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ENERGY EFFICIENCY

Energy efficiency mean efficient energy use in an any application or in any device. Also, we can say Energy efficiency, means using less energy to provide the same level of energy. For example, if a house is insulated, less energy is used in heating and cooling to achieve a satisfactory temperature. Another example is installing fluorescent lights or skylights, instead of incandescent lights, to attain the same level of illumination. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production process or by application of commonly accepted methods to reduce energy losses.

Energy efficiency is playing an increasingly vital role in our lives, for three main reasons:

1. The environment

The more energy we use, the more carbon emissions are pumped into the atmosphere and the more our reserves of natural resources such as oil, coal and gas are depleted. We need to reduce our reliance on these energy sources, and one way to do that is to make sure we all use energy as efficiently as possible.

2. The economy

The global economy is based heavily on oil and gas, and as these resources dwindle their cost will increase, causing financial imbalances around the world and resulting in energy poverty in many areas of society.

3. Money saving

Nobody wants to pay more than they have to for everyday necessities like heating and hot water, so it makes sense to be energy efficient. That way you fulfil your energy needs while paying as little as possible.

Energy Efficiency Ratio (EER)

An energy efficiency ratio is the ratio of the cooling capacity of any device (e.g air conditioner etc) measured in British Thermal Units (BTU) per hour to the total electrical input measured in watts. Air conditioners having high EER are considered to be most cost effective. For room air conditioners, it is called energy efficiency ratio or EER. For central air conditioners, it is called seasonal energy efficiency ratio or SEER. For instance, if a 10,000 BTU air conditioner consumes 2000 watts, then the EER of air conditioner is 10,000/2000 = 5. AC's with high EER consume less power but come with a higher price tag. The higher the ratio, the less the unit will cost to operate.

Making homes, vehicles, and businesses more energy efficient is seen as a largely untapped solution to addressing global warming, energy security, and fossil fuel depletion. Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily growing energy consumption. Energy efficiency often has taken a secondary position to new power generation as a solution to global warming in creating national energy policy. Some companies also have been reluctant to engage in efficiency measures, despite the often favourable returns on investments that can result. Modem energy-efficient appliances, such as refrigerators, freezers, ovens, stoves, dishwashers, and clothes washers and dryers, use significantly less energy than older appliances. Current energy efficient refrigerators, for example, use 40 percent less energy than conventional models did in 2001. Modem power management systems also reduce energy usage by idle appliances by turning them off or putting them into a low-energy mode after a certain time. Many countries identify energy-efficient appliances using an Energy Star label.

In industry, when electricity is generated, the heat which is produced as a by-product can be captured and used for process steam, heating or other industrial purposes. Conventional electricity generation is about 30 percent efficient, whereas combined heat and power (also called cogeneration) converts up to 90 percent of the fuel into usable energy. Advanced boilers and furnaces can operate at higher temperatures while burning less fuel. These technologies are more efficient and produce fewer pollutants. Using improved aerodynamics to minimize drag can increase vehicle fuel efficiency. Reducing vehicle weight can significantly also improve fuel economy. More advanced tires, with decreased tire to road friction and rolling resistance, can save gasoline. Fuel economy can be improved over three percent by keeping tires inflated to the correct pressure. Replacing a clogged air filter can improve a cars fuel consumption by as much as 10 percent.

SOLAR ENERGY STORAGE

Due to the intermittent nature of solar energy, storage of energy is required for night application. Both thermal and electrical energy can be stored for short and long periods of time for the betterment of human life and needs. The solar system is most economical without storage of energy and has many applications, particularly in PVT technology. A medium that stores all forms of energy to perform useful functions after some time is known as "energy storage." Forms of energy can be classified as follows:

(i) Potential energy: This takes the form of chemical, gravitational, electrical, temperature differential, latent heat. etc.

(ii) Kinetic energy: This takes the form of momentum.

Furthermore, there can be short- and long-term storage as follows:

Short-term storage:

In this type of storage energy is stored for short term. This storage utilized technologies, such as an insulated storage tank through sensible heat, directly store solar energy in the form of short-term energy. Even food, through the photosynthesis process, is a form of energy stored in chemical form. Solar energy is an intermittent and a time-dependent energy resource. It is available during sunshine hours. It can be stored for off-sunshine hours if required. It is stored for the use of energy requirements in day-to-day life.

Long-term storage: In this storage energy is stored for long term. various technologies, such as fossil fuels (coal, petroleum, natural gas), deep aquifers and bedrock, can store energy long-term. Fossil fuels indirectly store solar energy received by organisms and plants (dead and buried over a long period of time).

In general, the solar energy storage is classified in five categories viz. Thermal energy storage, Electrical energy storage, Chemical energy storage, Mechanical energy storage, electromagnetic energy storage. The overall solar energy classification tree is as shown in the Figure-1. Above all the thermal energy storage is commonly used for various applications.

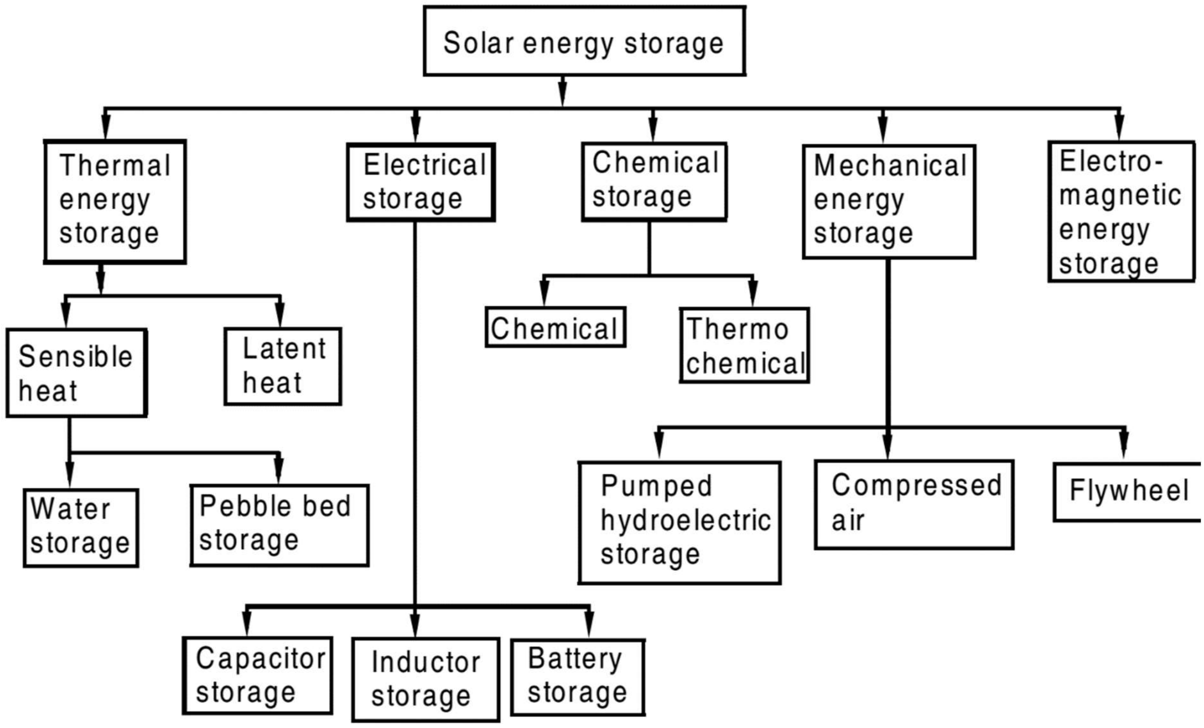

Figure-1 Solar energy storage classification tree

Commonly used thermal energy storage is further classified in three categories

1. Sensible heat storage
2. Latent heat storage
3. Chemical energy storage

1. Sensible heat storage

Sensible heat storage will be of two types, sensible heat in liquid or solid. The level of sensible heat-storage systems depends on the heat capacity and temperature difference during heating (charging) or cooling (discharging). It is observed that the amount of sensible-heat storage depends on the following parameters:

(i) higher specific heat;
(ii) higher thermal diffusivity
(iii) charging/discharging without loss of energy
(iv) low cost and maintenance
(v) stability

Liquid-Media Storage

Many liquids can be used for thermal storage. However, the water is most economically freely available with high heat capacity in abundant liquid for the short-term storage of thermal energy <100 °C. Water has the following advantages:

(a) It is nontoxic and non-combustible.

(b) It has low thermal conductivity and viscosity.

(c) The charging and discharging of energy can occur simultaneously.

Apart from the abovementioned advantages, water has some disadvantages. These are as follows:

(a) It freezes below 0 °C and boils over 100 °C.

(b) It is a corrosive medium.

(c) It has low surface tension and hence leaks easily.

Solid-Media Storage

Thermal energy (heat) can be stored in loosely, abundant available packed rock-bed material either in insulated box or underground for a temperature range of 100 °C with a solar air heater for space heating. It can also be used for much higher temperature ranges. The packed rock-bed material is simple in design with size ranging from 1 to 5 cm, is relatively low cost, and has a longer life. It is porous with a large surface area and facilitates fast heat transfer with a working fluid (water/air) as medium with minimum internal conductive loss. The amount of energy stored in a rock bed mainly depends on the thermo-physical properties of the rock bed, rock size and shape, rock porosity, etc.

Packed rock-bed storage material has following advantages:

(a) It is nontoxic and non-combustible.

(b) Use of a heat exchanger can be avoided.

(c) It lacks freezing and corrosion problems.

The system has also some disadvantages as follows:

(a) The storage capacity is large.

(b) There is a high pressure drop.

(c) Simultaneous charging and discharging is not possible.

Dual-Media Thermal Energy Storage (TES)

It is found that solid and liquid heat-sensible thermal-energy storage (TES) materials in the combined form provide a dual-media thermal energy storage. Some important dual media thermal energy storages are:

(a) Hybrid thermal energy storage: In this case, a water tank is surrounded by a rock bed and can be used for room and greenhouse space heating. Flat-place collectors connected in series are mounted on the inclined roof of a building/greenhouse that is connected to a system of water and a rock bed by water motor. The rock-bed water system is placed below the building/greenhouse in the basement. A hot-air blower is fitted between the room and the top of rock bed, which is porous. Furthermore there is connection between the floors of the building/greenhouse to the bottom of the rock bed to pass cold air of the building/greenhouse to the base of the rock bed. Furthermore, rocks and oil can be placed in a single insulated vessel.The rock-bed water system is placed below the building/greenhouse in the basement. In this case, the thermal energy produced by the concentrating collector at high temperature and pressure can be stored during the day, and power can be produced during the night. Such a system has been used for off-grid solar thermal-power applications.

(b) Concrete thermal energy storage: This system consists of a concrete floor, a concrete block, and packed gravel. There is provision of air flow thorough the concrete block for charging hot air and discharging cold air in the room. In the case of charging, hot air is circulated between the solar air collector and the concrete block. There is transfer of thermal energy from hot air to the packed gravel during charging (sunshine hours) and vice versa during discharging (off-sunshine hours). The packed gravel is porous to increase the surface area for maximum heat transfer. During discharging, the room air is allowed to flow between the room and the concrete block to the heat room.

(c) Ground thermal energy storage: It is well established that soil in the ground has a large thermal capacity and can act as a large reservoir of solar energy. It has insulating properties as well. Therefore, the ground can be potentially used for the storage of hot water available from solar energy at low temperature ranges.

2. Latent-Heat Storage (LHS)

Latent heat is thermal energy either absorbed (solar energy) or released by a substance during a phase change at constant temperature. The substance can be a solid or a liquid. Examples of phase change include the melting of ice (solid) into water (liquid) or the evaporation of water (liquid) into vapor (gas). In both examples, the temperature is constant. Most phase-change materials (PCM) have high thermal energy storage densities compared with sensible-heat storage materials. Latent-heat storage (LHS) systems are more expensive than sensible heat-storage media. For a latent-heat thermal-energy storage system, there are mainly three components as follows:

(a) a PCM for heat storage in a specific temperature range;
(b) a PCM container; and
(c) a heat exchanger for transferring heat between the working fluid and the PCM.

Applications of PCM Materials

Some important applications of phase change materials (PCM) in thermal storage systems are as follows:

(a) A Solar Cooker:
A cylindrical solar-cooker vessel is surrounded by PCM (with erythritol having a melting point of 118 °C and a latent heat of fusion approximately 339.8 kJ/kg) material. The PCM material is filled between the annular space between the outer surface of the cooking vessel and another cylindrical vessel. The outer surface is attached by a heat exchanger, which is connected to an evacuated tubular collector (ETC) through an insulated pipe. The flow of water between the ETC and the heat exchanger is under forced mode of operation. The cooking vessel has two hollow concentric aluminium cylinders. The hot water circulated through the heat exchanger placed in the PCM transfers its thermal energy to the PCM. All sides and the base of the conventional solar cooker can be surrounded by PCM materials to maintain a uniform temperature inside the cooking vessel. Even fluctuation of the temperature inside the cooking vessel is reduced.

(b) Greenhouse heating:

The floor of the greenhouse is constructed in a similar way except the packed gravel is replaced by the appropriate PCM material having a melting temperature of approximately the greenhouse temperature. In this case, thermal heating (charging) can be performed as follows.

(i) Hot air is passed from the solar flat-plate collector through a concrete porous block at a slow flow rate to enable maximum heat transfer between the hot air and the PCM material. In this case, the PCM material is melted when the passing hot air has a temperature greater than the melting temperature of the PCM material.

(ii) The hot water from a solar flat-place collector is passed at a slow flow rate through a heat exchanger placed between the concrete floor and the PCM material. The charging takes place in similar way as mentioned above.

(c) Space heating

In this case, thermal heating of room can be performed either through floor or facade heating. The design and construction of the floor and the facade of building depend on the level of heating needed and the size of the room.

(d) Solar water heating

In this case, a suitable PCM material with proper thickness and melting temperature is placed between the absorber and the back-insulating sheet. This can be a collection-cum-storage water heater/flat-plate water and air collector/evacuated tubular collector/concentrating collector. For such system, there will be no flow of fluid during sunshine hours due to the transfer of thermal energy from the absorber to the PCM material for the storage of heat (charging). Flow of fluid is required at the time of heating during night time (discharging).

(e) Waste-heat recovery

There is wastage of hot air (thermal energy) from an air conditioning unit; and wastage of hot water (thermal energy) from industries. A novel design of heat exchanger with a shell and a tube for low-temperature waste-heat recovery using PCM can be a good solution. The stearic acid (PCM material), which has melting temperature of 59 °C, fills the shell of the heat exchanger for thermal-energy storage. Hot waste fluid is used to flow through the tubes for the transfer of heat from the tubes to the shell during charging. During discharging, cold fluid is allowed to flow through tube, and heat is transferred from the PCM in the shell to the fluid.

3. Chemical-energy storage

Chemical energy is a form of potential energy. The storage capacity depends on its source. In this concept, energy is stored in the form of heat from chemical reactions. It is often of a larger magnitude than latent-heat storage. The idea of storing solar energy by the use of chemical reactions is not a new concept. Nature sores energy by the use of chemical reactions in photosynthesis. Chemical-energy storage (CES) is a two-step process, namely:

Endothermic (charging) mode: This describes a process or reaction in which the system absorbs thermal energy from its surroundings in the form of heat. Absorbed energy occurs either in the breaking or rearranging of chemical bonds. This produces more energetic species, which are stored.

Exothermic (discharging) mode: In this case, the reaction is reversed to produce thermal energy and regenerate the starting material.

A chemical-energy storage (CES) system has following advantages:

(i) The energy storage density of these systems are high.

(ii) These systems are suitable for high-temperature applications.

(iii) The chemical-reaction rate is fast.

(iv) These systems have fewer energy losses.

(v) It has easy transportability and an unlimited life.

Apart from these advantages, chemical energy storage (CES) has the following disadvantages:

(i) The underlying technology for CES is much more complex than the other two energy storage systems.

(ii) CES may have a hazardous effect on the environment.

The various types of CESs are:

(i) Hydrogen:

This is colourless, doorless, tasteless, and nontoxic gas and has potentials as a source of energy. It can be produced by the electrolysis of water (DC power from a PV module can be used for electrolysis). The produced H_2 gas can then be burnt to release heat, or it can be stored and/or distributed to the desired location.

(ii) Ammonia:

Ammonia can also be dissociated at realizable temperatures. Along with a heat engine, these reactions may form the basis of an efficient way to generate continuous electrical power from solar energy.

(iii) Liquid nitrogen:

Just like hydrogen, liquid nitrogen shows potential as a source of energy. It can be used to generate electricity or for refrigeration and cooling.

(iv) Oxy-hydrogen:

This is a mixture of oxygen and hydrogen. It releases high-pressure and high-temperature steam after ignition, which can be used to generate electricity.

(v) Biofuels and biomass:

This is another example of indirect solar energy chemical storage. It releases thermal energy after the burning of biofuels/biomass, which is stored in the bonds of molecules and atoms from photons of solar energy.