Technologies for Clean and Renewable Energy Production
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Lecture – 27
Solar Energy 2

Hi friends, now we will discuss on the topic renewable energy that is solar energy production part 2.

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The content of this discussion is the techniques for solar energy conversion to usable form, that is solar thermal and solar photovoltaic.

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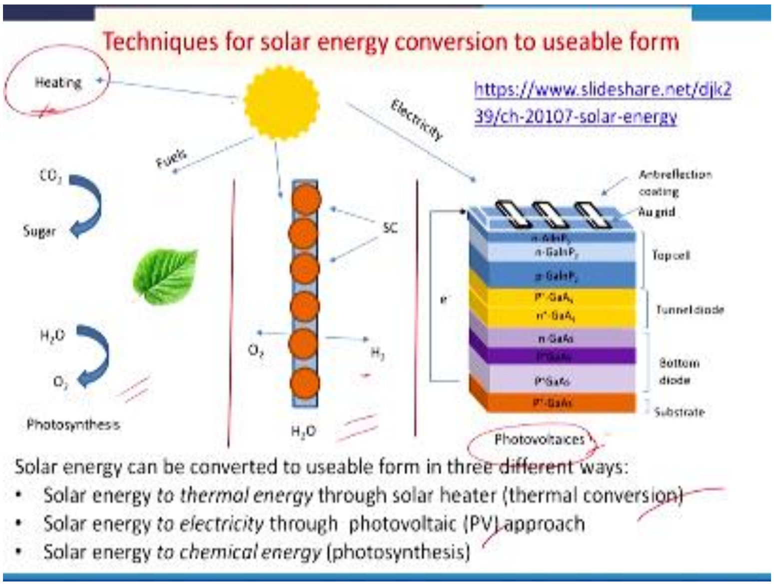

So if you see the solar energy can be used into different forms into different routes. So solar energy is converted to organic food, organic materials through the plants, through photosynthesis. Solar energy can be used to produce hydrogen, photocatalysis routes. Solar energy can be converted to electricity through photovoltaic routes. Solar energy can be converted to heating through thermal route and then that heat can be used further for the production of electricity.

So there are a number of ways or the routes through which the solar energy can be converted to usable form. So this is a very complex process, still the simulation of this process is not possible, this is under development, that is the hydrogen production through photolysis, this is already developed, this photovoltaic is also developed. So, we will discuss this thermal route and photovoltaic routes for the production of electricity by this solar energy. So we have thermal conversion and we have PV conversion, basically we will be concentrating on these two routes.

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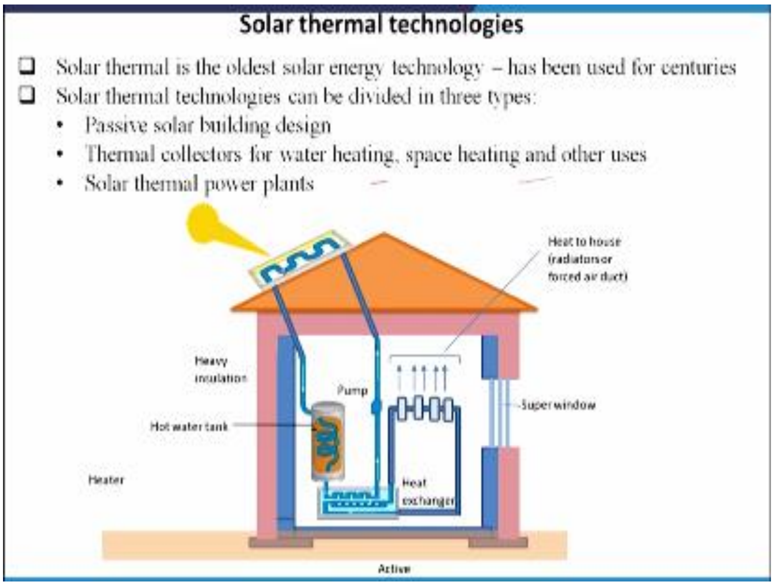

Now see already passive design of building helps us to get solar energy for heating applications, that is not actively or directly using some liquid or something to capture the energy and then like this, that is that building is designed in such a way that we are able to get some amount of energy automatically by that way, but by using some heating device also, we can collect more energy for this application. Here at the rooftop, we can use some heating device that is collector that will collect the heat.

Then we can send the liquid or that is water here cold water, it will pass through it, the sunlight is coming here and the water is heated and it is coming to this, and then there is some heat transfer, so then that way we can get the energy collected at the top is available in the room and then we can exchange this energy here also. So, here we have used some external device which is collecting the solar radiation and helping to heat the liquid pass through this particularly designed device so that is called solar thermal technology and where the thermal collectors for water heating, space heating and other uses we can use.

So we can send here the water or we can send here air also, if we send air, then also air will be heated and the room will also be heated, and if we use the water, then also the water will be heated and then can be used for other application, but this technology normally the temperature of water does not rise very high, then the temperature of water maybe 60-70 like this, 70 degree centigrade like this.

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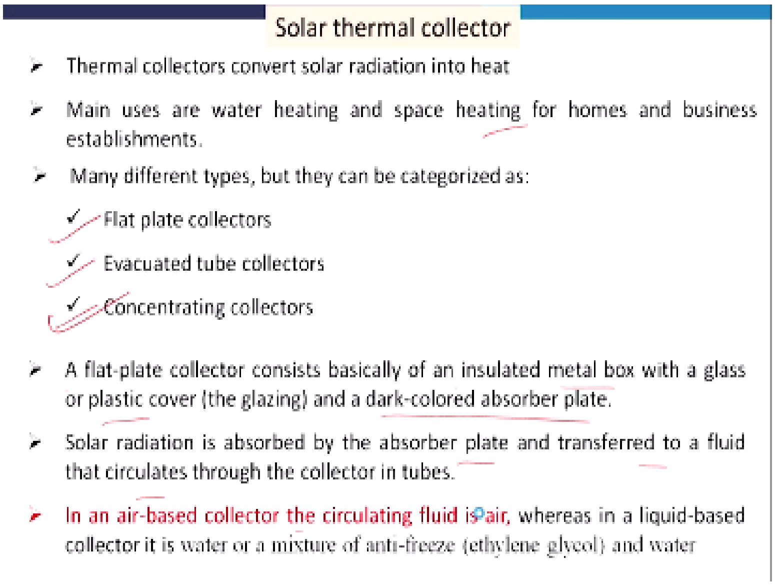

So, solar thermal collector, which we are using at the top, that may be of different types. It may be flat plate collector, it may be evacuated tube collectors, or it may be a concentrating collectors. So there are basically 3 types of collectors so far has been reported that is a flat plate, evacuated tube, and then concentrating collectors. So, we will be discussing these one by one. The main uses are water heating and space heating for homes and business establishment by this technology.

But when we use concentrating collectors, then we can get very high temperature water or even can produce high temperature steam and that can be used for the production of electricity in steam turbine. Now, we will see the flat plate collectors. A flat plate collector consist basically an insulated metal box with the glass or plastic cover and then a dark-colored absorber plates, so this is the construction of different parts of a flat plate collectors.

Solar radiation is absorbed by the absorber plate and transferred to the fluid that circulates through the collector in tubes and in air dry collector the circulating fluid is air whereas water can be used also as a fluid, and in some cases some anti-freezing agent is also used, otherwise if the temperature is lower inside the room below say 0 degree centigrade, it will be frozen, so that anti-freezing agent is also used to capture the sunlight when the temperature is very very less it is say below 0 degrees centigrade.

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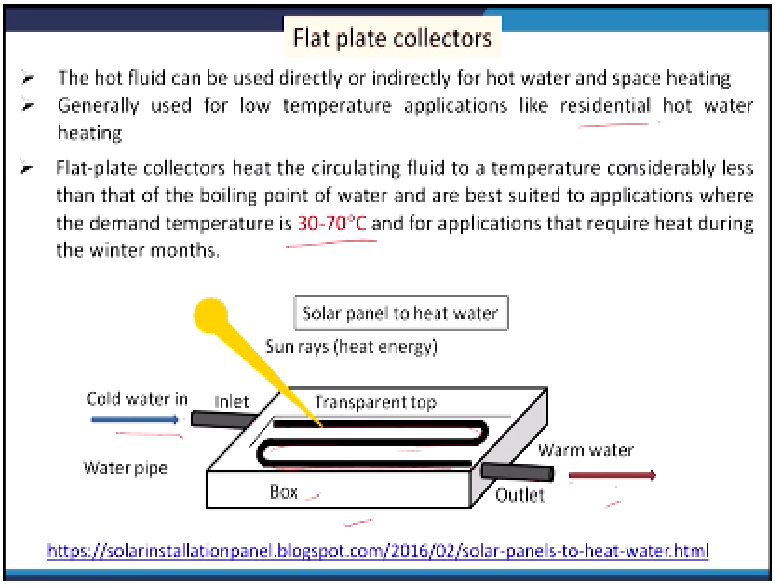

Here we see the flat plate collectors, here water is coming here, so we have your absorber plate, then sunlight is coming here and then absorber plates will absorb it and it will be heated up and then through which the tubes the water is going through so that will be heated and will be coming out. So, this is a very simple design of this, primitive design we can say, that is it is a box type arrangement.

Then from the top, the sun is coming, sunlight is coming and then from this we are having the water flow or air flow and we are getting here the heated water, but this method as I have mentioned that 30 to 70 degree centigrade temperature rise can be available in this case, we cannot get very high pressures steam that is the flat plate collectors, and basically these are used in home applications like residential hot water heating.

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Then evacuated tube solar thermal design came later. These collectors use a thermos bottle type arrangement or collector. So in this case, the vacuum is created so that the vacuum due to the availability of vacuum it is able to give the high temperature water, so the temperature of the outlet of this collector is more than that of the flat plate collector and the vacuum acts as insulator and reducing any heat loss significantly to the surrounding atmosphere either through convections or radiations making the collector much more efficient than the initial insinuating that flat plate collectors have to offer. So this is the features of this evacuated tube solar thermal collectors.

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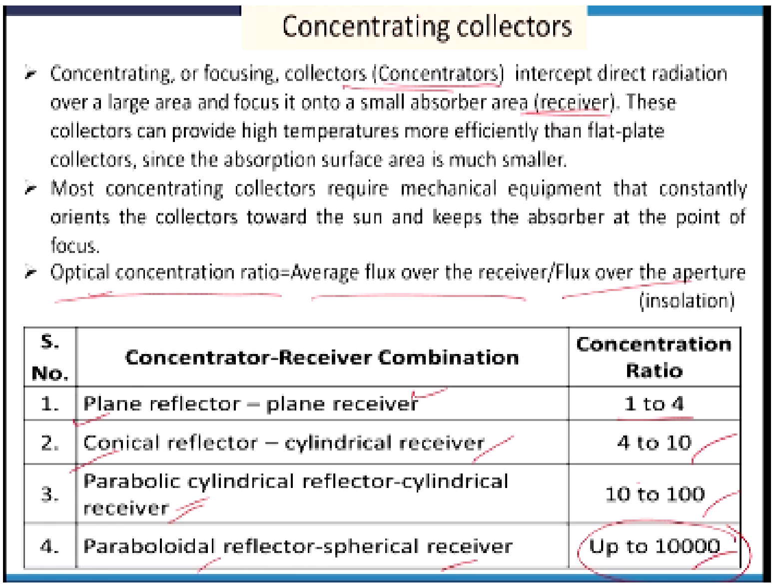

Then we are coming to concentrating collectors. So this is the latest development of this collector, that is sunrays after incident those are directed in such a way that will be focused on a certain point or in a central line. So the concentration of radiation will be higher at the receiver. So here we have two things, one is your concentrators and another is your receiver. So concentrators or collectors, so those are initially collecting the sunrays and then it is focusing these rays to a focal point, on a certain point that is the receiver.

So one is collectors and another is receivers. So depending upon the shapes of these collectors and receivers, the extent of concentration also varies which is defined by the optical concentration ratio that is average flux over the receiver divided by flux over the aperture of the collectors, that is how much insolation is coming on the collector and then how much insolation we are getting at the receiver. So receiver insolation divided by the collector insolation that is we can say optical concentration ratio.

As you see here for this, we need some mechanical help, that mechanical design will play a role, we may we may need to change the orientation of the collector or we have to equip it in such a way that maximum concentration is possible. So here we see the plane reflector plane receiver if we use, then the concentration ratio can be 1 to 4, but if we use the conical reflector and then cylindrical receiver, then you can get 4 to 10, if we use parabolic cylindrical reflector and cylindrical receiver, then you can get 10 to 100.

When it is paraboloidal reflector and spherical receiver that will give us 10,000 up to. So that is the maximum capacity or the maximum concentration we can get by this type of arrangement.

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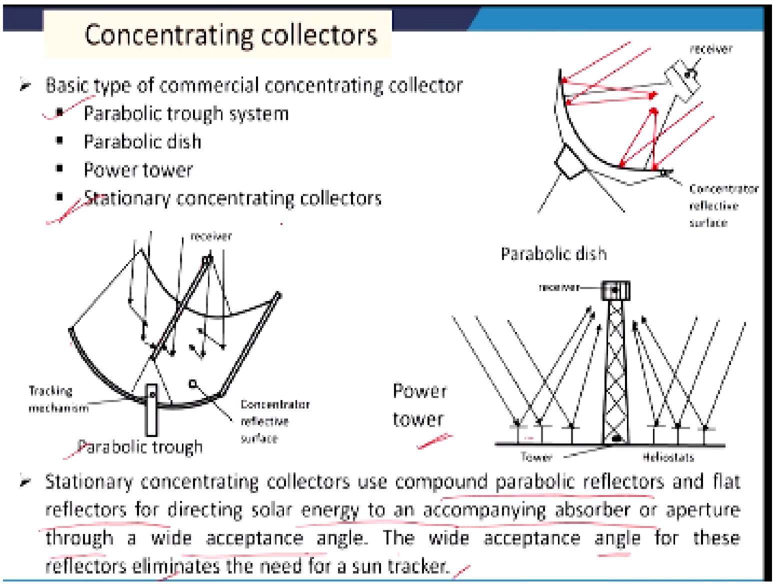

So we see here the different types of concentrating collectors, one is your parabolic trough system, so this is trough systems, like this type of structure it is the trough. So it will be if we have a tube here so water, rays will be coming here and these after reflection it is going and concentrating on this, so this is our receiver, so this is a parabolic trough. So it may be a parabolic dish, so here the parabolic surface, rays are coming, then incident, after its reflection it is going and then it is it is focusing on a point.

So there are some mirrors, here also some mirrors are there. So rays are coming and it is being reflected and it is being concentrated. So here it is, this rod is there, here the point is there for the concentration, and a receiver for the collecting of the concentrated rays. Here, we may have the power tower, so power tower, so we have mirror at the bottom, so ray will come and it will be reflected and will be focused on the point at the top, so this is called power tower. So these are 3 major important designs for the collection of the sunrays by these concentrating collectors.

Apart from these, we have stationary concentrating collector. So stationary concentrating collectors use compound parabolic reflectors and flat reflectors are used for directing solar energy to an accompanying absorber or aperture through a wide acceptance angle. So as the wide acceptance angle means due to the use of wide acceptance angle, these reflectors eliminates the need for a sun tracker, so sun tracker is not needed for this type of the stationery concentrating collectors.

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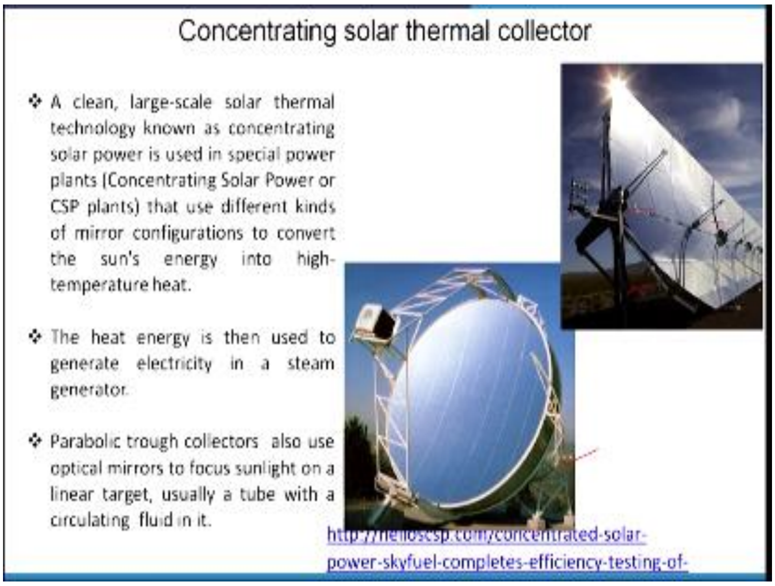

These are some photographs how it looks like, so parabolic disc and parabolic trough, so how it looks like it is shown here. So you see here, it is a disc that is after reflections it concentrates to this one point and then here it is a tube, so it is concentrated on a tube, that is the parabolic trough.

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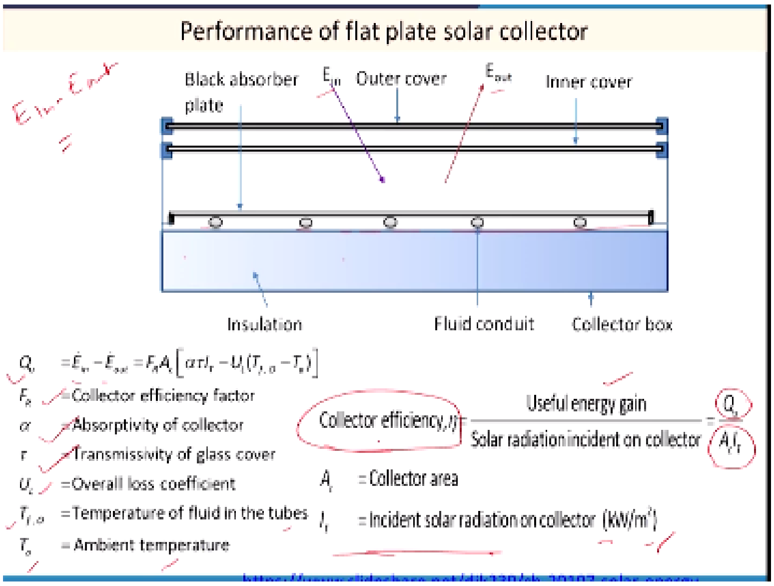

Now, we will see how can we calculate the performance of a flat plate collector, the primitive one say, how can we determine the collector efficiency, we will discuss now. So in a flat plate, as you have seen that one flat surface is there, so where we have here one surface and then sunray will come and it will be taken up by the plate and some amount of energy will go out. So energy in is your Ein and energy out is Eout. So Ein–Eout, so that is the energy taken up by the water or we can say that energy gained by the system.

So useful energy gain we can say that is equal to, Qu that is equal to Ein-Eout, that is energy which is coming inside this that will be absorbed first, that will be collected by the collector, then it is absorbed from the top and the transmitted towards the bottom where the liquid is flowing. So we have two terms here say collector efficiency that will influence the overall efficiency of the process, then absorptivity of collector, how the collector is able to absorb the solar radiation that will also influence the overall performance.

Then transmissivity of glass cover, so one glass cover at the top, so how it is transmitting the light so that will also influence the overall performance and here we have insulation, here through which the water is passing through the tube we have some insulation, so there will be some losses of heat energy through this if insulation is not proper, so that insulation loss is there, so overall loss coefficient is also considered which is important and will influence on the overall performance of the system.

This Tf and To, temperature of the fluid in the tubes and the ambient temperature that will also influence the performance. Another is important incident solar radiations on collectors, what is the radiation it is coming on the collector that will also influence the process performance. So if we want to get the collector efficiency here, this equal to obviously how much energy we are getting that is Ein-Eout divided by how much energy was available in the incident rays.

So if the surface area is Ac and It is incident solar radiation, so this is our total solar radiation in kilowatt per meter squared unit and this is our energy we are getting amount of heat we are getting from the system, so this by this, Qu/Ac into It is our collector efficiency.

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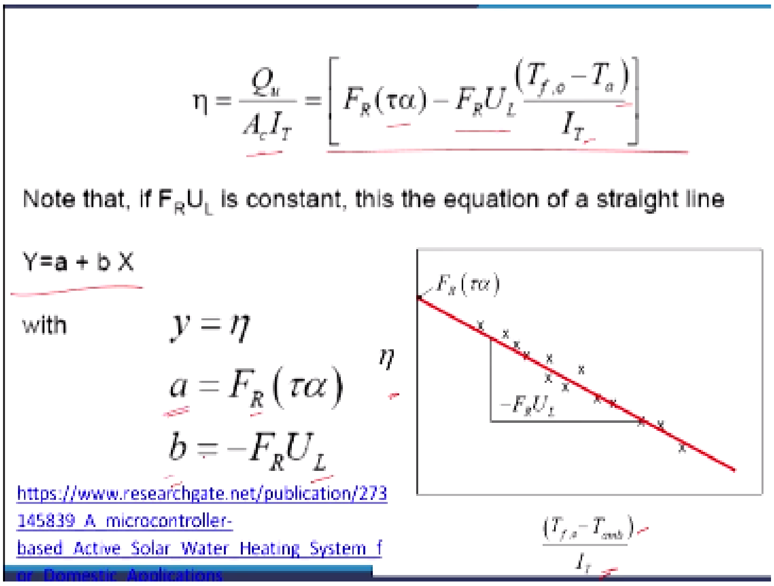

Now efficiency is equal to Qu/AcIt, but now what is our Qu, Qu is also this one that Fa, Fr that is equal to collector efficiency into Ac into alpha tau It – UL Tuf-Ta. So this is the expression for the Qu. So if we put this expression in place of Qu, so efficiency will be like this. So efficiency is equal to Qu/AcIt into FR tau alpha – FRUL into Tfo-Tu/IT. So now this equal to y is equal to mx+c type of expression, y is equal to a+b type of expression.

So if we plot efficiency versus this, we can measure the Tf, we can measure Tm Me and we can measure the intensity of the light which is coming that IT. So then we can plot and we can get the value of this A and B and A and B we can get the value of FR we can get the UL like this. So now we can get the value of A and B.

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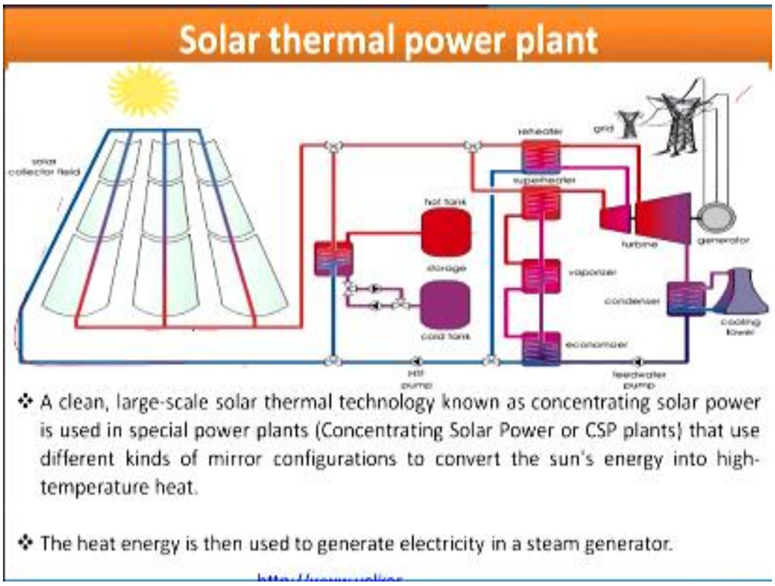

Now, solar thermal power plant. So how the solar technique, thermal technique can be used for the electricity production that part will discuss now. So we have some say some collector here, so we have collector, so that is a parabolic trough collector here, so these are the tubes so we are sending cold water, so it is going through these tubes and it is heated up and ultimately we are getting steam. So this steam is going and this can be used for different applications.

It can be used in hot tank and it can be going for the super heater and this can be used in a turbine for the electricity production. So this is the method through which the electricity is produced. The steam is generated here, it goes through this and it is after super heating, it goes there to the turbines, which is coupled with the generator, which gives us electricity and the exhaust steam is condensed and again used here or it can be sent here for the heat recovery or like this So this is the arrangement for the use of heat captured by the steam in this plant.

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So one example of this power tower in Barstow, California. This figure shows that how the solar energy is produced by the capturing of solar lights. So this is 10 megawatt solar power plant in Barstow, California, that is 1900 heliostats, each 20 feet by 20 feet is used and a central 295 five feet tower. So all are focused in this tower and then it gives us that amount of electricity.

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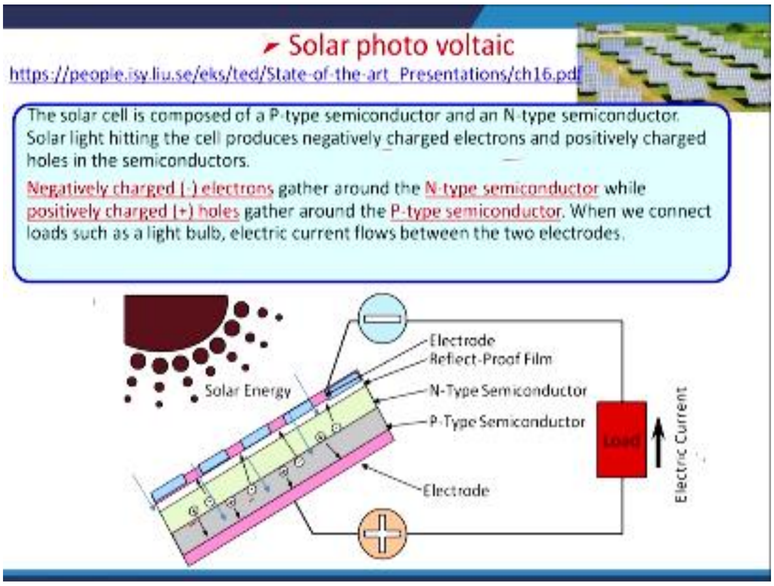

Now we are coming to solar photovoltaic. So solar photovoltaic, it is another type of technology and which is the latest development of the solar technology and most important one, which can give us electricity directly without the production of steam, unlike solar thermal route. So here what happens, solar energy comes on some surface which is having an N and P type semiconductors and then when the solar cell is P type semiconductor and N type semiconductor.

The solar light hitting the cell produces negatively charged electrons and positively charged holes, so negatively charged electrons and positively charged holes. So sunlight is falling on it and these holes and electrons and generated and then electrons are moving towards this N-type semiconductor and P-type semiconductor, those are the positive holes are moving towards it and they are collecting these things, and when we will add external load, then we will get electricity through it.

So we are getting the electricity now. So this method is the most important method for the conversion of electricity from the solar rays.

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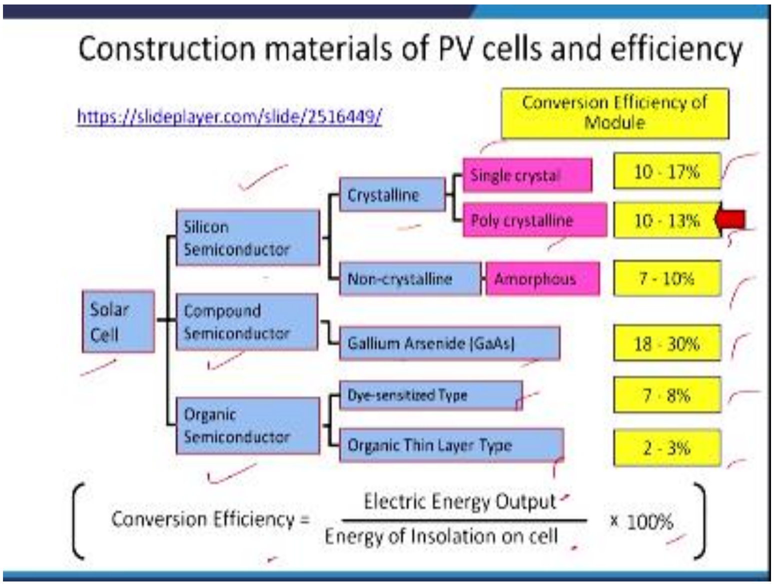

Now we will see different types of materials for the PV cells and their efficiency. So solar cell, it may be silicon semiconductor, it may be compound semiconductor, it may be organic semiconductor. So silicon semiconductor, it may be crystalline or amorphous and crystalline maybe single crystal maybe poly crystalline, and their conversion efficiency for the single crystalline 10 to 17%, for poly crystalline 10 to 13%, it may be non-crystalline that is 7 to 10%.

Compound semiconductor that is gallium arsenide, it is 18 to 30% conversion efficiency. Organic semiconductor that is dye-sensitized type, it is 7 to 8% and organic thin layer type 2 to 3%. So these are the different types of materials have been investigated for the production of electricity in a PV photovoltaic mode. Then conversion efficiency, obviously electricity output by energy of insolation on cell into 100 that will be in the percentage.

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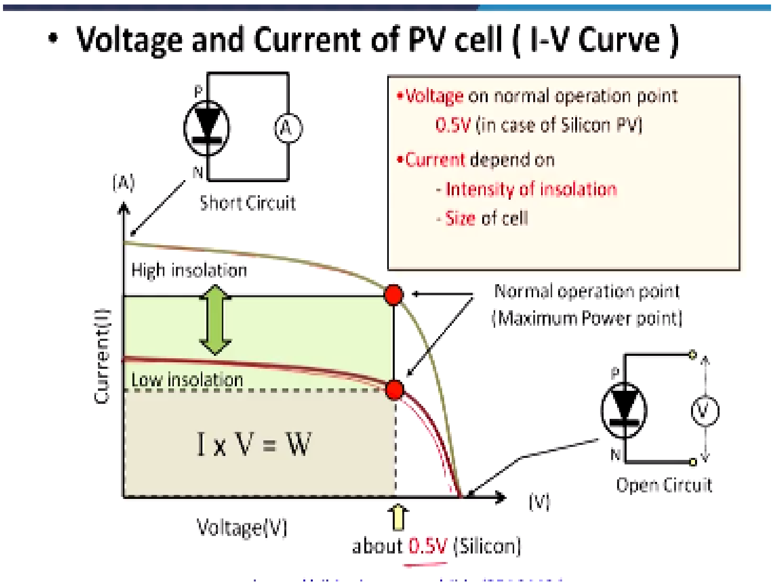

Now we will see the volt and current which can be achieved in this PV cell. So this is for low insolation, this is the graph people have reported and for high insolation. So 0.5 volt for silicon photovoltaic cell is available for a single cell and intensity of insolation and size of cell will also influence the amount of voltage generated.

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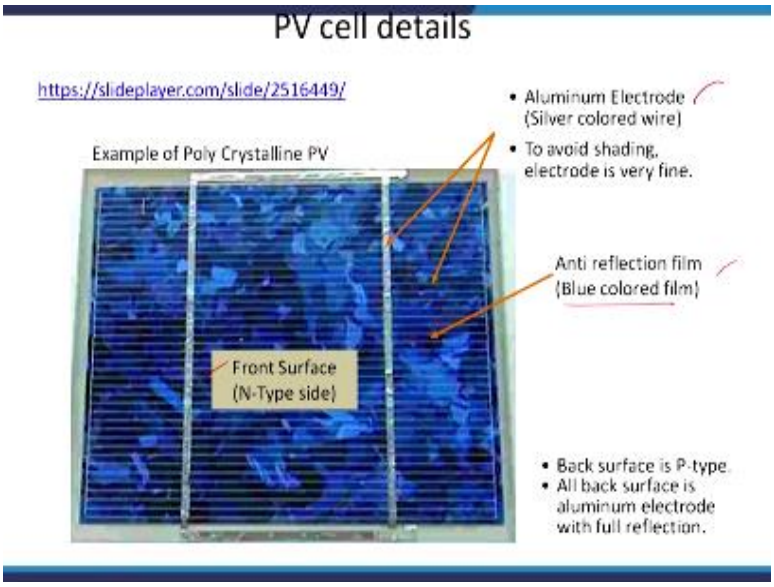

Now this is one photograph for PV cell which can give some details on this. So here, we have these are aluminum electrode and this blue colored film that is anti reflection film and then black surface, this black surface is P-type conductor semiconductor and all black surface is aluminum electrode with full reflection and this is front surface N-type side, so N-type side and P-type side is backside, that is black side.

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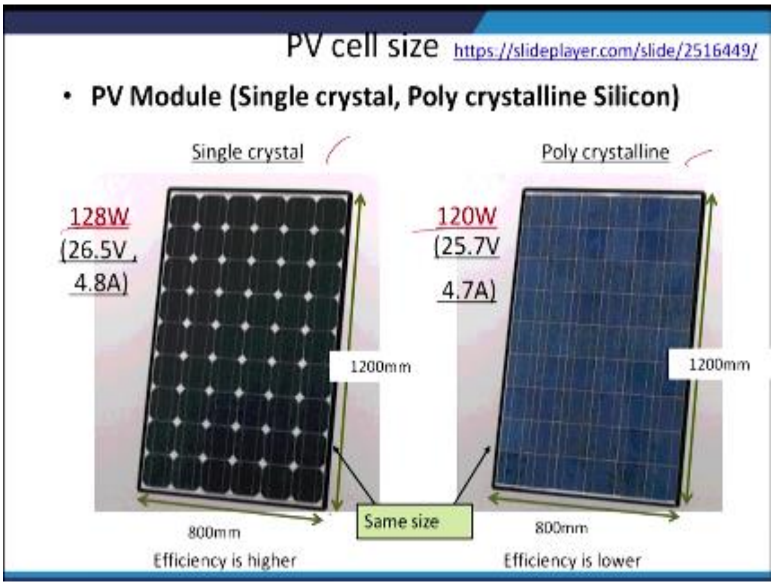

This is your PV module, one module single crystal, and this is your polycrystalline, so this is poly crystalline, this is single crystalline. So single crystals which has more capacity 128 watt, this is 120 watt, same size both are having, but single crystal will give some more capacity as it is evident from this.

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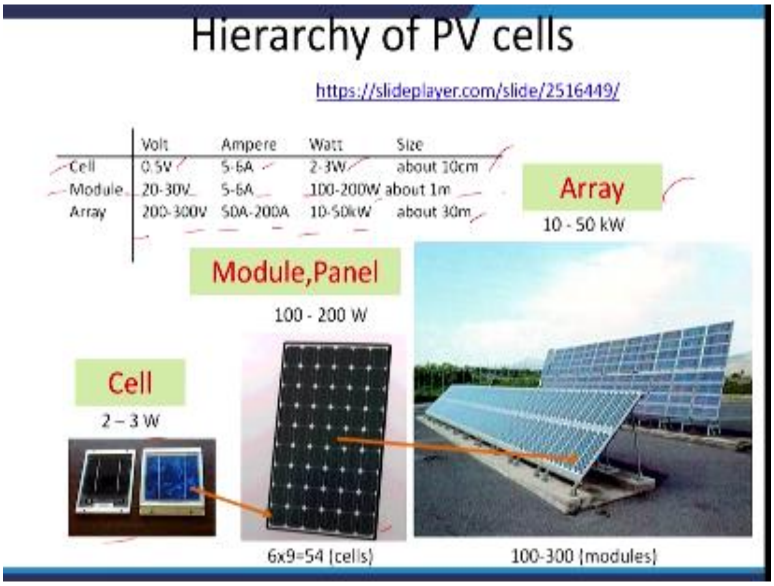

Then there is the hierarchy of the PV cells, so a single cell we see here, 2-3 watt, so this is black and blue, so alumina and N and P type that we were talking about the N type and P type semiconductor, so we are using it and 2-3 watt is generated, so you have 0.5 volt and 5-6 amps and 2-3 watt, so about 10 cm size. Then gradually the improvement came and then module structure came, so this is our module, so this module is able to give 20-30 volt, 5-6 amps and then 100-200 watt and 1 meter its size.

The number of modules was put in arrays and then we get array that is say 200-300 volt it is possible, 50 amps to 200 amps is possible, 10-50 kilowatt capacity was developed, and the size is around 30 meter. So gradually the PV cells developed.

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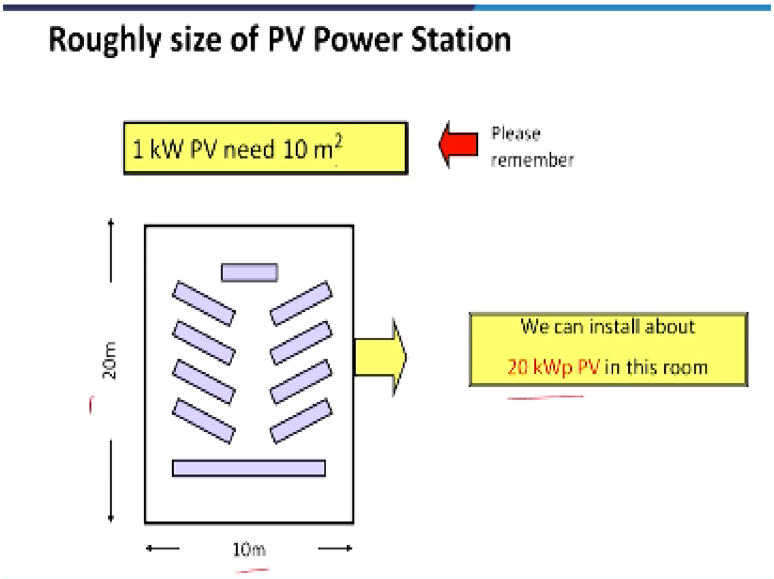

This is the roughly size of PV power station. If we need to get say 20 kilowatt power through PV techniques, then it requires 10 meter by 20 meter roof area. So 1 kilowatt PV need 10 meter square area for its production.

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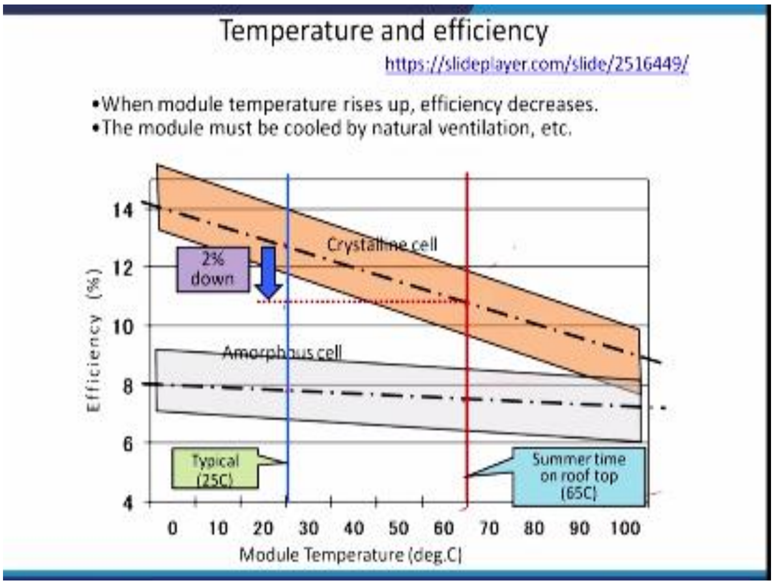

Now the temperature also influences the performance of this process. The temperature increases, efficiency of the process decreases. As shown here say a typical 25 degree centigrade we are having, if it is an amorphous silicon PV cell, then this will be having around 8% percent efficiency. If we go to say 65 degrees centigrade which is available in some places during summer at the rooftop, then there it is slightly less than this.

In this case for crystalline cell if it is around say 13% percent, so here it is coming to say 11%, so 2% down due to the increase in temperature from 25 to 65 degrees centigrade. So that way we have come to know that the efficiency of PV cell can also be changed with increasing the temperature. So up to this in this class. Thank you very much for your patience.