CH. 1

LITERATURE SURVEY

1.1. Introduction

In this chapter, we are talking about the Sun & the solar energy. The sun is a star, not much different from the billions of others in the universe. The main difference to us is that the sun is our star. Because we are much closer to the sun, its energy is more intense than that of the other stars and we can make use of its energy to meet our needs. The Sun radiant power comes from nuclear fusion processes, during which the sun loses 4.3 million tones of mass each second. This mass is converted into radiant energy; each square meter of the sun's surface emits a radiant power of 63.1 MW, which means that just a fifth of a square kilo-meter of the sun's surface emits an amount of energy equal to the global primary energy demand on earth.

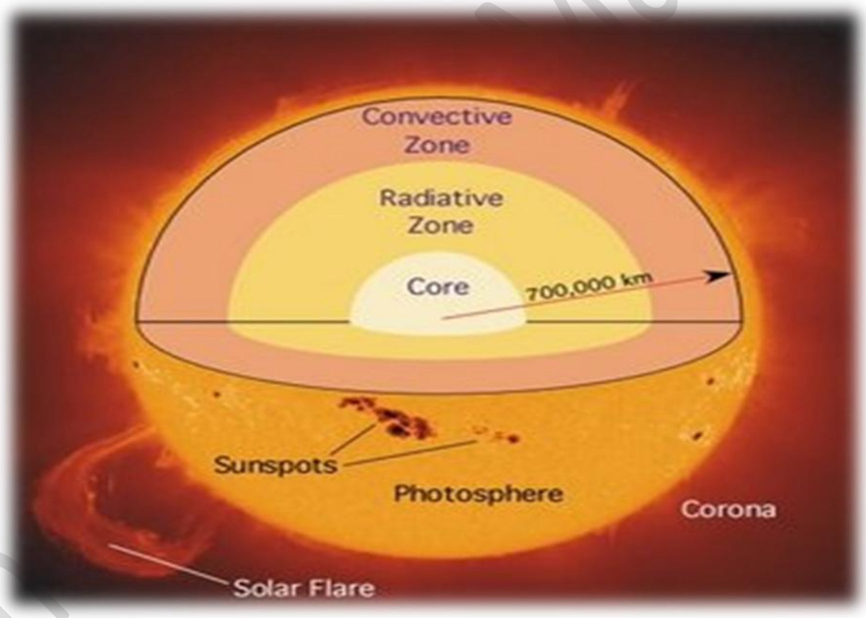

Fig 1.1 the Sun construction

The Greeks called the Sun it Helios, the Romans called it Sol. The Sun is, at present, about 70% Hydrogen, and 28% Helium by mass, everything else ("Metals") is less than 2%. This changes slowly over time as the Sun converts hydrogen to helium in its core. The Sun's energy output in each second is the result of conversion of about 700,000,000 tons of hydrogen into 695,000,000 tons of helium and

5,000,000 tons of energy (386 billion billion megawatts) is produced by Nuclear Fusion reactions. As it travels out toward the surface, the energy is continuously absorbed and re-emitted at lower and lower temperatures so that by the time it reaches the surface of the Sun, it is primarily visible light. For the last 20% of the way to the surface, the energy is carried more by Convection than by radiation. The surface of the Sun, called the photosphere, is at a temperature of about 5800 K.

A small region known as the chromospheres lies above the photosphere, the highly rarefied region above the chromospheres, called the corona, extends millions of kilometers into space but is visible only during a total solar eclipse (left). Temperatures in the corona are over 1,000,000 K.

For Solar systems designers, solar radiation characteristics and its natural should be understood. They must know the angles of solar radiations that fall on Earth to be able to calculate the amount of energy that can be useful for our demand and applications.

In solar water heating systems or solar electricity generation, we use solar collectors. We show the different types of solar collectors, its applications and the different devices used in the system.

In our solar water heating system we use the flat plate collector in thermo siphon solar water heating system.

1.2. Solar Energy

1.2.1 Solar Radiation characteristics

The sun fusion process generates intense energy that travels outwards as electromagnetic radiation. Electromagnetic radiation from the Sun takes the form of visible light (41%), Ultra violet, X rays, and Gamma rays (9%), and shortwave infra red energy (50%).

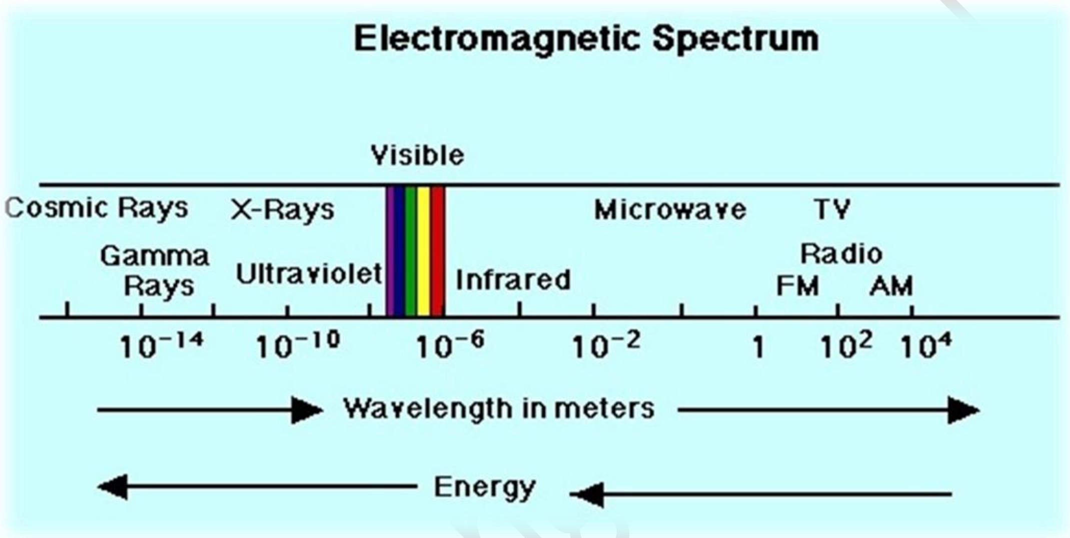

fig1.2 solar spectrum

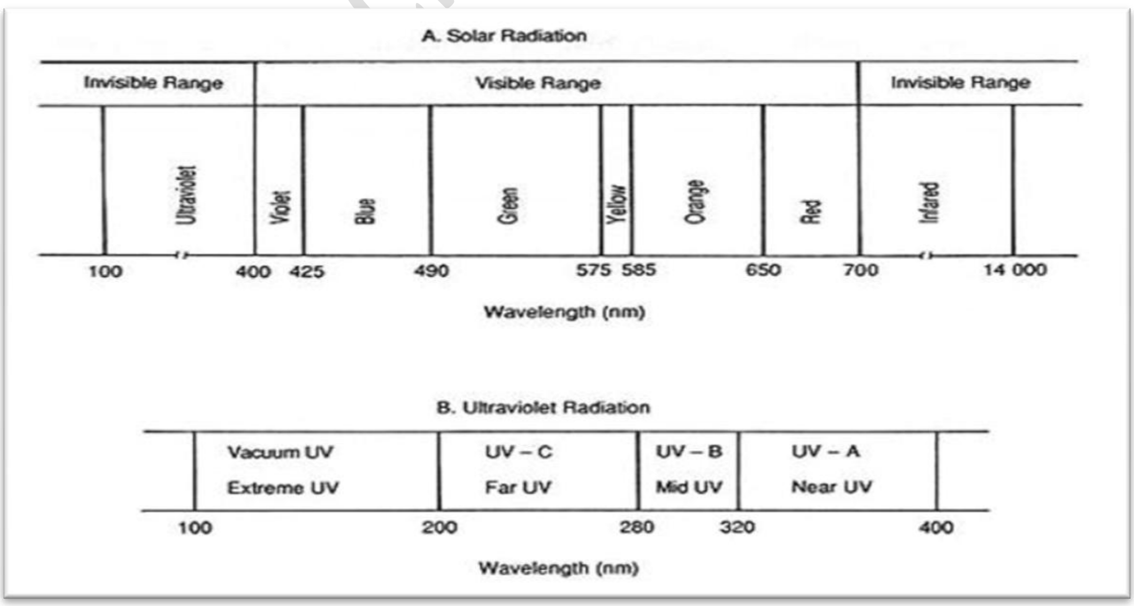

Fig 1.3 visible light wave length

Fortunately, only a small part of this energy reaches the earth's surface. Solar irradiance decreases with the square of the distance to the sun. Since the distance of the earth to the sun changes during the year, solar irradiance outside the earth's atmosphere also varies between 1325 W/m² and 1420 W/m². The annual mean solar irradiance is known as the solar constant and is 1367±2 W/m².

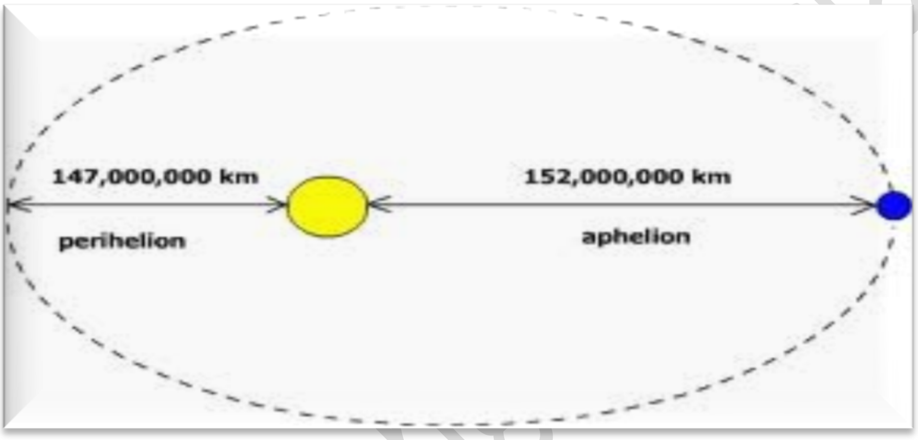

Fig 1.4 the Earth position during the year

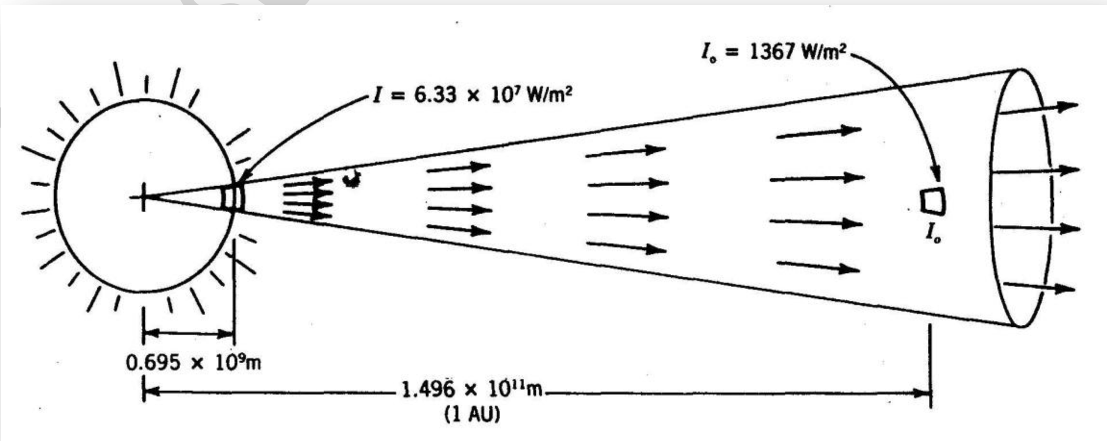

Fig 1.5 the divergence of energy from the sun to the earth.

Also atmosphere has its effect on solar intensity. As solar radiation passes through the earth's atmosphere, it is absorbed (the reason for some atmospheric heating), reflected (the reason astronauts can see the earth from outer space), scattered (the reason one can read this book in the shade under a tree), and transmitted directly (the reason there are shadows). At the surface of the earth, the sun has a lower intensity, a different color, and a different shape from that observed above the atmosphere.

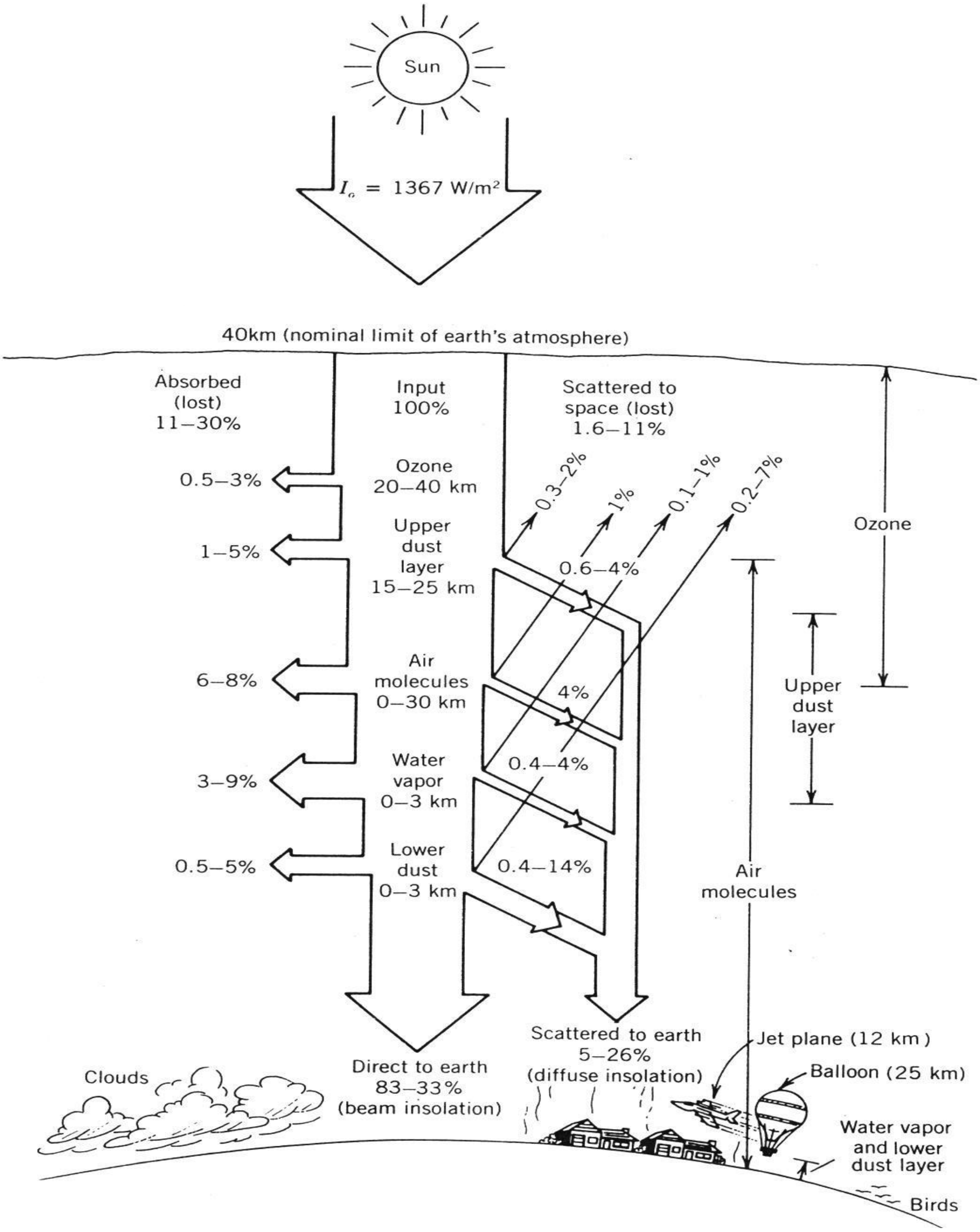

Fig 1.6 the effect of atmosphere on solar radiation falls on sun

1.2.2 Solar Angles & Energy calculations for Earth:

In order to understand how to collect energy from the sun, one must first be able to predict the location of the sun relative to the collection device. The sun position expressions are used to demonstrate how to determine the location of shadows and the design of simple sundials.

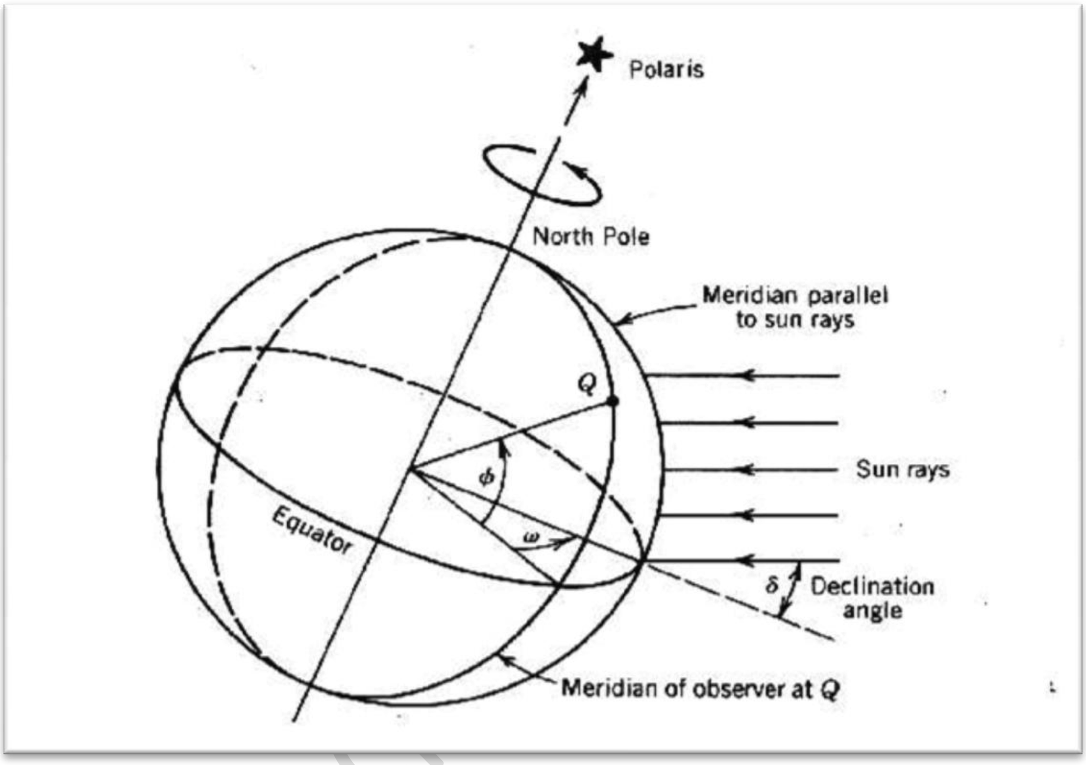

Fig 1.7 the angles of incident radiation on Earth surface

- **The Hour Angle (ω) :**

The hour angle is the angular distance between the meridian of the observer and the meridian whose plane contains the sun. The hour angle is zero at solar noon (when the sun reaches its highest point in the sky). The hour angle increases by 15 degrees every hour.

- **The Declination Angle (δ) :**

Equatorial plane is the plane that includes the earth. The declination angle (δ) it is the angle between the line that drawn between the earth and the sun and the earth's equatorial plane. In summer solstice it is the time of year when the northern part of the earth's rotational axis is inclined toward the sun; the earth's equatorial plane is inclined 23.45 degrees to the earth-sun line (about June 21), and the declination angle $\delta = +23.45$ degrees.

- **Latitude Angle (ϕ):**

  It is the angle between a line drawn from a point on the earth's surface to the center of the earth, and the earth's equatorial plane. The tropics represent the highest latitudes where the sun is directly overhead at solar noon, and the Arctic and Antarctic circles, the lowest latitudes where there are 24 hours of daylight or darkness. All of these events occur at either the summer or winter solstices.
- Of course if the solar radiation is incident on a surface tiltled to earth surface the **Tilt angle** will be included.
- This angles is used to calculate the **Solar Altitude, Zenith, and Azimuth Angles**

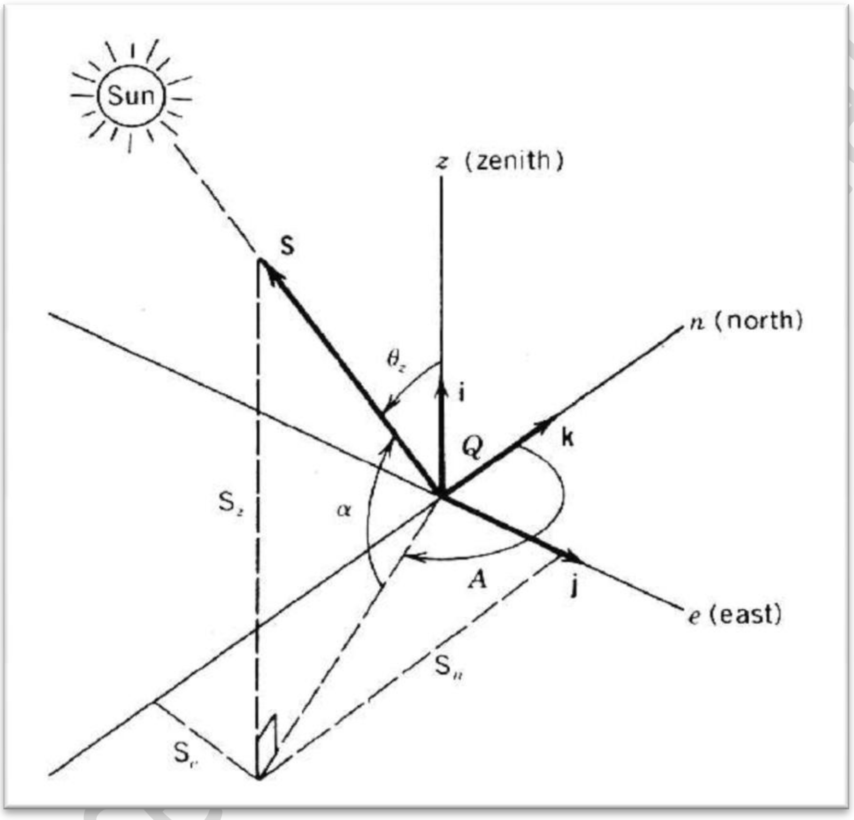

Figure 1.8 Earth surface coordinate system

- **The solar altitude angle (α)** is defined as the angle between the central ray from the sun, and a horizontal plane containing the observer.
- **The solar zenith angle (θ_z)** is simply the complement of the solar altitude angle.
- **Solar azimuth angle (A).** The other angle that defining the position of the sun. It is measured clockwise on the horizontal plane, from the north-pointing coordinate axis to the projection of the sun's central ray.

1.2.3 Useful Solar systems and applications

Solar energy can be useful by converting the sun's rays into electricity with the use of solar panels to supply power to the appliances use in our homes, converting the sun's rays into heat with the use of solar thermal collectors for warming water and is in our the swimming pools or converting the sun's rays into hot air for heating buildings or drying clothes . You can even cook food with solar energy.

With using thermal solar collectors we can convert sun rays into a form of thermal energy which can be used in any application or converted into any other form of energy.

1.3 Thermal Solar water heating systems

1.3.1 Introduction of Solar water heating systems

- **Solar water heating systems harness the sun's heat to pre-heat the water before it goes to your water heater, allowing it to use less conventional fuel (natural gas or electricity) to heat your water. Solar water-heating systems for domestic hot water include at least one "solar collector" that faces the sun to absorb its heat energy. Collectors can either heat water directly or heat a "working fluid" that's then used to heat the water indirectly through a heat exchanger. Propylene glycol is the most common working fluid and is an antifreeze solution. Unlike ethylene glycol (used in automobile radiators), propylene glycol is not toxic. In active solar water-heating systems, a pumping mechanism moves the heated water or fluid through the system. In passive solar water-heating systems, the water moves by natural convection. In most urban applications, flat plate solar collectors are placed on the roof of a building and used to pre-heat water which is stored in a supplemental storage tank. The system's storage tank is usually provided by the existing conventional water heater, a new high-efficiency conventional water heater designed to integrate with solar collectors, or a supplemental tank that stores only solar-heated water. In most cases, solar water-heating systems work together with conventional gas or electric water-heating systems.**
  - **Solar water heaters, sometimes called solar domestic hot water systems, may be a good investment for you and your family. Solar water heaters are cost competitive in many applications when you account for the total energy costs over the life of the system. Although the initial cost of solar water heaters is higher than that of conventional water heaters, the fuel (sunshine) is free. Plus, they are environmentally friendly. To take advantage of these heaters, you must have an unshaded, south-facing location (a roof, for example) on your property These systems use the sun to heat either water or a heat-transfer fluid, such as**

a water-glycol antifreeze mixture, in collectors generally mounted on a roof. The heated water is then stored in a tank similar to a conventional gas or electric water tank. Some systems use an electric pump to circulate the fluid through the collectors. Solar water heaters can operate in any climate. Performance varies depending, in part, on how much solar energy is available at the site, but also on how cold thewater coming into the system is. The colder the water, the more efficiently the system operates. In almost all climates, you will need a conventional backup system. In fact, many building codes require you to have a conventional water heater as the backup.

- **Solar Water Heater Basics**

Solar water heaters are made up of collectors, storage tanks, and depending on the system, electric pumps.

1.3.2 types of solar water heating systems

1.3.2.1 Passive systems

Passive systems are generally more reliable, easier to maintain, and possibly longerlasting than active systems.Passive systems move household water or a heat-transfer fluid through the system without pumps. Passive systems have no electric components to break. This makes them generally more reliable, easier to maintain, and possibly longer lasting than active systems.

Passive systems can be less expensive than active systems, but they can also be less efficient. Installed costs for passive systems range from about $1,000 to $3,000, depending on whether it is a simple batch heater or a sophisticated thermosiphon system.

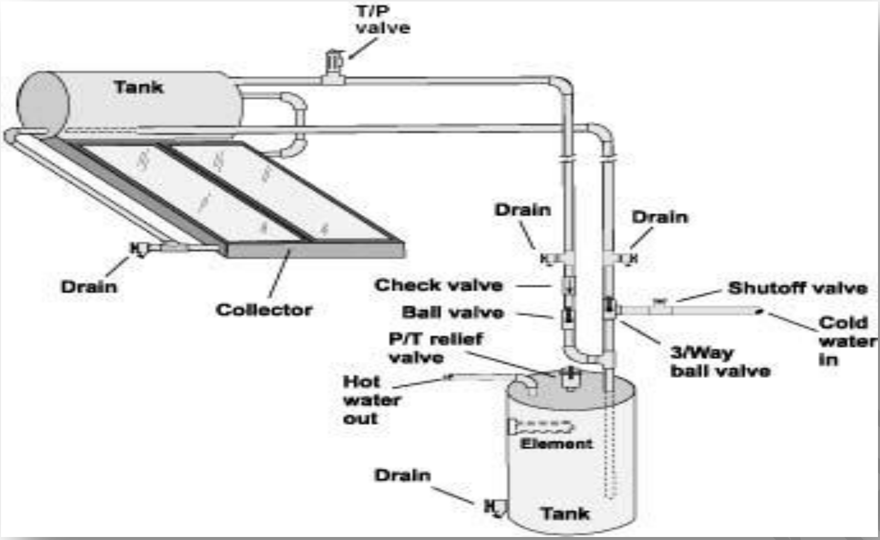

Figure 1.9 Passive system

1.3.2.2 Active systems

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. They are usually more expensive than passive systems but are also more efficient. Active systems are usually easier to retrofit than passive systems because their storage tanks do not need to be installed above or close to the collectors. But because they use electricity, they will not function in a power outage. Active systems range in price from about $2,000 to $4,000 installed.

- **Open-Loop Active Systems:**

Open-loop active systems use pumps to circulate household water through the collectors. This design is efficient and lowers operating costs but is not appropriate if your water is hard or acidic because scale and corrosion quickly disable the system. These open-loop systems are popular in nonfreezing climates.They should never be installed in climates that experience freezing temperatures for sustained periods. You can install them in mild but occasionally freezing climates, but you must consider freeze protection. Recirculation systems are a specific type of open-loop system that provide freeze protection.

They use the system pump to circulate warm water from storage tanks through collectors and exposed piping when temperatures approach freezing. Consider recirculation systems only where mild freezes occur once or twice a year at most. Activating the freeze protection more frequently wastes electricity and stored heat.

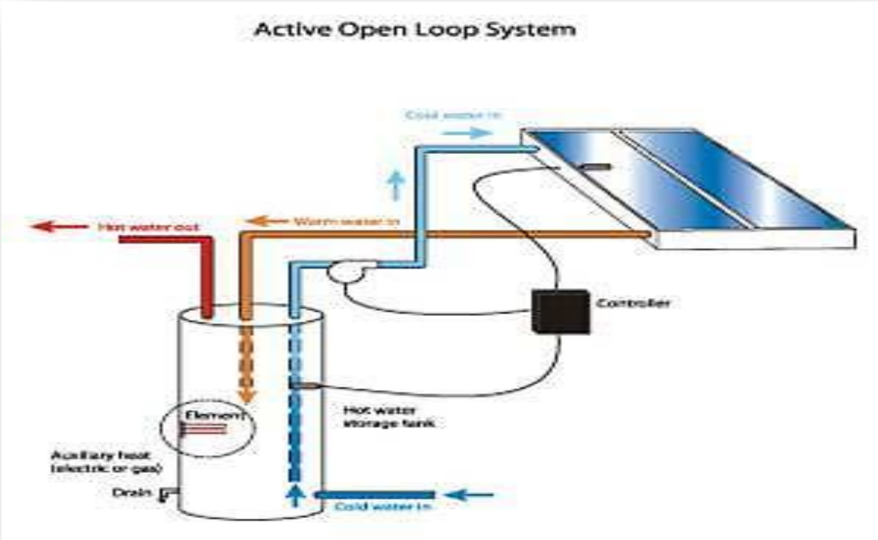

Figure 1.10 Open-Loop Active System

- **Closed-Loop Active Systems;**

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks. Double-walled heat exchangers prevent contamination of household water. Some codes require double walls when the heattransfer fluid is anything other than household water. Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection. However, glycol antifreeze systems are a bit more expensive to buy and install, and the glycol must be checked each year and changed every 3 to 10 years, depending on glycol quality and system temperatures. Drainback systems use water as the heattransfer fluid in the collector loop. A pump circulates the water through the collectors. The water drains by gravity to the storage tank and heat exchanger; there are no valves to fail.

When the pumps are off, the collectors are empty, which assures freeze protection and also allows the system to turn off if the water in the storage tank becomes too hot.

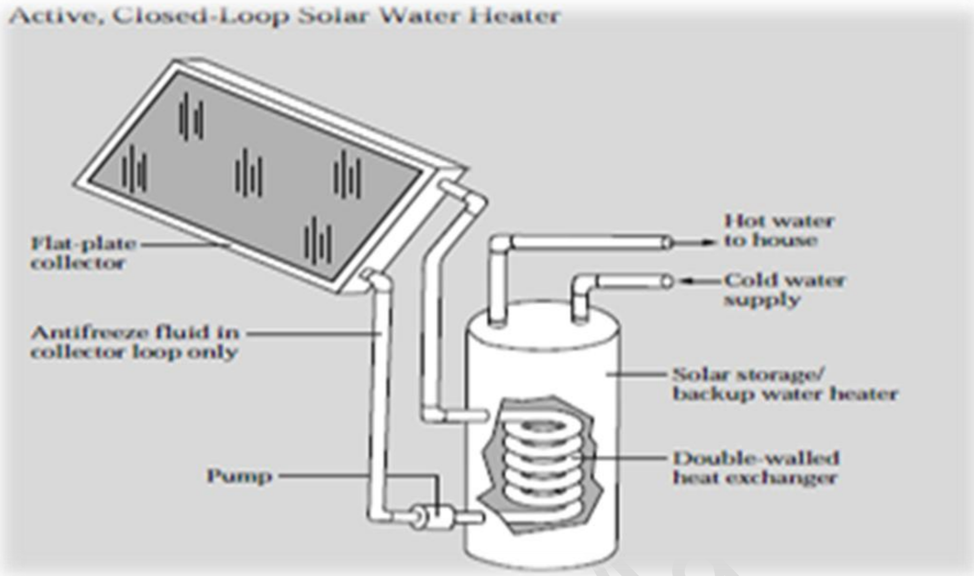

Figure 1.11 Closed-Loop Active Systems

1.3.3 Types of solar collectors for Water Heating

1.3.3.1 Flat plate collectors

A flat-plate collector, the most common type, is an insulated, weatherproofed box containing a dark absorber plate under one or more transparent or translucent covers.

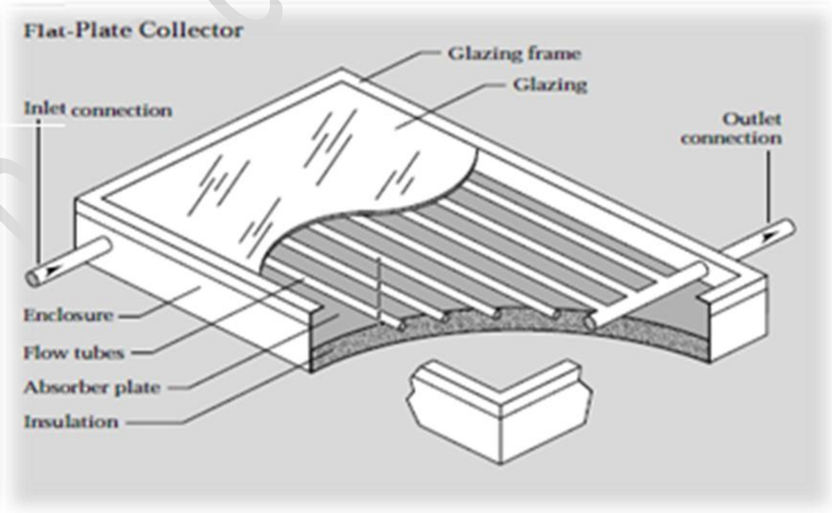

Figure1.12 Flat plate collector

1.3.3.2 Evacuated tube collectors

Evacuated-tube collectors are made up of rows of parallel, transparent glass tubes. Each tube consists of a glass outer tube and an inner tube, or absorber, covered with a selective coating that absorbs solar energy well but inhibits radiative heat loss. The air is withdrawn ("evacuated") from the space between the tubes to form a vacuum, which eliminates conductive and convective heat loss.

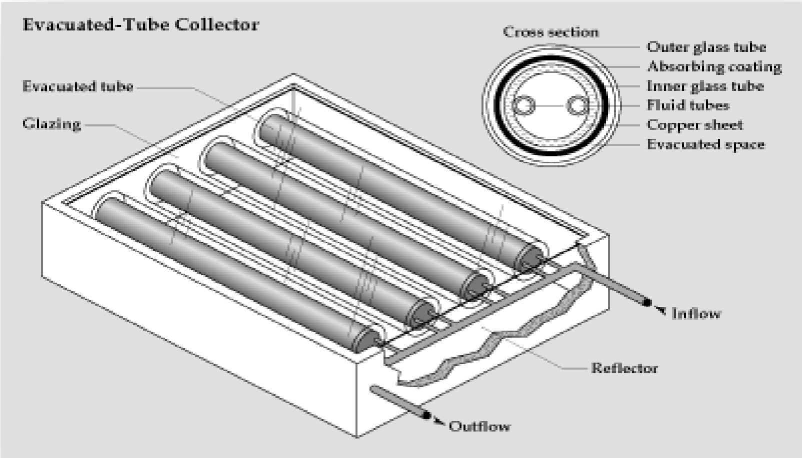

Figure1.13 Evacuated tube collector

1.3.4 Types of solar collectors for electricity generation

1.3.4.1 Parabolic trough

Concentrating collectors for residential applications are usually parabolic troughs that use mirrored surfaces to concentrate the sun's energy on an absorber tube (called a receiver) containing a heat transfer fluid. Most commercially available solar water heaters require a well-insulated storage tank. Many systems use converted electric water heater tanks or plumb the solar storage tank in series with the conventional water heater. In this arrangement, the solar water heater preheats water before it enters the conventional water heater. Some solar water heaters use pumps to recirculate warm water from storage tanks through collectors and exposed piping. This is generally to protect the pipes from freezing when outside temperatures drop to freezing or below.

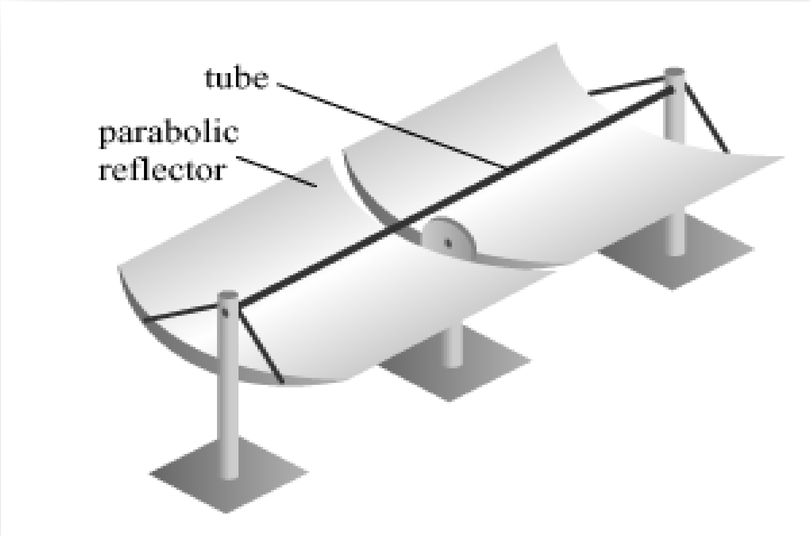

Figure1.14 Parabolic trough

1.3.4.2 Parabolic dish

It is the most powerful type of collector. One or more parabolic dishes concentrate solar energy at a single focal point, —similar to a reflecting telescope which focuses starlight, or to a dish antenna used to focus radio waves. This geometry may be used in solar furnaces and solar power plants. There are two key phenomena to understand in order to comprehend the design of a parabolic dish. One is that the shape of a parabola is defined such that incoming rays which are parallel to the dish's axis will be reflected toward the focus, no matter where on the dish they arrive. The second key is that the light rays from the sun arriving at the Earth's surface are almost completely parallel. So if the dish can be aligned with its axis pointing at the sun, almost all of the incoming radiation will be reflected towards the focal point of the dish—most losses are due to imperfections in the parabolic shape and imperfect reflection.

Losses due to atmosphere between the dish and its focal point are minimal, as the dish is generally designed specifically to be small enough that this factor is insignificant on a clear, sunny day. Compare this though with some other designs, and you will see that this could be an important factor, and if the local weather is hazy, or foggy, it may reduce the efficiency of a parabolic dish significantly.In dish stirling power plant designs, a stirling engine coupled to a dynamo, is placed at the focus of the dish, which absorbs the heat of the incident solar radiation, and converts it into electricity.

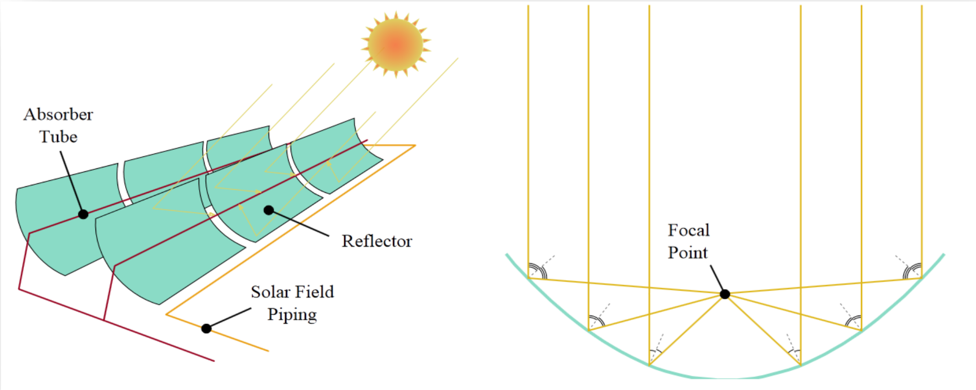

Figure1.15 Parabolic dish

1.4 Thermal storage systems

This chapter is concerned with three modes of thermal energy storage (TES), and these are sensible heat storage (SHS), latent heat storage (LHS), and bond energy storage (BES).

The SHS refers to the energy systems that store thermal energy without phase change. The SHS occurs by adding heat to the storage medium and increasing its temperature. Heat is added from a heat source to the liquid or solid storage medium.The thermal stratification is important for the SHS.

Heating of a material that undergoes a phase change (usually melting) is called the LHS. The amount of energy stored in the LHS depends upon the mass and latent heat of the material.

Developing efficient and inexpensive energy storage devices is as important as developing new sources of energy.

The thermal energy storage (TES) can be defined as the temporary storage of thermal energy at high or low temperatures.

Energy storage can reduce the time or rate mismatch between energy supply and energy demand, and it plays an important role in energy conservation. Energy storage improves performance of energy systems by smoothing supply and increasing reliability. For example, storage would improve the performance of a power generating plant by load leveling. The higher efficiency would lead to energy conservation and improve cost effectiveness. Some of the renewable energy sources can only provide energy intermittently.

Although the sun provides an abundant, clean and safe source of energy, the supply of this energy is periodic following yearly and diurnal cycles, The demand for energy, on the other hand, is also unsteady following yearly and diurnal cycles for both industrial and personal needs. Therefore the need for the storage of solar energy cannot be avoided

One of the important characteristics of a storage system is the length of time during which energy can be kept stored with acceptable losses. If solar energy is converted into a fuel such as hydrogen, there will be no such a time limit. Storage in the form of thermal energy may last for very short times because of losses by radiation, convection and conduction.

Another important characteristic of a storage system is its volumetric energy capacity, or the amount of energy stored per unit volume. The smaller the volume, the better is the storage system. Therefore, a good system should have a long storage time and a small volume per unit of stored energy.

1.4.1 Methods of thermal energy storage systems

There are three basic methods for storing thermal energy:

1.4.1.1 Sensible heat storage systems

Heating a liquid or a solid, without changing phase. This method is called sensible heat storage. The amount of energy stored depends on the temperature change of the material and can be expressed in the form $E = m \int_{T_1}^{T_2} C_p . dT$

where *m* is the mass and *C*p; the specific heat at constant pressure. *T*1 and *T*2 represent the lower and upper temperature levels between which the storage operates. The difference (*T*2 – *T*1) is referred to as the temperature swing.

1.4.1.2 Latent heat storage systems

Heating a material, which undergoes a phase change (usually melting): This is called latent heat storage. The amount of energy stored (*E*) in this case depends upon the mass (*m*) and latent heat of fusion (h_{fg}) of the material. Thus, $E = m\, h_{fg}$

The storage operates isothermally at the melting point of the material. If isothermal operation at the phase change temperature is difficult, the system operates over a range of temperatures *T*1 to *T*2 that includes the melting point. The sensible heat contributions have to be considered and the amount of energy stored is given by

$$E = m\left[\left\{\int_{T_1}^{T_*} C_{P,S}.\,dT\right\} + \mathrm{h_{fg}} + \left\{\int_{T_*}^{T_2} C_{p,l}.\,dT\right\}\right]$$

where Cp_s and Cp_L represents the specific heats of the solid and liquid phases and T^* is the melting point.

1.4.1.3 bond energy storage systems

Using heat to produce a certain physicochemical reaction and then storing the products. Absorbing and adsorbing are two examples for the bond reaction. The heat is released when the reverse reaction is made to occur. In this case also, the storage operates essentially isothermally during the reactions. However, the temperature at which heat flows from the heat supply is usually different, because of the required storage material and vice versa.

Bond energy storage systems are being proposed for use in the future for medium and high temperature applications.

1.4.2 Improvement of thermal storage techniques

The technology of thermal energy storage has been developed to a point where it can have a significant effect on modern life.

The major non-technical use of thermal storage was to maintain a constant temperature in dwelling, to keep it warm during cold winter nights. Large stones, blocks of cast iron, and ceramics were used to store heat from an evening fire for the entire night. With the advent of the industrial revolution, thermal energy storage introduced as a by-product of the energy production. A variety of new techniques of thermal energy storage have become possible in the past. A major application for thermal storage today is in family dwellings.

Heat storage at power plants typically is in the form of steam or hot water and is usually for a short time. Very recently other materials such as oils having very high boiling point, have been suggested as heat storage substances for the electric utilities. Other materials that have a high heat of fusion at high temperatures have also been suggested for this application.

Another application of thermal energy storage on the electric utilities is to provide hot water.

Perhaps the most promising application of thermal energy storage is for solar heated structures, and almost any material can be used for thermal energy storage.

The first-law efficiency of thermal energy storage systems can be defined as the ratio of the energy extracted from the storage to the energy stored into it $\eta = \frac{m\,C(\,T - T_O\,)}{m\,C\,(\,T_\infty - T_O\,)}$

Where mC is the total heat capacity of the storage medium and *T* , *T0* are the maximum and minimum temperatures of the storage during discharging respectively, and T_∞ , is the maximum temperature at the end of the charging period. Heat losses to environment between the end of discharging and the beginning of the charging periods, as well as during these processes are neglected. The first law efficiency can have only values less than one.

Two particular problems of thermal energy storage systems are the heat exchanger design and in the case of phase change materials, the method of encapsulation. The heat exchanger should be designed to operate with as low a temperature difference as possible to avoid inefficiencies.

If one tries to get an overview of heat storage systems one would be overwhelmed by the large number of possible technical solutions and the variety of storage systems.

The specific application for which a thermal storage system is to be used determines the method to be adopted. Some of the considerations, which determine the selection of the method of storage and its design, are as follows:

- The temperature range, over which the storage has to operate.
- The capacity of the storage has a significant effect on the. operation of the rest of the system. A smaller storage unit operates at a higher mean temperature. This results in a reduced heat transfer equipment output as compared to a system having a larger storage unit. The general observation which can be made regarding optimum capacity is that "short-term" storage units, which can meet fluctuations over a period of two or three days, have been generally found to be the most economical for building applications.
- Heat losses from the storage have to be kept to a minimum. Heat losses are particularly important for long-term storage.
- The rate of charging and discharging.
- Cost of the storage unit: This includes the initial cost of the storage medium, the containers and insulation.
- operating cost.

Other considerations include the suitability of materials used for the container, the means adopted for transferring the heat to and from the storage, and the power requirements for these purposes.

The time period over which this ratio is calculated would depend upon the nature of the storage unit. For a short-term storage unit, the time period would be a few days, while for a long-term storage unit it could be a few months or even one year.

For a well-designed short-term storage unit, the value of the efficiency should generally exceed 80 percent.

Table 1 gives an overview of thermal energy storage methods

Sensible Heat	Temperature change of the medium with highest possible heat capacity	• Liquid	Hot water, organic liquids, molten salts, liquid metals
		• Solid	Metals, minerals, ceramics
Latent Heat	Essentially heat of phase change	• Liquid-Solid	Nitrids, clorides, hydroxides, carbonates, flourides, entectics
		• Solid-Solid	Hydroxids
Bond Energy	Large amount of chemical energy is absorbed and released due to shifting of equilibrium by changing pressure and temperature	• Solid-Gas	CaO/H_2O, MgO/H_2O, $FeCl_2/NH_3$
		• Gas-Gas	CH_4/H_2O
		• Liquid-Gas	$LiBr/H_2O$, $NaOH/H_2O$, H_2SO_4/H_2O

1.4.3 applications in solar water heating systems

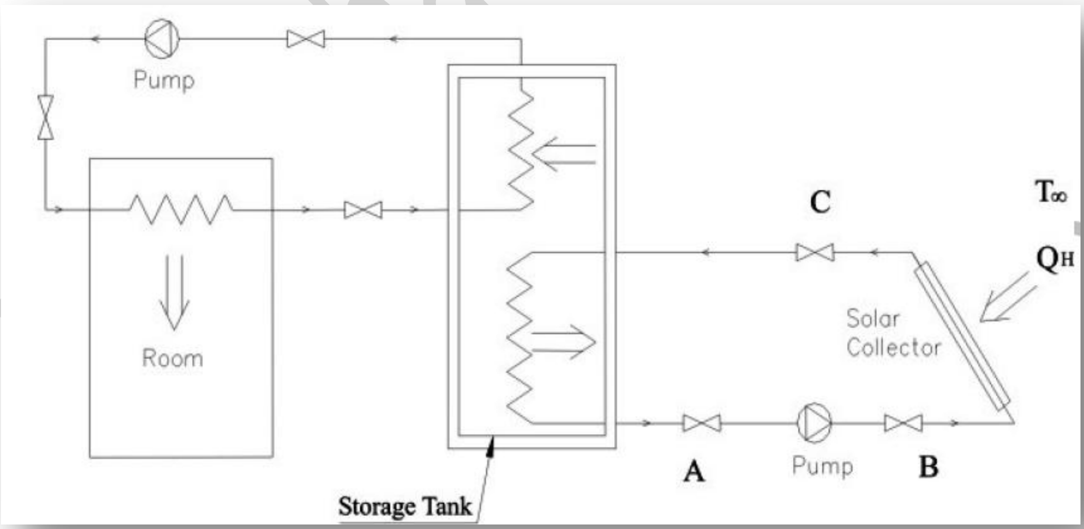

Figure 1.16 solar water heating systems

Consider the thermal energy storage system shown schematically in Figure 2. The system consist of a large liquid bath of mass m and specific heat C placed in

an insulated vessel. The system also includes a collector to give the collector fluid a heat gain and a room in which this heat gain is discharged.

Operation of the system takes place in three steps; charging, storage and removal processes. At the beginning of the storage process valves A, B, C are opened. Hot fluid from the collector at temperature T_{is} enters the system through valve C. This hot collector fluid is cooled while flowing through the heat exchanger 2 immersed in the bath and leaves at the bottom of the system at temperature T_{es}. The heat carrying liquid is then pumped to the collector with the help of pump 2. The fluid entering the collector takes Q_H from the sun and its temperature increases to T_{is} and the storage cycle is completed. While the hot gas flowing through the heat exchanger 2, the bath temperature T_b and fluid exit temperature of storage process T_{es} approach the hot fluid inlet temperature of storage process T_{is}. The heating process is allowed to continue up to the desired storage material (water) temperature. At that desired moment the valves A, B, C are closed. After the storage period D, E, F are opened, so the removal process begins. Cold fluid with constant mass flow rate flows through valve F and gets into the heat exchanger 1 and it receives energy from the liquid bath then leaves the system through valve D. This heated fluid is then pumped to the radiator to give heat to the medium (room) and the removal cycle is completed.

The system includes two controlling units to control the fluid temperatures. One of them is located at the collector outlet. This unit measures the temperature of the fluid at the collector outlet and compares it with the temperature in the tank. If the tank temperature is higher than the collector outlet temperature it stops the pump 2 automatically. The other controlling unit is located at the radiator outlet. If the radiator outlet temperature is higher than the tank temperature it stops the pump 1 automatically.

Many other applications of thermal heat storage are used in solar water heating system such as:

In flat plate collector solar water heating system the main thermal energy storage system is the storage tank which keeps the working fluid warm for required duration according the designs. For obtaining this task the storage tank should be insulated very well from the outside environment. It also obtains the heat exchange process between the warm working fluid and the cold feed water continuously so that it has an important task in the cycle.

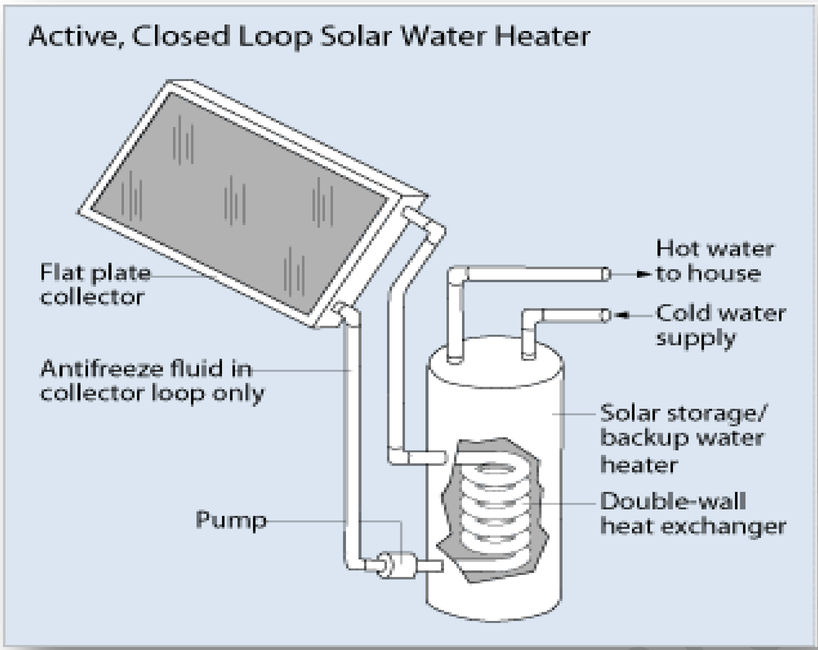

Fig 1.17 solar water heating system

Another example is of latent heat storage systems is shown in the following figure

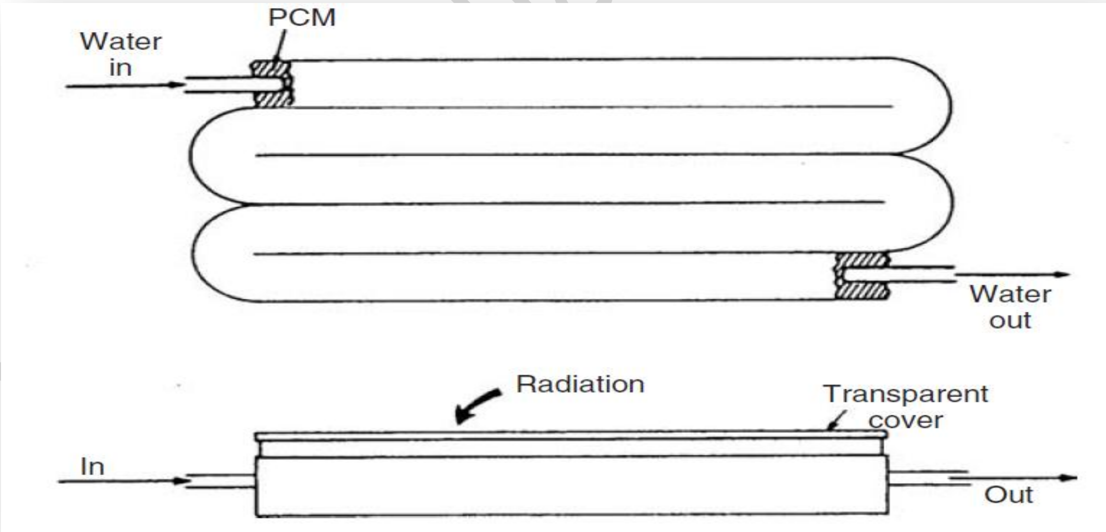

Fig 1.18 It is a solar thermal collector with tubes contained in PCM covered by other tubes to increase the heat consumed from sun during day.

1.5 Summary

In our project we use a flat plate solar collector in a solar water heating system.

In our project we use combined thermal energy storage system.

First we use the insulated storage tank containing water and this is a form of sensible heat storage system in which the change would be in the temperature of liquid water.

After that we use capsules filled with paraffin wax which is a phase change material and having a melting point at temperature of 50^{o}C inside the storage tank beside water, so that we use the two methods of thermal energy storage systems. We use sensible heat storage system due to rise in water. And we use latent heat storage system when we use encapsulated PCM inside storage tank.

Now we consider that latent heat storage is better than sensible heat storage so it is expected that we enhance the efficiency of storage system and hence of cycle.