ALMUSTAQBAL UNIVERSITY
Iraq – Babylon

RENEWABLE ENERGY TECHNOLOGY

Sustainable Path For a Carbon Free Future

Refrigeration and Air conditioning Techniques Engineering Department

Subject : Renewable Energy
Grade: 4th Class

Lecture:10 Module and Array design

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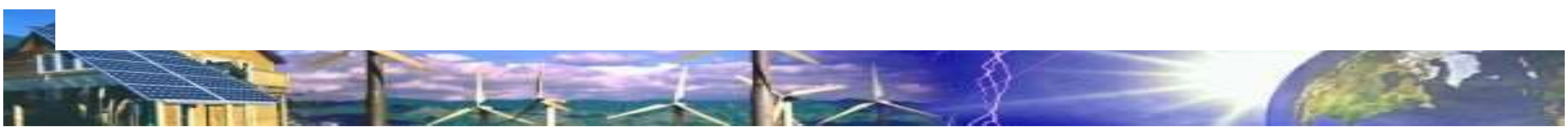


Module and Array design

Most commercial and industrial systems require a large number of collectors to satisfy the heating demand. Connecting the collectors with just one set of manifolds makes it difficult to ensure drainability and low pressure drop. It would also be difficult to balance the flow so as to have the same flow rate through all collectors

Module Design

A module is a group of collectors that can be grouped into parallel flow and combined series-parallel flow. Parallel flow is more frequently used because it is inherently balanced, has a low pressure drop, and can be drained easily. Figure 8.1 illustrates the two most popular collector header designs: external and internal manifolds.

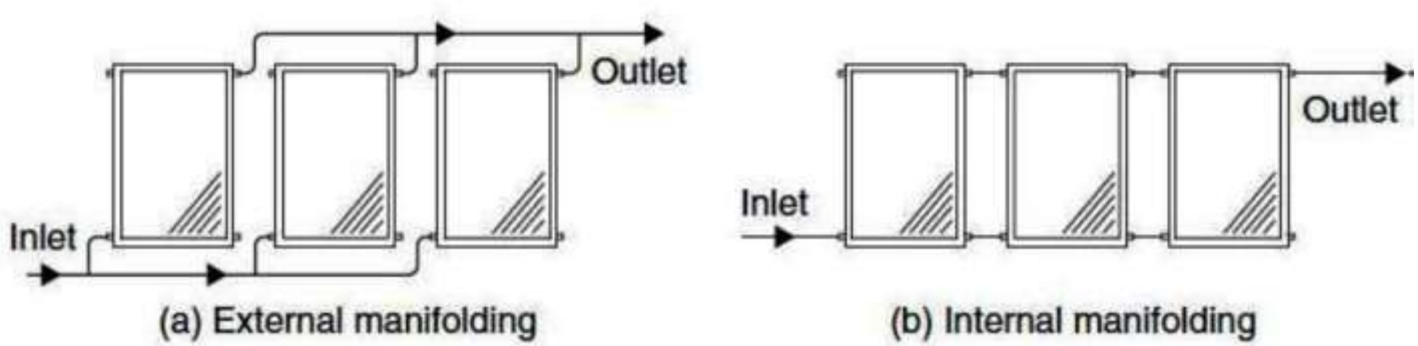


Figure 8.1 Collector manifolding arrangements for parallel flow modules

External manifold collectors are generally more suitable for small systems

. **Internal manifolding** is preferred for large systems because it offers a number of advantages. These are cost savings because the system avoids the use of extra pipes (and fittings), which need to be insulated and properly supported, and the elimination of heat losses associated with external manifolding, which increases the thermal performance of the system.

Module Design

When arrays must be greater than one panel high, a combination of series and parallel flow may be used, as shown in **Figure 8.2**. This is a more suitable design in cases where collectors are installed on an inclined roof.

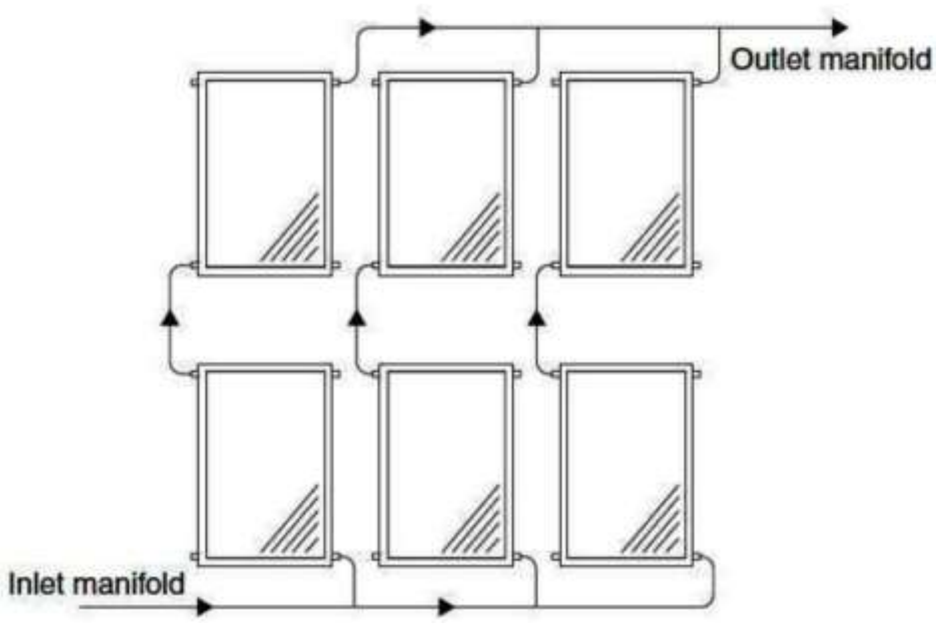


Figure 8.1 Collector manifolding arrangement for combined series-parallel flow modules

Array Design

Basically, two types of systems can be used: **direct return and reverse return**. In **direct return**, shown in **Figure 8.3**, balancing valves are needed to ensure uniform flow through the modules

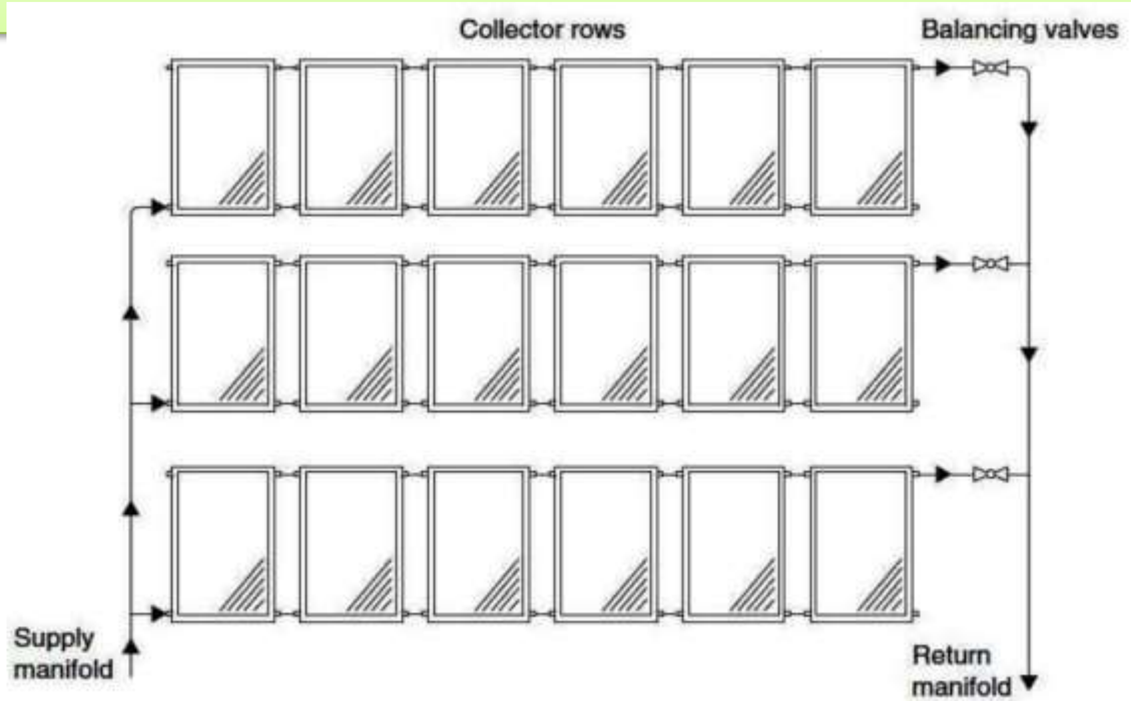
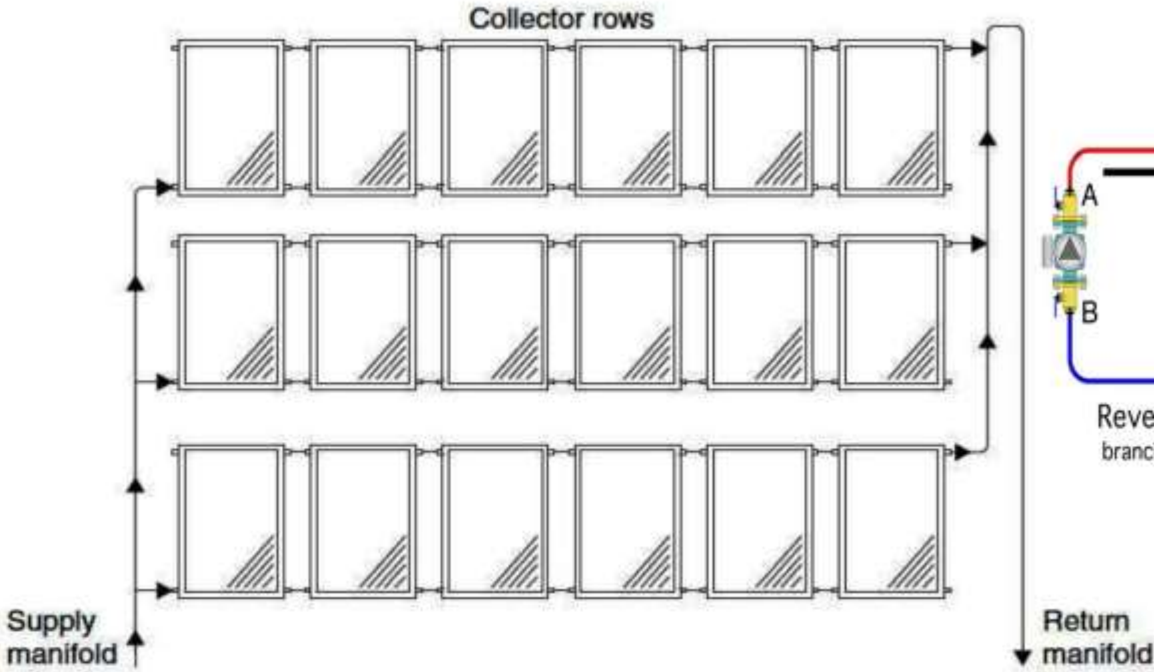
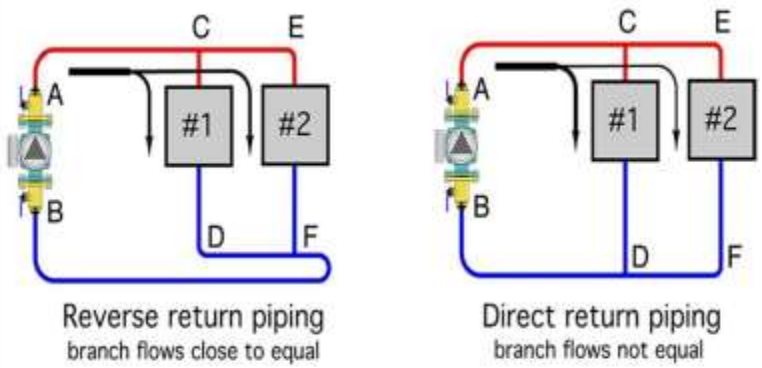


Figure 8.3 Direct-return array piping.

Array Design

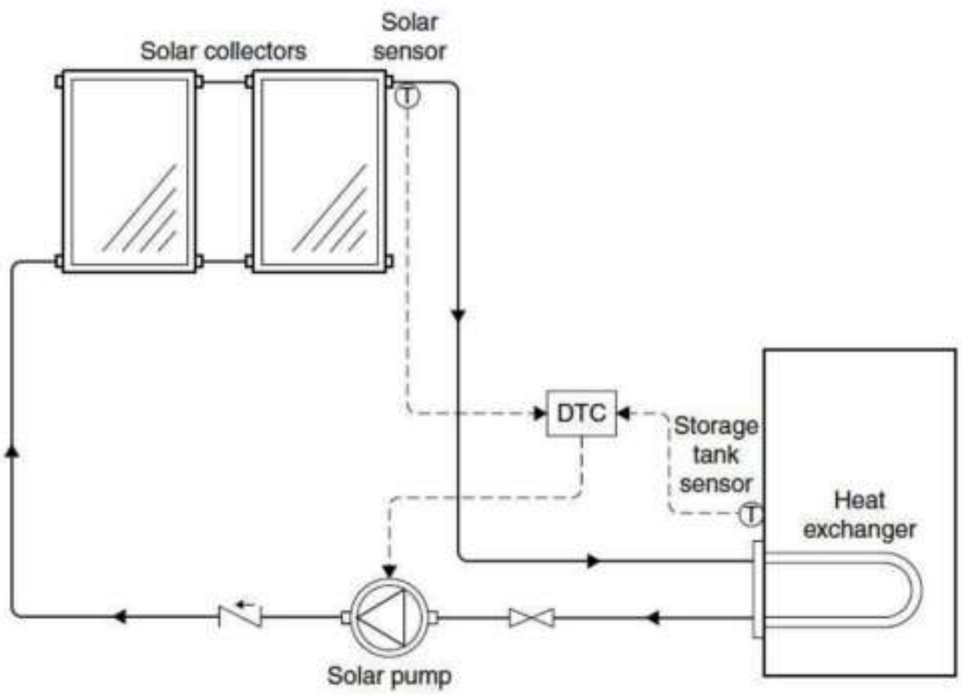
Whenever possible, modules must be connected in a reverse-return mode, as shown in **Figure 8.4**. The **reverse return** ensures that the array is self balanced, as all collectors operate with the same pressure drop

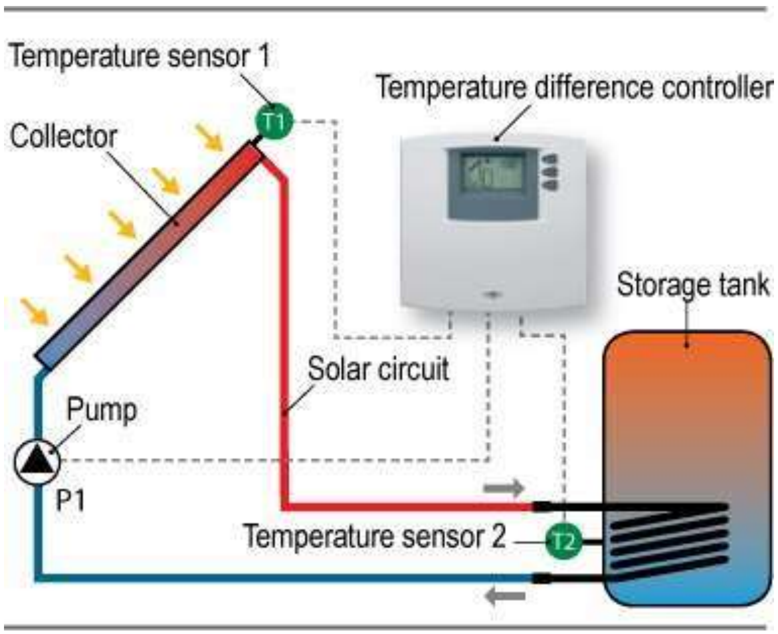




Differential temperature controller

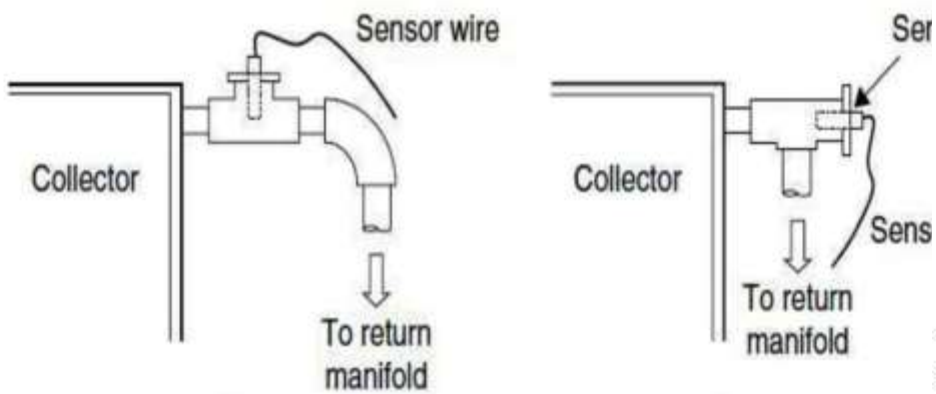
The basis of solar energy system control is the **differential temperature controller (DTC)**. This is simply a fixed temperature difference (ΔT) thermostat with hysteresis. The differential temperature controller is a comparing controller with at least two temperature sensors that control one or more devices. Typically, one of the sensors is located at the top side of the solar collector array and the second at the storage tank, as shown in Figure 8.5



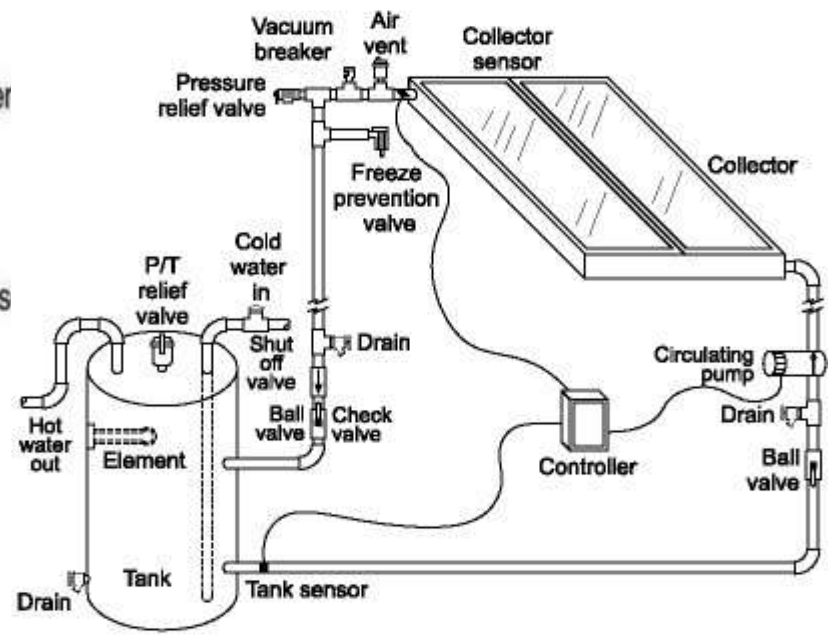


Placement of Sensors

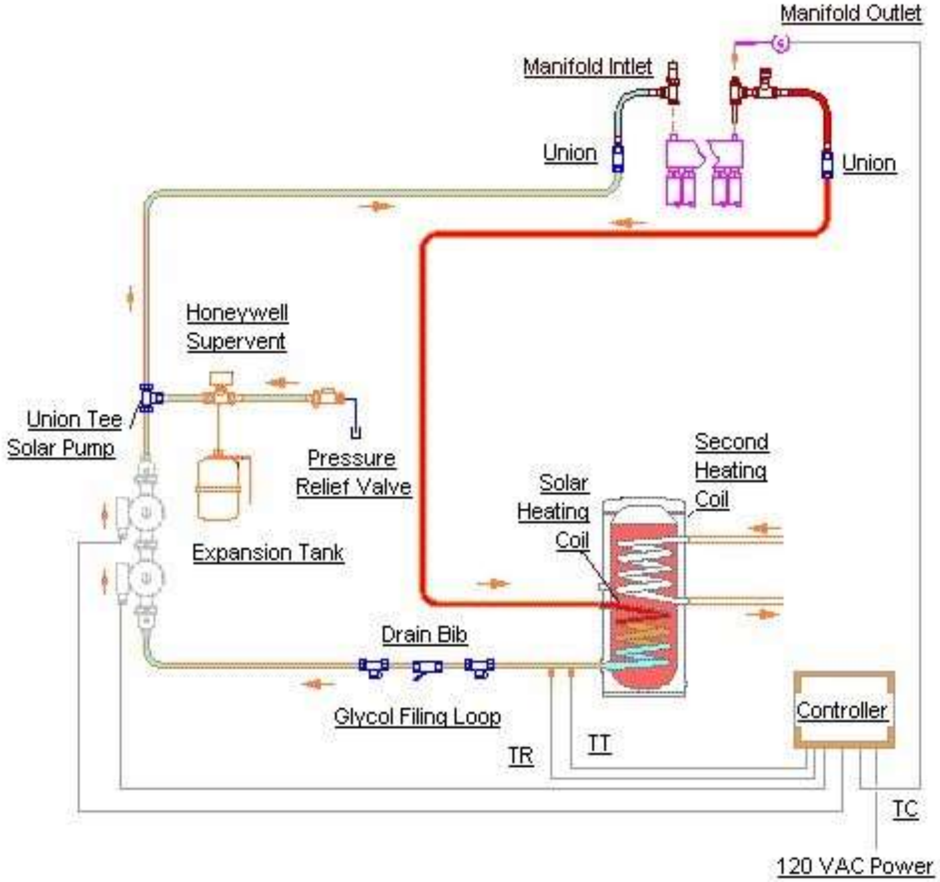
Usually a T piece is used and the sensor is placed in a deep well with a few drops of oil, which ensures good contact, as shown in Figure 8.6a, or on the side of the T piece, as shown in Figure 8.6b.



(a) Deep well (b) Side of T piece



Residential Solar Hot Water and Space Heating System



Hot water demand

The most important parameter that needs to be considered in the design of a water heating system is the hot water demand over a certain period of time (hourly, daily, or monthly). The energy demand, L, required for the generation of sanitary hot water can be obtained if the volumetric consumption, V, is known for the required time period. Also required are the temperatures of the cold water supplied by public mains, Tm, and the water distribution, Tw. Then

$$L = V \rho c_p (T_w - T_m)$$

for the monthly water demand, the following equation can be used:

$$V = N_{days} N_{persons} V_{person}$$

where

N_{days}: number of days in a month.

$N_{persons}$: number of persons served by the water heating system.

V_{person}: Volume of hot water required per person.

Hot water demand

Example : Estimate the hot water energy demand for a family of four, with medium normal consumption, cold water mains supply of 18°C, and water distribution temperature of 45°C.

Solution:

According to Table 3.4, the consumption per day per person is 40 L. Therefore, the daily demand, V, is 160 L/d or 0.16 m3/d.

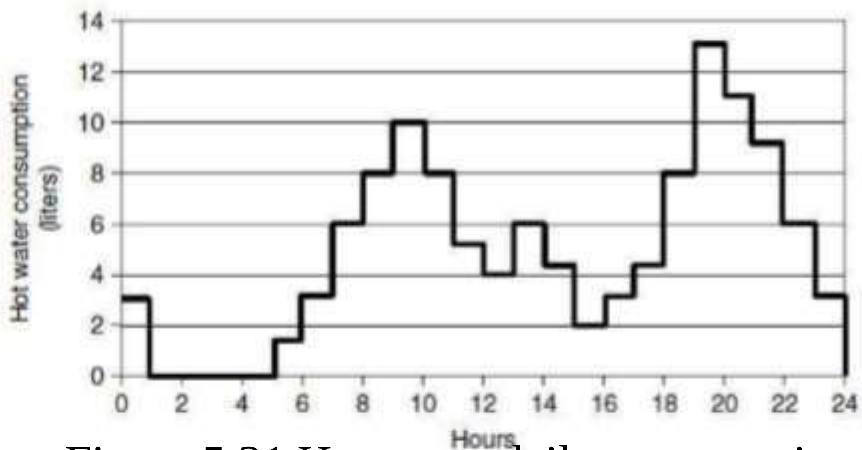


Figure 5.31 Hot water daily consumption profile

Guideline	Low	Medium	High
Normal consumption	26	40	54
Maximum consumption	66	85	104

Table 3.4 Hot Water Daily Demand for a Family of Four Persons in Liters per Person

Hot water demand

Example2 : Estimate the % energy savings of an electric water heater that heats 100 gallons of per day when the temperature is set back at 110° instead of 120°F. The basement is heated and is at 65°F. The life of the water heater is expected to be about 10 years. Use an appropriate cost for electricity and compare the operating expenses..

Solution:

Heat required (BTU) = m x C_p x (Temperature Difference)
Where C_p is the heat capacity of water (1 BTU/lb/F) and m is the mass of the water (Assume 1 gal has 8.3 lb of water and the 3,412 BTU = 1 kWh)

Hot water demand

Solution:

Energy required for heating the water to 120°F:

$$= \mathrm{m} \times \mathrm{C_p} \times \Delta \mathrm{T}$$

$$= \underbrace{\frac{100\ \mathrm{gal}}{\mathrm{day}} \times \frac{8.3\ \mathrm{lb}}{\mathrm{gal}}}_{\mathrm{m}} \times \underbrace{\frac{1\ \mathrm{BTU}}{\mathrm{lb}\ {}^\circ\mathrm{F}}}_{\mathrm{C_p}} \times \underbrace{(120 - 65)\ {}^\circ\mathrm{F}}_{\Delta \mathrm{T}}$$

$$= \frac{100\ \cancel{\mathrm{gal}}}{\mathrm{day}} \times \frac{8.3\ \cancel{\mathrm{lb}}}{\cancel{\mathrm{gal}}} \times \frac{1\ \mathrm{BTU}}{\cancel{\mathrm{lb}}\ \cancel{{}^\circ\mathrm{F}}} \times (120 - 65)\ \cancel{{}^\circ\mathrm{F}}$$

$$= 45{,}650\ \mathrm{BTU/day}$$

Hot water demand

In a year the energy required is:

$$\frac{45{,}650\ \text{BTU}}{\cancel{\text{day}}} \times \frac{365\ \cancel{\text{days}}}{\text{year}} = 16{,}662{,}250\ \text{BTUs per year}$$

In a 10-year period, the energy required is 166,622,500 BTU which is equal to 48,834 kWh.

$$166{,}622{,}500\ \cancel{\text{BTU}} \times \frac{1\ \text{kWh}}{3{,}412\ \cancel{\text{BTU}}} = 48{,}834\ \text{kWh}$$

Operating cost over its lifetime is:

$$\frac{48{,}834\ \cancel{\text{kWh}}}{1} \times \frac{\$0.09}{\cancel{\text{kWh}}} = \$4{,}395.06$$

Hot water demand

Energy required for heating the water to 110°F:

$$= \mathrm{m} \times \mathrm{C_p} \times \Delta \mathrm{T}$$

$$= \underbrace{\frac{100\ \mathrm{gal}}{\mathrm{day}} \times \frac{8.3\ \mathrm{lb}}{\mathrm{gal}}}_{\mathrm{m}} \times \underbrace{\frac{1\ \mathrm{BTU}}{\mathrm{lb}\ ^{\circ}\mathrm{F}}}_{\mathrm{C_p}} \times \underbrace{(110 - 65)\ ^{\circ}\mathrm{F}}_{\Delta \mathrm{T}}$$

$$= \frac{100\ \cancel{\mathrm{gal}}}{\mathrm{day}} \times \frac{8.3\ \cancel{\mathrm{lb}}}{\cancel{\mathrm{gal}}} \times \frac{1\ \mathrm{BTU}}{\cancel{\mathrm{lb}}\ \cancel{^{\circ}\mathrm{F}}} \times (110 - 65)\ \cancel{^{\circ}\mathrm{F}}$$

$$= 37{,}350\ \mathrm{BTU/day}$$

In a year, the energy required is:

$$\frac{37{,}350\ \mathrm{BTU}}{\cancel{\mathrm{day}}} \times \frac{365\ \cancel{\mathrm{days}}}{\mathrm{year}} = 13{,}632{,}750\ \mathrm{BTUs\ per\ year}$$

Hot water demand

In a 10-year period, the energy required is 136,327,500 BTU which is equal to 39,995 kWh .

$$136{,}327{,}500\ \cancel{\text{BTU}} \times \frac{1\ \text{kWh}}{3{,}412\ \cancel{\text{BTU}}} = 39{,}995\ \text{kWh}$$

Operating cost over its lifetime is:

$$\frac{39{,}955\ \cancel{\text{kWh}}}{1} \times \frac{\$0.09}{\cancel{\text{kWh}}} = \$3{,}595.95$$

Estimated % Energy Savings:

$$\$4{,}395.06 - \$3{,}595.95 = \$799.11\ \text{savings}$$

$$\frac{\$799.11}{\$4{,}395.06} = 18.2\%\ \text{savings}$$

Do You Have Any Questions?