Sustainable Architecture
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Lecture – 23
Sustainable Sites - III

Good morning, welcome back to this new lecture for the ongoing course on Sustainable Architecture. And in the previous week, we have been talking about Sustainable Site development as part of sustainable architecture. Now we have focused upon how to develop the sites. So, previously we have been talking about the selection of site and the overall development of site. While from today's lecture, we will be talking more about the design issues and how to handle them for development of sustainable sites.

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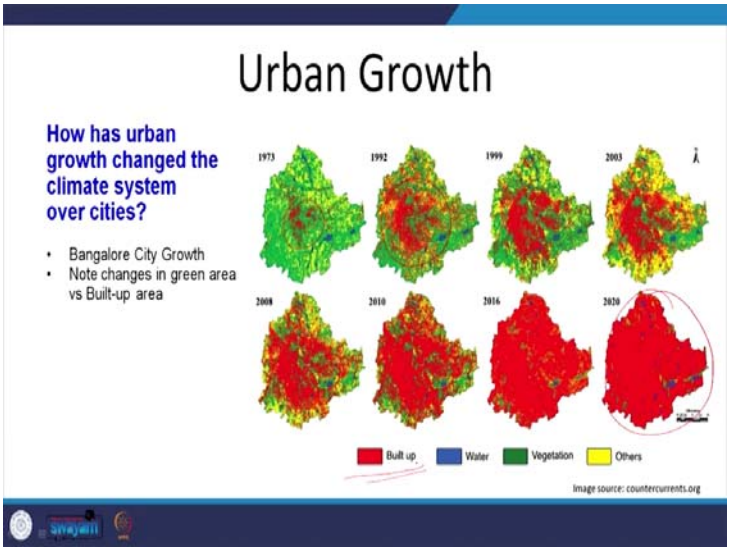

So, in today's lecture we are going to look at what urban heat island is, what causes urban heat island and through the development of site in a sustainable manner. What all do we need to do, what all do we need to look at while designing the site, so that this urban heat island can be mitigated or it is effect can be reduced. So, here we are looking at the city plan of Bangalore city and if you look at how it has been progressing. We see that more and more of the Bangalore has started getting constructed. And if we look at this image for 2020, we see that almost the entire of Bangalore is a dense city with built up area all over and this is not just the story of Bangalore; it is almost everywhere. So,

with this growth which we can see happening in terms of the built mass coming up in different cities, this is what happens.

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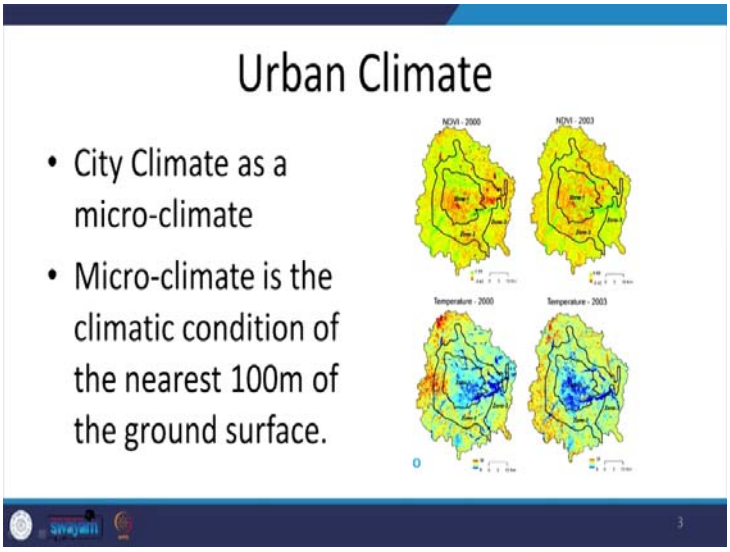

So, we are looking at temperatures and the NDVI values. So, here because of this addition of built mass which is replacing the vegetation, the greenery; we can see that the temperatures have been on rise. We experience them on a day to day basis. But what we are majorly seeing here as a focus is the microclimate of the city within the city boundary which is not physically defined, but this is our physical limitation. So, we experience that the micro climatic conditions of the city which is the first 100 meters from the ground surface, the temperature for this micro climate has been on a rise; it has been increasing. This is what urban heat island is.

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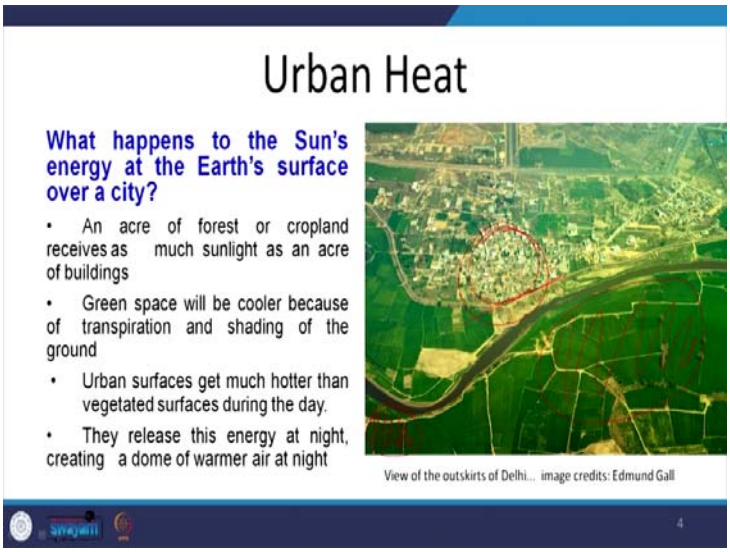

So, what actually happens and what causes this urban heat island is answered, if we ask the question that what happens when all the sun's energy which is coming uniformly across the surface of earth. I am not talking about the differences between tropics and polar, but if we consider cities and areas within the same latitude, we see that the earth's surface receives the same amount of energy here.

So, what happens if it falls say on a green patch like this which is an agricultural feed or there may be a forest somewhere, where there are bigger trees and as compared to that within the heart of the city. So, when the sun falls in this vegetated area agricultural field or a forest, this heat this solar radiation will be absorbed by the plants for their processes like photosynthesis and transpiration and it also shades the ground.

So, the sunlight is not reaching the ground for most part of the year. However, when we are looking at the city area, when we are looking at the city limit because of the buildings getting constructed, a lot of the solar radiation which is falling on the surfaces building surfaces is getting absorbed and then released during the night time. A large part of the solar radiation is also falling on the ground which also has been paved using different materials. So, this is the major difference which brings in the concept of urban Heat Island.

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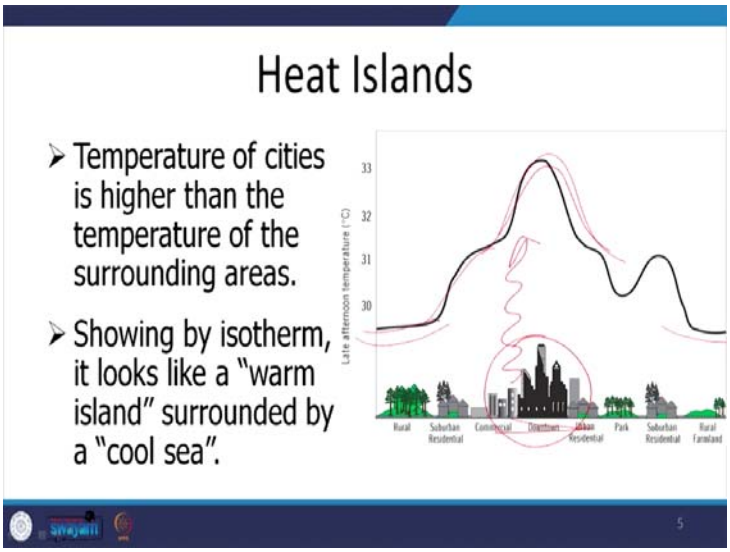

So, what happens is that the temperature because of a lot of heat which has been absorbed by these buildings and then reradiated during the night? So, the night time temperature suddenly increases, it increases in comparison to the rural areas and also the suburban areas which are not as dense as the downtown city. This phenomena where the temperatures of the cities increases as compared to the surrounding rural areas. This phenomena is called heat island.

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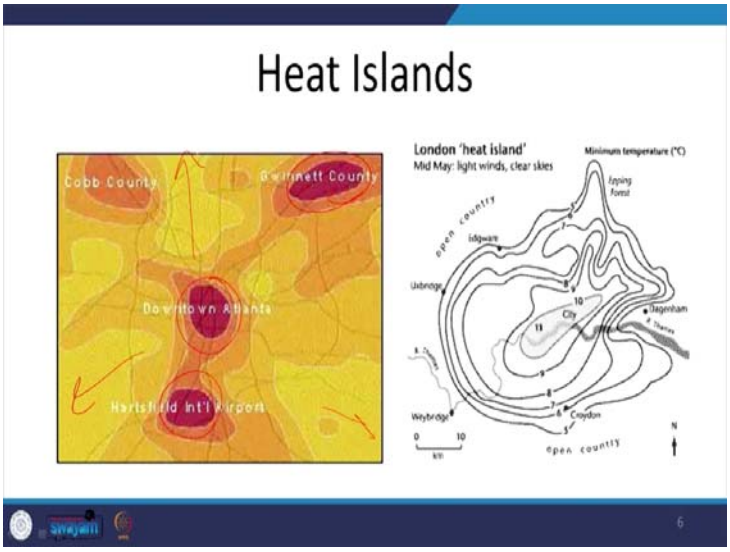

And this phenomena of heat island has been observed in all the cities across the world irrespective of their geographical or climatic context. The intensity of it may vary, but it is present everywhere. So, we can see a lot of different these isotherms these temperature maps where we can see that the downtowns are the hottest areas wherever there is a concentration of building activity. These are the hottest areas within the city and as we go towards the rural areas as we expand, these temperatures they fall down.

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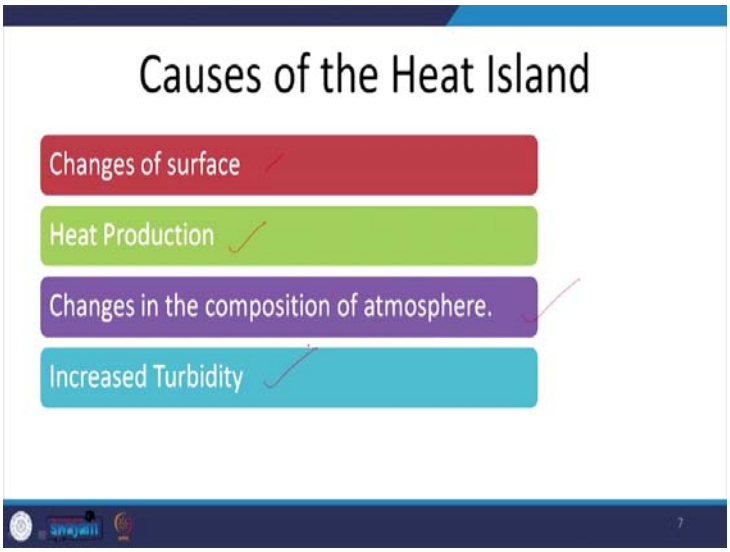

So what actually causes heat island? So, some of the most prominent causes of heat island, I will discuss today. So, one is change of surface, heat production, changes in the composition of atmosphere and increased turbidity. Let us look at each one of them in little detail.

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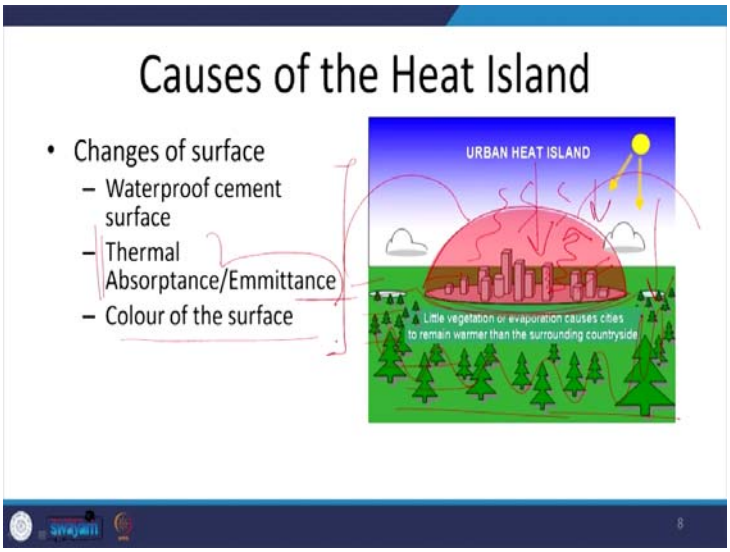

So, first is changes of surface. Now what is happening as I said in the very first slide that when we cut down the forest area and the greenery and we construct the buildings and the built mass comes up. So, this change in the surface is responsible for this heat island for multiple reasons. One, the heat which otherwise would be incident on the tree is utilized for different purposes like photosynthesis and transpiration as I said. Now this heat if it falls on the buildings will not be utilized for anything, so since energy overall remains constant. This heat this energy solar radiation is absorbed by these buildings and then reradiated during the night creating this urban heat island which is what we see.

Another is because of the moisture content which is not present in these built surfaces, these forests the vegetated cover also holds a lot of moisture and because of this the environment, the atmosphere also holds a lot of moisture. Because buildings cannot; these materials cannot hold moisture the city limits they become drier and the water content the moisture content further drops down in the downtown area in the heart of the cities where a lot of buildings have come up. That is further responsible for the heat island, increasing the intensity of heat island.

These surfaces hard surfaces have these thermal absorptance and emmittance to play a role, which is what when I talk about the green cover versus the built cover. And within the built cover, the different kinds of materials which are there will have different thermal properties, the amount of heat that they absorb and then they release later, emit.

So, on the basis of that the temperature variations would come into place and the heat island intensity would vary. So, the thermal properties of these surfaces have a large role to play and also the colour of the surface lighter. The surface more is the amount of heat that it reflects and hence lesser amount of heat is absorbed and further reemitted. So, these are the properties of the surface which impact the urban heat island and it is intensity.

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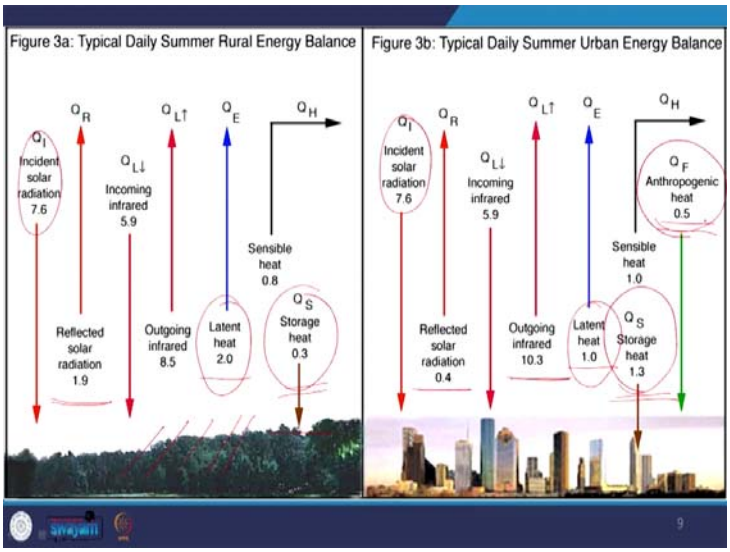

If you look at this image, we can very clearly see the difference between the rural areas and the urban areas. If you look at the total solar incident radiation which we assume that is the same, since it is the same latitude and the place receives the same amount of solar radiation, we can see the difference coming in. So, we have a lot of solar radiation reflected in case it is a rural area while lesser amount of solar radiation is reflected back to the atmosphere which implies that a lot of heat is absorbed by the materials. And if there is more heat which is absorbed, we know that a lot of heat will be released later in the form of infrared radiation. The long wave radiation which cannot escape the atmosphere and it will be contained within that. So, there will be more heat in the atmosphere causing the urban heat island.

Then we are also looking at the latent heat because there is more moisture in because of this vegetation, because of the greenery. We know that the moisture present will be able to take up more amount of heat from the atmosphere. While in case of urban areas, this

latent heat decreases. Another worry is the storage heat because there is not much hard surface in the rural areas and there is a lot of built surfaces hard surfaces in urban areas. This is the major cause of heat island effect coming into picture.

Another thing which is absolutely not present in the rural scenario is this anthropogenic heat. Now this anthropogenic heat is what has been added to the environment because we consume the fuel.

For example we are running cars in urban areas now that is adding to the anthropogenic heat, we are adding a lot of air conditioners to our building that is adding to the anthropogenic heat. So, this is a major cause of worry. So, this is what overall causes our cities to be warmer, hotter and that is what we are calling as heat island.

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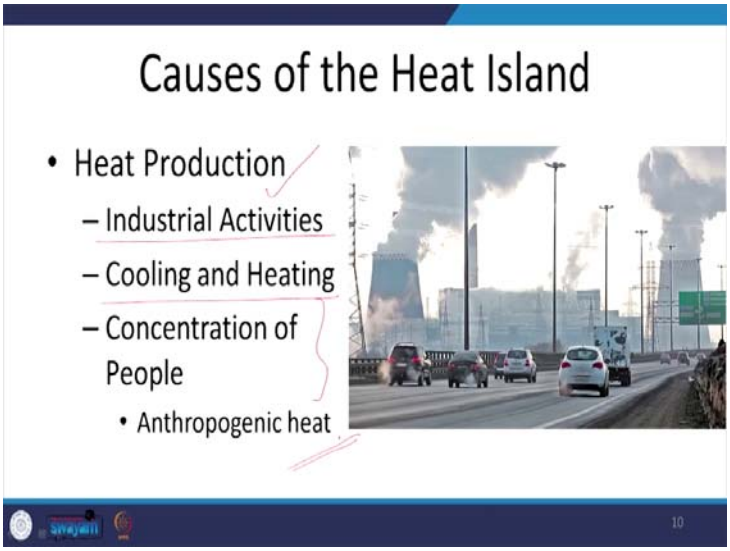

Another major cause of heat island which we have seen in the energy balance diagram just now is the Heat Production. So, in cities we have industrial activities being carried out, we have cooling and heating of buildings of our indoor environment which is adding to the anthropogenic heat outside and also there is a lot of concentration of people in the cities unlike the rural areas which are sparse which are not as dense. So, all of that together is adding to a lot of anthropogenic heat in the cities and the atmosphere in the environment. So, that is another major cause of heat island.

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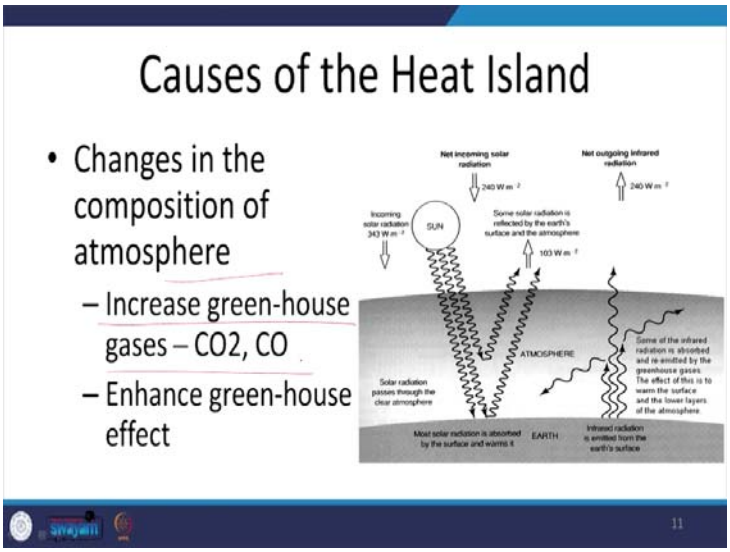

Then we also have the changes in composition of atmosphere. Now when we are adding when we have more and more of industries and when more and more of greenhouse gases are being increasingly added to the atmosphere so, we very clearly know what greenhouse effect is and these gases they absorb these are suspended particles that there not just these gases but the suspended particles. So, all of these they absorb a lot of heat which is there in the atmosphere, which is coming from the sun and it is also being rereleased in form of this long wave radiation.

When it is absorbed, it increases the temperature of the atmosphere. Greenhouse effect is what is helping us survive. If greenhouse effect was not there probably earth would not be a habitable planet. But today what is happening because of the increased concentration of these greenhouse gases like carbon dioxide, carbon monoxide. Now these two are the commonly taken names, but these are the gases which have least global warming potential. There are gases which are much more, they have more capacity to absorb the heat the nitrogen oxides and the sulphur oxides and many more gases like that which absorb a lot of heat and are the major culprit towards the greenhouse effect.

So, all these will impact and they will add up to the rising temperatures. Now since the concentration of these gases is more in the cities because, there are more vehicles which release these greenhouse gases or there are more industries which will release these

greenhouse gases and all. So, we will have the heat island effect more pronounced in the cities.

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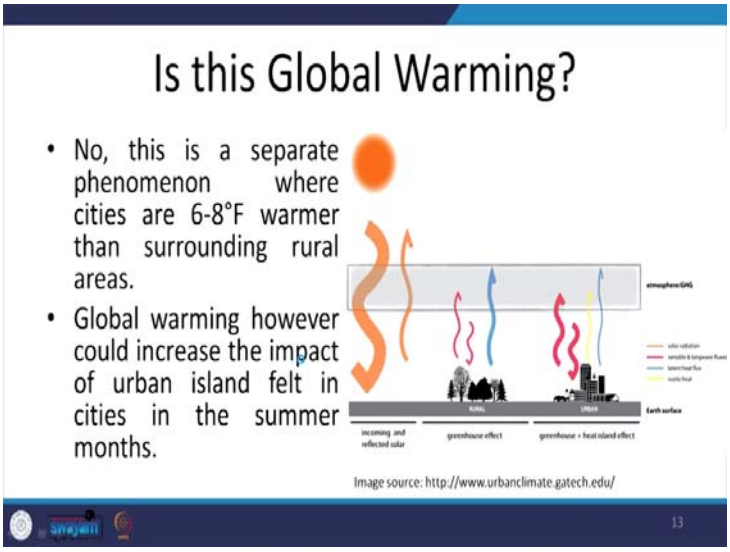

So, when I say greenhouse effect, no it is not global warming. Greenhouse effect is just the phenomena, but yes when there is an increase in the presence of these greenhouse gases beyond a limit, it will lead us to global warming which is actually because of the presence of these greenhouse gases.

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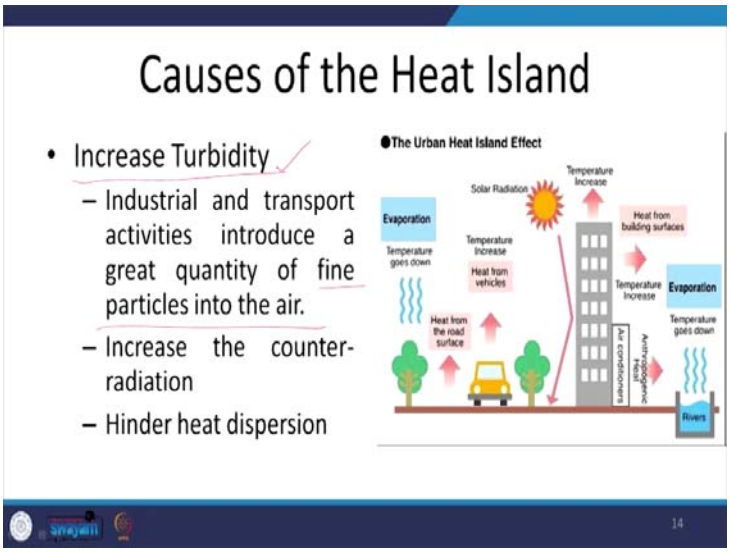

The last one of the most prominent causes for heat island is the increase in turbidity. By increase in turbidity we mean that the suspended particles, the when in very fine particles which are suspended which are release in the air and they remain suspended which absorb the heat, retain it and further heat up the atmosphere are more in cities. So, if we go from a city or an urban area to a rural area, we would see that the suspended particles suddenly disappear. So, there is less of dust, there is less of other suspended particles, when we go from urban to rural and this increase turbidity presence of the suspended particles is a major cause for this urban heat island.

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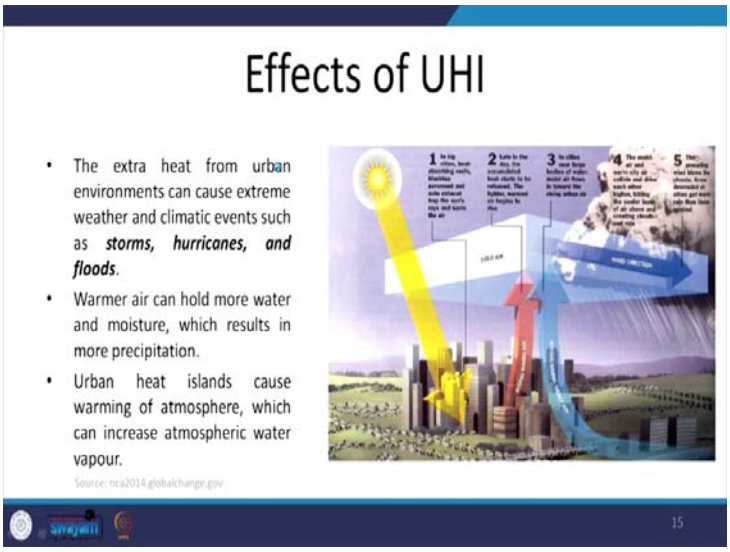

So, all these together lead to heating up of the environment atmosphere in the city area, so there is an increase temperature and we now know what urban heat island is. So, what is the effect of urban heat island? Now urban heat island effects in multiple ways, so we are looking at the environmental impacts of urban heat island and not the social impacts and the economic impacts here. Now the urban heat island can actually change the weather pattern in a city. It may impact on the precipitation pattern how the rains are received within a city. So, if the city becomes much hotter, now depending upon the geographic context, the city may not allow for the formation of clouds and hence the precipitation or in some other cases it may that is totally dependent upon the geographic location and the context.

In some other cases, it may happen the other way around, the city may attract and allow formation of more clouds leading to a flood like situation. So, this is an impact of urban heat island. Another major impact is on how the winds are formed. So, the winds may be pronounced because there is low pressure which is created, so the winds may be pronounced in some of the cities.

Again I repeat here it may be it is dependent upon the geographic location and the context of a city or place. So, these are some of the effects of urban heat island. Besides that as the temperature of the city increases, there is further requirement of energy to keep our indoor environment cool and comfortable so we add more air conditioners.

In rural areas, we do not need air conditioners because the outer environment is comfortable and we can be comfortable at those temperatures. While in a city because of this urban heat island, we further need to cool down our indoors and that adds to anthropogenic heat and it is a cycle. So, that is another impact where the energy consumption goes up, because of the urban heat island because people are not comfortable.

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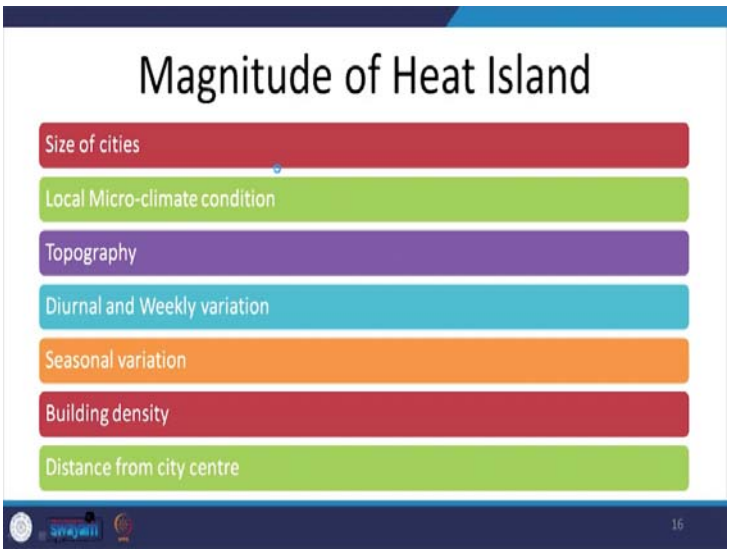

So, when we are looking at impact of a heat island, it is also dependent upon the intensity or the magnitude of this heat island and that further depends upon a lot of these factors which are listed here.

So heat island may be there, but the magnitude will vary from city to city and that I said as I just mentioned is also based upon the geographic location. And some of these parameters like the size of the cities; bigger cities have a tendency to have an intense urban heat island. The local micro climatic conditions that is dependent upon the Topography and the Geography both. So, we have the local micro climatic condition then the diurnal and weekly variation. The seasonal variation which is also again a geographic condition resultant of a geographic condition, then the building density how dense the city is the smaller cities could also be very dense and then the distance from city centre.

So, within a city, there would be variation in the magnitude of heat island depending upon which is the denser part of the city and as we move away it may vary.

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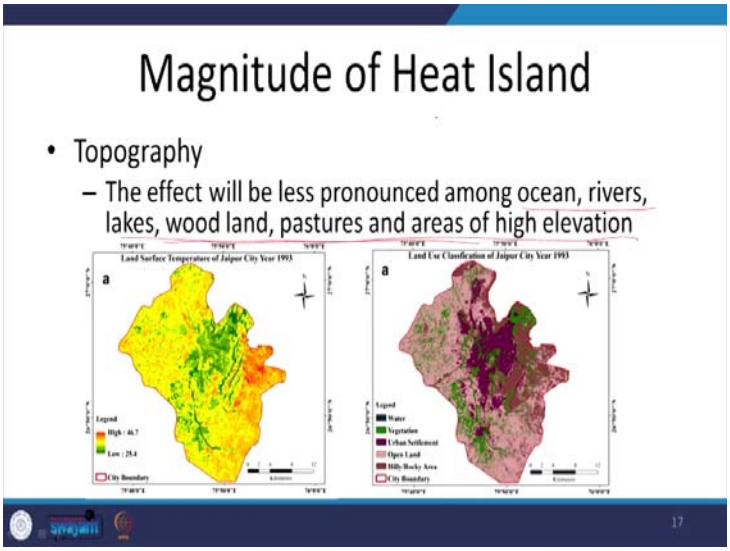

So, if we look at each of these parameters individually so, we have Topography. So wherever we have cities which are closer to oceans, rivers, lakes, forests pastures and at high elevation where the altitude is high, we would see that the urban heat island is less pronounced. Because of the presence of water body and the winds that it creates and also because the rural areas or the surrounding areas are flooded with vegetation this all these together help to reduce the urban heat island.

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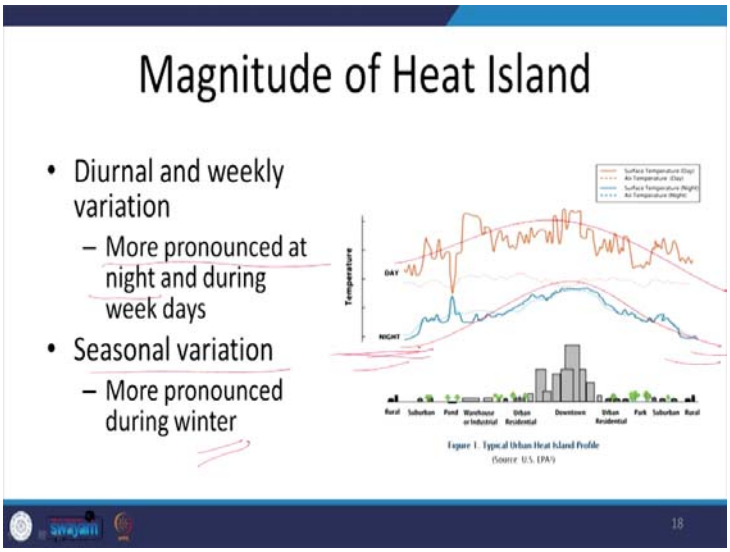

The next is diurnal and weekly variation. So, the urban heat island is more pronounced during nights, because that is the time when these suburbs are cooler. When the suburbs have already cooled down, the rural areas have cooled down, that is when the difference between the rural areas and suburban area is more pronounced as compared to the daytime when a solar radiation is present. So, it will be not that steep, there is seasonal variation as well. So, UHI urban heat island is more pronounced during winters for the same reason that the rural areas and suburban areas are cooler there are colder.

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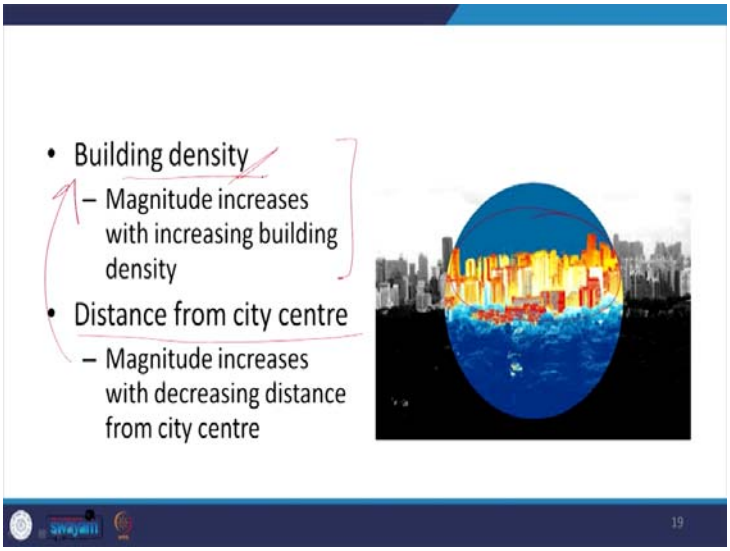

Another one is building density. So, the denser the city is so if we see that the urban heat island is more pronounced in the downed town, because there is more of the hard surface the built mass is more in the city centre in the core of the city. And so all the reasons that we have just seen there are more hard surfaces, there is less of surfaces which allow water to percolate down and allow the moisture to be added up, there is less of vegetation and all these factors together. So, wherever there is higher building density, we will have greater magnitude of UHI and that is reflected in the distance from city centre.

So, usually the city centre is the area where you find higher building density, because everybody wants to be in the city centre close to the city centre because that is the economic hub and that is the activity hub. So, it implies it directly you know affects the building density. So, closer to the city centre usually implies higher building density and then higher magnitude of urban heat island.

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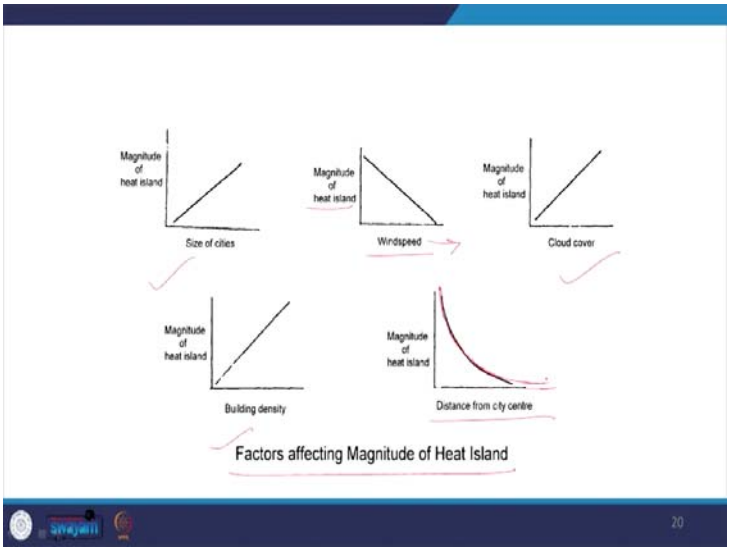

So, if we look at these factors which affect the magnitude of heat island, we can see that the size of cities the building density and the cloud cover are directly proportional to the magnitude of heat island. However, if we look at the factor of wind speed, so greater is the wind speed lesser is the magnitude of heat island and it is inversely proportional. So, as the wind speed increases, the magnitude of heat island decreases; the same as with distance from city centre.

So, as the distance from the city centre increases the magnitude of heat island decreases. But if we look at the distance, so as we are coming far from the city centre we can see that initially it is a very steep curve and then it gradually becomes flat. So, if we go further away, it will not have much impact and we would have the same amount of heat island present there, so that is what it implies. So, we know which factor to consider more and which factor will be affecting more.

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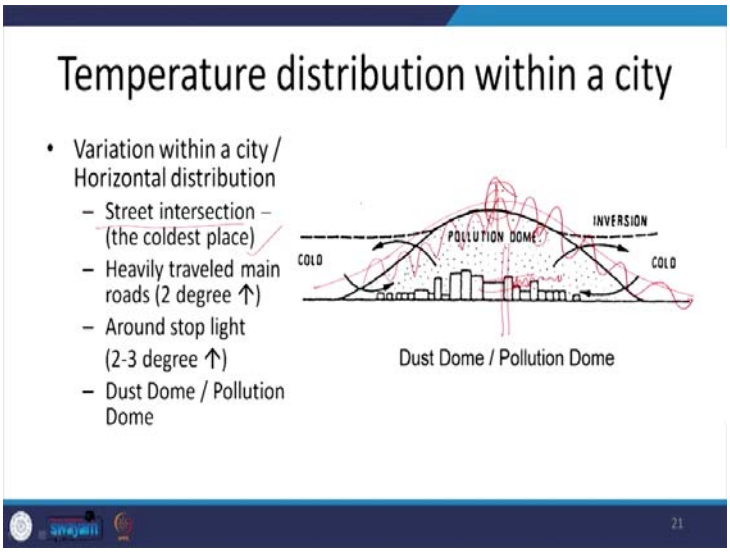

Another is temperature distribution within the city. So, people have conducted a lot of studies across the world and they have identified that the intersection of the streets are the coldest spots within the city. So, overall if we see this is the curve that the city follows for a UHI, but within that there might be some variations. So, these variations this could be a street intersection, where there is a heavily travelled main road it could be further higher. Wherever there is a stoplight, wherever there are stoplights on the streets where vehicles stop for a longer duration, so because of the addition of anthropogenic heat again it may go up. So, within the city there is this distribution of urban heat island.

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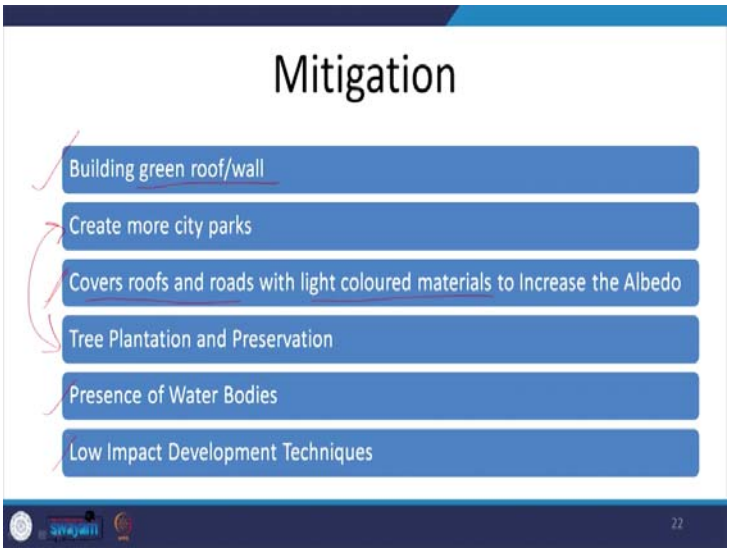

Now, once we have established that these are the factors which lead to urban heat island, we will now look at mitigation strategies and we are looking at these mitigation strategies from architectural point of view. So, how do we develop our sites if you want to mitigate urban heat island?

Now this is critical factor while we develop our design our site for sustainable site development. We are looking at some of the mitigation strategies here; one very important one is the green roof or green wall. Here we also have the tree plantation and preservation which is connected to creating more city parks, when we are looking at an urban level when we looking at a larger development level. So, creating more spaces with vegetation leaving more area as green is another, but most important mitigation strategy.

The next one is where we select the materials carefully. So, we have to use the materials which are light coloured materials and which have a higher SRI value, I will come to what SRI value is in subsequent slides. But the choice of materials, so we talking about vegetation as the prime strategy so where we can leave more area on the ground for adding vegetation trees, plants just green cover or if you do not have enough areas to be left on the ground, then adding greenery to the roof and wall so that the hard surfaces are reduced.

If we cannot even do that then select the materials which are light coloured and which have higher SRI values. So, that less and less amount of heat is absorbed and converted into long wave radiation. Other strategies also have the presence of water bodies and low impact development techniques; let us go over couple of these in subsequent slides.

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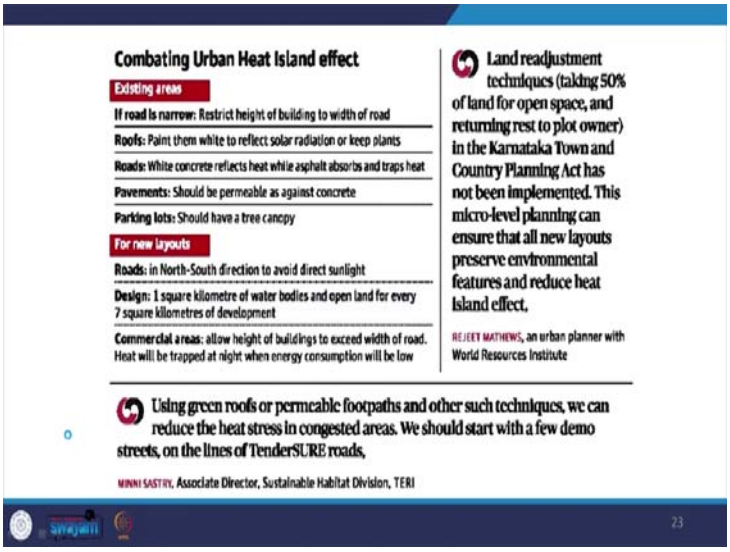

So, if this is what Teri published so, Teri is the energy research institute which works largely on the in the energy domain and when they were discussing about this urban heat island effect, they talked about some of these strategies, which are common strategies and are also common sense strategies.

For example parking lots should have a tree canopy and this is such a simple strategy, but it is a very effective strategy because most of the parking lots are paved with hard materials. Another very interesting strategy is to have height of the buildings to exceed width of the road. Here we are talking about the canyon ratios. So, we if we look at the traditional settlements we would find that the streets are quite narrow us compared to the buildings which are quite tall on their sides. Now that helps in keeping the streets shaded throughout the day almost throughout the day. So, streets which are essentially hard paved, they require hard surfaces.

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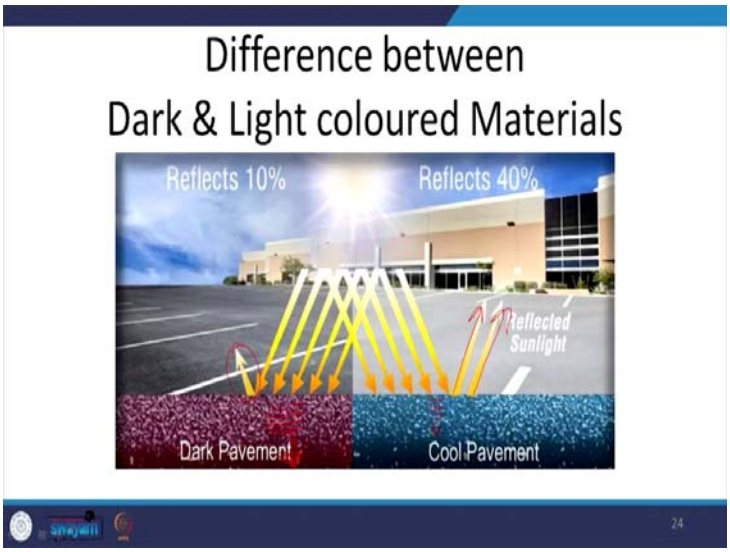

So, when we reduce the amount of direct solar radiation falling on them, we are reducing the amount of heat which will be absorbed and further reradiated. So, some of these design strategies will be employed while we are talking about design of site for sustainability. So, we are choosing we are talking about the materials. So, always a light coloured surface is better and should be preferred over a dark coloured surface and pavement. Lighter surfaces they reflect more of the incident sun while dark surfaces they reflect less.

If the surface is reflecting more, there is lesser amount of radiation which will be absorbed, as compared to the other one where larger amount of radiation will be absorbed because lesser has been reflected. Now that is first property and we should try to reflect as much heat as we can. Now there will always be a design sense which should prevail. We cannot have the surface of the building painted all white and create glare to the building which is right opposite it. So, we have to be judicious enough in selecting the colours. However, all the roof surfaces can definitely become white coloured surfaces and that has been a very commonly practiced strategy in traditional architecture as well.

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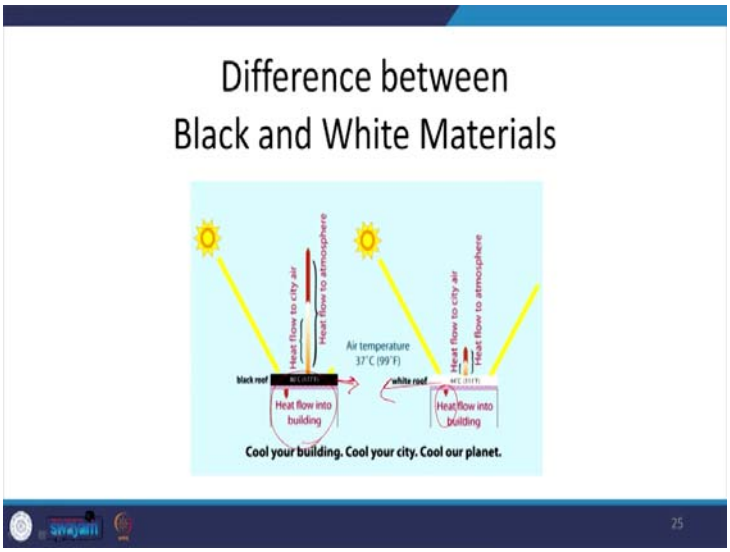

So, if we look at the scientific data, if we look at the values we would see the difference between the black surfaces and the white surfaces. And we see the amount of heat which flows into the building from a dark coloured roof surface is much more than what is coming through a white coloured surface. Because larger percentage of this heat is reflected back in a white surface.

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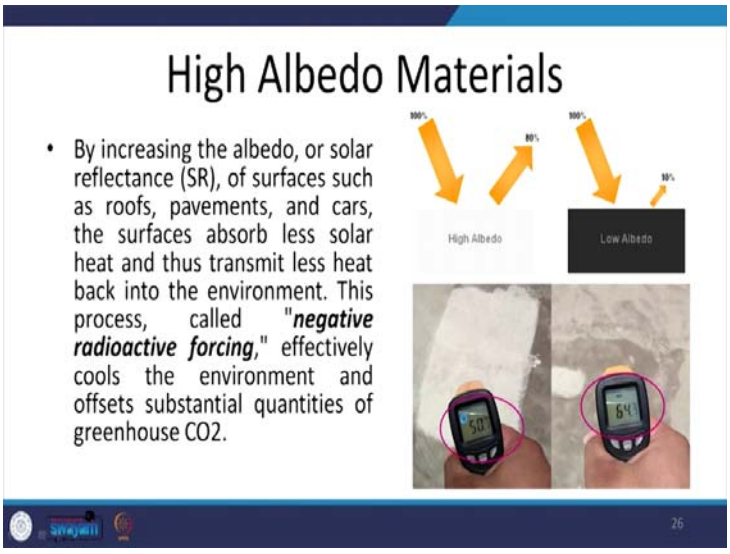

So, here we are talking about reflectance when we are selecting the colours. The another property which we have here is the Emissivity.

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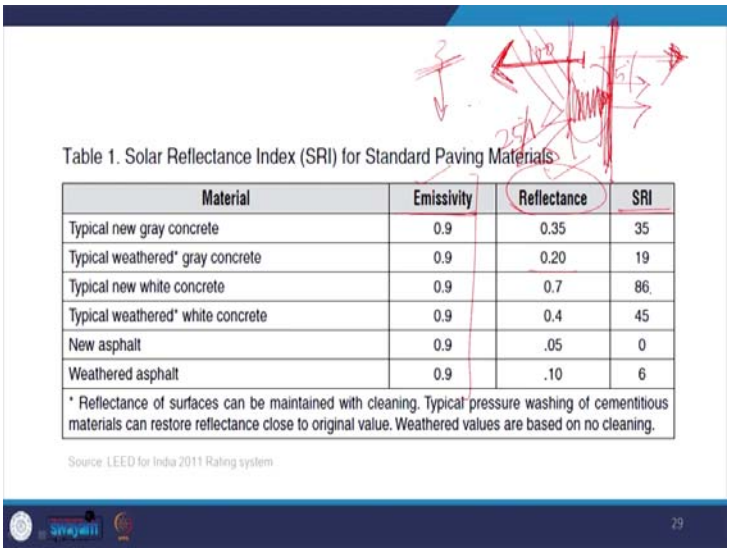

So, once we have reflected the amount of heat which we can or the amount of radiation which is incident on the surface, the rest which is absorbed after reflecting part of it will be emitted. So, if we look at say a surface now there is 100 percent of the radiation which is incident. If we reflect around say 25 percent which is for a typically weathered grey concrete around 20 percent of it will be reflected back through the material surface itself. The rest 75 percent of it has been absorbed by the material. Now of this which is absorbed not all will be transmitted inside.

During the time which is night time when the outside temperature falls down, the amount of heat which is absorbed will be reradiated to outside. When the temperatures fall, when the temperature of this surface is higher than the atmospheric temperature, then a part of this heat will be released outside. And if assuming the indoor temperature is also at the same temperature as the outdoor one, then it will also release equally to the inside.

Now this depends upon the temperature difference between the surface and the outdoor air. So, it will be re radiating or emitting this heat which is absorbed. Now what we are looking here is to emit all that heat which is absorbed, so all of it is released, it is re radiated. If that happens then and if we are able to reduce the amount of heat which is transfer to inside by providing some sort of insulation or a barrier, most of the heat which will be absorbed will be re rereleased reradiated and there will be less of heat which will be transferred inside.

So, of this entire heat which is incident only 5 percent or 10 percent for a material with high SRI value will be transferred inside, which is what the intent is. So, we should be selecting now this SRI value which I was discussing which is the solar reflectance index is a combination of these two properties immittance, emissivity and reflectance and higher the SRI value higher is the amount of heat which is reflected back which is released.

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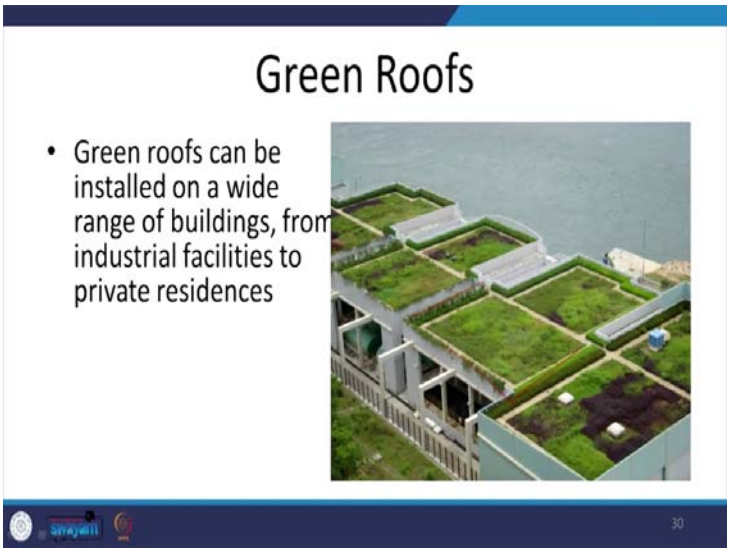

The other strategy as we have just seen is Green Roof. So, if we now roof is the part of the building which absorbs which receives maximum amount of solar radiation. So, if we turn our roofs surfaces into green roofs where the vegetation is, it will reduce substantially the amount of heat which is received by the building the hard surface.

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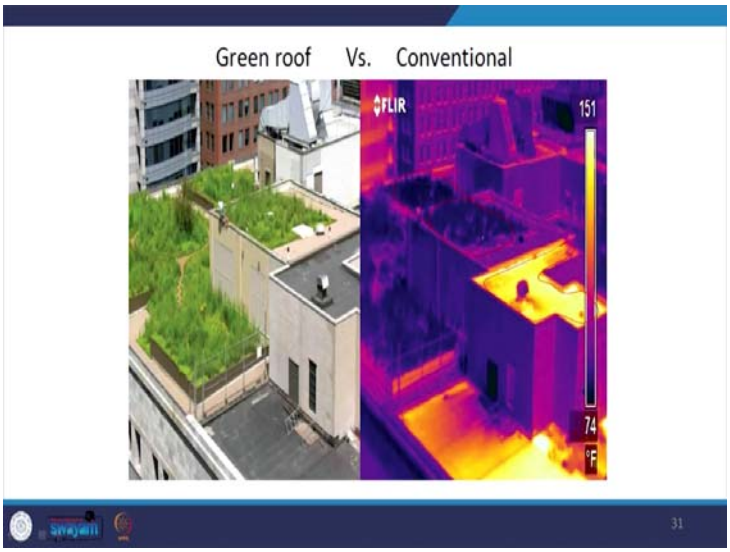

So, this is the thermal imagery which shows the green roof versus a conventional roof. Now these darker temperatures are cooler. So, we can see this part of the roof which is green roof and we can see this part of the roof which is actually a dark coloured surface and we can see the stack difference between the two surfaces.

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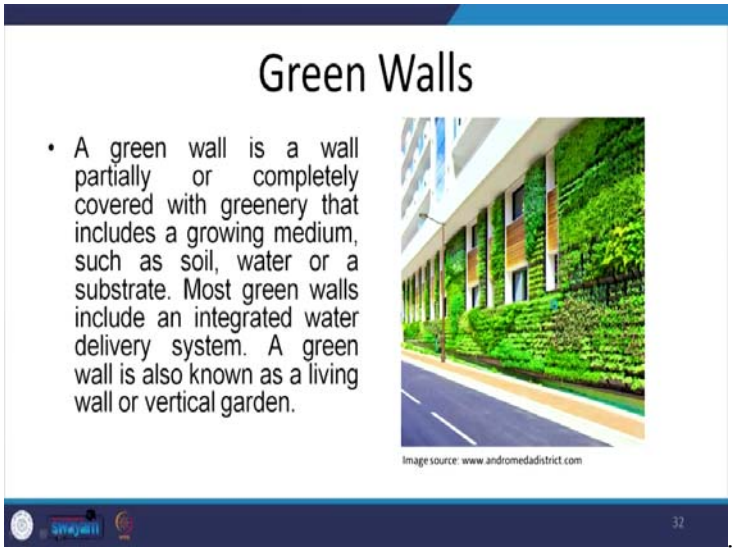

The same strategy when applied to the walls will be called as green walls. So, here we will have vegetated walls green walls. Now there may be multiple strategies, where we may have added attachments placed on the walls where the greenery could be added. It

could be that the wall itself is green where it supports vegetation or in multiple ways. But this is the concept of green wall.

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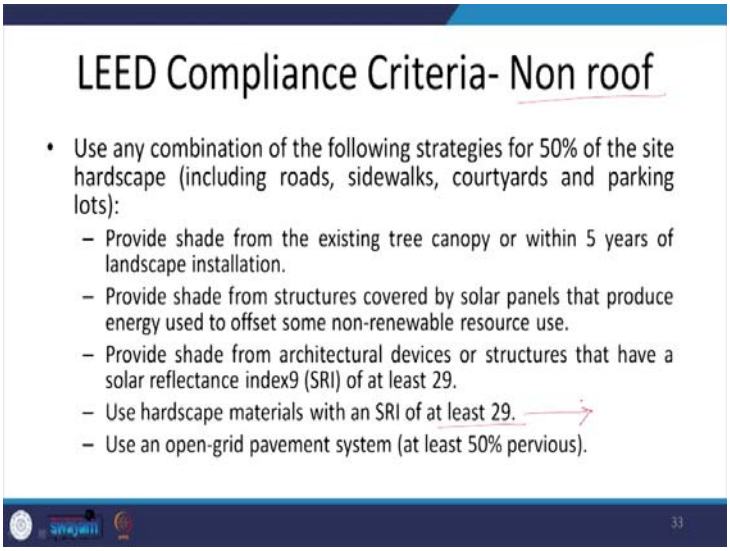

Now, when we are looking at the green building rating systems, so all of these that we have discussed these strategies can be used in green buildings and they will be evaluated positively. So, we have two compliance criteria's, where one we are talking about the non roof components when we are talking about UHI and we will be talking about the roof components when we talking about UHI.

So, these two criteria and these strategies which are used which are to be used are the ones which we have just discussed as part of mitigation measures. So, these mitigation measures can be employed in our buildings and they will help us in achieving credits, while we are going ahead with green building compliance green building ratings.

If you look at the non roof criteria, we have to ensure that the hard surfaces the hardscape on the site at least 50 percent of that follows the strategies which we have just discussed. So, at least 50 percent of the entire site hardscape has to use a combination of these strategies and we are talking about in terms of the SRI numbers, then at least an SRI of 29 has to be achieved for at least 50 percent of the site hardscape. Now here when we are talking about the non roof components non roof areas in a site, we have to also see that the SRI does not go very high.

Very high values of SRI imply that they will have very high reflectivity and that can also be a cause of glare. So, the number has been limited to 29 and we should not be using very high SRI values on non roof components.

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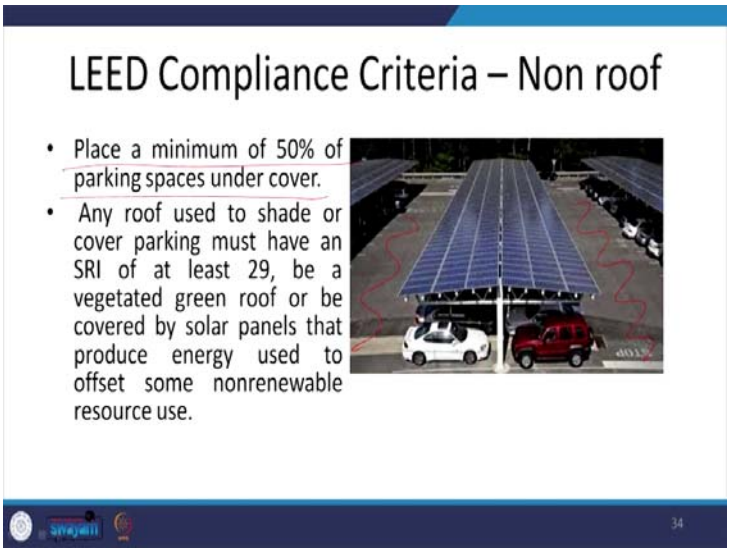

Some of the strategies which are mentioned in these green building rating systems, here I am taking an example of lead compliance criteria. But there are different credits and there are different compliance options in other green building rating programs as well. This is just for giving an example that what is it that green building rating systems are talking about. So for example, placing a minimum of 50 percent of parking spaces under cover is one very important strategy, because most of the parking spaces are hard paved areas.

So, putting all the parking areas under a cover, now this could be the green cover this could be trees this could be covered under trees.

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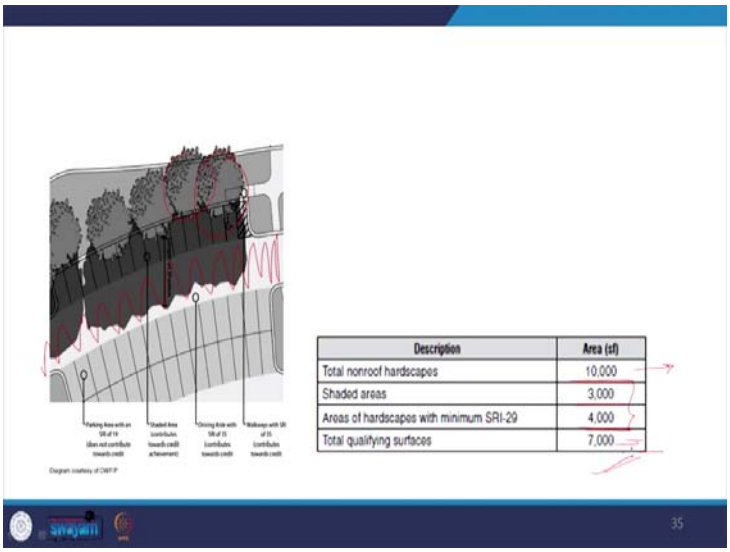

This particular image shows an example of one of the development projects. So, here they have calculated the total non roof hardscape as 10000 square feet, out of that 3000 square feet is shaded under the trees. So, this is shaded under the under the trees and then we have some areas which have used materials which have minimum SRI of 29. So, maybe they have some light coloured pavement material which is used on these.

So, together it makes a total of 7000. So, around 70 percent of the non roof area is following one or the other of these strategies and that is how it will qualify. So, because the minimum was 50 percent, so this qualifies in this case. So, this is how the compliance to one of these criteria will be shown.

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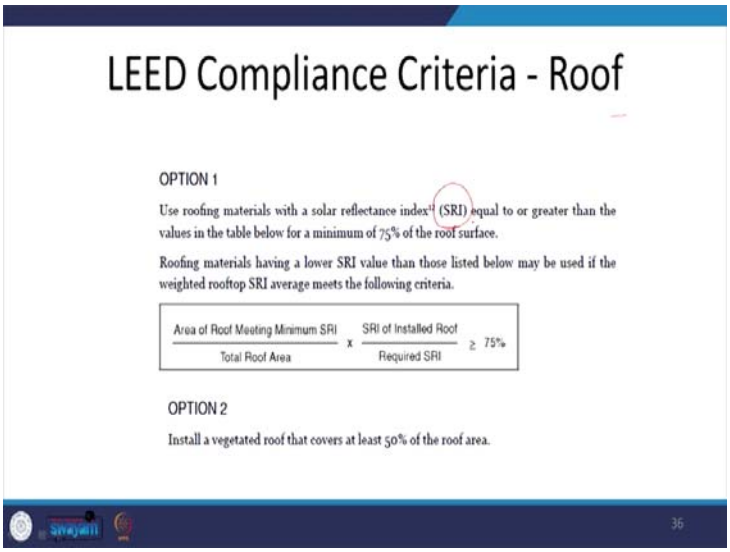

The next criteria important one is Roof, when we are talking about roof we are largely talking in terms of SRI. Now this SRI could be through vegetation the green roof could be through use of materials which have higher SRI. Here again the compliance is shown for at least 75 percent of the roof surface, which has to follow this combination of strategies.

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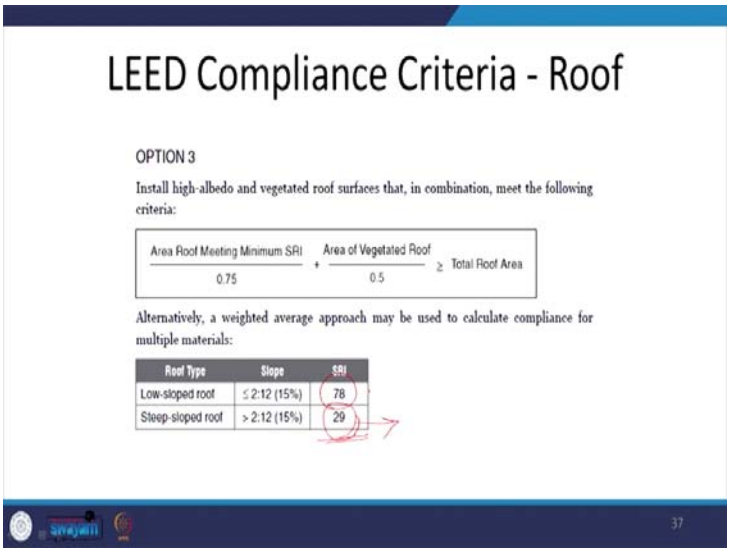

And when we talk about the SRI numbers, we see that the low sloped roofs should have a minimum SRI of 78 while the steep sloped roof. Because again there is a potential for

this one causing glare to the building is limited to 29. Here we are talking about the total roof area 75 percent of that to be following these to be following these strategies of either SRI or the vegetated roof.

So, we will stop here while we were discussing about the criteria the mitigation strategies, which we can adopt for urban heat island mitigating the impact of urban heat island, while we are developing the buildings and building complexes. In the next lecture we will be continuing with the sustainable site development and we will be looking at the storm water and how do you handle the storm water issues when we are developing the sustainable site.

Thank you very much for joining us. See you again in the next lecture.