by larger industrial facilities and/or remote communities. They could also be used as supplemental or peaking power.

3. *Large* (more than 1000 kW). These photovoltaic systems are used in utility-owned large-scale power-generating stations often located in desert areas.

At their current costs, photovoltaic cells can provide electric energy at 25 to 30 cents per kWh. The largest use of photovoltaic cells today is in supplying remote electric power. Electric utilities are expanding their capabilities with photovoltaic generation. Pacific Gas and Electric Company recently installed over 1000 kW of photovoltaic generation. Southern California Edison Company has entered into a joint venture with Texas Instruments Company to produce photovoltaic cells called Spheral Solar Modules that produce power at 14 cents per kWh. Limited production is expected to begin in 1994.

Industry offers a number of applications for photovoltaics, but the actual usage has been limited in size and scope. Ideal applications would have the following characteristics:

1. The equipment operates on dc power.
2. Substantial sunlight is available.
3. The user can tolerate random losses of power.
4. Power is needed when the sun is shining.

Photovoltaics is one of the cleanest, most environmentally benign energy technologies. Many proposals have been made to combine the photovoltaic generation of electric energy with the production of hydrogen through electrolysis. The hydrogen would then be used as the energy supply to be marketed primarily for use in automobiles. Alternatively, the hydrogen could be stored and then burned at a later time to produce electric power when the sun was not shining.

13.4 INCORPORATING SOLAR FEATURES INTO BUILDING DESIGN—AN EXAMPLE

The new building to be constructed for the Florida Solar Energy Center (FSEC) provides a good example of some of the areas for saving energy in a facility by utilizing solar energy features. The design objective for this building was to "incorporate the latest solar and conservation building techniques" [10]. Extensive simulations using the DOE-2 program (discussed in Chapter Nine) were conducted to compare alternative design features, and to estimate the energy savings from new design features.

One of the first design decisions was to locate the building on the site with the long axis facing north-&Ôuth to minimize solar gains and reduce cooling loads, an important consideration in Florida. Both the roof and the walls of the building were coated with a low-absorbance material to further reduce cooling loads. Three-foot wide overhangs are used above the windows to reduce solar heat gains through the glass. Super-windows with spectrally selective coatings and double glazing were also chosen.

Daylighting was used extensively in order to minimize the energy devoted to artificial lighting. To enhance the use of daylighting, all offices are located on the perimeter wall of the main building. The north and south faces of the building utilize an extensive amount of glass. The windows are long, but only 4.5 feet high; the roof overhangs help limit the morning and afternoon solar heat gain, while still providing interior illumination. Above each window is a two-foot high "light shelf" which reflects additional illumination into the building. One of the buildings has a triangular-shaped section, and the windows on its southwest side have fixed shading devices to block direct sun while allowing reflected and diffuse light to enter. The top floors of the main building and the library contain "light wells" to introduce natural daylight to the interior.

Almost 400 photosensors were installed in the facility to measure light levels, and to provide inputs to the dimmable electronic ballasts to control the energy used by the T8 fluorescent lights. The electronic ballasts for the lights allow the power and illumination levels to be varied between 5% and 100% of their maximum output. The DOE-2 simulation showed that daylighting was able to reduce the energy needed for lighting by 46% over the entire year; mid-day reductions averaged 60% for all areas of the building. The payback for the 400 photosensors was less than six months.

The bottom-line energy savings resulting from this new building design using energy efficient and solar features is impressive: the overall energy savings compared to the base-case design was a 70% reduction in utility bills and a peak cooling demand reduction of 88%. Additional solar features such as solar water heating and photovoltaic cells for powering the lighting system are also under investigation. These features may even further reduce the energy use and energy costs for this facility.

13.5 WIND ENERGY

Much has been said about wind energy and its potential. Although the potential in the United States for wind energy is many times greater than the present consumption of electrical energy, this potential will never be obtained due to aesthetics, construction cost and radio-TV interference problems [11]. However, wind energy has proved to be the most cost-effective of the solar technologies, and 1500 MW of electric power generation is located in the state of California.

The power density of wind is given by

$$\frac{P}{A} = \frac{1}{2}\rho V^3 \qquad (13\text{-}1)$$

where A = area normal to the wind (ft^2)
ρ = density of air (about .075 lb/ft^3)
V = velocity of air (mph)
P = power contained in the wind (Watts)

This can be rewritten as follows (K is a constant for correcting units):

$$\frac{P}{A} = KV^3 \qquad (13\text{-}2)$$

where K = 5.08×10^{-3}

$$\frac{P}{A} = W/ft^2$$

$$V = mph$$

Unfortunately, only a small percentage of this power can be obtained. It can be shown that theoretically .5926 of the power can be extracted, but practically only 70% or so of that can be obtained. Consequently, only .70 × (.5926) or about 40% of the power is harvestable.

Example 13-3: Find the power in watts per square foot that can be produced from a 10-mph wind. How would this power change if the wind velocity were 20 mph?

Solution: Using Equation 13-2, the power per square foot is found as:

$$\frac{P}{A} = \left(5.08 \times 10^{\pm 3}\right) \times \left(10^3\right) \times (.40) = \underline{2\ W/ft^2}$$

If the wind speed increased to 20 mph, the power would become:

$$\frac{P}{A} = \left(5.08 \times 10^{\pm 3}\right) \times \left(20^{3}\right) \times (.40) = \underline{16.3\ W/ft^2}$$

These figures demonstrate why it is necessary to find areas with consistent high wind velocities. The difference between a site with 10 mph winds and with 20 mph winds is a factor of 800%.

Just a difference in average wind speed of 3 mph is enough to change the wind characterization of a site. Good, excellent and outstanding wind sites have been described as having average wind velocities of 13, 16 and 19 mph, respectively [12].

Wind speed offers other problems. Too little wind will not initiate power output for most windmills. The wind speed must be above a "cut-in" speed unique to the windmill. Too much wind creates other problems that could conceivably destroy the windmill, so most windmills feather out at some high wind speed.

Industry has done almost nothing to utilize wind. Usually industry is located in congested areas where windmills would not be popular. Furthermore, industry is not likely to develop wind energy as an energy source until it is more cost effective.

13.6 BIOMASS AND REFUSE-DERIVED FUEL

13.6.1 Energy from Biomass

The term *biomass* includes all energy-producing materials that come from biological sources, such as wood or wood wastes, residues of wood-processing industries, food industry waste products, sewage or municipal solid waste, waste from food crops cultivated as energy sources, and other biological materials [13]. Both economic and environmental benefits can be achieved when biomass is used as a source of energy for space heating, process heat, or electricity production. If the biomass comes from a waste product, the cost is usually low; this source may have the added benefit of avoiding the cost of disposing of the waste. Utilizing waste biomass sources not only provides an inexpensive source of fuel, but also solves an environmental disposal problem as well.

Four main technologies are available for converting biomass to usable energy forms. The first is simply burning the biomass to provide direct heat for space and process heating, or for cooking. The second is burning the biomass to produce steam which is then used to generate electrical energy. The remaining two technologies involve converting the biomass to liquid or gas energy forms so that it can be transported to other locations for use.

13.6.2 Energy from Refuse-derived Fuel

Another area for renewable fuel utilization in industry is *refuse-derived fuel.* About 70% of the typical household refuse is combustible, but a higher percentage of industrial wastes is usually combustible. In fact, some industrial waste is a fairly high-quality fuel, as pulp and paper mills have proven for years. Although there are some successful applications of fuel derived from municipal waste, this book is concentrating on industrial—institutional energy management. In the rest of this section we will only discuss industrial-institutional applications.

Combusting waste reduces the volume of the waste by 80% or more which makes it easier to handle. Consequently, one of the big savings for refuse-derived fuel is in reduced disposal costs. In some industries, this disposal savings may be much larger than the economic value of the actual Btu content of the fuel.

Some typical heating values for various types of industrial wastes are shown in Figures 13-14 and 13-15. As shown in these tables, many sources of industrial waste have significant Btu content. Refuse-derived fuel is certainly a fuel source worth considering.

The following is a suggested procedure for analyzing waste fuel sources:

Step 1. Determine the heating value and quantity of the waste.

Step 2. Determine the technical feasibility of utilizing the waste (burning, pyrolysis, anaerobic digestion, etc.). Include necessary pollution control and ash disposal costs.

Step 3. Develop a system design including waste fuel handling, preparation, firing, and disposal. Estimate the cost involved.

Step 4. Perform an economic analysis including all incremental costs identified in step 3, and all savings over conventional fuels. Don't forget the savings in disposal costs and any tax incentives (tax credits or preferred depreciation schemes) from federal and state governments.

Figure 13-14. Wood waste characteristics.
(From *Instructions For Energy Auditors.* U.S. Dept. of Energy, 1978)

	Wood, avg, seasoned (%)	Wood waste, Douglas fir (%)	Hogged fuel, Douglas fir (%)	Sawdust (%)
<u>Proximate analysis:</u>				
Moisture	24.0	35.9	47.2	44.9
Volatile matter	65.5	52.5	42.9	44.9
Fixed carbon	9.5	11.1	8.9	9.5
Ash	1.0	.5	1.0	.7
<u>Ultimate analysis:</u>				
Hydrogen	7.2	8.0		
Carbon	37.9	33.5		
Nitrogen	.1	.1		
Oxygen	53.8	57.9		
Sulfur	–	0		
Ash	1.0	.5		
High heating value (Btu/lb)	6300	5800	4670	4910

Figure 13-15. Heating values of industrial waste fuels.
(From *Instructions For Energy Auditors*. U.S. Dept. of Energy, 1978)

Fuel	Heating value Btu/lb	Heating value Btu/ft^3
Solid Fuels:		
Bagasse	3,600–6,500	
Bark	4,500–5,200	
Wood Waste	4,500–6,500	
Sawdust	4,500–7,500	
Coffee grounds	4,900–6,500	
Rice hulls	5,200–6,500	
Corn cobs	8,000–8,300	
Municipal refuse	4,500–6,500	
Industrial refuse	6,600–7,300	
Coal	8,000–24,000	
Liquid fuels:		
Black liquor (pulp mills)	4,000	
Dirty solvents	10,000–16,000	
Gasoline	20,700	
Industrial sludge	3,700–4,200	
Naphtha	20,250	
Naphthalene	18,500	
Oil waste	18,000	
Paints and resins	6,000–10,000	
Spent lubricant	10,000–14,000	
Sulfite liquor	4,200	
Oil	18,500	
Gas fuels:		
Coke, oven gas		500–1,000
Refinery gas		1,200–1,800
Natural gas		1,000

If you go through this procedure at least once for each alternative, you should make the most cost-effective decision.

At some stage, the analysis should include the incorporation of waste from another industry or a municipality so that economies of scale might be obtained. However, extreme care should be taken to ensure that these other sources are reliable in quantity, flow rate, and quality.

The technology for burning waste fuel is rapidly becoming more developed and the equipment is commercially available. Some of the technologies receiving attention include the following:

- Burning raw refuse in water well incinerators
- Shredding, pelletizing, or otherwise preparing fuel and burning in boilers
- Anaerobic digestion where waste is converted to gas in an oxygen-free atmosphere
- Pyrolysis or thermal decomposition of waste in the absence of oxygen

The following paragraphs summarize some applications of refuse-derived fuel:

- A large communications company converted a natural gas-fired boiler to burn methane from a nearby landfill. The plant's consumption of the landfill gas is expected to be between 200,000 and 300,000 million Btu per year. The plant expects to save around $60,000 per year from the use of the landfill gas. The cost of the conversion was $1 million, but it was paid by the supplier of the landfill gas [14].
- A county in North Carolina expanded its operation involving burning municipal waste to cogenerate electric power and steam. A 5 MW steam turbine generator was added to sell electric power to a major state utility, and to sell steam to a chemical and fertilizer firm located nearby. The firm will buy about 100,000 pounds per hour of steam from the county-owned and operated facility. The county calculated the payback time for the new addition at just under seven years [15].
- A dairy farm in Georgia installed a 190-hp engine running on biogas from an anaerobic digester to drive a 55 kW electric generator. Waste heat from the engine was used to increase the effectiveness of the

digester by keeping it warm, and to dry the sludge from the digester prior to using it for bedding material. The overall efficiency of the cogeneration system was about 60%. The biogas from the digester had an energy content of about 600 Btu per cubic foot—or nearly 60% of the heat content of natural gas [16].

13.7 WATER MANAGEMENT

Water management is the efficient and effective use of water. Like energy management, the main goal is to improve profits or reduce costs. Water management is included in this text on energy management because water and energy utilization are intricately intertwined in most organizations. As water consumption goes up, so does energy consumption, and vice versa. Water management is included in this chapter on renewable energy sources because water is renewable and is often an efficient energy source. For example, water in cooling towers is a very inexpensive source of cooling.

Why worry about water? The sheer volume of water used in this country each day is staggering. Each person in the United States consumes directly and indirectly almost 90 gallons of water per day. At the same time, water costs are going up rapidly, and some sources are drying up (e.g., Midwestern aquifers).

Industry can save dramatic amounts of money and water through attention to its water-consuming equipment. In this section we will demonstrate how to save dollars and gallons of water in industrial water use.

There are three primary types of water users in industry. They are boilers, cooling towers, and process equipment.

13.7.1 Savings from Boilers

In boilers the primary ways to save are the following:

- *Blowdown.* Blowdown should be reduced to the minimum possible, which is determined by the feedwater quality and the amount of condensate return. Reducing blowdown also saves large amounts of energy.

- *Condensate return.* Condensate should be returned to the boiler whenever economically feasible. This saves water by reducing the amount of new makeup water needed and by reducing the amount of blowdown required. Returning the condensate also saves substantial amounts of energy and water treatment costs because condensate is essentially distilled water.

- *Steam leaks and steam traps.* As already demonstrated, steam leaks are extremely expensive energy losses, but significant amounts of water are also lost in steam leaks. An estimate of the amount of water lost can be obtained by dividing the annual loss in Btus by the enthalpy of evaporation. Stuck-open steam traps are steam leaks if the condensate is not returned and are still wasteful even if it is returned.

13.7.2 Water Savings from Cooling Towers

In cooling towers, the primary ways to save are the following:

- *Bleed.* Bleed in a cooling tower is almost identical to blowdown in a boiler. The purpose is to prevent impurity buildup. Bleed should be reduced to a minimum and reused if possible. Sometimes bleed can be used to water lawns or as rinse water makeup. However, careful attention must be paid to the chemicals in the water.

- *Sewerage charges.* Often sewerage charges are based on the amount of water consumed. Yet water consumed in a cooling tower does not go into the sewer. Negotiations with municipalities can often reduce the sewerage charge substantially if large cooling towers are present. Usually about 1% of the flow rate of water must evaporate for each 10°F drop in water temperature.

- *Preventive maintenance.* As baffles become broken or clogged with dirt and slime, the cooling capability drops dramatically. Since a 1°F drop in condensing water temperature can mean a 3 percent savings in electrical chiller input, preventive maintenance of cooling towers is important.

- *Tower water.* Often cooling tower water can be used directly for process cooling instead of using chilled water. When this is possible, large amounts of energy can be saved at the cost of higher water consumption. The trade-off is almost always cost effective.

13.7.3 Savings in Industrial Processes

It is much more difficult to generalize on ways to save in processes since water can be used in so many different ways in industrial processes. For example, water can be used to cool furnace walls, cool air compressors, wash, rinse, surface-treat, coat, test products, and cool molds and for a wide variety of other uses. The following paragraphs discuss some of the ways water and money can be saved in industrial processes:

- *Use water flow restrictors in shower heads and sinks*. As much as 60% savings in water and energy costs can be realized when flow restrictors are installed.

- *Recycle rinse water*. Often rinse water can be recycled by simple filtering or treatment. In one company, $30,000 and 30 $\times 10^6$ gal of water were saved annually by simply running rinse water through a sand filter and reusing it.

- *Reuse cooling water*. Often air compressors, small chillers, and other equipment requiring cooling are cooled with once-through cooling water (i.e., water from the tap is run through the equipment one time and dumped into the sewer). In the same room, tap water may be used as boiler makeup water. Because the cooling water is hot, usually about 105°F, if the cooling water is used as boiler makeup water, significant amounts of water and energy can be saved. One company found it could save about $1300 and one million gallons of water per year for each air compressor by reusing the cooling water in other places or by recirculating it through a small cooling tower.

- *Reduce flow rates to the minimum necessary.* Usually, water flow rates are liberally set in washing, coating, or rinsing operations. By setting flow rates at minimum levels, significant water can be saved along with the energy required for pumping.

- *Cover open tanks. Often heated tanks are open at the top*. Floating balls, cantilevered tops, or flexible slit covers can be used to cover the tanks and reduce evaporation and heat loss. One plant saved about $12,000 per year in energy and water costs by covering their heated tanks.

There are many other ways to save dollars and water through water audits, but it is difficult to develop a general list. Each plant and each operation are unique and require individual engineering study. The preceding discussion should serve to stimulate some ideas.

In terms of total water studies, water audits at manufacturing locations uncovered the following potential:

- One plant saved $77,000 annually in energy and water cost and 32×10^6 gal of water.

- Another plant saved $20,000 annually in energy and water cost and 12×10^6 gal of water.

- A rubber hose manufacturer saved $31,000 in water cost alone and 50×10^6 gal of water per year.

- A metal cylinder manufacturer saved about $20,000/year and 36×10^6 gal of water.

The potential for real savings is large. In the future, water management will be critical as costs continue to climb and water sources dry up.

13.8 SUMMARY

In this chapter we analyzed alternative energy sources and water management opportunities. First, we examined solar energy options. Active and passive solar systems were studied, and photovoltaics was examined.

Active solar systems were found to be effective but expensive since they normally require backup and storage systems. Passive solar energy, which is cost effective today, offers substantial potential for reducing energy costs for heating; however, backup systems are usually needed here too. Finally, although the future is promising for the reduced cost of photovoltaics, present applications in industry are only for remote sites where other energy sources are too expensive.

Although wind energy is not very promising as an industrial energy source in the near future, refuse-derived fuel is cost-effective in many locations today. Savings result from reduced energy cost and reduced handling and disposal costs.

Water management was discussed in the last section. Water management can yield large dollar and water savings and be cost effective. Because water use is often intertwined with energy use, reductions in the amount of water used can often result in a concurrent energy savings.

REFERENCES

1. "The Potential of Renewable Energy," An Interlaboratory White Paper, SERI/TP-260-3674, U.S. Department of Energy, March, 1990.

2. *Ibid.*

3. *Climatic Atlas of the United States*, GPO, Washington, D.C., 1968.

4. *Introduction to Solar Heating and Cooling Designing and Sizing*, DOE/CS-0011 UC 59A, B, C, Washington, D.C., Aug. 1978.

5. *Engineering Principles and Concepts for Active Solar Systems*, Solar Energy Research Institute, Hemisphere Publishing Corporation, Washington, DC, 1988.

6. R.W. Hallet and R.L. Gervais, *Design, Startup, and Operational Experiences of Solar One, in Progress in Solar Engineering*, Edited by D. Yogi Goswami, Hemisphere Publishing Corporation, Washington, DC, 1987.

7. D. Yogi Goswami, "Solar Energy and the Environment," *Proceedings of the Energy Systems and Ecology Conference*—ENSEE '93, Cracow, Poland, July 5-9, 1993.

8. John H. Parker, "Uses of Landscaping for Energy Conservation," *Star Project Report 78-012*, Florida Governor's Energy Office, Tallahassee, FL, January, 1981.

9. "Landscaping Can Reduce Energy Bills," *Grounds Keeping*, Intertec Publishing Company, February, 1993.

10. Danny S. Parker, "The Florida Solar Energy Center—Preliminary Analysis of Potential Efficiency Improvements," FSEC-RR-26-91, Florida Solar Energy Center, Cape Canaveral, FL, December, 1991.

11. W.C. Turner, Senior ed., *Energy Management Handbook*, Third Edition, Fairmont Press, Atlanta, GA, 1997.

12. "The Potential of Renewable Energy," An Interlaboratory White Paper, SERI/TP-260-3674, U.S. Department of Energy, March, 1990.

13. Ibid.

14. Amy Gahran, "Landfill Gas Cuts Boiler Fuel Bills at AT&T by $60K/yr.," *Energy User News*, January, 1993.

15. Mark Dunbar, "County Expands Steam Plant, Adds Waste-to-Energy Cogen.," *Energy user News*, October, 1990.

16. Doug M. Moore, "Biogas Powered Cogeneration System at Mathis Dairy," *Industrial Energy Conserver*, Industrial Energy Extension Service of Georgia Tech University, September, 1987.

BIBLIOGRAPHY

Goswami, D. Yogi, *Alternative Energy in Agriculture,* CRC Press, Boca Raton, FL, 1986.

Goswami, D. Yogi, Editor, *Progress in Solar Engineering,* Hemisphere Press, Washington, DC, 1987.

Instructions for Energy Auditors, U.S. Department of Energy, Washington, D.C., 1978.

Kreider, Jan F., *Solar Design: Components, Systems, and Economics,* Hemisphere Publishing Company, Washington, DC, 1989.

Kreith, Frank, *Economic Analysis of Solar Thermal Systems*, MIT Press, Cambridge, MA, 1988.

Meckler, Milton, *Innovative Energy Design for the 90's,* Fairmont Press, Atlanta, GA, 1993.

Myers, John, *Solar,* research report, Oklahoma Industrial Energy Management Program, Oklahoma State University, Stillwater, Oklahoma, 1981.

Rosenberg, Paul, *Alternative Energy Handbook,* Fairmont Press, Atlanta, GA, 1993.