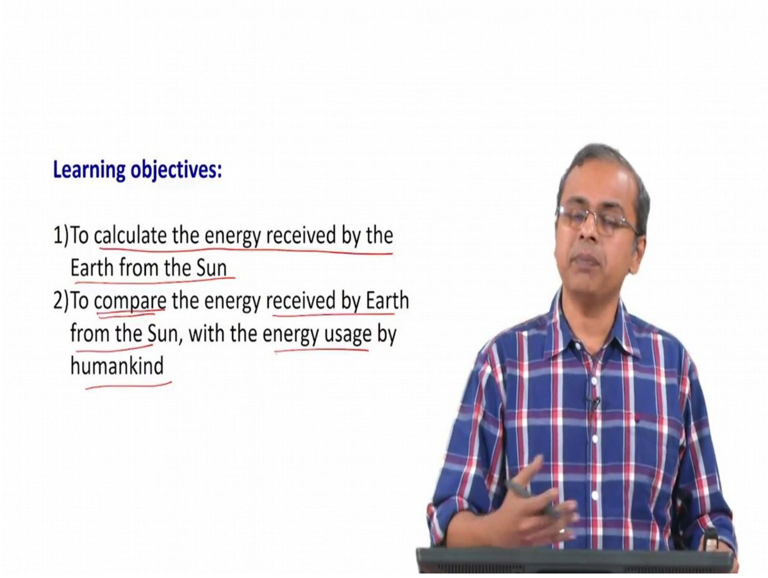
Non-conventional Energy Resources
Prof. Prathap Haridoss
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture - 08
Solar Energy: The Sun to Earth Transaction

Hello. In this class we are going to look at the basic idea of Solar Energy. We recognize that in today's world a lot of people talk about solar energy and there is a lot of emphasis on solar energy, many new companies are coming up with solar energy based products.

So, we need to get a better sense of what it is that the; what is possible with this you know this arena of solar energy. And as an initial step in the direction, we will look at what we will see in this class, which is basically the transaction between sun and earth in terms of you know how much energy is coming from the sun. I am just titling it as the sun earth transaction. But basically we are going to look at how much energy reaches our earth from the sun, and you know what is it in the context of our existence and our usage and demand etcetera. So, this is what we are going to look at. So, it is solar energy the sun to earth transaction.

(Refer Slide Time: 01:13)



So, our learning objectives for this class are to calculate the energy received by the earth from the sun. So, every day I mean during the daytime except maybe in places which are you know if you have I mean if you are near the poles and then sometime in the winter, you don't get any sunlight, but beyond that almost any other place on earth we are just getting sunlight every day.

So, there is a lot of energy that is coming from the sun to the earth. So, we would like to calculate put some number to it, what is this energy how much is this energy that is coming to us from the sun. So, that's one calculation that we going to do. So, we are going to do that in this class it's a very important it is I mean in some senses a straightforward calculation, but still a very important calculation because it puts a lot of things in perspective. So, that's why we will go over it.

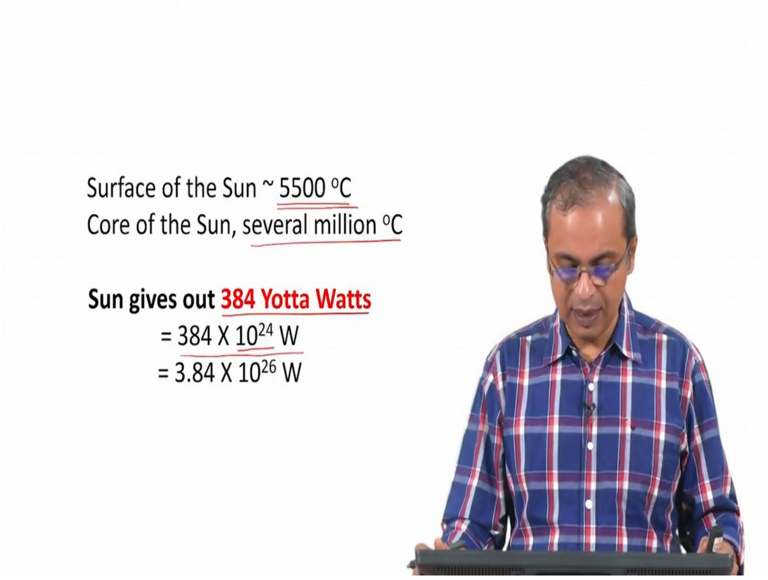
Then we are going to compare what energy we are receiving from the sun relative to the energy that we use okay. So, so we are going to compare it the energy received by earth from the sun, with the energy usage by humankind. So, energy usage by humankind we have already seen in some of our previous classes I have mentioned it, we are using about 500 Exa joules of energy every year in our present state of usage, there are various reasons based on which this will this is likely to increase. There are also technological advances that are happening all the time which may help us you know sort of level this off in some way.

So, we don't know exactly what number it will settle, because on the one hand there is a large section of the world population that is still not as developed as some other sections of the world population, and always there is a desire for everybody to be developed it is natural. And therefore, simply based on those numbers you can expect the energy demand of the population to go up in a big way.

At the same time new technologies come which essentially help you do the same job with a lot less energy. So, simply because everybody in moves up in lifestyle of their you know behavioral aspects and so on and in lifetile lifestyle accomplishments, it does not necessarily mean that the energy usage will also go up in exactly the same manner. So, if we know double the population has the same kind of lifestyle, it does not mean energy will be double it maybe something else. So, that's something that we have to keep in mind.

So, these are factors that are competing with each other, the number of people who are trying to improve their lifestyle and the new technologies which help you get the same lifestyle with less energy usage. So, these are the competing factors based on which the energy demand over a period of time will change. So, in any case we do have this number of 500 Exa joules barrier and that's something we will refer to in the through this class ok.

(Refer Slide Time: 04:04)



So, let's start with the sun, the surface of the sun is about 5500 degrees centigrade. So, just under 6000 degrees centigrade

So, you can actually you know that temperature is not terribly terribly high. In the sense we do experiments in the lab, sometimes you are doing arcing, you are doing welding, welding arcs are there various arcs are there, there are various places in relatively common place situations where you are getting close to this temperature, you may not be at 6000, you may not be at 5500, but you may be getting somewhat close to this temperature. In our you know laboratories routinely we do we have furnaces which have the 1000 degree centigrade, 1500 degree centigrade and so on. If you start going past 1500 into 2000 degrees centigrade or something you will need a little bit more specialized furnaces, but when you do things like arcing and so on you may get even higher temperatures.

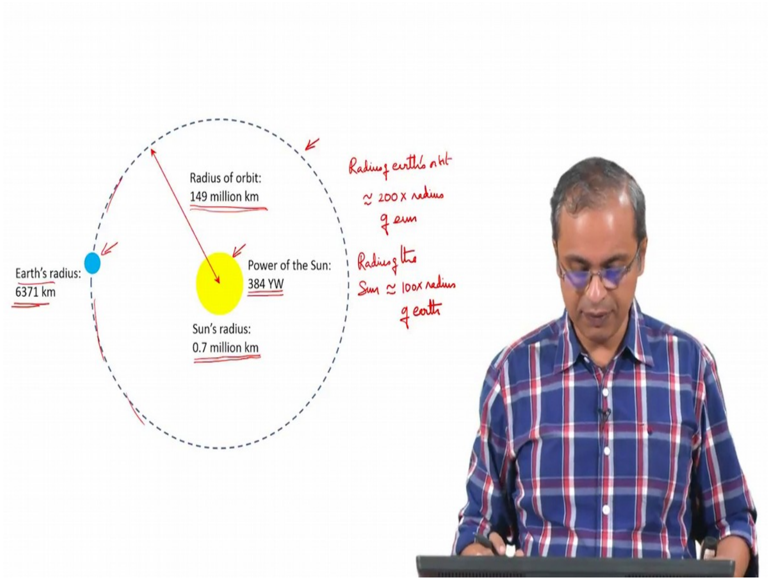
So so, that's the surface temperature of the sun, it is not terribly high relatively speaking the interior is much much much much higher. So, you can see here that the core of the sun basically our current estimates put that temperature at in several millions of degrees centigrade. So, that's where you know fusion reaction is going on which gives us all the energy that we receive right. So, that is in several million degree C, the surface is about 5500 degrees C. So, people have actually studied the sun carefully, and they have a sense of what is the power of the sun. So, you know when you put a light bulb in your house you say you know 100 watt bulb 50 watt bulb and so on. So, if you think sun is a bulb that is giving you light what is the power of this bulb. So, that is the number that you see here.

The sun gives out 384 Yotta watts. So, again you know this is the reason why I went through that scale of quantities in one of our first classes, mainly because you see these kinds of numbers you have to have some sense of what is this number what is the significance of this number how big or how small that number is. So, you can see here Yotta means 10 power 24. So, 10 power 24 is that you know order of magnitude, that gets referred to as a Yotta and. So, 384 Yotta watts means basically this number. Here 384 into 10 power 24 watts.

So, you can think of it as though there is this bulb which is out there which is which has 384 into 10 power 24 watts bulb, and that's the bulb that is you know lighting our lives. In fact, it is the bulb that is running our lives through the best if you look at it scientifically right now if there is no sunlight, you would not have photosynthesis, and if you didn't have photosynthesis the I mean the plants would die, the animals would die and the life as we know it would not be able to sustain itself.

So, critical to our sustenance is the sunlight arrival of sunlight to you know enable the photosynthesis. So, that is very critical to us. So, that's all enabled using this light bulb that is out there sort of you can call it a light bulb, but basically it is the sun, which gives us 384 Yotta watts. So, I simply put that down as 3.84 into 10 power 26. So, that's the starting point of our calculation because that is the power of the sun, and from there we want to estimate what is earth receiving. So, that is the thing that we are trying to estimate.

(Refer Slide Time: 07:26)



So, if you take this image here, it puts a few things into perspective and then we will see how we have to go about this calculation.

So, you can see here some important parameters, the first thing is this number that we just saw 384 Yotta watts that's the power of the sun. Then there is the sun which has a radius of a 0.7 million kilometers radius. So, 7, 00,000 kilometers is the radius. Earth is sitting at an orbit is going around the sun in a in an orbit of this radius roughly 149 million kilometers is the radius of that earth's orbit. It won't be a perfect circle, but we can assume a guess always in all these calculations some approximation we will do. So, we will assume it is a circular orbit of 149 million kilometers. And then you have earth here which is which you see here and as you can see I mean it is its radius is 6371 kilometers that is the radius of the earth.

Before I even get into more details of this image that I am just showing you, I will alert you to the fact that this image that this sketch that I have put here now put together here, is not to scale okay. So, because simply because if it were to scale we would simply wouldn't be able to see things in any reasonable manner on this screen, but it is definitely not to scale and that's that's something that you should keep in mind. So, quite simply for example, this is only 0.7 million kilometers diameter right I mean sorry radius, and this is 149 million kilometers. So, technically this distance this radius of this orbit radius of earth's orbit is approximately 200 times, 200 into radius of the sun ok.

So, earth's orbit if you take it's roughly 200 times the radius of the sun, clearly the image that I am showing you here does not have this circle at 200 times the size of the radius of that circle is not 200 times the radius of the sun. So therefore, right there it is not to scale. So, that is point number 1, also again if you compare the size of the earth as shown in this image versus the size of the sun. If you see again radius of the sun that is 0.7 million kilometers, so that 700000 kilometers and earth is about 6371 kilometers, we just assume that is also about 7000 kilometers. So, you are looking at a factor of 100. So, this is earth is about 7000 the sun is about 7, 00,000. So, radius of the sun is approximately 100 times radius of earth.

So, if you compare a clearly both in terms of the comparison of the radius of the sun with the radius of the earth, and comparison of radius of the sun with radius of earth's orbit in both those specific aspects, this sketch that I am drawing here is not to scale. So, that's just something that you should keep in mind, I mean it is not very relevant to our calculation immediately, but you should keep that in mind when you see such images as to what is the sense of scale that is something you keep in mind right.

So, now, what are we going to do? We need to find out what is the energy that is coming from the sun to the earth right. So, now, this power that is being released by the sun is going out in all directions uniformly. So, a power is watt is joules per second. So, 384 Yotta joules per second is leaving the sun and heading out in all directions uniformly ok.

So, you have to see. So, this same energy is going to arrive at this orbit right this entire earth's orbit as it if you think of it as a concentric sphere. So, if you can think of a sphere that is the size of the earth's orbit and in the middle there is the sun, whatever energy has been released from the sun that as it goes out will eventually go past this orbit right. So, this orbit is a sphere we are actually using only one circle in that sphere, which is where the earth is rotating right or revolving. So, after sitting in one circle in the sphere, but that is a sphere. So, this energy uniformly goes out through that bigger sphere. So, that entire energy is going out to this bigger sphere, but earth is there only in one location in the sphere, it is not there in the entire sphere. It is there at a given instant of time at a given second earth is located at one particular position in that sphere. And it also has a finite size small size. So, out of all the energy released from the sun per second, only the energy that is coming to the location where earth is present at that instant that is the only energy it is in a position to absorb or it is in a position to receive right, rest of the energy goes somewhere else.

So, if earth is only now taking away say 1 percent of the space in that entire sphere, then only one percent of the energy will reach the earth. So, something like that. So, that's the kind of idea that we are trying to look at here. So, we are taking the same energy, it is going through the sphere that is the earth's orbit and in that sphere wherever the earth is located the size of the earth, that much only the earth is able to grab. So, this idea we are going to put down in some numbers alright. So, that's what we will see in our next couple of slides.

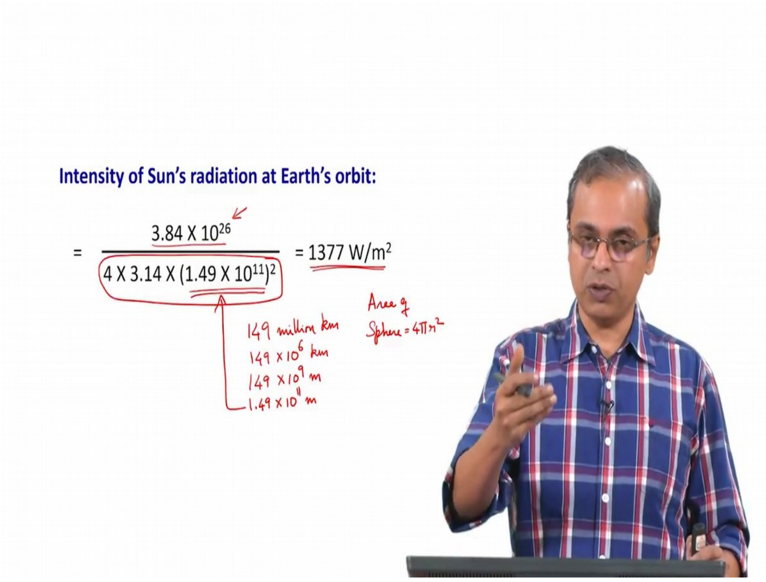
So, if you look at the intensity of the. So, we now have the power of the sun which is 384 Yotta watts. So, we have to convert this to an intensity. Intensity means how much power per unit area. Now clearly as the as you go away from the sun as you go further and further away from the sun, this energy is distributed over larger and larger surface area okay.

Therefore, the intensity which is the energy per unit area keeps decreasing, which is always the case right you are very close to a flame you feel more intense heat from the flame, you move away and away and away you feel less heat correct? Same thing sun is there if you very close to the sun, you feel extremely high intensity of the sun as you move further and further away, you sense lower and lower intensity.

That is basically got to do with this idea that the energy is getting distributed over a larger area, you are only one small fraction of the total area right. So, we are taking 384 Yotta watts, we want to see in this orbit that you see here in this orbit what is the intensity of this power, this power that is coming out this so many Yotta watts.

In terms of intensity at this orbit what is that intensity? How many this many joules per second is coming out from the sun, how many joules per meter square is there at the earth's orbit every second. So, that's the idea that we want to see. So, for that we have to understand; what is the area of corresponding to the sphere, that is the earth's orbit and then you divide 384 by the area of that sphere. So, that it has now been distributed across that entire area of that sphere that's the first calculation we want to do.

(Refer Slide Time: 14:42)



So, the same number here 384 into 10 power 26 that is the intensity of the sun; and if you look at the earth's orbit which is 149 million kilometers; so 149 million kilometers, that is 149 into 10 power 6 kilometers, that is the same as 149 into 149 into power 9 meters.

Right it is kilometers becomes meters. So, that is 10 power 9 and then that is the same as 1.49 into 10 power 11 meters I just put a decimal place there. So, that's the number that you see here. So, you have 100 and; 1.49 into 10 power 11, that's the radius of earth's orbit. So, the area of corresponding to the sphere of earth's orbit is simply area of sphere equals 4 pi r square; where r is the radius of that sphere, and r happens to be this value this 1.9 into 10 power 11 meter right.

So, the denominator is this area of that sphere, and this is the sphere corresponding to earth's orbit. So, if you had large sphere the size of earth's orbit that is the area of that sphere. Now the suns energy that the sun is releasing every second is now distributed by the time it reaches earth's orbit, it is distributed across this entire sphere equally that's the point right.

So, per meter square what is that energy, that is what we are trying to get; this is the energy released totally per second and this is the area. So, if you do the division, if you just complete this calculation, you arrive at 100 and 1377 watts per meter square every second. So, that's also there per second it is arriving so, but this many I am sorry the watts is already there. So, that is already joules per second. So, intensity is in watts per meter square right per second. So, it's already there in this watt unit.

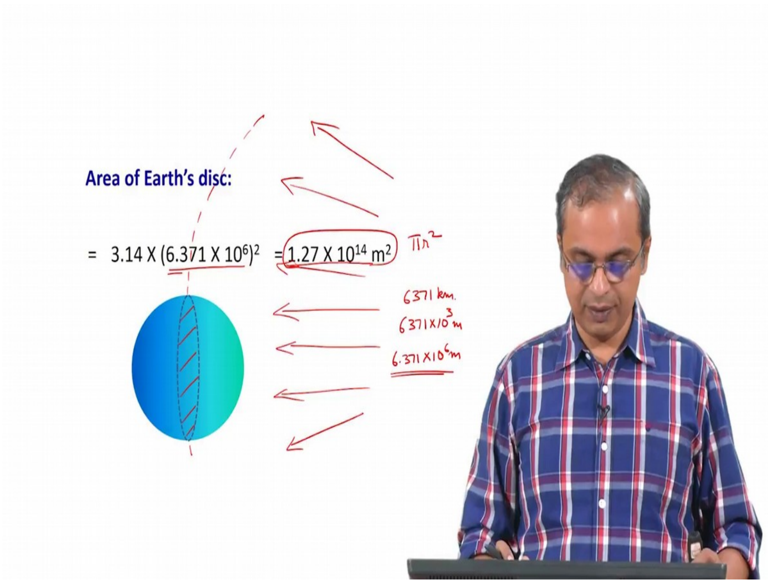
So, 1377 watts per meter square, this is the intensity of the energy that is reaching the earth's orbit by the time it reaches earth's orbit. Because you are further away it has dropped to this which is coming to our earth. Now earth's orbit as I said this is a sphere the size of the earth's orbit right, but we are only a small fraction of that orbit okay. So, if you see here, if you go back here, this is the this whole sphere that you see corresponding to this dotted line it's a huge massive sphere, that that is all around as an imaginary sphere.

This is an imaginary sphere around the sun that we are looking at, and the on the on your slide it is a two-dimensional circle, but you can think of it as a sphere which is you know sticking out of the surface and then going below the surface, in that the earth occupies only this region right. This small region that you see here is what the earth is occupying, and so, it will cut it will receive energy relative to this, that region there that's the energy that it that will fall on it. Its like a big light that is there that is lighting up the room, you stand in one location in the room. So, only a small fraction of the light falls on you, rest of the light is going everywhere else in the room right.

Same idea is there, sun is there it is putting out a huge amount of energy; earth is standing in one location. So, only one part of the energy falls on the earth, all the rest of the energy goes all around and actually goes out into space it is not really falling on any object near us of course, it falls on the moon, it falls on other planets etcetera, but basically it is otherwise it is just hitting out right. So, that is the overall picture. So, now, what we are calculating is; what is the amount of energy that is going to fall on earth. So, that's what we are doing. For that we have found out per meter square what is the energy that is there in earth's orbit or power that is there in earth's orbit and then we are going to look at what is the area that is the earth, and that is all that is going to fall on the earth.

So, intensity at earth's orbit is this value, 1377 watts per meter square.

(Refer Slide Time: 18:57)

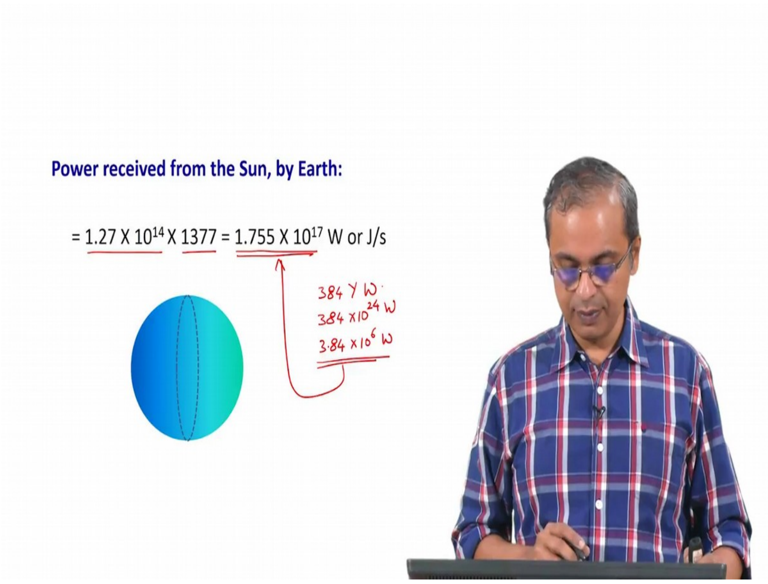


Then in the earth's orbit as I said this is the cross sectional area of earth okay. So, this is the orbit you can think of this as the orbit, it is in an orbit and this is the cross sectional area of in that orbit right. So, in that cross sectional area you will have the sunlight that is arriving. It is actually sunlight is heading off in all directions you can see here. So, sunlight heads off in all directions only some is falling on the earth. So, this part that is falling on the earth is what we are trying to calculate. So, for that first we need to calculate the cross sectional area of earth, which is simple again same thing it is pi r square and so that is pi, and this is the radius of earth. So, that is 6371 kilometers. So, that is 6371 into 10 power 3 meters or 6.371 into 10 power 6 meters.

So, that's the radius of earth in meters and then this radius is what we are plugging in here and so, we get the cross sectional area of earth as 1.27 into 10 power 14 meter square. So, that's the cross sectional area of earth, and that's the cross section that is receiving the sunlight. The sunlight is falling on it and so, even though I see I may have a 3 dimensional shape, essentially only the light that is corresponding to this flat version of my image is what is receiving the light. The 3 dimensional shape may add some I know some shading to the light as it falls on me, but this is the light that I am intersecting the cross section of this flat surface is what intersects the light. So, rest of it goes back right so that is basically what we are doing.

So, earth is spherical we are taking the cross section and that cross section is what is receiving the light. So, that is the cross sectional area that we see here and so, if you and we also have the intensity of the radiation at the earth's orbit. So, intensity is in watts per meter square that is how diffuse the energy has become by the time it reached earth's orbit, in that watts per meter square this many meter square are intersecting that are in a position to absorb that energy. So, if you multiply this with that intensity, you get the total amount of power that is reaching the earth right. So, this is what we are going to do.

(Refer Slide Time: 21:27)



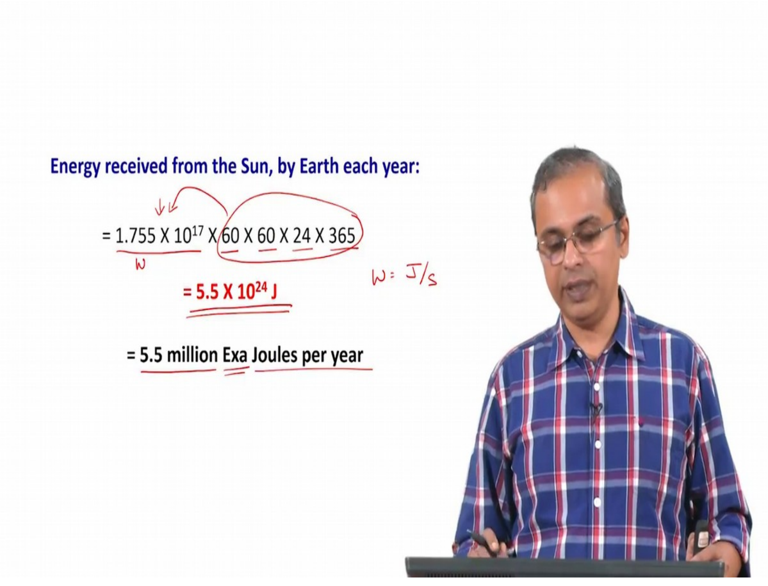
So, these are the two numbers we got, the previous slide we got this 1300 and I mean actually no two slides ago, we got this intensity at the earth's orbit as 1377 watts per meter square. And then in the previous slide previous calculation we got this in a mean area corresponding to us cross section is 1.27 into 10 power 14 meters meter square.

So, if you multiply these two, this is the amount of power that is falling on the earth. So, 1.755 into 10 power 17 watts or joules per second is arriving on the earth. So, sun is far away, it is releasing a very large amount of power. So, we had this value here which we will take from this place 384 Yotta watts, that's the amount of power that is being released by the sun and. So, 384 Yotta watts and that was 384 into 10 power 24 watts or 3.84 into 10 power 26 watts. This is the power of the sun that is that's being released by the sun, but it is getting diffused as you go further and further away, because it is getting distributed across lot of places and then the earth because it has a small size out of this total large number that is being released by the sun only this much is being captured by the earth ok.

So, out of this only so much is captured by the earth's surface, because that's all the surface of the earth if earth were a larger planet more energy would fall on it in the same orbit. If you had earth as a larger planet more energy would fall on it or if earth were closer to the sun, if earth were closer to the sun, then by the time the suns energy reaches that orbit, it will still be at higher intensity because it is not; it's still closer to the sun. So, higher intensity will be there. So, earth will absorb more energy for the same duration of time. So, if you get closer to the sun, you get more energy at the same amount of time. If you are further from sun relative to the earth you will again get less energy or if you are in the earth's orbit with a larger size for earth, you will get more energy.

So, these are the different ways in which you can you know change these numbers, but we have a certain orbit for the earth, we have a certain size for the sun, we have certain power from the sun, we have a certain size for the earth. If you take all these factors into account, this is the amount of power that is arriving at the surface of the earth from the sun. So, that's the number that we have available to us and is therefore, of interest to us.

(Refer Slide Time: 24:10)

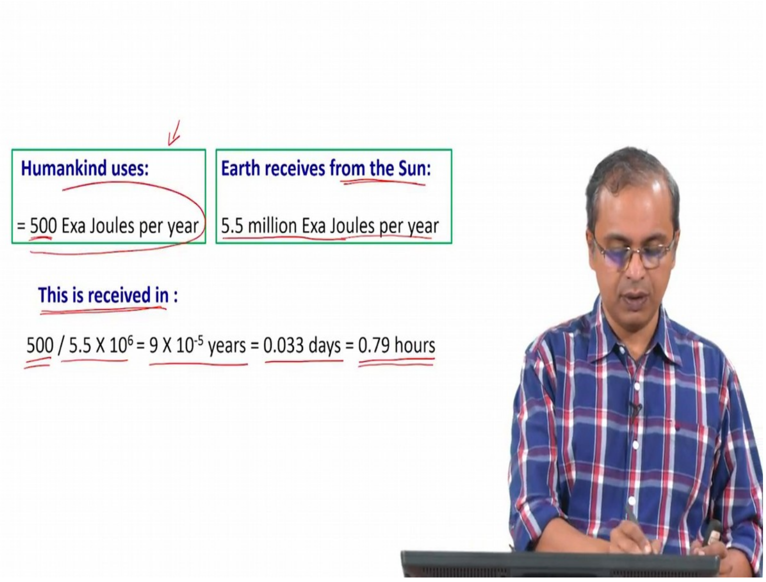


So, now if you now see the energy power, this is in watts per, this is the watts that we have here which has reached us from the sun. So, 1.755 into 10 power 17 watts is reaching the earth every second. So, that. So, basically every joules sorry these many joules is arriving every second, so that's the power in watts. So, 1.755 into 10 power 17 watts is the power that is being received by the earth.

And so, what is the consequence of this on a year round basis. So, if you want to see what is the total energy received by earth per year just from the sun. So, then you have to take this power which is the amount of energy received by the earth every second right. So, it is watt is in joules per second. So, this many joules is arriving on the surface of the earth every second. So, if you want to calculate what energy we received in the entire year, we have to multiply simply by the number of seconds in a year.

So, for that we have 60 seconds per minute, 60 minutes per hour, 24 hours in a day and 365 days in a year. So, actually this number that if you calculate, you will get some fairly large number some you know in basically it will amount to a huge amount of seconds, that are there in every year and this seconds if you multiply by this power, you get the total amount of joules that is reaching the earth every year from the sun okay. So, if you do the calculation you arrive at this number. 5.5 into 10 power 24 joules is arriving at the earth every year from the sun. So, that is 5.5 million Exa joules. So, 10 power 18. So, 5.5 million into 10 power 18 joules per a year is arriving from the sun on the earth.

(Refer Slide Time: 26:15)

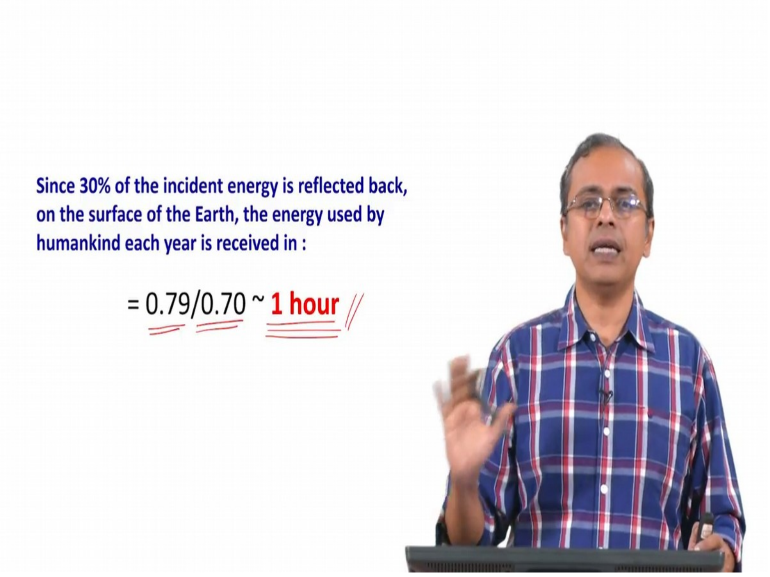


So, we have now some two interesting numbers that we have that we can compare. We know as of today that humanity uses 500 Exa joules every year okay and from the sun from the sun we are receiving 5.5 million Exa joules every year okay. So, sun is sending to us 5.5 million Exa joules and we are using 500 Exa joules. So, these are two numbers that are of interest. So, if you compare these two numbers okay. So, given that we get 5.5 million Exa joules from the sun every year, it is of interest to see in how much time will we receive 500 Exa joules?

Okay so, 500 Exa joules will take how much time? So, if you divide 500 Exa joules by 5.5 million Exa joules, you will get the amount of time in years that it takes for the sun to give us that much energy. So, if you do that, if you do 500 divided by 5.5 into 10 power 6, 5.5 million Exa joules they are both in Exa joules now 500 Exa joules divided by 5.5 million Exa joules, you get 9 into 10 power minus 5 years. So, 9 into 10 power minus 5 years, we receive this energy that we that humanity seems to be using every year okay. That if you convert that today's that is 0.033 days if you convert that to hours that is 0.79 hours ok.

So, as of now humanity or humankind is using 500 Exa joules every year, but right now it is using it from a wide variety of sources of energy. In fact, most of the energy we use as we have seen typically is coming from fossil fuels is coming in fact, a lot of it is coming from coal, and from other you know resources that are associated with nonrenewable sources of energy which are also not clean, but all told together we are using 500 extra joules of energy right. Now if you just keep that number in mind and not worry about the source at the moment, and you compare that against what we are receiving from the sun; then it turns out that every 0.79 hours the amount of energy arriving from the sun to the earth is equal to what we are using, which is this 500 Exa joules per year.

(Refer Slide Time: 28:48)



It also turns out that when radiation arrives at the earth from more than one location there is actually some amount of reflection. So, due to that reflection actually even though that energy arrives at the top surface of the atmosphere; from the sun it is arriving at the top surface of the atmosphere some of it is getting reflected back.

So, it turns out about 70 percent goes through and reaches the surface of the earth; meaning where we stand now when you stand outside on the in when you are out for a walk, and you feel the sunlight reaching you, that's only about 70 percent of the sunlight that arrived at the top part of the atmosphere. So, 30 percent got lost due to reflections both at the top part and also some interior parts of the atmosphere, but 70 percent reaches you on the ground. So, wherever you are about 70 percent of what showed up at the top surface reached you. So, that is the calculation. So, if you take that also into account, this the amount of energy that we use per year instead of 0.79 hours, it takes a little longer because 30 percent is getting reflected only 70 percent is coming to us. So, if you just divide that by 0.7 it's about one hour.

So it takes a little longer for the amount of energy that is to get the same amount of energy, because some of it is getting reflected right. So, if 100 percent comes it would take 0.79 I mean hours. So, that is the way we have to look at it right. So, we get it in about one hour. So, if you see here, that's the interesting part that you want to focus on; that the entire energy that we use in a year reaches us from the sun in just one hour. So, that is a very phenomenal piece of information that we have to appreciate and understand.

I mean in many ways when we talk of you know non conventional sources of energy, really the the source of energy that would make the most difference to mankind is if we find a way to tap the solar energy effectively. Because as you can see even with today's level of advancement with the level of energy usage that we do, every hour we are receiving energy from the sun equal to what we use what we require in the entire year. Okay so, in the entire year whatever energy we are utilizing, all that energy is being received from the sun by us every hour. So, you can imagine even if we are inefficiently tapping this energy that much room for error we have. We have so much room for error and still we would be completely satisfied.

So in other words the point you have to understand is, with the clean source of energy like solar energy you have abundant amount of room for you know satisfaction of all of humanities needs okay. So, all of humanities needs can be met just by solar energy, if you just know how to tap it that's really all it is. It is already arriving at us we are not even doing anything; you don't even have to drill to get this solar energy. It's just coming straight at you just stand outside it is hitting. So, that energy is already there, you just step out it is already reaching you. We simply need to know how to capture it, and use it where we want. So, you have an automobile you should know how to capture it, use it an automobile, should know how to capture it use it in your house, you should know how to capture it you sit in your office.

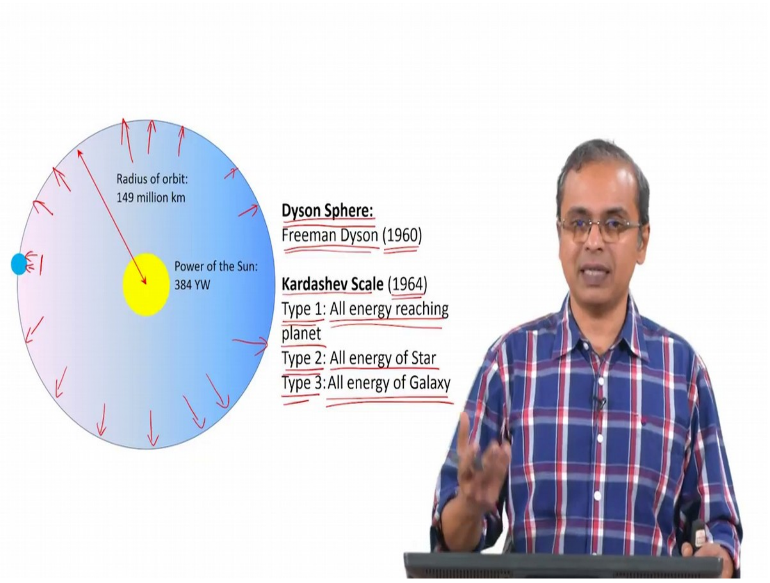
So, this is really all that we have to do. If you know how to do this, we really have an abundant source of clean energy which has no other ramifications because anyway it is coming on earth, and anyway earth has gotten used to it or wherever we are on earth, whatever this as of today it is already in equilibrium with this amount of sunlight that is reaching us.

So, in all those ways it is already a clean source of energy, we just need to know how to tap it. And you can imagine the level of comfort we have, here it's not even you know even if all the I mean if all of the world starts living this fanciful lifestyle, maybe we will go up by a factor of 10 or 20 in our energy usage or maybe even 30. Even if we do that, we have you know; I mean we have a factor of 365 into 24 that is the number of you know hours that are there in a year right. So, we are looking at something like 7000 and 8000 hours that are there more than 8000 hours in fact, in a year.

So, if you look at more than 8000 plus hours in a year, that is the margin of error we have. Every hour we are going to get enough energy for the entire humanity for the year, and you have 8000 plus hours to deliver that energy. So, that much amount of energy. So, even if you put 10 percent error, 100 percent error you double the amount of energy you said, you triple the amount of energy, you go up by a factor of 20, go up by a factor of 30 in the energy usage, you still have way more energy arriving at earth than we are possibly using right. So, that is a beautiful piece of information for us to have to understand and latch on to so, that we can you know build on it.

So, this is the point that I really wanted to emphasize in the calculation today, that we receive as much energy every hour as we require for the entire year. But that's not all, there are some more interesting ideas given that this context is there and that's what I will touch upon briefly in the next slide. What I am going to show you in the next slide is a bit futuristic, but it is it's more from a physicists have thought of imaginary situations, where we can do even better than this and that is basically all that I am trying to point out.

(Refer Slide Time: 34:05)



So, you can see here in the 1960s there was a physicist an English man who lived in the US his name was Freeman Dyson. So, he suggested that you know if it were possible to construct a sphere the size of the earth's orbit, then you can capture all the energy that is coming towards the earth's orbit. So, whatever energy, so right now we only capture the energy that is coming here right, we only capture the energy that is coming to the earth, but what about all this energy that is going away we are not able to capture it right.

So, if we had a hypothetical I mean we really managed to if our technology advanced far enough, that we could make a sphere. Some thin thin material sphere which is the size of earth's orbit, then you can actually capture all the energy that is coming from the sun. As opposed to only what is coming in this cross section, all the energy that is coming from the sun can actually be captured, but this is only a theoretical concept because as of now at least. Because, nobody knows how to construct such a sphere, I mean we are no struggling to make we just about making buildings, which are you know say a 100 floors, 150 floors tall and so on. And those are our major accomplishments as of today, and many countries try to no out of prestige issues they will try to build very tall buildings.

So, that's really how far we have come; to build something in earth's orbit that extends the size of the earth's orbit, it is itself something that we have not even really imagined in any serious sense, and this may not be the only implementation for it, there may be other implementations where you do only partially this activity to get more energy. But in any case we have not really looked at it, where would we get the material for it, where would we get the material to build such a structure let alone go about building it. We may not have enough material on earth; to build even a thin you know structure which extends the orbit of the earth. But in any case it is an interesting concept to keep in mind and that's why it is you know it is the in fact, specifically referred to as the Dyson sphere named after the man Freeman Dyson and you can go look it up you will find in interesting information on this.

And incidentally as an aside as an extension of it, there is something called as the Kardashev scale, which was sort of postulated in 1964, it is actually an extension of this it is also by a physicist in this in this instance Russian physicist, where he basically tried to imagine how civilizations may develop over a period of time and possibly what you can how you can put a scale to measure the extent to which civilization has developed.

So, in this scale for example, he talks of three types of civilizations, type 1, type 2 and type 3. This is almost mostly a theoretical discussion at this point; type 1 civilization would be a civilization that is harnessing all of the energy that is arriving at the planet okay. So, the discussion that we just had that you know all the energy that is coming from the sun reaches the surface of the earth in whatever energy we receive from the sun even in one hour, takes up I mean is able to cover the requirement that mankind has for the entire year, right

So, if you know how to capture that energy right if you capture that energy or you capture all the sunlight that is coming from the sun to the earth every year, if you manage to do that then you are a type 1 civilization. If you have advanced to the point, where all the energy that is coming from the sun to the earth, all the energy received by the planet is actually being captured by the planet and harnessed by the planet, and used by the planet as a civilization I mean of course, it is going somewhere in to be the ecosystem and something in various things are happening. But as an as a advanced technology civilization that is what we could think of ourselves as human beings. If we have managed to find the devices that capture all the energy that is coming from the sun to the earth the entire year, if you managed to that then we are a type 1 civilization.

So, if you actually look at it from that perspective, even today we are not a type 1 civilization. If you think you know we are very, we are so developed, we have all these smart phones, and we do all sorts of fancy things, we fly all around the world, well does become a small place yes all those things are true, all those things are true but from this context of our ability to capture all the energy that is arriving on our planet, we have not even reached there.

In fact, we are not even reached a place where we are capturing one hour of the energy that is coming to our planet, that is why solar energy is still such a I mean it is seen by the fact of solar energy devices are still such a small fraction of the energy devices that we use in the grand scheme of things. So, you see you saw that in all those statistics, all the renewables everything is falling in that you know just a few percent of the entire energy is you know supply scheme that is there, and clearly solar energy is much smaller fraction of that also. So, we have not even come close to capturing what arrives on earth every hour, and forget about the 8000 odd hours that are there in the year right.

So, if you reach that 8000 odd hours year limit you are a type 1 civilization we have not reached that. Type 2 civilization would be a civilization that has advanced so much, that it is actually able to capture all the energy of the star that is powering the that civilization. So, a type 2 civilization would be of this nature. One which would have something like a Dyson sphere around it's star, and capture all the energy from that star right.

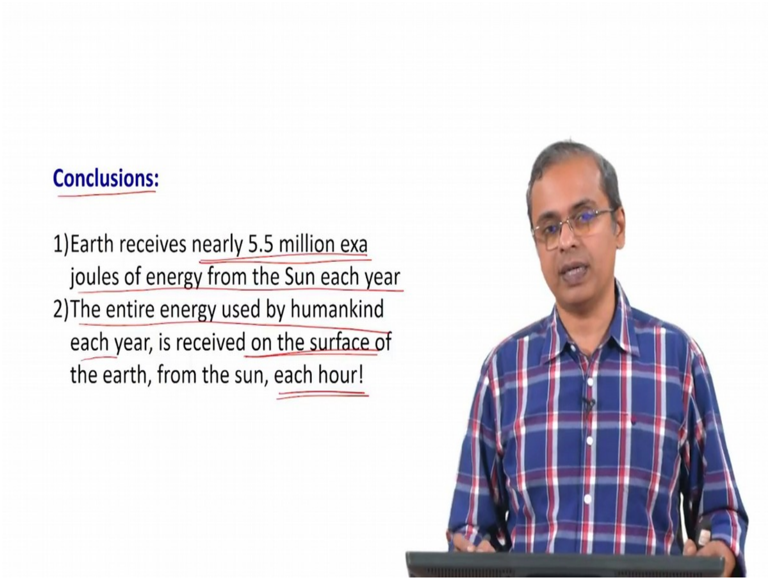
So in fact, this is an interesting concept from the perspective of you know science fiction, it is also an interesting concept from the perspective of scientists who are looking for life forms elsewhere in the universe, they are looking to see if there is some massive structure that is a that does not fit the natural scientific evolutional evolutionary processes. So, we know what kinds of stars are there, we know what kinds of planets are there at least we have learnt a lot. There may be still a lot more to learn and then I am sure there is a lot more to learn what we have learnt a lot.

So, if you see a structure which is the size of earth's orbit and we are able to measure a structure which is the size of a huge orbit, but it is not having the characteristics of a star; that means, it is probably some artificial structure which is blocking a star right. So, this is one way in which you can guess if there is you know advanced life elsewhere in the universe. And once in a way they will stumble upon something that looks like it, and then they find that maybe it is something else and so on.

So, those kinds of things are there in the news. So, you should if you get a chance on the internet, use a search engine and then search for Dyson sphere and get an idea of it. type 3 is a I mean is beyond our imagination certainly, even type 2 is beyond our imagination because I really cannot see how we will build something that covers our entire orbit, but in any case at least notionally that is seems like something that that can be considered, if at all there is a way to do it, but type 3 would be one which uses all the energy of the galaxy that it is representing. A civilization that is present in a galaxy that uses all the energy of the galaxy.

So, this is just a scale it does not mean that there are people who would be who are actually using this or that we are even going to do anything like this, but it is a scale that shows you the kind of energy that civilization might use, and and therefore, it is something that is of interest from a scientific perspective and also from you know technology perspective. So, these are some aspects and as I said Dyson sphere is something that is interesting to look at.

(Refer Slide Time: 41:33)



So, we did some calculations in this context and so, to conclude here and if we can briefly look at some of the key things that we sort of saw in this class. First thing being that the earth receives nearly 5 and a half million Exa joules of energy from the sun each year. So, that's a huge amount of energy, it is not something that we should I mean ignore or think that it is not much simply because of what we are seeing on the ground.

On the ground we see that solar energy devices are just coming up, they have not really taken over the market as we would like them to take over. We don't yet have every house and every automobile powered by solar devices, although that seems like a very interesting concept seems like something that we should be doing because all you need to do is put a solar panel on top of your house right. Once you put a solar panel sunlight is anyway already coming on it. So, it's not like you have to do anything about it you see there is no generator there, you don t have to put a; you don't have to supply diesel to it nothing. You just have to put this panel and wiring to your house that's really all it is. Once you do it the solar energy is already being tapped by your house. So, we potentially we could we could all do that.

Similarly, with automobiles, you could have the roof of an automobile the top of the automobile, the front of the automobile, back of the automobile, except the windows. Literally other than the windows, every other surface of the automobile could have solar panels pick up solar energy and then power the automobile. So, potentially we could do all this, we don't do it right we do not yet do it, we do we do have some street lamps that are powered by solar panels and so on, but we have not reached that stage of usage of solar devices and solar products, where we can feel that you know we are actually considerably tapping these solar incoming energy right.

So, sometimes just looking at the minimal amount of solar products, out there we may have this wrong notion that maybe there isn't enough in that field, but really if you look at it this is a huge amount of energy that is arriving, which all of a very very large fraction of it we are just wasting. And wasting in the sense we are ignoring we are doing nothing about tapping. A very huge fraction of it is just being not even we are not even trying to tap it, it is all just falling it's all it's like you know all the energy coming and we is just falling all around us and we are not doing anything about it.

It's standing it's like standing in a rain and it is a huge amount of rain coming down on you and you are basically having a small cup which can capture only one drop of a water at time, and then you say this is all the water I m able to get and there is all this water that is falling all around you. We are basically in that situation, there is all this sunlight that's falling all around us we don't tap any of it, we have the small panel with which we capture you know one small percentage of the sunlight and that's all we are capturing.

So, today our level of development our level of deployment of the solar panels is like that. Much of it is just going completely wasted we are not capturing it or making use of it. And as I said the great promise of solar energy, the huge promise of solar energy is the fact that the entire energy used by humanity each year is being received by the on the surface of the earth each hour.

So, every hour not on some you know long duration, every hour we are receiving all the energy that we need for the entire year that is the biggest promise of the solar energy. That you know you get this massive amount of energy at such a short period of time and it is clean, it is as clean as it gets because that's how the world has developed that's how the you know entire all the biology that is all the life that has formed on earth has all developed at some fundamental level due to the sunlight that's been coming into the earth. And then this is where we are the planet that is in equilibrium with the at some kind of a dynamic equilibrium with the sun, and all of that energy has arrived here, right.

So, this is where we are. And clearly if we manage to tap this energy we have a very clean source of energy, right.

So, with this I would like to conclude; in this class we have looked at the transaction of energy from the sun to the earth, we looked at what is the power of the sun, we have looked at how that power diffuses as it arrives at the earth's orbit, we looked at our earth's cross-sectional area and said you know out of all this energy that the sun is sending out in all directions what is the energy that reaches the earth on the earth's orbit. And therefore, we know the power of the sun that is arriving on the earth, and then we have you know convert that converted that to joules and joules per second and then looked at how many joules are arriving per year. And then finally, we compared it with the total amount of joules that we need every year as of today.

And with that we find that we are in a very promising ground. We are in a very good situation, we have some lot of promise here, and potentially wonderful things can happen in this arena of solar energy and how it is utilized in our society.

Thank you.

KEYWORDS:

Solar Energy; Energy coming from Sun; Temperature at Sun's Surface; Energy in Joules from Sun; Energy in Watts from Sun; Power of Sun; Intensity of Sun; Clean Energy; Dyson Sphere; Kardashev scale

LECTURE:

Power of the Sun in terms of Solar energy is enough to meet humanities energy needs. This energy is quantified and the rate at which it is replenished is calculated. Weather the amount of solar energy falling on earth is sufficient to meet our needs ? This lecture discusses about where we stand with respect to Solar energy in terms of usage and tapping**.**