Technologies for Clean and Renewable Energy Production
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Lecture - 26
Solar Energy 1

Hi friends, now we will discuss on the second part of the course that is renewable energy production. In the first part, we have covered how the fossil fuels can be processed to produce clean energy and in this part we will discuss on the renewable energy production and in the introduction class we have discussed that different types of renewable energy resources are solar energy, hydroenergy, biomass energy, wave and tides, geothermal energy, etc. So we will discuss on this topic in this part along with energy conservation and now we will discuss on solar energy.

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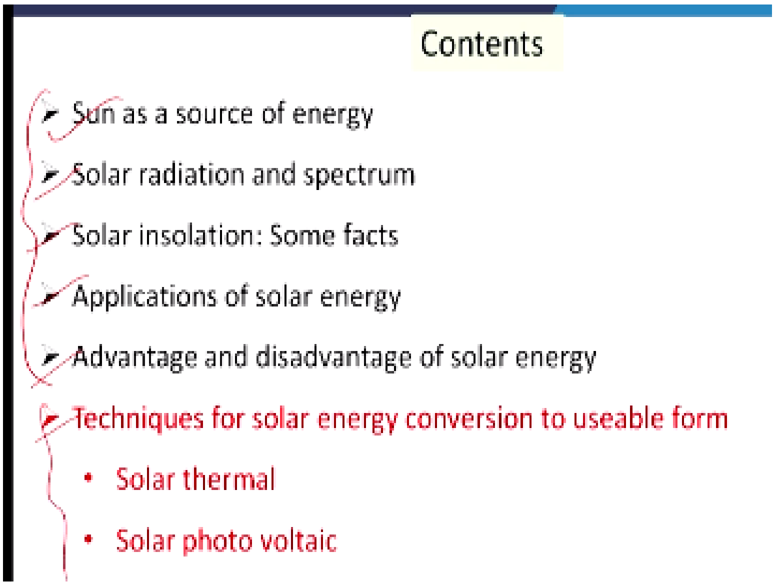

The contents are sun as a source of energy, then solar radiation and spectrum, then solar insolation, then application of solar energy, advantage and disadvantage of solar energy, then techniques for solar energy production or conversion to usable form that is solar thermal and solar photovoltaic. So in the first part, we will be discussing up to advantage and disadvantage and the second next class we will discuss this part.

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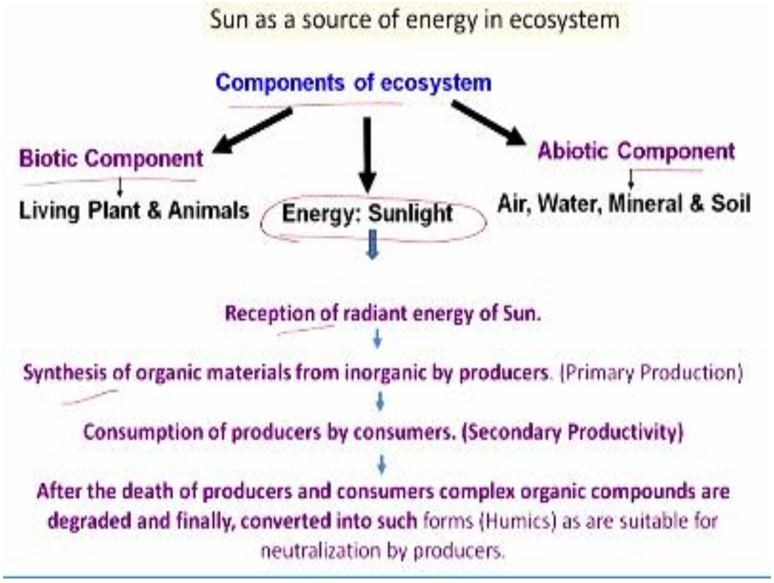

So as you know that sun is the source of all type of energy in the ecosystem and we cannot consider any life without the energy, and if we see the components of ecosystem, obviously the biotic component are most important one and then abiotic components which are required for the survival of that and another is your sunlight that is the energy. So this energy is very very important component for the ecosystem. This energy comes from the sunlight as you know, the solar radiation that is accepted by the plants.

The plants use it for the conversion of organic compound through photosynthesis and that is the source of energy to others that is the producers, then consumers. So if we see the primary, secondary and tertiary consumers, all living organisms are dependent on this energy stored in the food produced by the primary producers. Now we will see how much energy is coming from solar system to the earth and how much is being consumed by different living organisms and what is the scope for the utilization of solar energy to convert it into some other usable forms.

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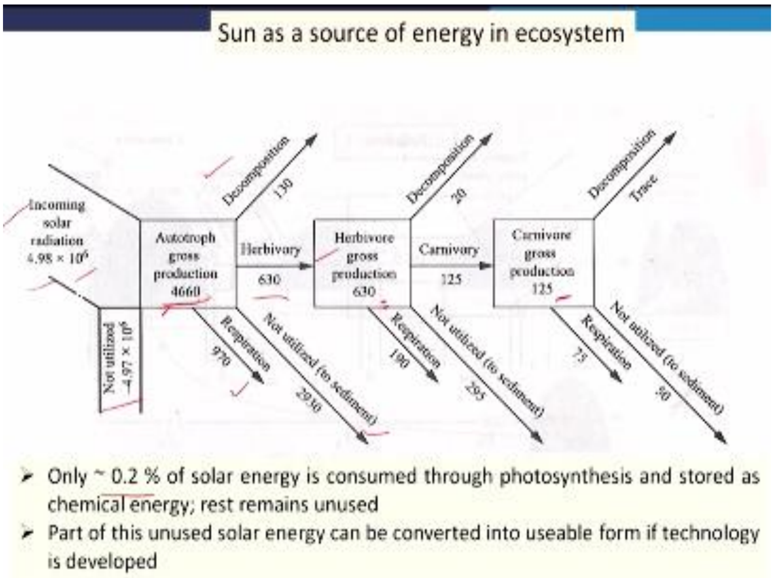

So here this figure shows us that incoming solar radiation is around say 4.98 into 10 to the power 6 unit. If this is the total radiation, then out of it non-utilized is 4.97 into 10 to the power 6 unit. So, only 0.2% solar energy is used by the autotroph for the production of organic compound and it is around say 4660 unit. So out of this 4660 unit which is taken up by the producers or the plants and grasses etc, so they sent around 630 units to herbivores and rest is lost, either respiration, decompositions and not utilized, that is the sediment

So, this is the distribution of the total 4660 units of energy and 630 is coming to herbivores, then out of 630, 125 is going to carnivorous. So, these are the distribution of solar energy which is coming to the earth and taken up by the plants through its photosynthesis for organic compound productions and the forward flow. So, it is very clear that most of the solar energy is remained unused, and if we can develop technology to harness this one to convert the solar energy to usable form, then it can be a good option and that can be renewable energy for our use. Then, you see what is the source of this solar energy?

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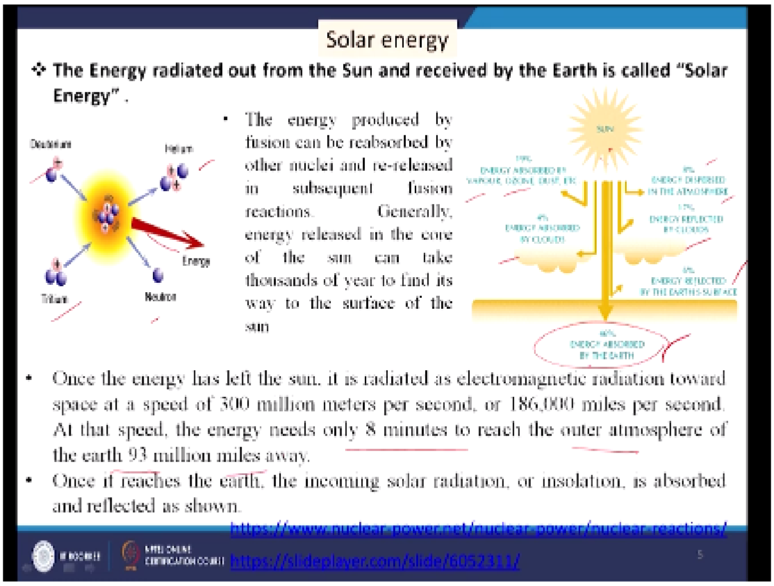

We know that there are different types of fusion reactions are going on in the sun and the energy is released due to these fusion reactions, so here say deuterium, tritium they are fusing and producing helium and then neutron and energy is released. So this huge amount of energy produced in the sun it is taking some time to come at the surface of the sun, say it may take thousands of years, and then when it is coming to surface of the sun, then it is radiated and it is coming towards the earth.

If we see from the sun the energy is coming to the earth, so out of the total radiation which is coming towards the earth, around 46% is absorbed by the earth and 6% percent is deflected by the earth's surface. So remaining part of the energy is not able to come to the earth's surface because of clouds and ionosphere, etc. So, we see here energy dispersed in the atmosphere is around say this 8% percent and energy absorbed by the vapors and ozone and dust is around 19% percent and for cloud we see a 4% percent energy is absorbed by clouds and 17% percent is reflected by the clouds.

So, this is the total energy distributions from the sun which is coming through the different sources to the different parts and ultimately we are getting 46% percent of energy absorbed by the earth. Now this energy comes to the earth in terms of radiations and with a very high speed and that say it takes 8 minutes to reach outer atmosphere of the earth that is 93 million miles away from the sun. So, this is the way the radiation reaches to the earth's surface.

Now if I want to use this energy, if we are interested to use these energy, we have to know more about the characteristics of these and then we have to think how the technology can be developed. So, we will see now what is the maximum available solar energy per unit area per unit time, on that way solar constant has been defined.

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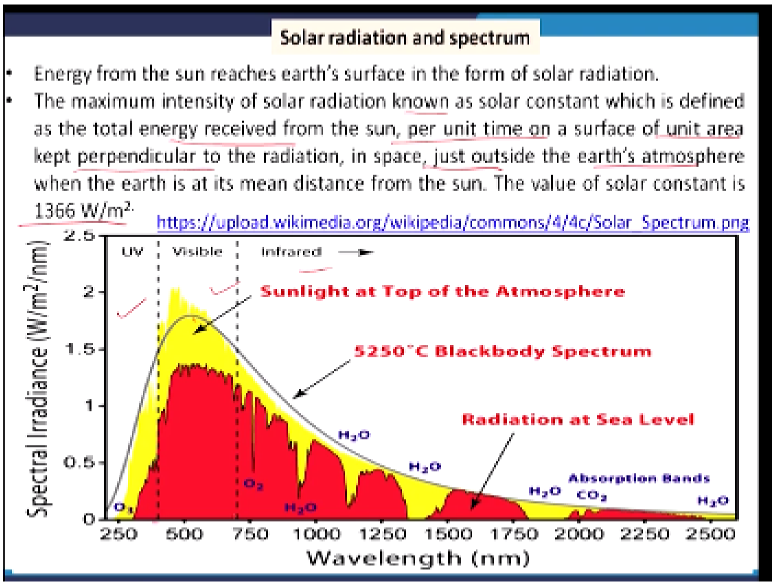

Solar constant is the maximum intensity of solar radiation which is defined as the total energy received from the sun per unit time one a surface of unit area kept perpendicular to the radiation in space just outside the earth's atmosphere, so in the earth's atmosphere its end at that time if we place a surface which is perpendicular to the radiation so per unit area per unit time how much radiation is coming that is called the solar constant and this value is 1366 watt per meter square.

This figure shows us that UV, visible, and infrared all are available in the solar radiations and we see spectral irradiance is highest in case of visible light, so this is within say 400 to 700 nanometer of wavelength.

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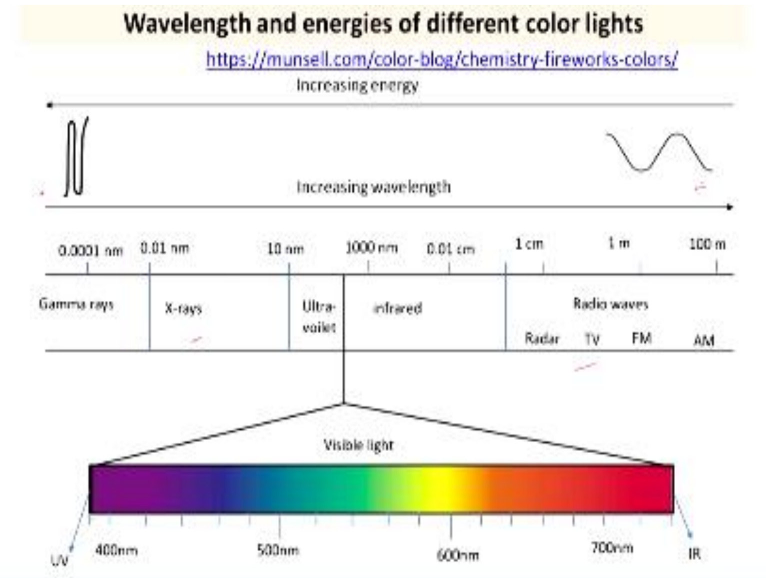

Now, we will see the different wavelength of solar radiations we have that is visible light here to here. Other we have say gamma ray, x-ray we have, infrared. So more the wavelength as you know the energy is less, and so that is why this part is having high energy, this part is having less energy. So these are the different types of rays which are available in the solar radiations coming to the earth.

So we have to trap these, the energy associated with this radiation and convert it into usable form, so that is the basic concept of the energy conversion from solar to electricity. Now, we will see the solar insolation. So we have discussed about the solar constant that is the maximum possible energy intensity which is coming to the earth at the atmosphere of earth's end and now at any location on the earth's surface, the radiation is also coming and that radiation intensity will be defining a solar insolation.

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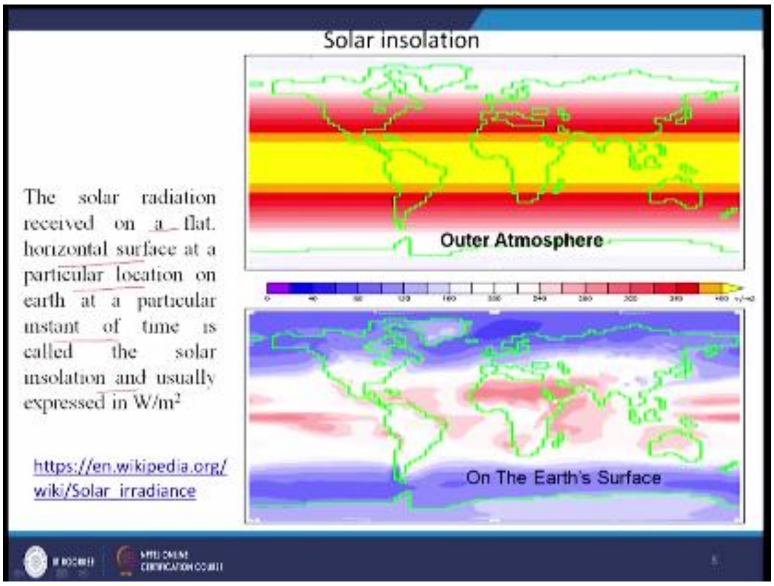

So the solar radiation received on a flat horizontal surface at a particular location on earth at a particular instant of time is called the solar insolation and usually expressed as watt per meter square. So the solar constant was also watt per meter square, then insolation is also watt per meter square.

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Solar insolation: Some facts

- Solar insolation at a place may vary because of :
  - ✓ Angle of incidence
  - ✓ Daily variation
  - ✓ Seasonal variation and geographical location of the particular surface
  - ✓ Atmospheric clarity
  - ✓ Shadows of trees, tall structures, adjacent solar panels, etc.
  - ✓ Degree of latitude for the location
  - ✓ Area of surface, m^2
- Solar insolation is not available equally everywhere

Now there are many factors which influence the solar insolation, what are those? Angle of incidence, daily variation, then seasonal variations and geographical location of the particular surface, then atmospheric clarity, then shadows of trees, tall structures, adjacent solar panels, then degree of latitude for the location and area of surface, what is the surface we are considering for the collecting of the solar radiations that will also influence.

Then solar insolation is not available equally everywhere in the world because all those factors are not equal, it is variable, that is why the solar insolation is also different from place to place. Now we will see what are those factors. So we have seen that angle of incidence is the important factor for the insolation.

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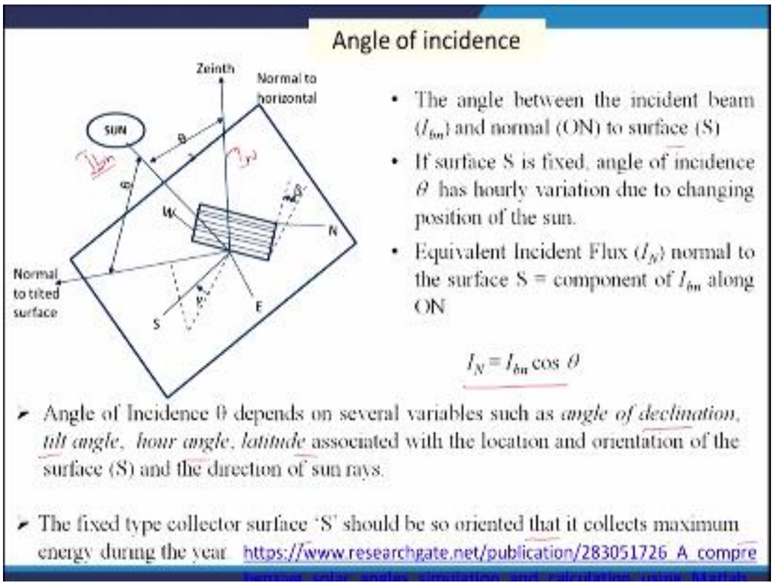

So what that angle of incidence is, say if we have one flat plate, then that plate is fixed on a particular area, then sun rays are incident on it so that incident beam and the normal to the plate will make some angle, here the theta, that is called your angle of incidence. So the angle between the incident beam and normal to the surface is, this theta is your angle of incidence. Now so if it is our Ibn, this is the intensity of light here, so in this case normal to this we will be getting In, so In is equal to Ibn into cos theta, so this is the relationship between this In and Ibn.

Now the angle of incidence, this will also depend upon many factors like say angle of declination, angle of tilt, then hour angle, latitude associated with a place. So these are the different factors which influence the angle of incidence. Now the fixed type of collector surface S should be so oriented that it collects maximum energy from the sun, so that is the main objective that maximum energy will be collected on the collector.

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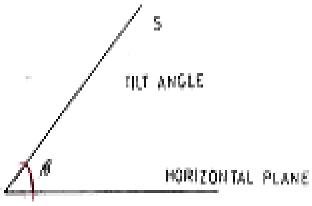
Tilt angle or Slope angle (ß)

- The angle between the collector surface plane and the horizontal plane is called the tilt angle or the slope angle and is designated by β.



- For vertical surface $\beta = 90^0$
- For horizontal surface $\beta = 0^0$
- β is always positive.

- For sun tracking collectors/reflectors, the angle β is changed automatically to track the sun.
- For fixed type collectors/reflectors, angle β is constant.

Then see what is the tilt angle. So if we keep one plate, then from the horizontal line it will make an angle, so this is a horizontal plane, then this surface is making angle, so this is called beta or tilt angle. So this tilt angle will be 0 when the surface is horizontal at that place or it will be 90 degree when the surface is vertical to the surface. So beta is always positive and this beta for a fixed collector it is fixed, but for sun tracking collectors, this beta value can change with time to track the sun to get the maximum radiation from it.

Now hour angle is also one important term which is related to the energy production or the capturing of the radiation from the sun by the collector.

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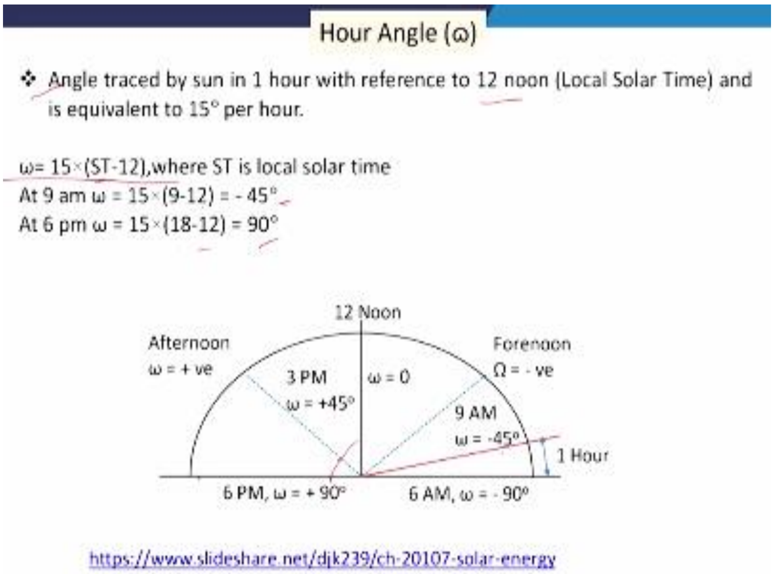

So here we see this hour angle is defined as the angle traced by sun in one hour with reference to 12 noon. So at 12 o' clock in the noon, w is equal to 0, then what will be the value of hour angle, we can calculate by using this formula, w is equal to 15 into ST minus 12 where ST is the local solar time. So at 9 a.m. if we want to find out the w value, so w at 9 a.m. will be 15 into 9 minus 12, so minus 45 degree. So this side we are getting minus 45 degree, here we are getting. Now at 6 p.m. that will be 15 into 6+12, 18 minus 12, so 90 degree, so we will be getting 90 degree at 6 p.m.

So here we are having this angle, so this is our hour angle. So hour angle will also influence the intensity of solar radiations on a on a plate or collector.

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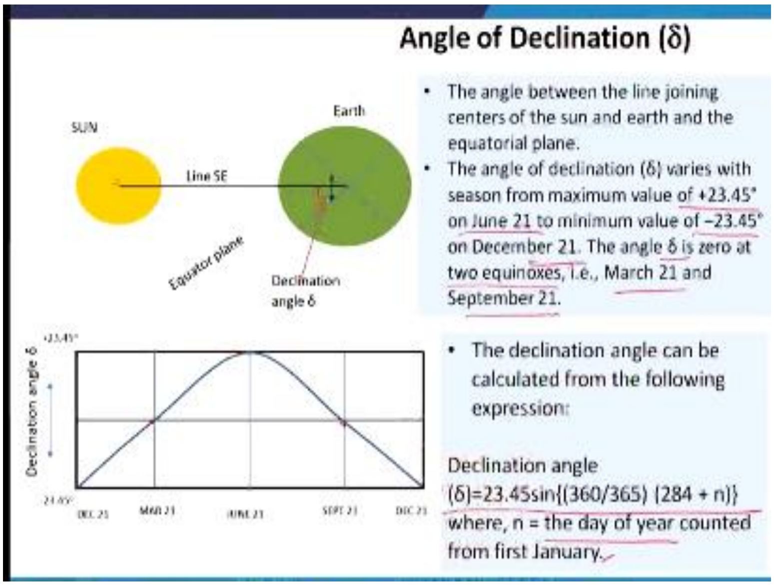

Then angle of declination, that is another parameter which is defined as the angle between the line connecting the center of earth and sun with the equator plane. So equator plane we have here and this is our sun and earth, so this angle is our angle of declination. So angle of declination will vary from time to time, seasonally throughout the year this value will change. As we know that the maximum value is +23.45 degree on 21 June and minimum is -23.45 degree on December 21. The angle del that is the declination angle is at two equinoxes that is March 21 and September 21, the del will be 0.

So what we will see, this is 21 December and here it is we are getting 21 June, so this is 2 and this is our 0, so this is our 0 value, two equinoxes we are getting here. So we can calculate what will be the del value on any time by this formula, del is equal to 23.45sin 360/365 into 284+n where n is the day of the year counted from the 1 January, say 1st January, 2nd January like this how many days from the 1st January that is, if we put here, then we will get the value of del. This value will also influence the solar radiation incident on a particular area of a collector.

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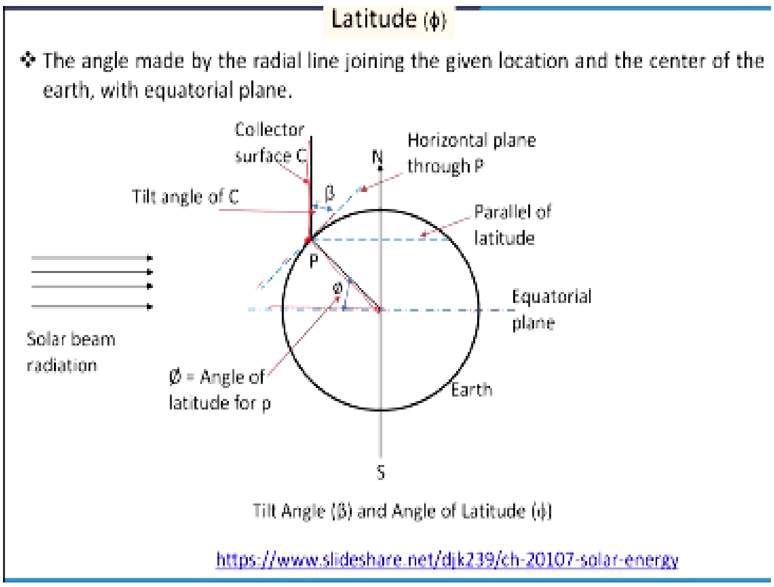

Then latitude will also influence the insolation value. So here what is this, as you know that this is the angle between the radial line joining the center of the earth and the point where the collector is situated with the equatorial plane. So this is our equatorial plane and this is our point where we have put a plate collector say, so this is our collector, this is our point on the earth’s surface, so this point and this is connected by this earth’s radius, and this is our equatorial plane, so this angle is called latitude.

So latitude will influence the solar insolation on the surface of this collector along with this beta also, this is our horizontal plane to the surface and this is also the beta is our tilt angle. So tilt angle and latitude both will influence the insolation value at this point or at any point. So these are the factors which influence the availability of insolation on sun. Now what we will do with this solar energy, initially the solar technology for the conversion of this energy of the radiation to the electricity was not matured and at that time also the solar energy was used.

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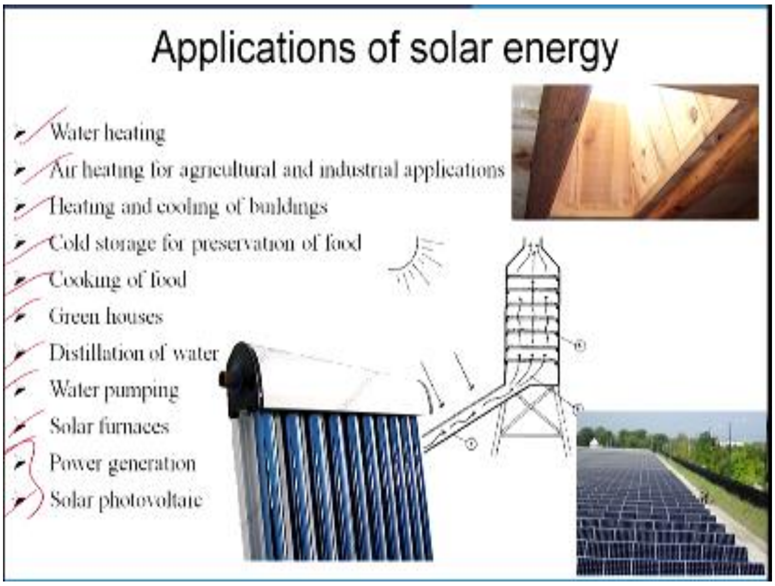

Important applications of this energy are water heating and then air heating for agriculture and industrial applications like say drying up any crops or any feedstock for processing or even say waste sludge, sludge drying everything are some example. These are some example of the application of solar energy directly in industry and in agriculture. Then heating and cooling of buildings, to heat and cool building that solar energy can also be used.

So we have to design the buildings in such a way that we can capture energy when needed from the sun and we can avoid energy from sun when needed, so there is passive design of buildings, we will discuss that. Then cold storage for preservation of food that is also an application of solar energy, people have used it, cooking of food, then greenhouses, just I have told that we have to design the building in such a way that it will be consuming less amount of energy, distillation of water and water pumping, solar furnaces, and then power generation and solar photovoltaic.

These are the two latest development on the solar technology, that is power generation and then solar photovoltaic, we will discuss those part in the next class.

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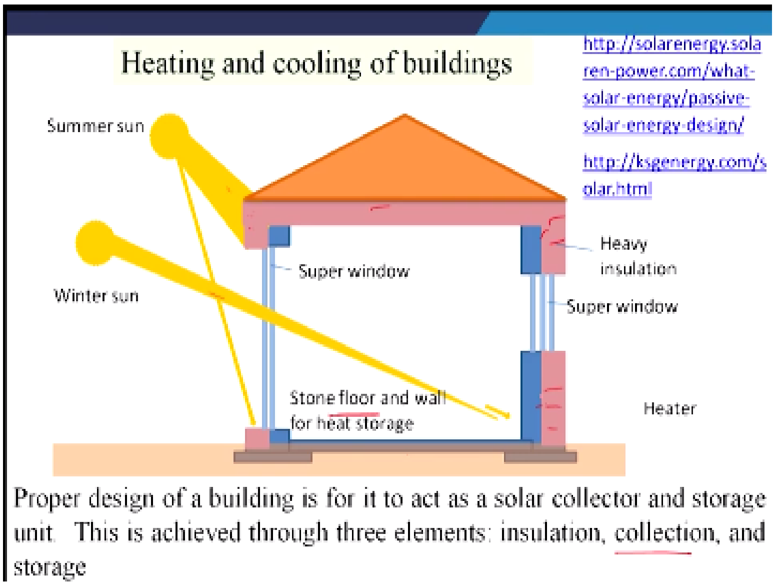

Now we see the heating and cooling of buildings, how this can be done? So if we see that during summer, the sun will be literally at more elevation and then it will be coming to the top part of the roof and if it is extended, some part is extended at the roof, so that summer sun can be arrested, it will not be allowed to come into the house to some extent we can manage, but in winter, here the sunlight can come through the windows.

So these windows which is the light which is coming in the house, then we can store it, we can make some stone floor so that will be capturing the heat which is coming through the solar radiation inside the room and then you can put some insulation, so more higher the insulation we will be able to keep the heat in the room for a longer period. So one is your we have collection, then another is your storage by using this material so you can store the heat, and then reduction by insulation, these are the principles to design the buildings that is called passive building design.

So passive solar design that is nothing but a set of practices that accommodate the local climate by letting the sun into the house into the building in the winter and keeping the sun out in the summer, so this is the principle it is designed in such a way.

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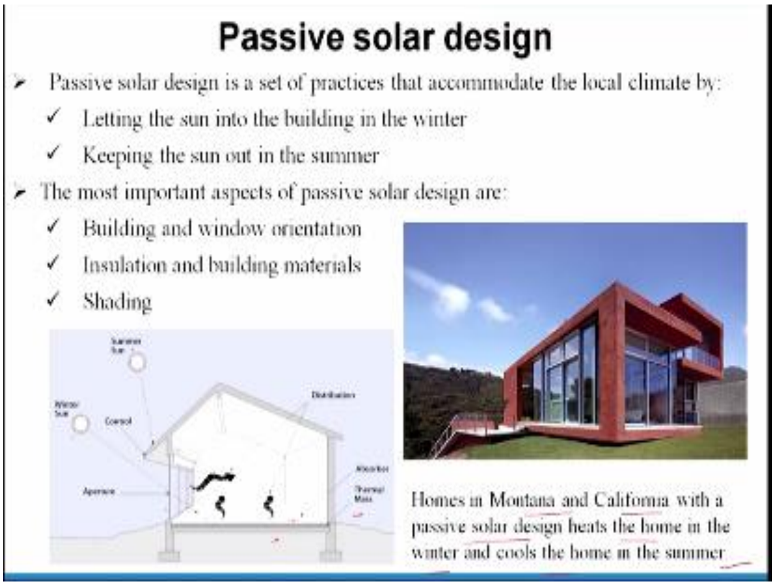

Some example is here. Homes in Montana and California with a passive solar design heats the house in the winter and cools the home in the summer and here we see here, this is our summer sun at higher elevation, so it is coming here, and that winter sun at lower elevations, the sun is coming to inside the room. So if we have that we are talking about that absorbers, we have to use some materials which can absorb heat and we will also use some thermal mass though thermal mass can capture more heat than them.

So we can select some thermal mass which can store the heat and can supply to the room and we should have some ventilation arrangement also. So these are the technique or processes or the practices we can say through which we can make the building a green building and reduce the energy requirement for the building and this can be done basically by using windows in the south face.

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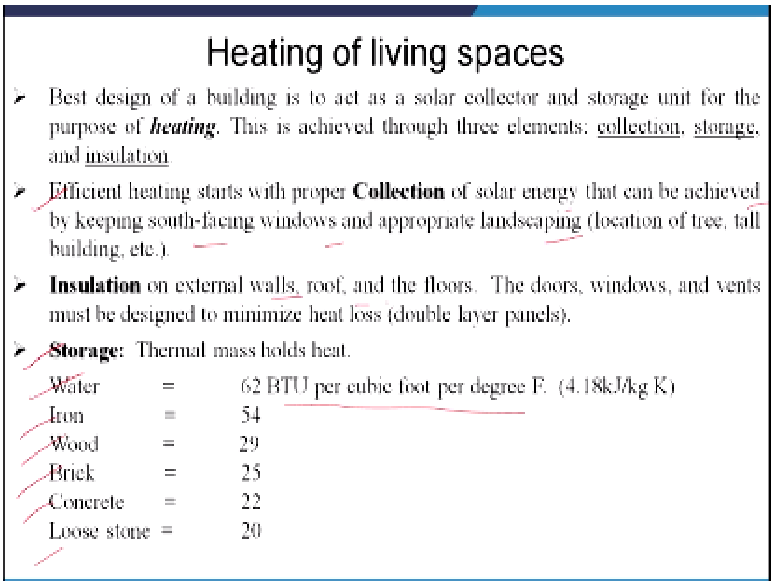

So efficient heating starts with proper collection of solar energy that can be achieved by keeping south facing windows and appropriate landscaping and then that is the collection part. Storage we can do using thermal mass, some examples are here water, iron, wood, brick, concrete, loose stone, the different amount of energy they can store per cubic feet per degree Fahrenheit, so it is given, some data are given.

Insulation that also to reduce the loss from the room and on external walls, roofs, and the floors we can use some insulating materials so that the building can be of green building in nature.

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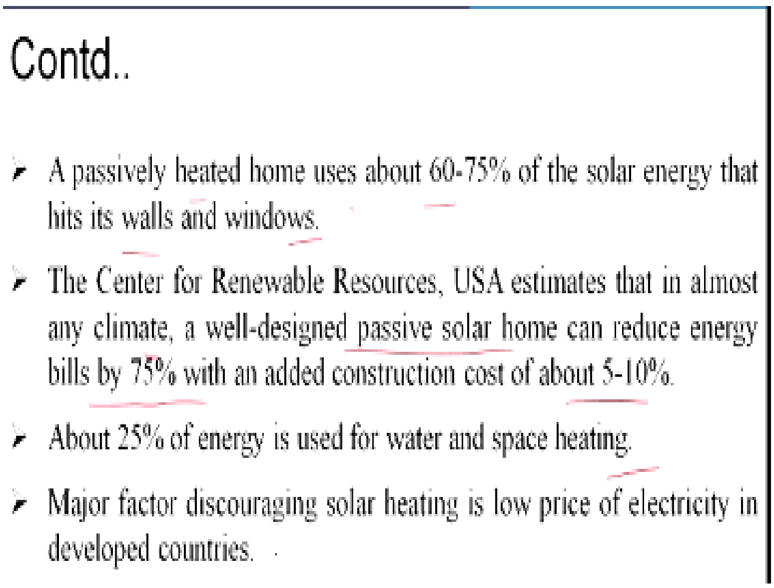

By this design, it has been reported that a passively heated homes uses about 60-75% of solar energy that hits it walls and windows. The Center for Renewable Resources, USA estimates that in almost any climate, a well designed passive solar home can reduce energy bills by 75% with an added construction cost of about 5-10%. About 20% of energy used for water and space heating.

The major factor for which the solar energy is not being used widely is its cost, previously it was very costly, but now the cost has reduced and application of solar energy is becoming a reality and people are getting more interest day by day to use solar energy in different applications.

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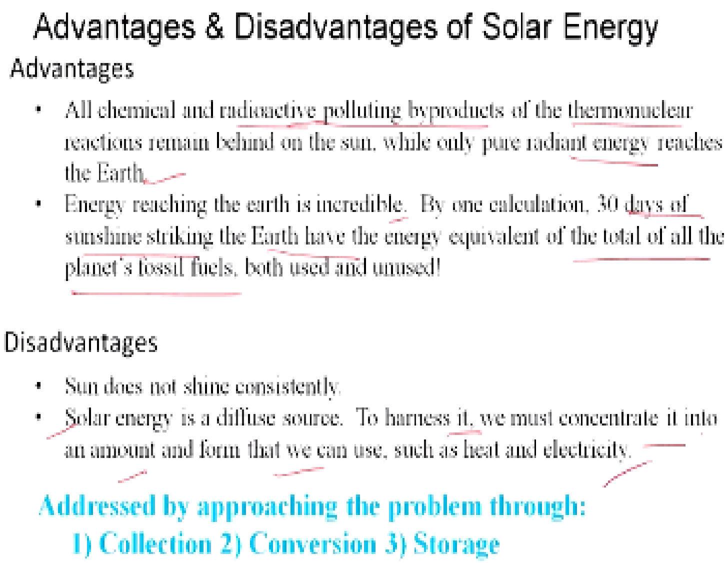

Now advantage and disadvantages of this solar energy if we think, then obviously whatever the reaction is taking place for the production of this energy solar energy that is taken place in sun, so earth is not getting any pollutants from this. So all polluting byproducts through chemical, radioactive, and thermonuclear sources, those are inside the earth, only pure form of energy reaching to the earth, that is one major advantage of this solar energy that it is pollution free.

The energy reaching the earth is incredible, it is huge amount of energy. A calculation says that 30 days of sunshine striking the earth have the energy equivalent of the total of all the planet's fossil fuels, both used and unused. So these are the advantages of this process, it can be very good to renewable source, it will never end. It also has some disadvantages because sunshine is not a continuous process, it is not continuously, it is not consistent, there is a cloud, there may be rainy season, or at the night time we will not get sunshine.

So what we have to do, solar energy is a diffuse source, so to harness it, we must concentrate it into an amount and from that we can use such as heat and electricity, etc. So we have to store, we have to convert the solar energy into some form of electricity, then we have to store it, then only this technology will be very very interesting and a great success. So, up to this in this class. Thank you very much for your patience