Energy Efficient Architecture
Lecture 9

Photovoltaic Generation

What is Photovoltaic Generation? Whatever we are going to get from the sun, a heat source, from this we convert and store to benefit from heat energy or to store light energy from the sun and use it in the form of electricity, these two are called Photovoltaic Generation. As you see in this picture, the sun that radiates as heat can be absorbed by the solar heat collector from which the heat is used to make hot water or heat interior spaces, this is to utilize the Sun's heat energy and then, the next one is Photovoltaic cells which uses the light from the sun, stores it in the photovoltaic cells and is used like electricity to power electrical appliances like light bulbs, lights or it can even be used in other electrical appliances such as televisions, fans, etc.

Advantages of Photovoltaic Generation - No need for fuel: Inexhaustible sunlight is used as the source of electrical energy. Clean energy: No emission of environmental pollutants such as NOx and CO2. The advantages of photovoltaic generation cannot be understated or overstated because the presence of the natural renewable energy sun can be primarily used to a great extent because it doesn't release any harmful gases that lead to ozone depletion. We also don't need any other external fuel to store or convert this type of energy and can be used to meet our everyday needs. No need for troublesome operations: System approach is automatic. There is no need to switch on or switch off the system when there is sun or no sun. This is an automatic operation, when there is sun this is going to start working automatically and when there is no sun, it is going to stop automatically. The occupant doesn't need a constant maintenance or building services team to maintain this type of a system. Simple system configuration, easy maintenance - since the system has no movable parts, maintenance is easy. Since this system as no movable part, maintenance is easy. It doesn't need any service management system or a separate person to maintain this. It is very easy for occupants to do themselves.

The Principle of Electricity Generation by Photovoltaic Cells - A photovoltaic cell stores the light energy from the sun and the light energy gets converted into your electricity. This is done by your photovoltaic cells. What happens is, on your PV cells, light energy falls upon them and gets trapped. Due to the presence of N-type silicon and P-type Silicon which gets accelerated due to the stored light energy and moves freely in the box in which it is stored and it gets activated. After it gets activated, it gets connected to your electrode, anode and cathode and can be connected to your electricity bulb and can be converted from light energy to electricity. To have a closer look, A photovoltaic cell comprises of P-type and N-type semiconductors with different

electrical properties, joined together. The joint between these two semiconductors is called 'P-N junction'. This system that converts light energy to electricity has both P-type and N-type semiconductors which have been connected towards P and N junction. This is the point at which your bulb can be connected or any other appliances can be connected to convert from light energy to electricity. Sunlight striking the photovoltaic cell is absorbed by the cell. The energy of the absorbed light generates particles with positive or negative charge (holes and electrons) which move about or shift freely in all directions within the cell. When the light has been struck on the photovoltaic cell, it activates the p-type and n-type within the box and it starts triggering the action by making it freely move throughout the box which creates a type of energy.

The electrons (-) tend to collect in the N-type semiconductor and the holes (+) in the P-type semiconductor. Therefore, when an external load such as an electric bulb or an electric motor, is connected between the front and back electrodes, electricity flows in the cell. The n type starts collecting negative electrons and the P-type starts collecting positive electrons which begin to combine and start creating electricity.

Photovoltaic Generation Output - when it is a fine day, from morning to evening when there is proper sunlight, it can provide a good amount of generation of electricity. When it is cloudy, the lux level or the light level fluctuates. Depending upon the presence of light, the output generation also varies. As you can see in this graph, it fluctuates from being more and less due to the presence of clouds that cannot be predicted. On a rainy day, the presence of sun is very minimal, almost nil and this makes the electricity being generated less. Just due to the presence of an overcast sky or scattered light the generated output by photovoltaic cells is also very less. Depending upon the climatic condition or the climatic zone where you are staying, if there is a very good amount of sunlight, it is much more beneficial for you to use photovoltaic cells. If you are staying in places where there is an overcast sky condition or there is no sunlight usually or very less amount of sunlight, the usage of photovoltaic cells becomes less effective. Photovoltaic Generation output varies depending on weather. On rainy or cloudy days when sunlight is not available, generation capacity drops. Electrical energy that can be extracted from sunlight shining on the Earth is approximately 130 W/m2 on a fine day. However, considering temperature increase and power conditioner efficiencies, the actual amount of electrical energy available from photovoltaic generation is approximately 100W/m2 at most. Even though it varies depending on the cloud condition or the weather in the place where you are situated, on a fine day when you have a very good amount of light, photovoltaic cells can produce almost 130 watts/m2 but due to the presence of higher temperatures and the heat loss that is going to happen, effectively what you can convert from 130 is 100 W/m2. Therefore a large photovoltaic module area is needed to generate a large amount of electric power. Higher the amount of PV

cells you have, the higher the amount of electricity that you are going to receive. Initial investment will be a little high but the returns of this investment will be almost three to five years after which you will be running electrical appliances free of cost.

Battery Technology - the one in which you are going to store this type of energy and you are going to use it but there is no source. Battery technology has grown rapidly due to the widespread use of rechargeable solid-state batteries in computers, vehicular applications and portable electronics. We have observed that batteries have been produced in large numbers and the efficiency of these batteries have also increased. For example, even the lamp lights we used earlier comprised of storage capacity of 1 hour but now a days we can have 19 hours of storage capacity for the same battery due to the advancement they've been making in the same field. Batteries contain a number of voltaic cells; each voltaic cell consists of two and half cells connected in series by a conductive electrolyte containing anions and cations. Each photovoltaic cell has two half cells which is being conducted in a series of conductive electrolyte which contains anions and cations and is going to create electricity. The anions are the positive ones and the cations are the negative ones. Batteries store electricity in a chemical form inside a closed-energy system. They can be recharged and reused as a power source in small appliances, machinery and remote locations. Advances in battery technology may one day help to solve our energy crisis. The articles on this page explore advances in battery power technologies. Inside the rechargeable battery or the normal battery, if you open even a small AA or AAA battery, what you'll observe is a black semi solid content which is being present inside, constantly moves and collects the positive and negative points and connected to create electricity. The same thing happens in battery technology as well. It has a liquid state inside, can be recharged, reused and it creates or stores electricity and this is mainly advantageous or your dislocated from your energy source and you need to store energy and use it later on, this system becomes very effective.

Next is, Thermal Storage. What you have seen in battery storage is storing electricity and the thermal storage in which you are going to store your heat energy. Why store energy? Solar energy is a time-dependent energy source. Load does not match available energy. Cost consideration - avoid peak use and short term or long term storage. The heat that is produced in solar energy is restricted for a typical Indian condition - morning six to evening six. After that we don't have solar energy. If we need to use the same solar energy, it is ideal to store the thermal energy during the morning time and utilize it at night. Load does not match available energy. You might require peak energy at places at times when there is no sun at all. For that you might need to store the energy and use it when you need it on a full effective scenario. Cost consideration - avoid peak usage - short term or long term storage. It can vary between the two especially if you are storing the energy during the day time and using at night it

becomes a short term storage. If you are storing your thermal energy throughout three, four days, even through summer and then using it during the winter becomes a long terms storage. A solar energy process with storage (a) incident solar energy, GT collector useful gain, QU and loads, L, as a function of time for a three day period.

This is how depending on the fluctuation on each day, it can be observed and stored in the energy storage in the system you are going to design and can be utilised later on. There are two types of energy storage system - one is passive energy storage system, second is active energy storage system. In passive energy storage system, as you'd observe in this image, this solar radiation gets directly hit by this wall which is like a trombe wall which is considered like a material high thermal mass which is concrete or brick that observes the sunlight and stores it in the wall and when it is cool at night, it emits the thermal energy is absorbed in the morning to the interior spaces and keeps the occupants within the interior space in thermal comfort. This is passive. It can depend on the day and the time, how much light energy is available, etc. Active solution is where the light is the heat energy that is made to fall on a cell and is being collected or stored with the usage of battery technology and is being further used. Depending on the usage and need, active and passive systems can be chosen depending on the need of the occupant.

Energy Storage

Solar energy or the product of solar processes can be stored as - electrical energy, chemical energy, mechanical energy and thermal energy.

How thermal energy storage works? Storage of solar thermal energy - Sensible heat storage and Latent heat storage. Sensible heat storage is a heat storage system that uses a heat storage medium and where the additional or removal of heat results in a change in temperature. ($Q=mc\Delta T$).

There is a heat medium or a material with a very high specific heat capacity which means the material can store a lot of heat within it. For example - water and concrete have high specific heat capacity. Storing heat energy in those type of systems and then using it later on is called Sensible heat storage. Latent heat storage - a heat storage system that uses the energy absorbed or released during a change in phase, without a change in temperature (isothermal). When storing a system and if there is no change in temperature and you are using it when there is change in phase of time, it is called Latent energy storage.

Storage capacity - storage capacity of solar system depends on the availability of solar radiation, the nature of the thermal process, the economic assessment of solar vs auxiliary energy,

physical and chemical properties of the storage medium employed. Depending on how much solar radiation the place is going to have and what kind of thermal process you are going to use. How much capacity you need to store your solar energy in. Depending on all these factors, you need to choose your system of storage.

Storage Media - The choice of storage media depends to a large extent on the nature of the solar thermal process. Water storage, air based thermal storage (eg - packed-bed storage), storage walls and floors, buried Earth thermal storage and phase change storage. These are some of the mediums in which your store your energy. Let us discuss one or two of these mediums to have a better understanding.

Storage walls - A storage wall (eg: Trombe wall) is a sun-facing wall built from material that can act as a thermal mass, such as stone, concrete, adobe or water tanks, combined with an air space. Trombe wall is a wall which is constructed with high thermal mass. Thermal mass is a material which can prevent from fluctuating which doesn't transmit outside energy to the interior is called thermal mass material. Example of thermal mass is concrete, adobe and brick walls. Here, there is a blazing system and a small air gap is being maintained and then we have the wall which is being constructed with thermal mass and the incident solar radiation falls here, heats up this air this is being absorbed through the thermal mass and during the night when there is very less temperature the heat absorbed by the thermal mass is going to emit inside and is going to heat up the interiors. During the day, when the temperature outside is very high, the cold temperature at night is going to be maintained during the day as well. Insulated glazing and vents to form a large solar thermal collector. Here as you observe, there are small vents which is being provided to have inlets and outlets as well to take in fresh air and get rid of the used air. As the incident solar radiation falls, it heats up. This is effective when there is high variation between day and night. This storage valve can be adopted effectively to maintain your room temperature constantly without day and night fluctuations. Next is Buried Earth Thermal Storage which uses Earth energy to store your thermal energy and to circulate it later on. This is an example for long term storage system. Designed as a concrete container that is either partially or completely submerged in the Earth. It is lined to seal it against vapour diffusion and is thermally insulated. The storage medium is water. Say, water is being stored in this urban tank since Earth maintains a constant temperature after 60cm from the surface of the land. This can be used to store thermal energy as well, in which the water is being put in a huge thermal mass, such as concrete is being built and then thermal fluctuation is being avoided due to the presence of concrete in the wall and due to the presence of temperature that is deep in the ground, because of this temperature can be maintained to the same degree in which you drop in for a long term usage. This is an example of a central storage tank in which your hot water is being generated by this collector in which the heat of the sun is being utilized

and hot water is created and being stored in central storage tanks and then it is being circulated during the night.

Recycle and Reuse Materials

Let's move on to next part of the presentation, re-cycle and reuse materials. What is recycled or reused materials? In a factory, a product gets made and then you use the product. After the product is used, you dump it in a dustbin or throwing it away. The same product is taken by Pre consumer in which it is segregated according to the items and again sent to the factories in which the product is being made again and again sent to the consumers. The capacity of the product being used over and over after being used up is called recycled and reused products. The cycle it undergoes is called re-cycling.

Construction waste recycling is the separation and recycling of recoverable waste materials generated during construction and remodeling. The waste that is being created during construction can also be recycled and the materials that are being demolished or scrapped down can also be recycled or reused. It undergoes the same process of segregation, sending it to factory, making it a new product and sending it back to customers. Construction by nature is not an eco-friendly activity. If you are using a lot of wood and after the building is demolished after 50 - 60 years, the wood is burnt and in turns adds to the pollution in the environment. Rather, use it once again for construction purposes, it will be beneficial for the environment. It reduces ozone depletion and causes to greener gases.

Need for adoption of proper methods of recycling - it reduces the demand up on new resources. cuts down the cost and effort of transport and production. Use waste which would otherwise be lost to landfill sites. It's important to be used because it is good to use the product again and again rather than making it or contributing or adding to the environmental waste which is going to deplete our own environment and is going to cause ozone depletion.

Viable Technology on Construction waste recycling - When considering a recyclable material, three major areas need to be taken into account here - Economy, Compatibility with other materials and Material properties. When you are recycling a material, you need to understand how much money are you going to invest into the process of recycling. If a new product is available for 10 rs and you are going to recycle the product for 100 rs, it doesn't make any sense to recycle, people would rather purchase the original. The economy is very important on a driving factor to create a material and undergo such processes. If it can be combined with another material, to add strength to it, to make it equivalent to a new and a fresh product is also important. The material property can be adjusted and altered. Until what extent it can be

used, what is the significance of the material property due to its usage; gives much more opportunity for the users and consumers to change their choice at times.

Commonly recovered construction materials - Asphalt Paving, Land CLearing Residuals, Wood, Gypsum Wallboard, Buildings, Metals, Concrete, Roofing (non-asphalt shingles) and Brick. These are usually the materials and we see that is being used and recycled in different sizes or sent to the factory once again, created into a new material and then brought back to construction sites.

Some of the materials we are going to discuss are; Asphalt Paving - Asphalt is crushed and recycled back into new asphalt. Recycled asphalt paving can be used to pave the road. When the roads are scraped off, the same pieces of asphalt can be taken, burnt (it changes from solid to liquid) and can be added to new asphalt to create new roads and pavements etc.

Land clearing Residuals - Trees and bushes can be recycled as compost or mulch; soil can be reused as fill and cover. When you are cutting down trees, it can be used as a fertilizer, compost or it can even add to biogas formation. There are wide range of benefits of land clearing residuals that can be put to effective usage.

Wood - reuse timbers, dimension lumber, plywood, flooring, molding, lumber longer than 6 feet. Clean, untreated wood can be recycled, re-milled into flooring or chipped/ground to make engineered board, boiler fuel. The usage of wood, we can use timber over and over again to use it for windows and doors or it can be used for shutterings or converting it from one element to a different element. This wide range of usage applies to wood.