Strategies for Sustainable Design
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Lecture 33
Design for Net-Zero Energy, Lighting, Ventilation, Views and Human Comfort

Hello everyone in this lecture we will discuss about design for net zero energy building, lighting, ventilation, views and human comfort in an overall sense.

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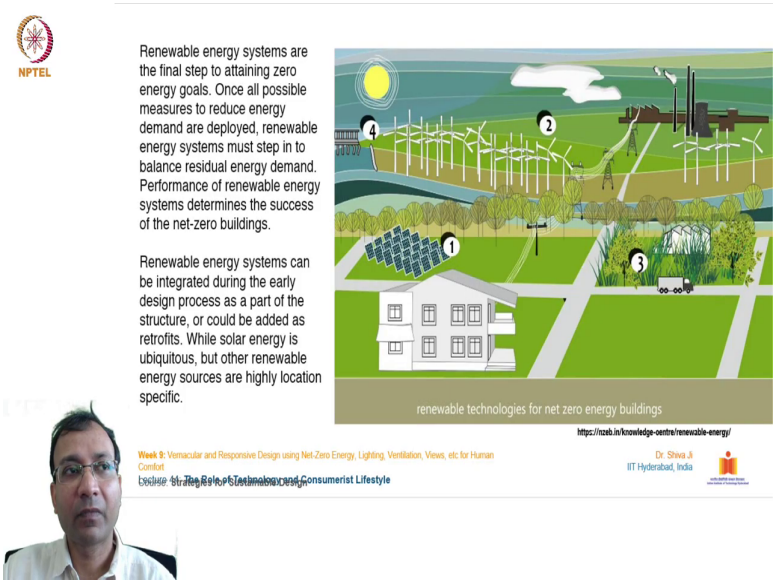

So, if you see a if you see this illustration this, we talk about what are the ways in which we can generate electricity generate power on any given site. So, here we have some options you can see a solar photovoltaic cell and we have windmills we have other a geothermal a ways other we have, harvesting ways to harvest energy from the tidal waves et cetera. So, and we have a biomass over here. So, there are several ways in which the electricity can be harvested on any given site. Compared to a centralized power generation unit.

For example, you can see here in this background this is a thermal power plant. So, it is a bigger it is big in capacity and similarly on the same scale it will have immense or a huge amount of a waste generation emissions and creating by-products so all of those things. So, how this can be taken care of using a natural means using a these the energy systems which are available plenty for our utilization. So, how we can (minima) how we can maximize uses of such energy sources on our given site and we can go independent of the grid.

So, that is whole thing we are discussing about over here. So, the integration of these renewable energy sources in our projects is a matter of integration from the inception of the

project. The, these things can be installed or retrofitted also later on. But, it is better that if we integrate them since the conception of the project because it will help so help us in a planning the facility in such a way so that we can minimize the energy consumption also. We can create a parallel electricity distribution system also if there is any need.

So, we can keep we can keep provisions to handle renewable energy sources on our site. Well, solar energy is a ubiquitous thing. We can harvest solar energy at most of the places but other energy sources are a place based a place is specific. So, it depends what kind of facility what kind of geography or climate we have. For example, biogas; for biogas though this can also be utilized at most of the places but these windmills and hydraulic electricity geothermal energy. So, these three things are place's specific climate and geography and topography specific.

So, we have to be cautious in site selection. Also what kind of site we are given and accordingly which renewable energy source is suitable for our location. Further, in this a provision for combined approach of energy supply should also be make. For example, if we have surplus energy to supply to the grid so how that can be distributed back to the system? So, those provisions should also be there in case us if there is some emergent situation and we need to draw electricity from the grid then we have that provision also.

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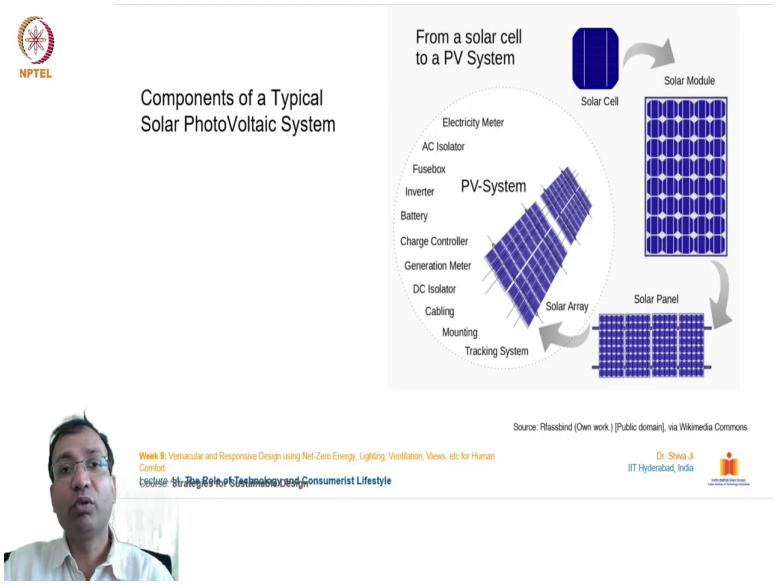

So, moving on in this how a solar photovoltaic cell and these panels works. You can see this is the unit solar cell here on the top. Then a number of these solar cells form this solar module

and a number of these modules form a solar panel. And then a panel several units of panels together they form this solar array.

So, you see that this is how it is increasing in its scale and well there are other components also for this solar voltaic (photo) photoelectric photo-electricity based power generation. We, we require electricity meter, AC isolator, we need fuse box inverter, battery, charge controller generation meter, DC isolator cabling, mounting, tracking system, etc.

So, with the help of all of these components one can easily install these units on our projects. Well, government of India through it is a ministry of renewable energy resources they have this provision to facilitate a subsidized and easy installation of solar photovoltaic cells in the individual households also. So, one can avail this facility by visiting their website and they are or may be contacting the local contact person.

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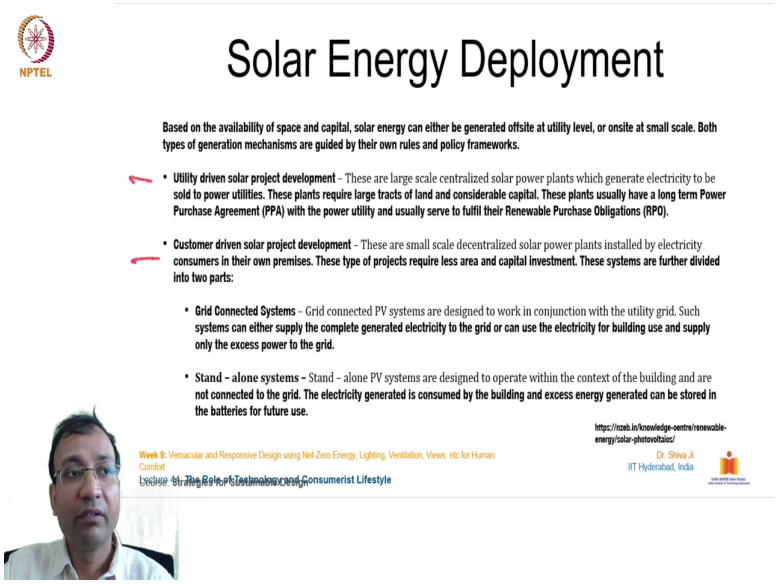

Further, so solar energy deployment; how it takes place? So I will quickly introduce this detail to you. Based on the availability of space and capital solar energy can either be generated off site at utility level or on-site at small scale. Both types of generation mechanisms are guided by their own rules and policy frameworks.

The first one: utility driven solar project development. In this these are a large-scale centralized solar power plants which generate electricity to be sold to power utilities. These plants require large tracts of land and considerable capital. These plants have a long term

power purchase agreement with the power utility and usually serve to fulfil their renewable purchase obligations.

Second, customer driven solar project development. So, these are small scale decentralized solar power plants installed by electricity consumers in their own premises households etc., or maybe individual projects such as maybe an institutional campus or something. These types of projects require less area and lesser capital investment compared to the previous one. These systems are further divided into two parts. The first one the grid connected systems.

Grid connected PV systems are designed to work in conjunction with the utility grid as I said. If we have surplus electricity to sell to the grid or in case if there is some emergency situation and we need to buy electricity. For example, if our own a site based production is lesser than the consumption then we are will be forced to buy. Such systems can either supply the complete generated electricity to the grid or can use electricity for building use and supply over the excess power to the grid.

Second, stand-alone systems. So, standalone PV systems are designed to operate within the context of the building and are not connected to the grid. The electricity generated is consumed by the building and excess energy generated can be stored in the batteries for future use. So, these are structures you understood, these are the standard formats of a solar energy power generation and its deployment.

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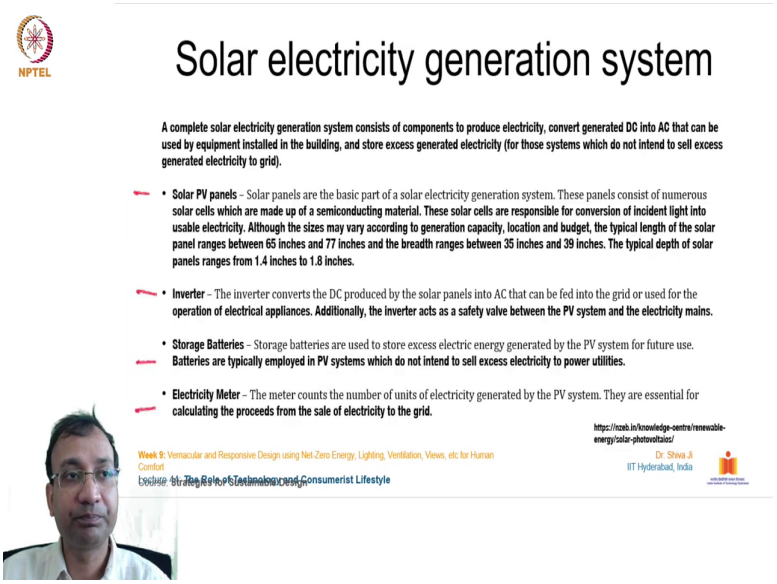

Further, solar energy electricity generation system: so a complete solar electricity generation system consists of components to produce electricity convert generated DC into AC that can be used by equipment installed in the building and store excess generated electricity for those systems which do not intend to sell excess generated electricity to the grid. So, what are these mediums solar photovoltaic cells panels, solar panels are the basic part of a solar electricity generation system. These panels consist of numerous solar cells which are made up of semiconducting material.

These solar cells are responsible for converging of incident light into usable electricity. Although, the size may vary according to generation capacity location and budget, the typical length of the solar panel ranges between 65 inches and 77 inches and the breath ranges from 35 inches to 39 inches. The typical depth of solar panel ranges from 1.4 inches to 1.8 inches. The next component is inverter. The inverter converts the DC produced by the solar panel into AC that can be fed into the grid or used for the operation of electrical appliances.

Additionally, the inverter acts as a safety wall between PV system and the electricity mains. You may have seen inverters; these small screen inverters are also installed in our household these days. The next one is storage batteries, power storing batteries. The storage batteries are used to store excess electric energy generated by the PV system for future use.

The batteries are typically employed in PV systems which do not intend to sell excess electricity to the power utilities. The next one electricity meter. Well, the meter counts the number of units of electricity generated by the PV system they are essential for calculating the proceeds from the sale of electricity to the grid.

Well, for various purposes we need the electricity a meter first to understand how much power generation is has happened. Secondly, how much of a utility how much a electricity is used on the premises and thirdly how much is going out or if in case we are a buying in then how many how much we are buying in.

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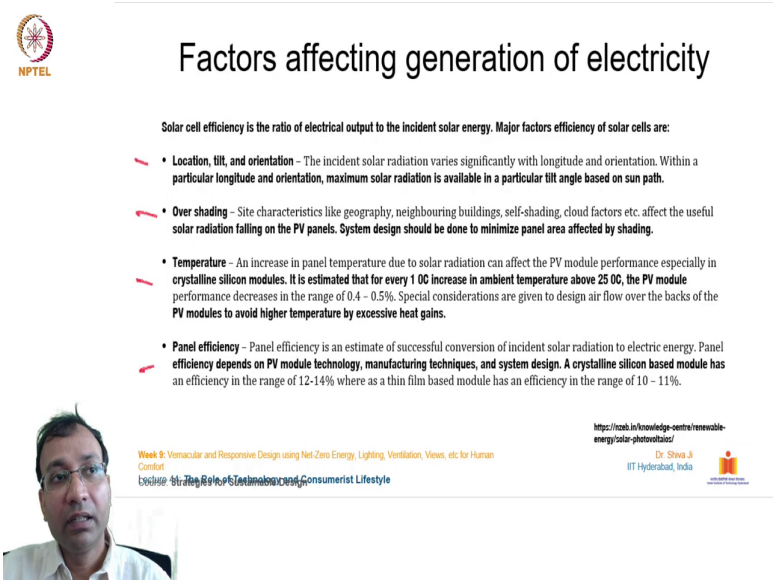

Further well, there are some factors affecting generation of electricity, we will go one by one. Solar cell efficiency is the ratio of electrical output to the incident solar energy, major factors efficiency of solar cells are first one; location, tilt and orientation. The incident solar radiation varies significantly with longitudinal orientation. Within a particular longitude and orientation maximum solar radiation is available in a particular tilt angle based on sun path.

Well, our earth is a kind of a sphere and sun keeps moving and keeps changing its path over the year. So, from a line of Cancer to the line of Capricorn it keeps moving every day it changes its orientation a little bit. So, depending upon the time of the day and year of the day the sun's the intensity of sun's rays which are falling on a given particular place they change.

So, by changing the orientation of the solar panels towards the sun we can maximize the receiving capacity. Second, over shading site characteristics geography neighboring buildings, self-shedding cloud factors they also affect the useful solar radiation falling on the PV panels. System design should be done to minimize panel area affected by the shading.

Well, there should not be any obstruction in between of course the PV a panels and the sun because they will affect the overall the receipt of the solar radiation the solar light on the panels. Next, we have this temperature. So, an increase in panel temperature due to solar radiation can affect the PV module performance especially in crystalline silicon modules.

Well, it is estimated that for every 1 degree centigrade increase in ambient temperature above 25 degree centigrade the PV module performance decreases in the range of 0.4 to 0.5 percent.

Special considerations are given to design airflow over the backs of the PV modules to avoid higher temperature by excessive heat gains. So, we see the higher the temperature in the atmosphere goes the, there will be a certain amount of decrease in the overall receipt of that energy and the power generation.

So, we must take care of this excessive heat to not to allow this excessive heat to heat up the PV panels. Finally, we have a panel efficiency to panel efficiency is an estimate of successful conversion of incident solar radiation to electric energy. Panel efficiency depends on PV module technology manufacturing technique and system design.

A crystalline silicon based module has an efficiency in the range of 12 to 14 percent. Whereas, a thin film based module has an efficiency in the range of 10 to 11 percent. So, depending upon the brand make capacity and the capital amount required for an investment we can go for this deciding factor.

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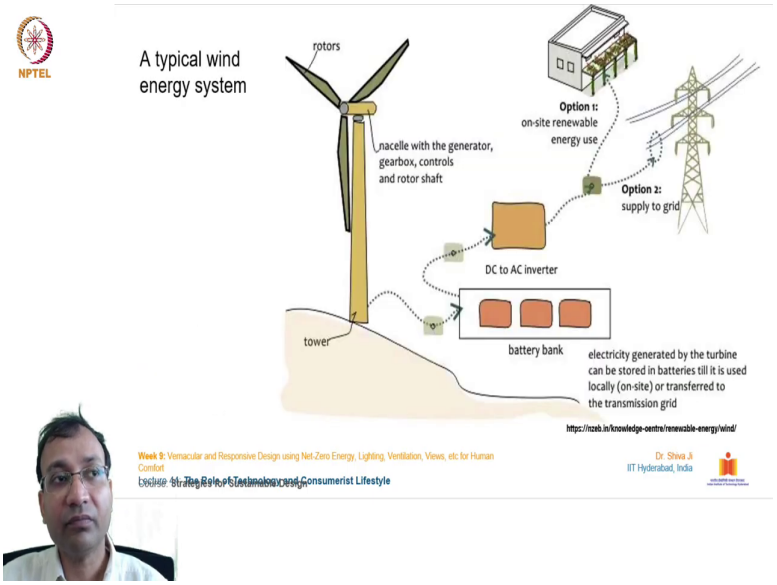

Next, if you see in the windmill a typical windmill an energy system has this these many components. So, you can see from here the first one the windmill itself so it has this tower and it has its rotor over here typically three rotors per windmill. And these are nacelle here with the, this power generating unit at its central axis over here. So, it has a gearbox control rotor shaft etcetera and it generates, this is the unit which generates the electricity.

And from here this electricity through the help of the cables it goes to the either a battery bank it goes to a DC to AC conversion. Then it goes for a for example on-site uses or maybe

supplying to the grid. So, this is a typical layout of a windmill based energy generation system. So, here you see electricity generated by the turbine can be stored in batteries till it is used locally on site or transfer to the transmission a grid. So, that it can go to the national grid or a state grid and can it be sold to external agencies.

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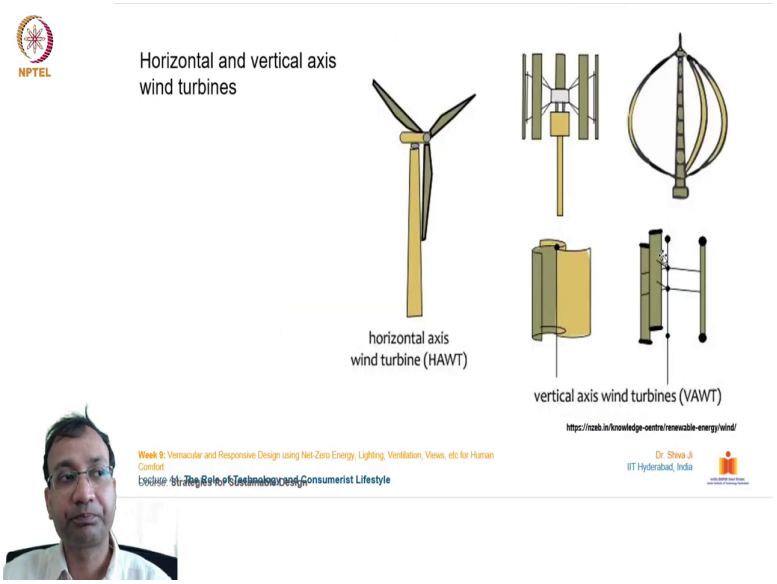

Typical this the units of the wind turbines if you see they have a certain architecture, certain like the design of their structures is a varies depending upon their usage capacity, etc. So, these are typical a two structures the vertical axis based and a horizontal axis based. So, this is a horizontal axis base the conventional one which we have seen. So, we have seen them in a huge scale very big so these have a horizontal axis wind turbine they are called HAWT. And these ones these are examples of a vertical axis wind turbines called as a VAWT.

So, you see this is how they are, their components, their, these rotors are designed in such a way and arranged in such a way. So, these are suitable for small scale power generation units such as household or maybe institutional but these ones are the bigger scale commercial ones which are huge in scale and they are installed for big scale wind mill energy generation systems.

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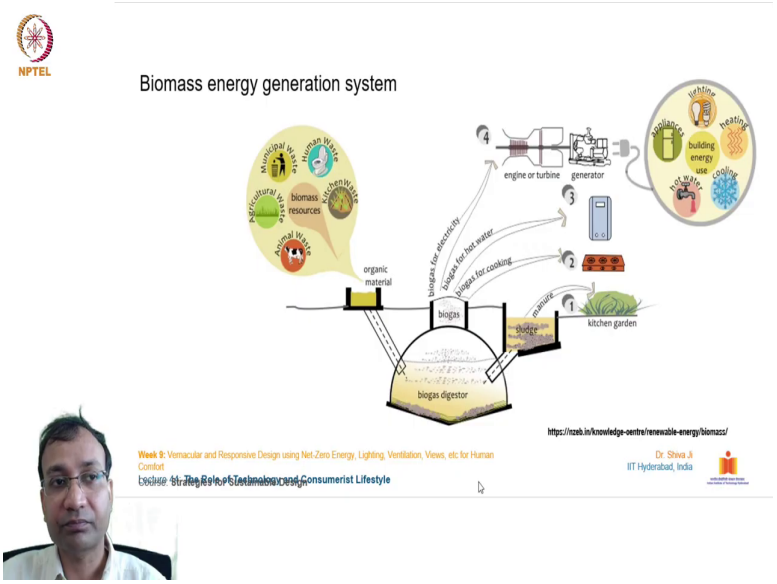

Further, coming down to biomass energy generation system. So, this is a typical illustration how this biomass energy generation system works. So, first and foremost we collect the organic material that organic material can include animal waste cow dung, etc. Then agricultural waste the leaves and other leftovers and then a municipal waste also comes into this human waste also excreta, kitchen waste vegetables, fruits chopping, etc. So, these collectively they can be they can constitute this biomass like a resource organic material.

And these are they are thrown into this a biogas digester over here and this is a sealed chamber where this it starts emitting this bio gas. And then this bio gas taken for a various type of a usages. For example, biogas for electricity generation biogas for heating the water for a domestic use even biogas for a cooking. So, you may have seen this facility being used in Indian villages for a very long period long period of time. Because, in Indian villages earlier there used to be a number of a cattle every household almost every household used to have a certain number of cattles.

So, this mechanism of biogas was promoted for a very long period of time several years ago several decades ago. And I myself have seen several such examples in my village and my other neighboring villages. So, where there is a cooking system these are a gas stoves were fueled by this biogas facility.

And the sludge part of it goes for a becoming a manure and it can be further thrown into the agricultural fields for I know it becomes a natural fertilizer. So, from here if it is a produced

as electricity well there are several possible uses it can go to, depending upon the volume of the electricity which is generated the amount of electricity generated it can serve to a household maybe a micro neighborhood or a neighborhood. So, this is how it typically works. So, this is illustration.

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Some examples from here on I would to show the net zero energy buildings which are existing right now in India. So, there are several but I have chosen a few examples to give some idea to you can maybe look for your own city or maybe a city, in your, in your nearby city where this kind of luxury projects are existing. You can go for a detailed case study for your understanding how this project is executed, how it was designed, how it was constructed and how it is performing in this a operation stage. And also this will give you deeper insights about designing net zero energy building.

So, the first one here this example taken is a Infosys building, this is a Pocharam it is a locality in the city of a Hyderabad. So, the location Hyderabad and it is an office, office building it was a newly constructed climate where, where it is situated is hot and dry. And the project area you see over a 27000 square meters. And this is connected to the grid. And the EPI if you see over here 75 a kilo watt hours per square meter per year is this you this you see this range over here for this power generation on this particular this project.

So, next we have this IGBC building Indian Green Business Centre. This is also located in the city of Hyderabad and this is also an office project well this was earlier an existing

building when it was converted into a a net zero energy building lately. Well, climate is same hot and dry and then it the EPI over here is 80 kilowatt hours per square meter per year. So, you see here this is a little more than the previous one this Infosys centre. So, these both of these projects are situated in the city of Hyderabad.

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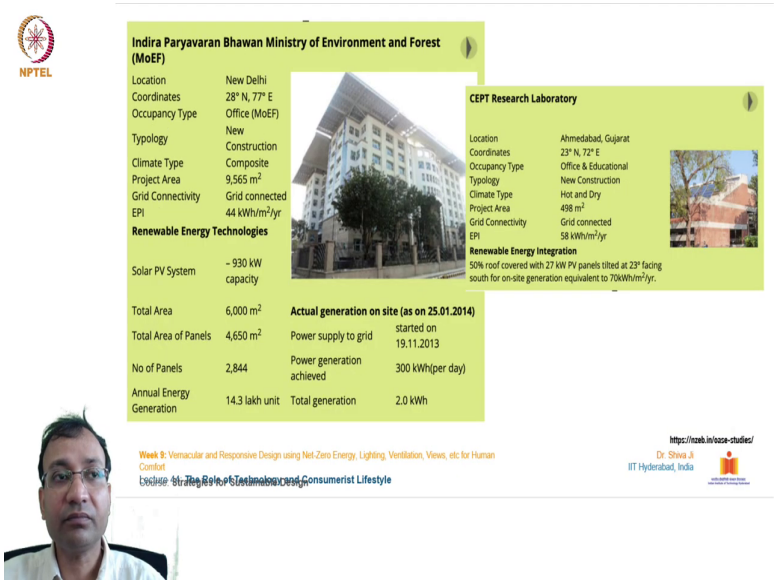

Further, we have the first net zero energy building example this is Indira Paryavaran Bhavan. This earlier this building used to belong to ministry of environment and forest in the locality area. And this is in the city of a New Delhi. So well, primarily this building is an office building even now it is being used as an office building and the EPI over here is 44-kilowatt hour per square meter per year. So, this is a range and it has this see the solar photovoltaic system so it has given 930-kilowatt capacity.

So, you see over here this overhang on the roofing so this overhang is the structure which supports the solar photovoltaic solar panels on top of this building. So, almost all of this the top of this building excluding this little cut out which allows sun and light to pass in the middle of this building. So, except that cut rest of this surface the top surface of this building is covered in the photovoltaic solar cells. For its own power to meeting its own power needs on the daily basis.

So, here on this project if you see the total surface area is around 6000 square meters. And the total area of panels installed on this site is a quite huge 4650 square meters. Which is over 75 percent of the total surface area of this project. So, which is huge if we in terms of a ratio if

we see. And total number of panels 2844 installed and annual energy generation is 14.3 lakh units which is a quite sufficient.

So, this building takes care of its own power requirements as well as it supplies electricity to the great. Second, in this slide we have CEPT research laboratory from Ahmedabad, Gujarat. This is an office and educational purpose building. It is it is also a new construction climate hot and dry project area 498 square meters.

And also, this has the EPI of 58-kilowatt hour per square meter per year. So, in this if you see a renewable energy integration 50 percent of roof covered with 27 kw PV panels tilted at 23 degrees facing south on the side generation equivalent to 70-kilowatt hour per square meter per year. So, this is the range and in it works.

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Next, we have two more examples. So, this is a Humanscapes this is from Auroville, Tamil Nadu. So, this is community housing project it is a new type of construction it is located in a warm and humid climatic setting. And the project area 1680 square meters and this is connected with the grid also.

Next, we have this example of a household a small-scale project RNA multi-purpose office cum residence. So, this is a located in a Sri Lanka and this is office cum residence building. And it was earlier an existing building and this was done as a retrofitting. This is situated in a tropical climate 312 square meter and this is also connected with the grid. So, this is an

example of how a small household and house unit can also go for such power generation things.

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So, this slide talks about the world GBC. So, the definition of world GBC is a net zero carbon building is highly efficient highly energy efficient with all remaining energy from one site or offsite renewable sources. So, the target of this is if you see a utilizing these four methods how this can be implementing in the building sector.

So, by government engagement by training and education by corporate engagement and by certification programs so the target for a year 2030 is to that all new buildings must operate at net zero carbon. And by 2050 the target is to go for 100 percent of the buildings must operate at net zero carbon.

So, this is kind of a very promising target kept for the year a 2050 where all buildings must go for a becoming a net zero energy building projects. And the key principles derived from here a major and disclosed carbon. So, the carbon is the ultimate metric to track and buildings must achieve an annual operational net zero carbon emission balance based on the metered data.

Second, reduce energy demand. Prioritize energy efficiency to ensure that buildings are performing as efficiently as possible and not wasting energy. Thirdly, generate balance from renewables, supply remaining demand from renewable energy sources preferably on-site followed by off-site or from offsites.

Lastly, fourth improve verification and rigour. Overtime progress to include embodied carbon and other impact areas such as zero water and zero waste. So, not just zero a net zero energy

building but zero water and zero waste building also. So, this is a target taken by this world green building council WGBC. So, this is quite a promising and this is the approach or the strategy which will enable us to achieve sustainability target which we have discussed in the previous lectures. So, individually in our own capacity we must work to strive for this goal.

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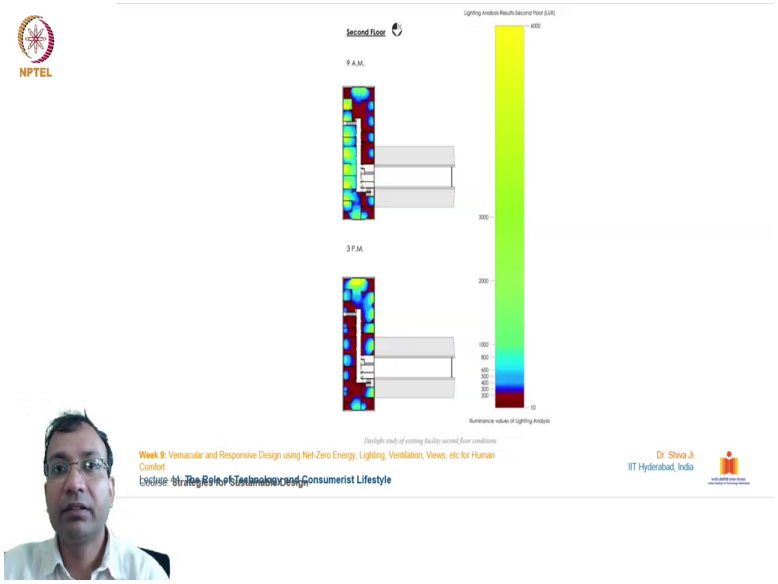

This slide talks about this the calculation of a light the incident light in any a given space. So, you see with the simulation through this software at the two times of the day this is a from second floor, it is example I have taken. So, you see at the 9am and the three level how the lux level is changing this is a chart given over here the illuminance value of lighting analysis.

So, ranging from 10 to 6000 lux so you see with this colour coding how these windows are enabling this particular, this set of rooms in the morning hours to get a sufficient light. And in the evening hours at this site. So, why is this kind of simulation and analysis is important. Because to understand how our building, how our design is going to be have once it is executed.

So, one we can understand we can have a real time look of this how is going to perform through the help of these simulation methods. So, we can take help of a such simulation softwares some of them are open source and freely available over the internet for our uses. So, I would suggest you look for it you google for it you go for some open source free software you install in your computer it hardly takes a few mbs.

And you conduct your studies you will have I know a better understanding how to perform a day lighting analysis for your projects. And accordingly, you can change your designer you can improve your design so the overall productivity overall and natural light consumption can go higher. Resultantly, we can depend lesser on the electricity-based requirements. So, the criteria which I have been discussing several times we must reduce our dependence on the generated electricity rather we should consume more and more of a natural lighting in our building premises.

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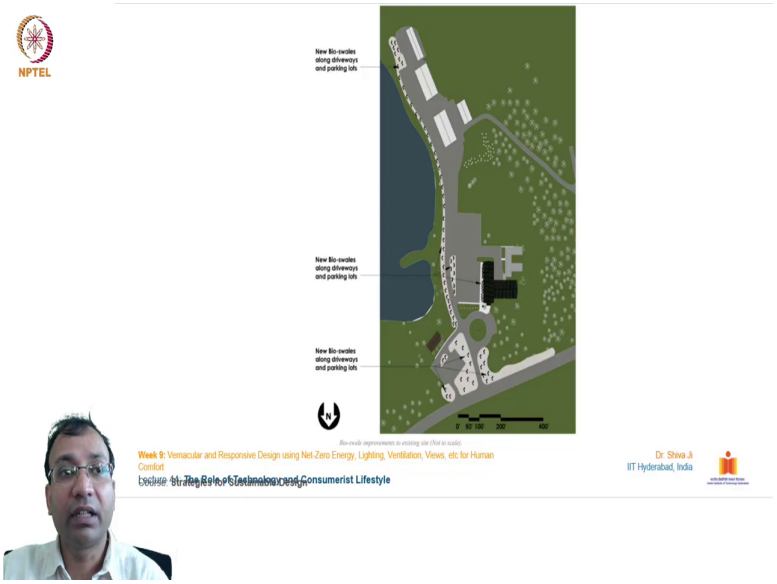

Further, I have taken some examples over here for your understanding. So, this one talks about the bio swales. Bio swales are the man-made trenches, linear trenches which runs for a longer distance. They can actually help us increasing the recharge of rain water to the ground. So, the you see in this illustration how these bio swales are created along the this paved a movement place this road so that the all that the rain water which falls on this surface can get accumulated in this bio-swale.

And this will help recharging in the ground. So, these are the, some means which we can adopt on our sites. For increasing the recharge of the groundwater, improvement of the particular matter in the air. So, the by planting a number of vegetation how we can improve the air quality in the vicinity in a surrounding area. So, these are small, small details with which overall ambience or the atmosphere of any place can be improved over the time.

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Now, we will discuss about some, some other forms of pollution and some human comforts. So, lighting is one of the less talked about pollution in the excess of this lighting how it becomes a requirement then it turns into a polluting element. So, you see this illustration and so this talks about a lighting which we generally use in the night time how it becomes a polluting thing for the nocturnal life other wildlife forms and other birds. So, they get a disturbance in their sleeping pattern or in their own normal activities they feel disturbed.

So, and then the excess light obscures the night sky also. So, in the cities which we observe these days we observe a halo kind of our formation of this light. It becomes even more intense with the presence of aluminium the dust particles and the suspended particles in the air. So, the overall effect multiplies and the overall light remains for a longer period of time almost on the whole night obscuring due to the clear sky. And these days no more stars are visible from the skies in the cities.

So, that is one of the after effects of this light pollution. Secondly, rather than assisting these are, these plants also feel disturbance. Because, they are they are all along with these birds and other nocturnal animals these plants also have their this the daily cycle. When they go for the rest and you may have heard plants also excrete this CO_2 in the night time. So, this is spillage of light in excess in the night time disturbs clear cycle also. So, and then again spilling off the light in a neighboring property.

And also creating like unnecessary lighting condition for the neighbors. So, there are multiple ways you can understand these phenomena. So, that over in an overall sense this hinders with the human comfort the comfort and the condition required for other life forms. So, we must take care of a lighting design in our projects. So, that it does not becomes a polluting thing for the other others.

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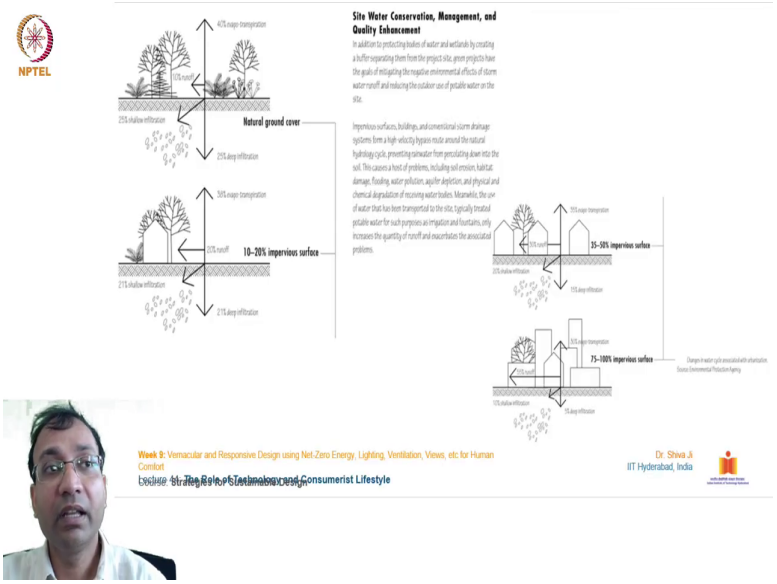

Next, in this thing we can focus on a site water conservation management and quality enhancements. So, the how the surface which we usually a pave and how we can plan to pave in such a way so that the water also keeps by penetrating inside the top layer of the list on the surface. It does not completely go as a runoff because the runoff water goes to the to the rivers and eventually to the oceans depriving the chance of getting this water in a top surface. So, this pavement design also should be taken care of properly allowing this water penetration in the ground.

So, you can see in these illustrations. So, here with the 25 percent of shallow infiltration and 40 percent goes in a vapour transport transpiration through the plants and the overall this surface. 10 percent water goes as a runoff in this condition when there is a huge vegetation ample amount of vegetation is there. It is a natural ground cover and the second one there is a 10 to 20 percent impervious surface.

So, here only 21 percent goes for a shallow infiltration 20 goes for a runoff and 21 percent goes is as a deep infiltration. Further, in this illustration if you see the overall it has a 35 to 50

of impervious surface on the ground level. So, it increases this runoff, runoff has increased 30 percent and on this shallow and deep infiltration are respectively 20 and 15 percent only.

Whereas, in this case this last one 70 where there is this impervious surface to the amount of 75 to 100 percent the runoff water is more than 50 at 55 percent. And this the deeper penetration and shallow penetration is only a 10 and 5 percent. Which is a worrisome situation which causes actually scarcity of water in the top soil level. So, we must take care of these situations for a pervious a site designed where the top surface taken care of.

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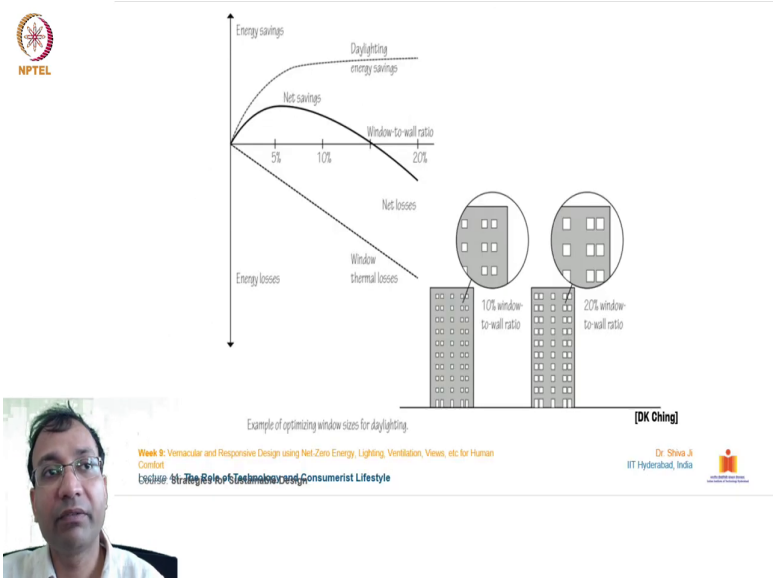

Further, in this next illustration if you see the here it is shown for optimizing the window sizing for a day lighting. So, how this can be taken care of. So, in this scale if you see in this illustration here first figure 10 percent window to wall ratio WWR here it is 20 percent window to wall ratio 20.

So, in these both of these situations you can see how the it drives the net saving here on this x axis this is window to wall ratio 5, 10, 15 and 20 percent. So, the day lighting how much of energy saving goes and window thermal losses so both are all of these three things are plotted over here on the scale of this energy savings or energy losses.

So, the on the saving part if you see more than when we are going for a 10 percent there is a usual saving over here if we are going for a lesser than that then this in this area the daylighting saving and the net saving is relatively a much lower. So, we can plan this WWR ratios to increase the daylight efficiency in our buildings.

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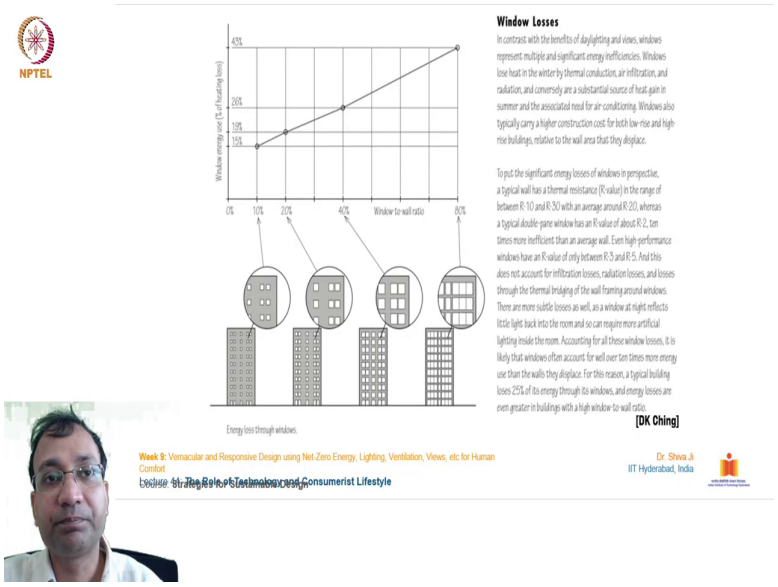

Further, through how much the losses through the window. So, the window energy used over here on this y scale percentage of a heating loss and on this scale we have this WWR ratio from 0 to 80 percent. So, you see with this illustration you can understand how much the WWR is talking about. So, here the window panes are huge the number of panes are more and the sizes are larger relatively in this one the window openings are much smaller.

So, from the window energy uses if you see from 15 percent to 43 percent this is how it is increasing. So, more the opening area more this heating loss at this range so this is quite evident from here. So, WWR is a very important factor to be considered in the design. So, you can take help of these daylighting software which I suggested earlier for the simulation of your designs and you can rectify before the project goes for a construction.

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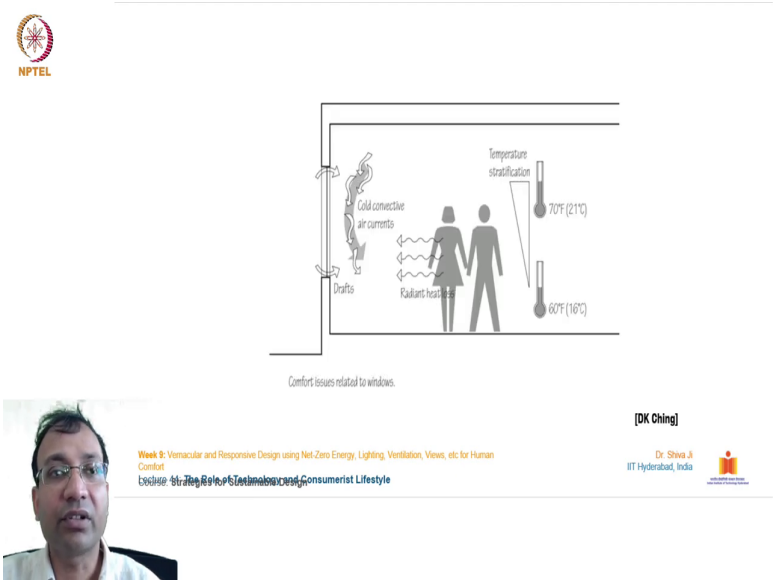

And in this one a comfort issues related with the windows are explained over here. So, you see there are several phenomena at the same time a body you may be aware of our body keeps radiating energy heat you know from our body. So, this is here and windows depending upon the climate and weather outside.

Either they receive or they lose the heat energy from inside and temperature stratification from here a 16-degree centigrade to 21 degrees centigrade. So, the cold convective currents they go down you may be aware of and the hot convective currents they go in the top level. And then from the ventilators they go out. So, this is how the ventilation and natural ventilation this convection system works inside a confined space.

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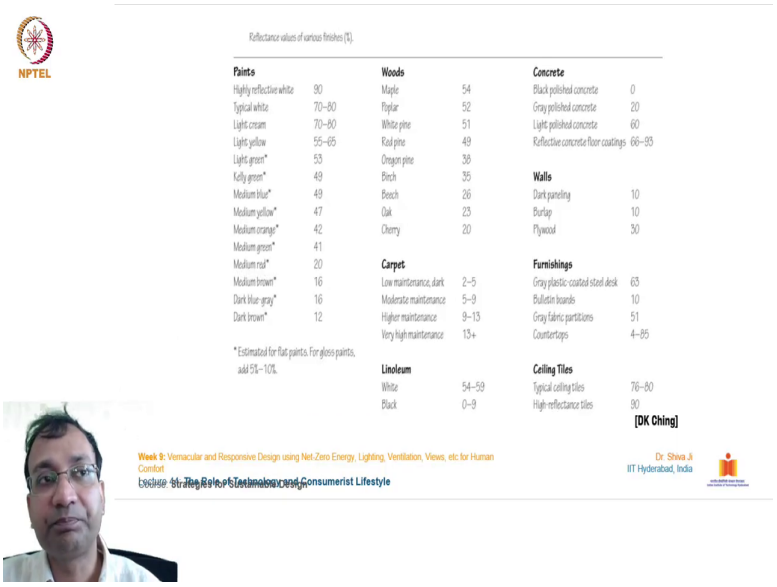

Here in this slide, I have taken reflectance value of different finishes. So, you can see in the paints what is the reflectance value so if it is highly reflective white it reflects up to a 90 percent, if it is a dark brown only 12 percent in between we have all of these shades and the colours you can understand from here how much is the respective reflectance of these paint materials. Further, we have wood, so in the wood from cherry to maple. And this range you can understand from 20 to 54 percent of reflectance.

Similarly, we have the different other materials also such as carpets, linoleum, concrete, walls, furnishings and ceiling tiles. So, you can see these high reflective tiles which are installed on the roofing systems to minimize the heat load on the top floors. It comes in a range of 90 percent of reflectance which is quite considerable.

So, this table helps us understand what kind of a finishing materials we should use in our buildings and the components of the building depending upon the location of that project in any given climate topographical level or in this weather conditions. So, depending upon the time of the year we can choose a such a finishing material for normal life building premises.

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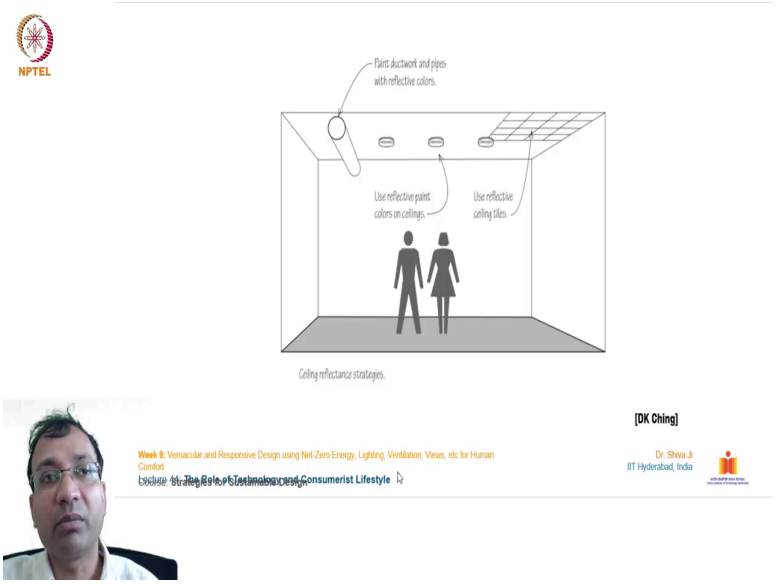

Further, for the inside a ceiling reflectance strategy and also, we can similarly choose the carpet materials, the wall finishes, the ceiling finishes etc. The other a materials using a reflective ceiling tiles here if we want to propagate a more light in a diffused manner we can use a reflective paints on the ceilings.

We can go for a paint duct work and pipe with reflective colour. So, the ducts and pipes which pass inside the interior spaces which are very clearly visible from a beneath we can paint them also. You may have seen some restaurants or maybe theatres where the public areas, in the public areas they keep all of these ducts and pipes exposed and they clear they colour it in a dark black.

But some places depending upon the application and the uses if it is a factory. So, sometimes they colour it in a white to create this reflection so that there is ample light, diffused light everywhere. So, that one can see what is going on. So, it depends on the application and the uses accordingly we can choose the surface materials and other things.

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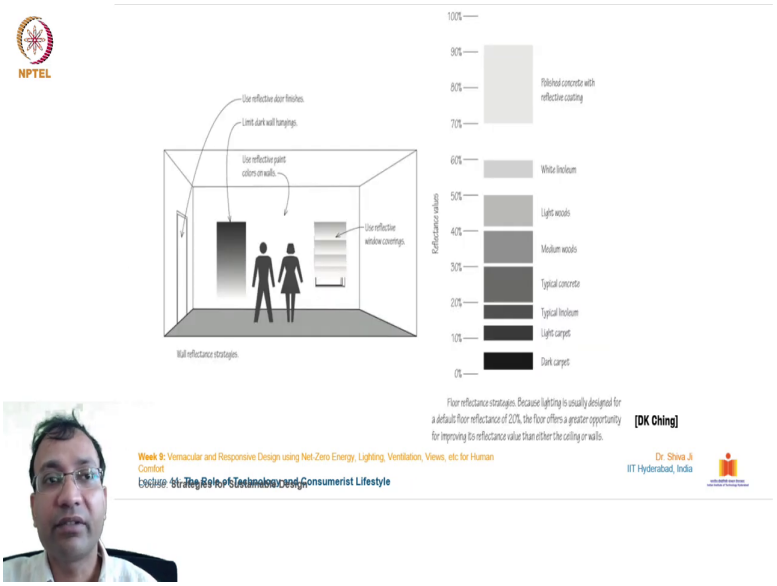

On this range these floor reflectance strategies because lighting is usually designed for a default flow reflectance of 20 percent. The floor offers a greater opportunity for improving its reflectance value than either the ceiling or walls. So, you see these dark carpets reflectance is almost close to 0 percent between this 0 percent to 5 percent.

And then we have this polished concrete with the reflective coating so this has the reflectance value of 70 to 90 percent. So, in between we have this white linoleum, white wood, medium wood, typical concrete, typical linoleum and light carpet. So, in these also we can go for choosing this flooring material.

Because flooring is the one component which reflects the lights to the a fullest. Because most of the electrical lights are also installed in the ceiling and they throw light to the floor and then that lights either will be get absorbed or will be reflected by a certain extent. So, we can choose this flooring material with the (()) (40:54) approach, how much of a reflectance, how much of a diffused lighting we want inside any given space.

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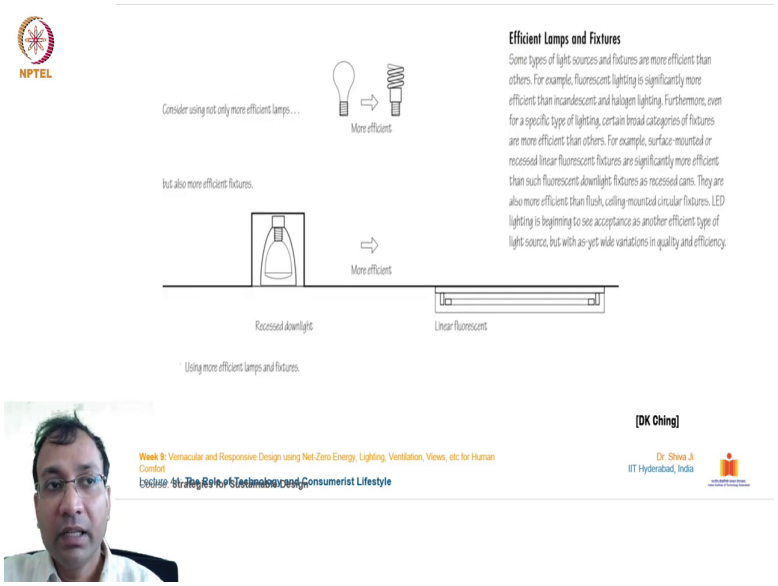

So, similarly in this we are talking about for the lighting. So, the how these are coves and these are fixtures can be planned for creating the ample and the desired lighting levels inside any given space. So, you understand from here consider using not only a more efficient lamps and also the compared to this surface area this has a wider surface area and this reflects light in a more diffused manner.

So, we cannot see the in the tungsten filament here in in this system of this CFL light. So, this works as a more diffused light source. Further, we have such arrangements in the ceiling you see this cross section over here. It is a cove recessed down lighter is put up installed over here.

Which gives its lighting it throws its light in a given direction only a given area only it does not it spills much light to the other neighboring areas. So, such strategies and compared to this if you see go for these fluorescent tube lights so they scatter light to a wider surface area. So, depending upon the space and application we can go for choosing the, these luminaires also.

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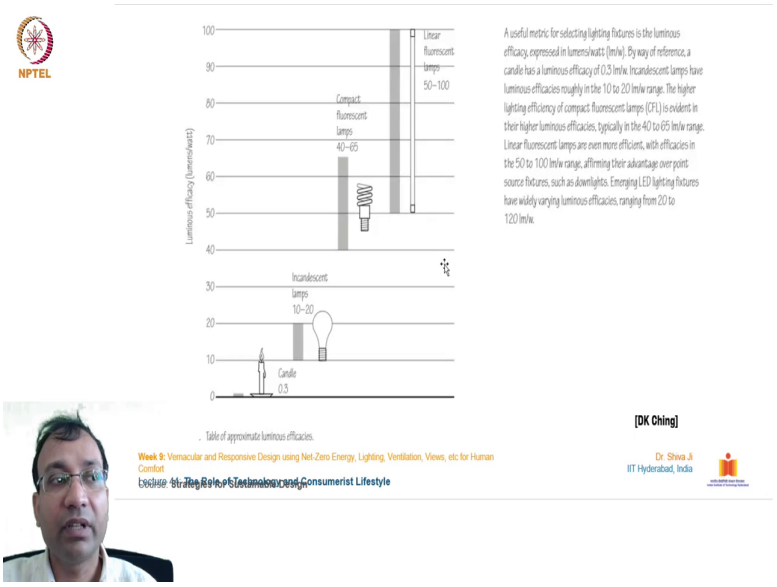

Here so this is a relative chart kept here on this table for your understanding which shows the approximate luminous efficacies of these many luminaires. So, from 0 candle to you can see it up to a 100. So, it starts from a candle from here so it goes to incandescent bulb, then we have this CFL bulb, then we have this fluorescent lamp these tubes so in a range of 50 to 100 to a 40 to 65 10 to 20 and up to 0.3. So, this is efficacy of these luminaires so accordingly we can choose and place them.

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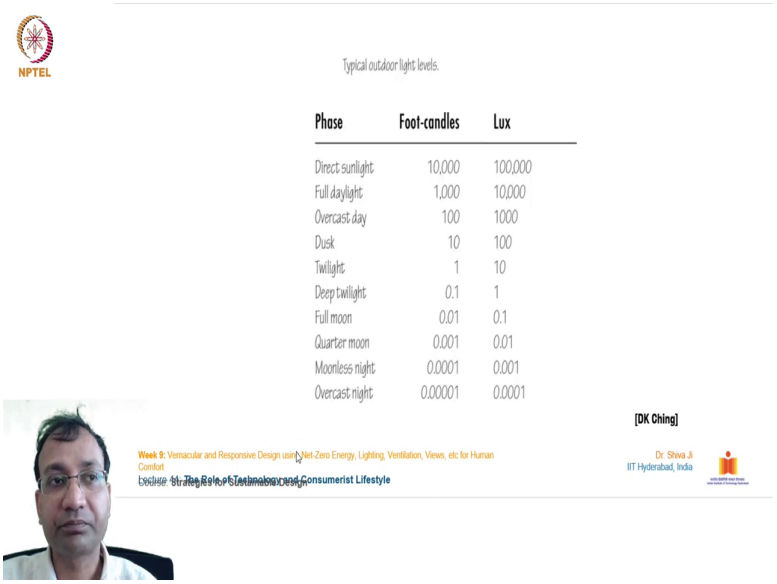

Further, a typical outdoor light level based on the of this source so these are sources of these light. For example, the ubiquitous the direct sunlight the sun it gives up to a one lakh lux

level the light a full daylight we receive approx 10000 lux and an overcast day it has around approximately 1000 lux. At the time of dusk, it offers 100 lux of a light level, at the twilight we get a 10 and the deep twilight we get 1 and on our full moon day we get lux level of 0.1.

In our quarter moon day, we get a 0.01, moonless night 0.001, overcast night we get only 0.0001. So, this is a relative comparison of these outdoor light levels in a broad day, a sunny daytime. And in an overcast night which is as a is very dark. So, you can understand and relate from here how the lighting levels in external outdoor it varies depending upon the hour and the seasonal effects.

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Further, in this slide we are discussing over here mapping wind conditions for the wind power system. So, any place you may be aware of depending upon the month of the year. There is always this prevailing light conditions. So, in this one this plotting this wind diagram is plotted over here.

So, depending upon the month, these months have very little wind, these months have average, these months have the high winds over here so this is plotted here on this rose diagram. Further, we have this hourly average speeds at what hour of the day how much of wind is observed.

And on the daily average speeds then we have a daily frequency distribution. So, these charts are helpful in understanding what kind of a wind patterns what kind of wind movements are existing on any given site location. And accordingly, we can go for designing the, our

buildings. We can choose in this manner; we can choose the location of the doors and windows and other openings and we can strategize depending upon the requirement do we want a cross ventilation we want either we do not want a cross ventilation and things that.

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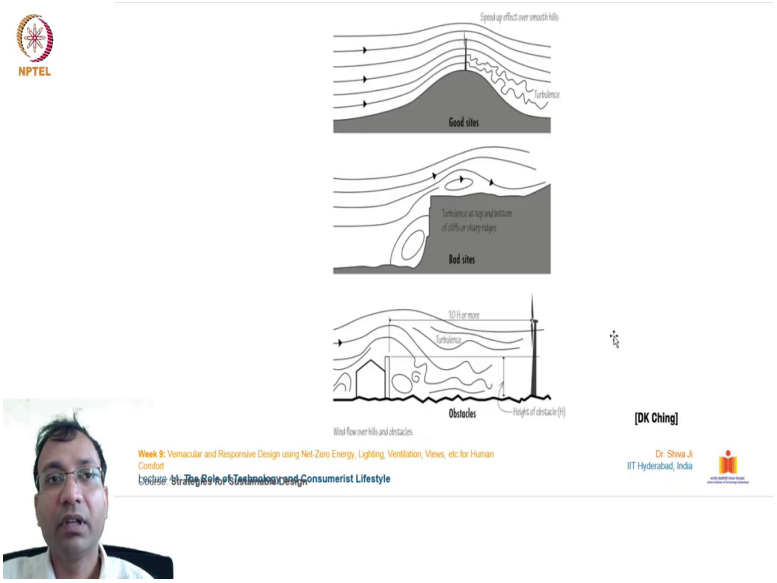

Further, this we have discussed before but one more time how the topography helps in creating turbulences or the wind patterns. So, strategically you can see over here in this first sketch this is a good location for of for placing a windmill. So, that it receives the compressed flow of air which is a high in velocity compared to the other regions. And other these places in the foreground and a such kind of places where there is a sudden rise in the topography it creates these are turbulences.

So, this is not a preferable location for having houses because there will be a turbulence in the year most of the time of the day and the year. Similarly, these the urban obstacles also such as a large scale building structures or chimneys or these warehouses they also create this hindrance in the overall movement of the air. And they create in term turbulences. So, these also structures are necessary to be taken care of while we are designing for the wind movement in our premises.

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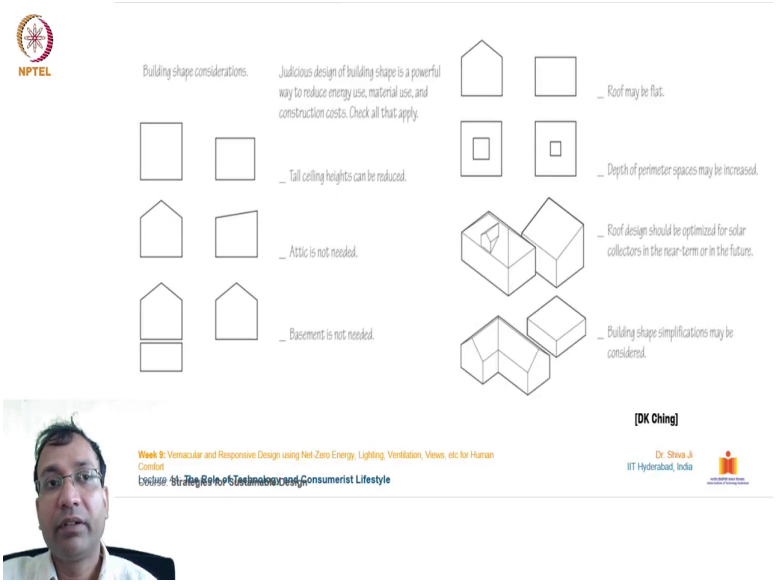

Further, here in this slide we have building shape considerations what kind of shapes will perform in and what kind of.

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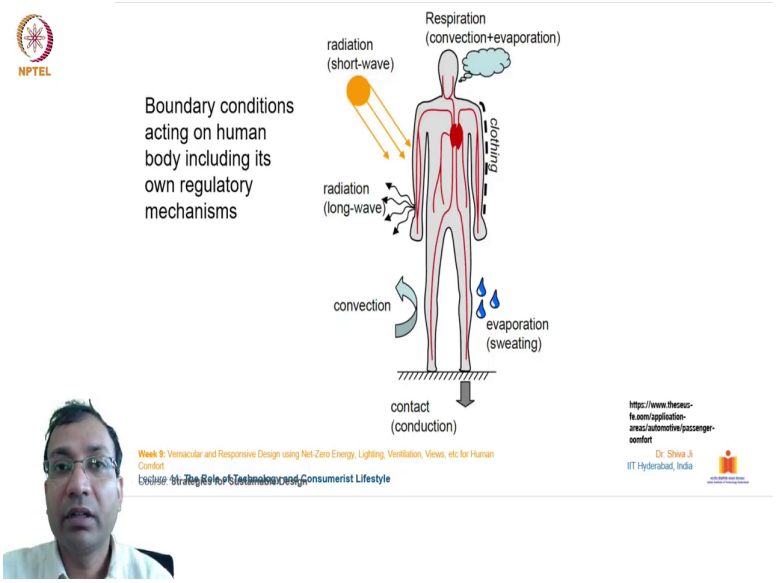

So, in this illustration we can understand more what are the boundary conditions acting on any human body. Including our own regulatory mechanisms bodily mechanisms and also. So, which enables these human comfort situations which we desire for. So, we have this sun as a major source of a radiation and heat for us. So, it emits these short waves which are received by our body and at the same time we keep radiating some heat from our bodies. And then in turn we have this respiration with the convection and evaporation at the same time.

Evaporation is a phenomenon of a sweating you can understand easily and then well we have this protective layer of these clothing. And then we have a convection the air which passes through touching our bodies. If it is a cooler, it keeps on absorbing some heat from our body or if it is hotter we it keeps on giving some heat back to our body.

And when we touch any a surface such as a ground or furniture or anything we keep conducting some heat to that body and resulting into some heat loss from that touch. So, or in an overall sense you can understand this is how this the thermal energy is a exchange keeps on happening on anything a human body. So, the amount of energy what we receive, the amount of energy what we release through different means of convection and conduction etc. So, in and around this in the next illustration you will understand.

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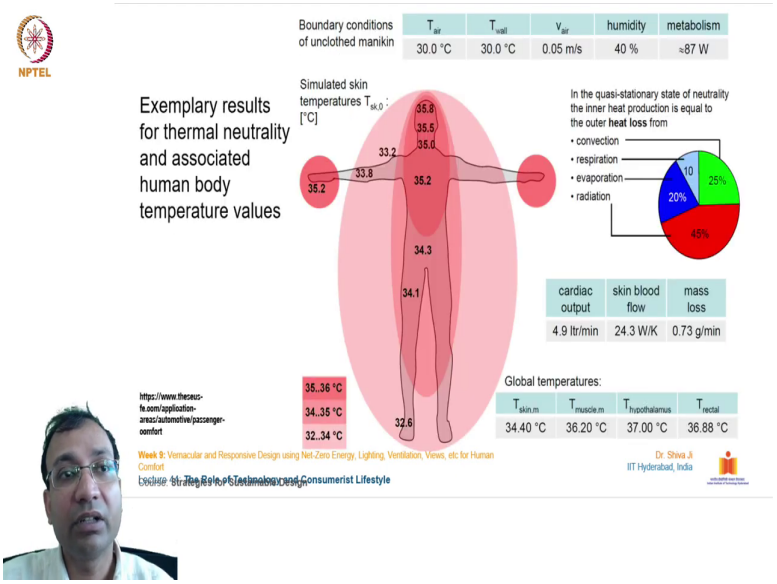

At this temperature scale of a 35, 37 degrees. So, the, our bodily temperatures and the different organs they also vary you may have a notice hour a fingers and other ears so they work as a heat releasing units you may have a seen these the hotter ears. So, some physiological conditions here work as a heat radiating unit and they release a heat in the a here through convection trying to establish the equilibrium of the body temperature.

So, you can understand from here are these body conditions of an unclothed a mankind. So, the if air is at a 30 degree centigrade and the volume is 30 degrees and the air velocity at a 0.05 meter per second speed humidity at 40 percent and whatever activity at 87 watts. So, in this kind of situation how body is going to a perform.

So, you see in this quasi-stationary state of flag neutrality the inner heat production is equal to the outer heat loss from you can see these many sources. So, the convection up to 25 percent, respiration 10 percent, evaporation 20 percent and radiation up to a 45 percent. So, this is an exhaustive a diagram an illustration of how our bodies a thermal neutrality that the tendency to create an equilibrium in the heat part it works.

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Further, a different, different activities and they are a metabolic equivalent MET. This is the term over here you can understand when we are a sitting a performing an activity which is not very exhaustive such as reading. So, this is taken as a 1 MET. Then if you are playing an instrument having some a small activity if you are performing this is a 2 MET. Then if you are working on the computer it has taken as a 3 MET.

If you are gardening or doing some a normal activity some a little not that a heavy an extensive activity that is 4 MET. If you are biking, cycling etcetera that is 5 MET. If you are riding staircase you may have, I have experienced when we keep on riding these staircases for a longer period of time we feel stressed so this is 6 MET condition. If you are performing a considerably a good amount of this physical activity jumping rope etcetera or so that qualifies for 7 MET.

And if you are running around jumping heavily that is under the range of 8 to 10 MET. So, this is this activity and this metabolic equivalent scale you can understand. So, the this is important to release the heat and to consume the energy to spend the energy what we absorb

from a food and all that. So, this helps in creating that established an equilibrium metabolic activity in our body.

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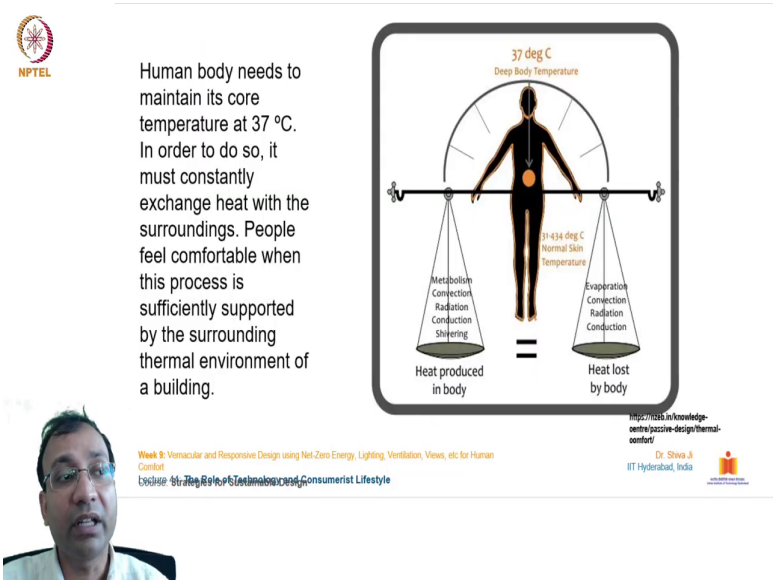

Further, in this table we have this equilibrium. So, on the one hand we have this heat produced in the body and then on the other hand we have heat lost by the body. So, the activities you can see over here you can understand how our body establishes a balance. And once that balance get disturbed we experience some medical conditions such as a fever. Fever is a one of the major symptomatic reflections of some disturbance going on under a body inside the body.

So, the activities over here which produced which produce heat inside our body are metabolism. Convection, radiation, conduction, shivering, etc. they result into increase of the temperature inside our body. And evaporation, convection, radiation, conduction, etc. they are also responsible for release of the heat from our body. And a normal human skin a temperature ranges between a 31 to a 34 degree centigrade.

A maximum up to a 43.4 degree centigrade as you can see from here. And average is a body temperature the deep body temperature inside which we measure through these thermometers. Such as when we insert in our mouth or maybe when we insert with the deep inside our, these arms over here inside the are these sides. So, these readings give our inner body at temperature that is the standard is a 37 degree centigrade.

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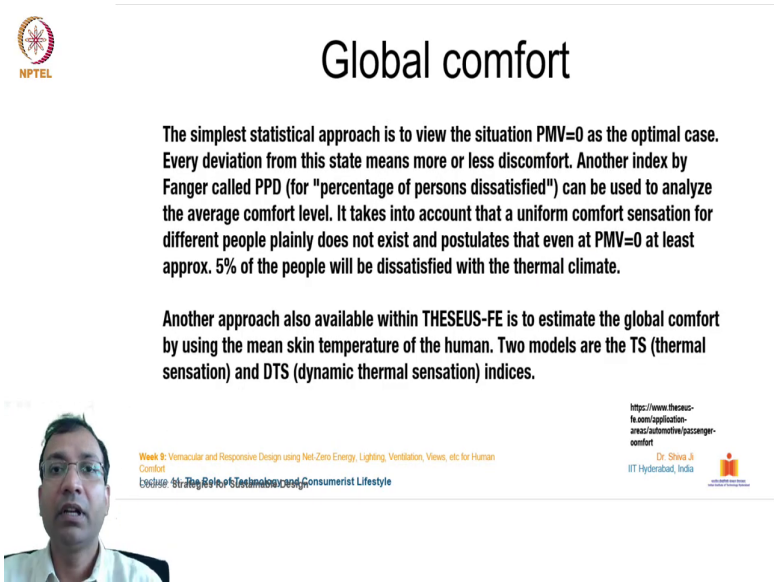

So, here we will talk about global comfort and with respect to a human body. So, the simplest statistical approach is to view the situation PMV is equal to 0 as the optimal case. Every deviation from this state means more or less some kind of a discomfort. Another index by Fanger called PPD for percentage of persons decertified can be used to analyze the average comfort level.

It takes into account that a uniform comfort sensation for different people plainly does not exist and postulates that even at PMV at 0 at least approx 5 percent of the people will be dissatisfied with this thermal climate. Another approach also available within THESEUS-FE is to establish the global comfort by using the mean skin temperature of the human. Two models are the TS thermal sensation and DTS dynamic thermal sensation indices.

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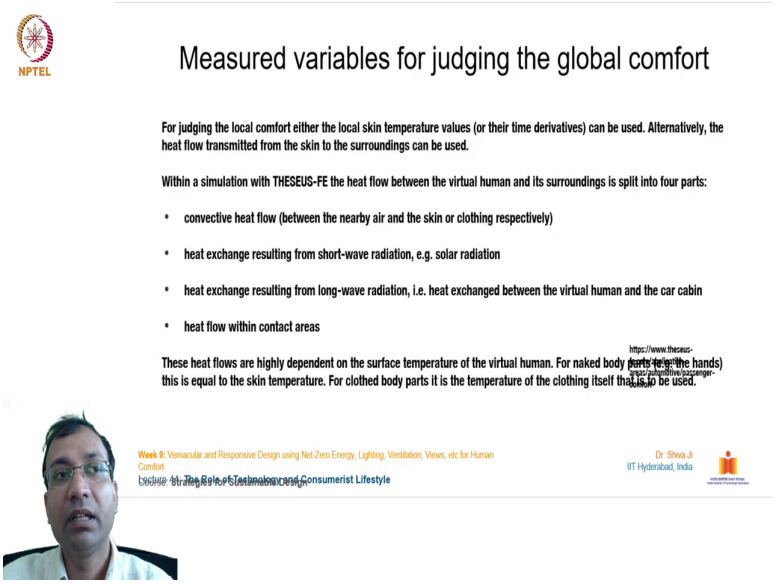

Some measured variables for judging the global comfort over here for judging the local comfort either the local skin temperature values or their time deviations can be used. Alternatively, the heat flow from transmitted from the skin to the surrounding can be used. Within, a simulation with THESEUS-FE the heat flow between the virtual human and its surrounding is split into four parts.

These are; convective heat flow between the nearby air and the skin or the clothing respectively. Second, heat exchange resulting from short wave radiation that is a solar radiation. Thirdly, heat exchanger resulting from long wave radiation that is heat exchange between the virtual human and the car cabin.

Lastly, heat flow within contact areas. These heat flows are highly dependent on the surface temperature of the virtual human body. For naked body parts easy like hands etc., this is equal to the skin temperature. For cloth body part it is the temperature of the clothing itself that is to be used. So, this is how this works.

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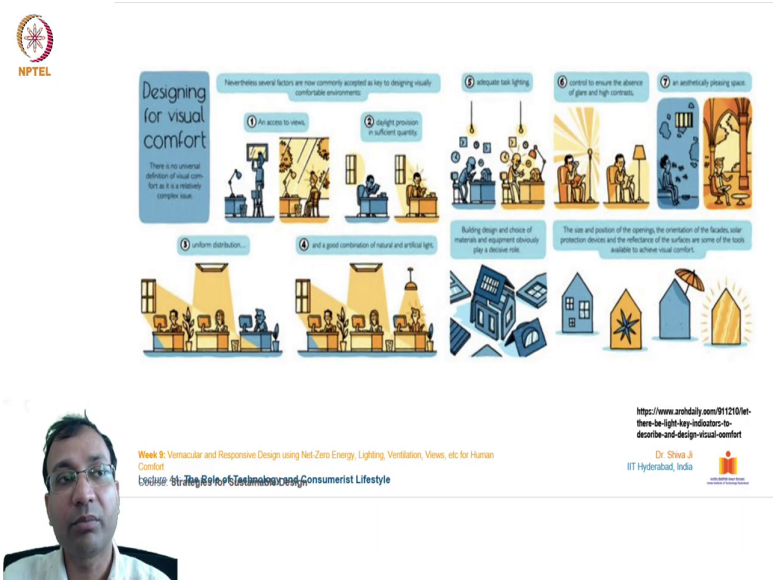

And from here on we will see some illustrations of like human comfort situations for thermal conditions are concerned, lighting levels are concerned, wind conditions are concerned, the acoustic conditions are concerned. So, this is for our understanding this is source from this website you can go and refer it has some more interesting insights and illustrations to depict certain conditions.

So, from here you see this designing for a visual comfort well this person is looking for some access to the views. And if related to him if you see if this person has a person has the exposure to the outside and a good view. So, relatively who will be a pacified and who will be contented is I think is very, very evident. This person is getting a lesser amount of light from the way from this window, this person is getting ample amount of light from the window for reading and normal activities.

Similarly, here this person has this lighting which is a giving a very lesser a quantity and the amount of water. The lux level is very little on the working top over here. And this has the ample luxury lighting level. So, these are the different conditions which depict certain conditions we which we usually also encounter in our daily life.

When we feel there is low light then we feel intended to switch on the luminaires and increase the lighting level to meet the comfortable conditions. So, this is a very generic psychological phenomenon as far as this lighting levels are concerned you can see in the these more illustration. A person who is confined inside a space, a person who is sitting

outside and a space where there is some, some spaces there these are lit and some workstations are not properly lit.

So, creating an imbalance so we must take care of a such workstations also where this natural light cannot dig deeper. Creating a balanced approach and similarly what parts of the building what components and surfaces of the building should have how much of a proportion as a opening that also should be really thought of that. That is the overall objective to understand from here.

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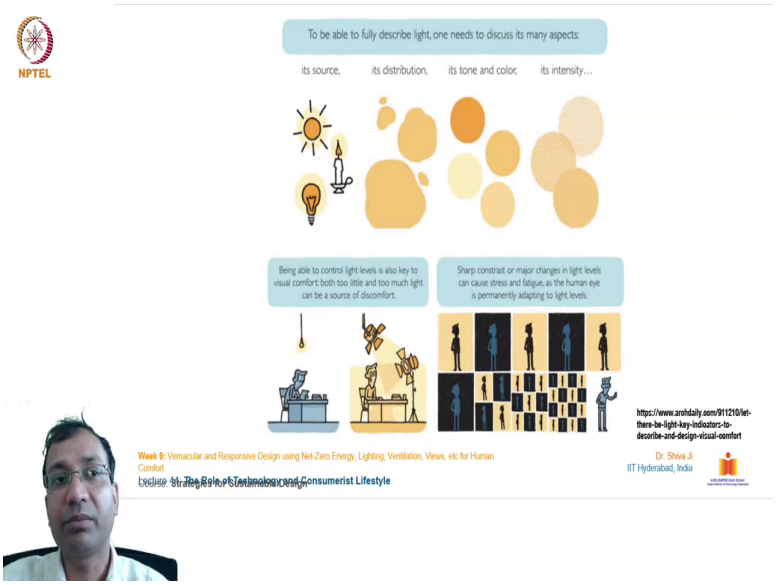

And in the lux level you see how this person has this light condition and this has a too much of light. So, we will both are causing an imbalance and a discomfort over here. So, we must take a balanced approach in creating a light.

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And then socio psychological conditions for a visual comfort. So, how a sometimes we want dim lighting for example for a fine dining experiences and all when we are sitting in a place where we just want attention to the person who is sitting around. So, in this condition well this becomes a desirable luxury lighting level. So, it depends on uses also and similarly you can see there are several of these illustrations how they have impact on the overall a comfort condition of any human person.

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Further, into this a sociological effect, psychological effect of a thermal comfort. So, a person who is feeling cold a person who is feeling hot the kind of differences they will feel. And

yeah similarly, they will put on the clothing. And similarly, they will go outdoor or maybe refrain from going outdoors so such conditions are labelled over here.

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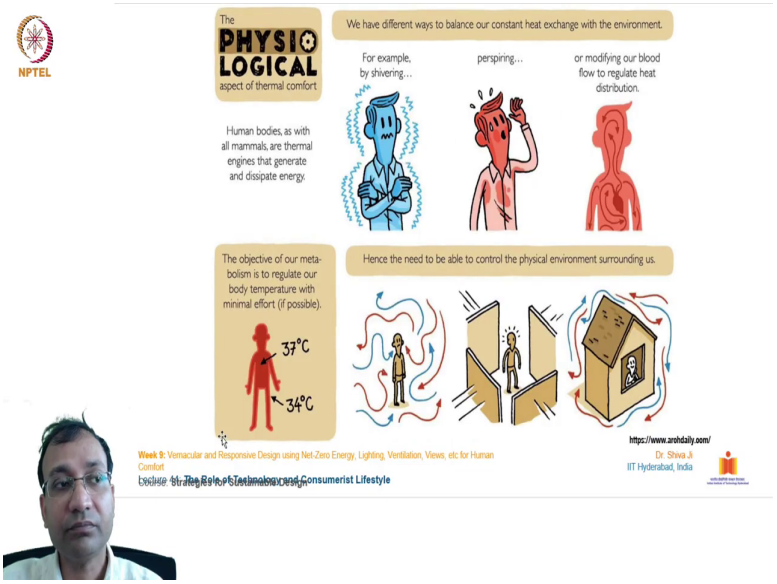

Some more how the spaces how the buildings can be designed to work around such turbulent heating conditions. Sometimes, they cause a dense discomfort by when the temperature drops significantly. Sometimes, they feel discomfort when the temperature rises significantly.

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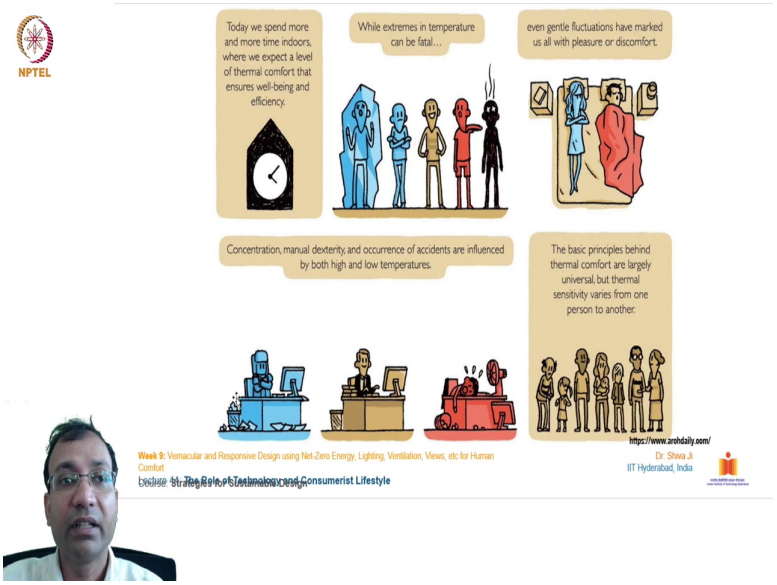

So, how to establish a balance over here so this you can understand there are some illustrations which talk about in the same given a room. One person feels cold one person

feels hot so how this a varies from a person to person also, how it is very, very individual and personal.

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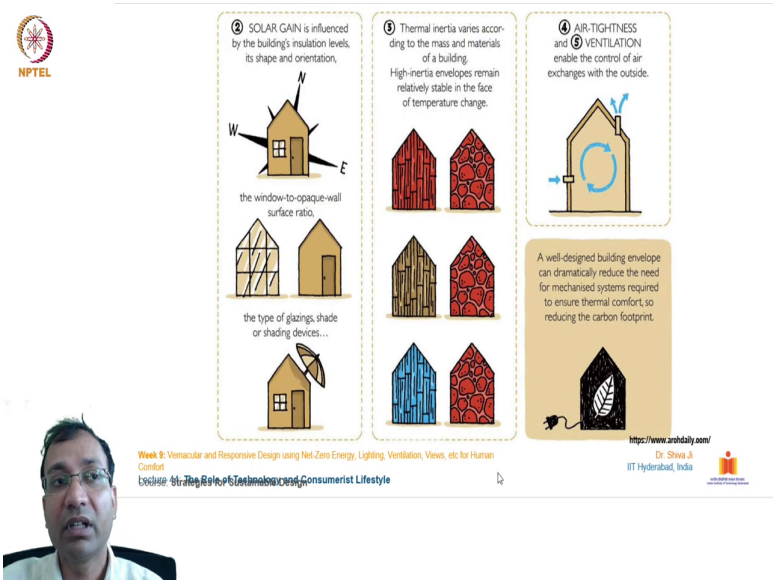

So, how these things can be taken care of in any given a spaces design is the task for us to deal with the, with deliberation.

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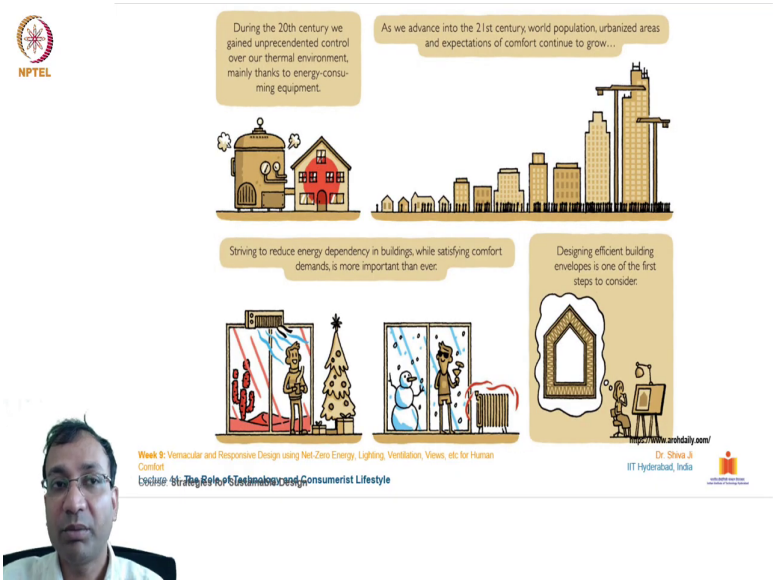

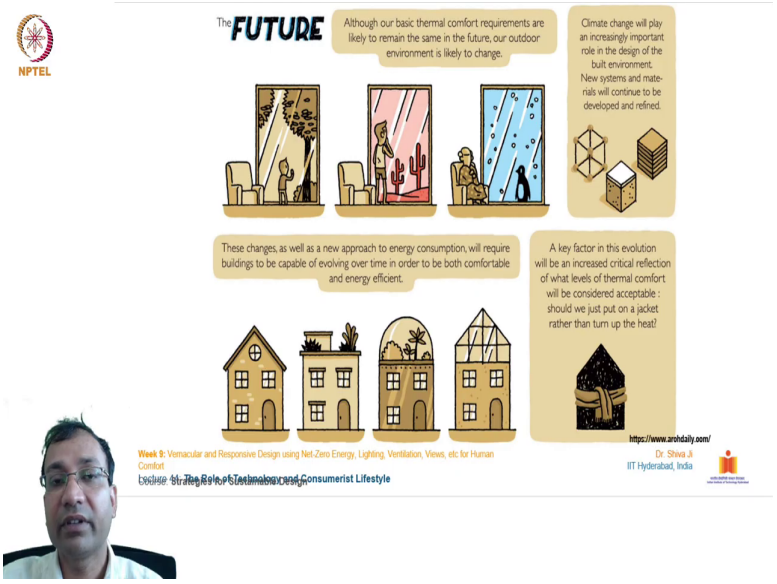

So, maybe you can go through these illustrations in your leisure time you can take it as a as a leisure activity for yourself and you can go much in detail how the future is going to look and how we can design the future of habitation which we have discussed in one of our lectures.

How this is going to be in these illustrations you see here at the bottom this house has its own controlled environment to grow even a vegetables and things and this is completely a closed from outside to the outside world. So, the how the future is going to be like for the human the comfort conditions that also we can understand from here.

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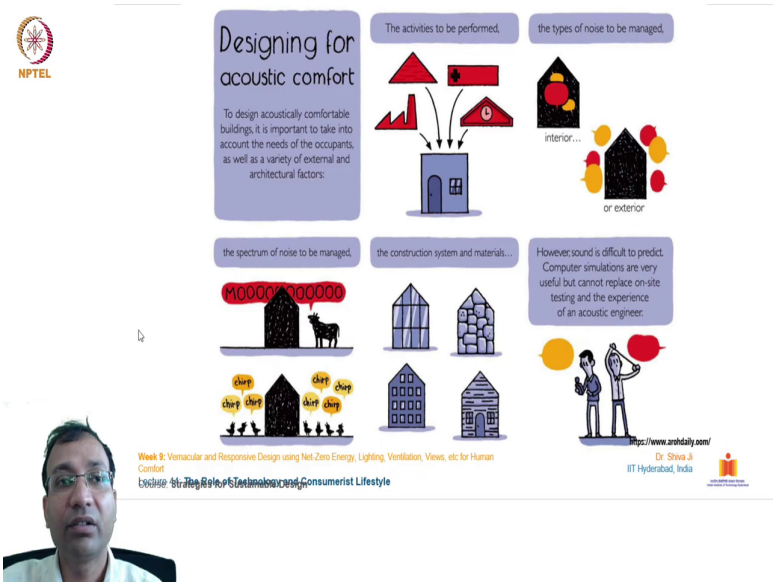

So, this is designing for acoustic comfort, what are the sources of noise the and how those noise also sometimes become the musings such as a chirping of the birds. So, we feel good when we hear these. But, the moment there is other kind of a infrastructure or maybe heavy activities if they start producing a noise such as factories and other a mechanical units or maybe a heavy exhaust from an aircraft so we feel a terrible terribly discomfort.

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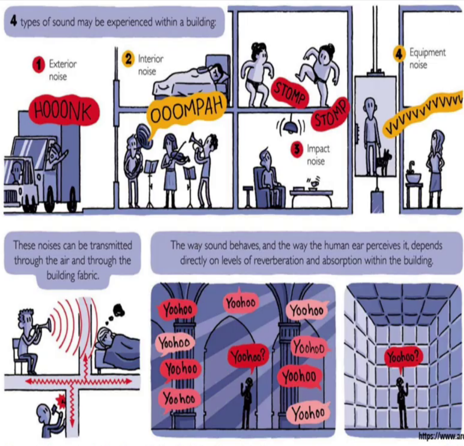

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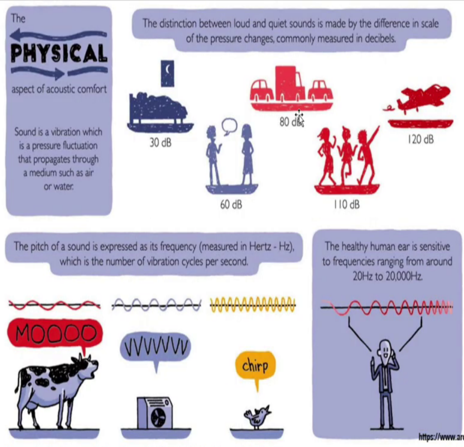
Week 9: Vernacular and Responsive Design using Net-Zero Energy, Lighting, Ventilation, Views, etc for Human Comfort

Lecture 41: The Role of Technology and Consumerist Lifestyle

Dr. Shiva Ji
IIT Hyderabad, India

NPTEL



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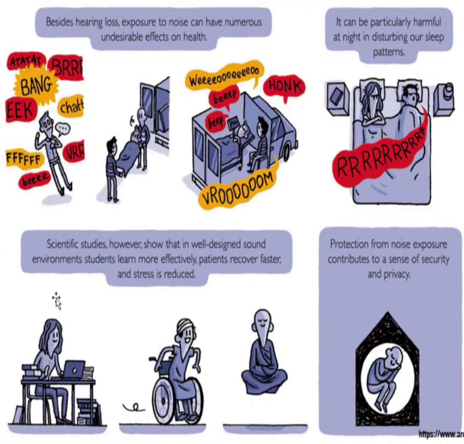
Week 9: Vernacular and Responsive Design using Net-Zero Energy, Lighting, Ventilation, Views, etc for Human Comfort

Lecture 41: The Role of Technology and Consumerist Lifestyle

Dr. Shiva Ji
IIT Hyderabad, India

NPTEL



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So, accordingly we can choose the material which help dealing with this acoustic condition. So, some of these instances are beautifully illustrated over here. How the different activities inside a building premises, sometimes they become musing, sometimes they become the causes of discomfort. And also, how these things can be taken care of in our design that is a matter of our deliberation.

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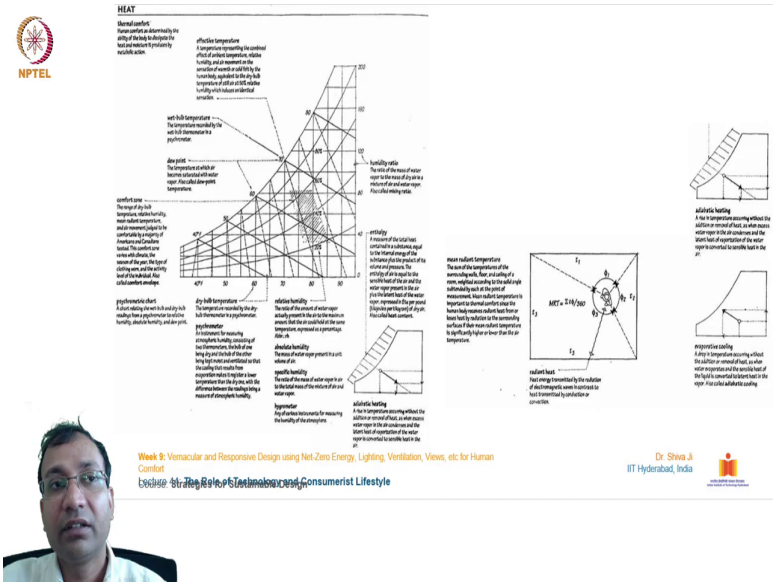

So, this is you may be aware of this so this is psychometric chart. So, this is this varies from place to place, every place has their own psychometric chart which is which depicts the comfort zone for humans. In the this plotted diagram of the heat, the relative humidity, the wind conditions, the dry bulb temperature, etc. so this chart is a very crucial a piece of information for designing spaces designing buildings. So, we must consider this psychometric chart.

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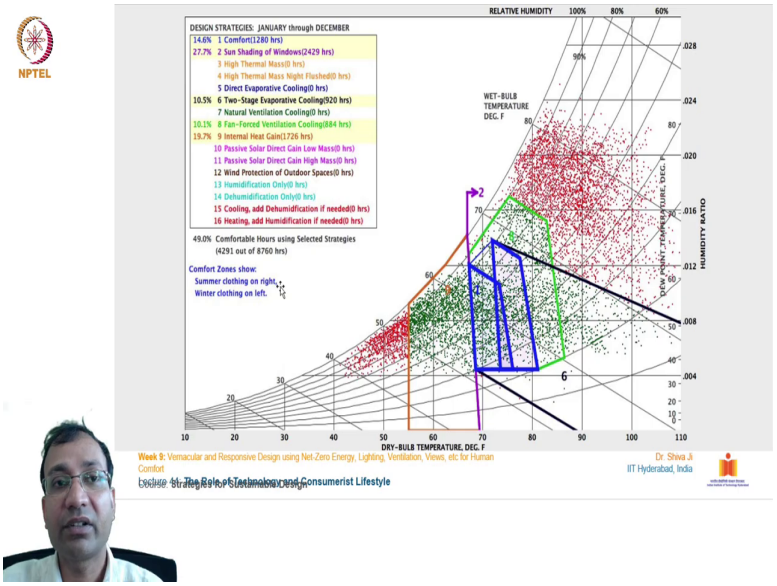

And also, this is a typical chart where this data is actually filled in over here you can see these are dots. So, this is depiction of this is a dry bulb temperature. On this range we have this relative humidity over here. So, this is 100 percent 80, 60, or 40, 20 and things that. So, you see these boxes drawn in blue over here so these are truth sets of human comfort conditions for a winter month and for slower months. So, we strive to bring the comfort conditions in this area in our design spaces.

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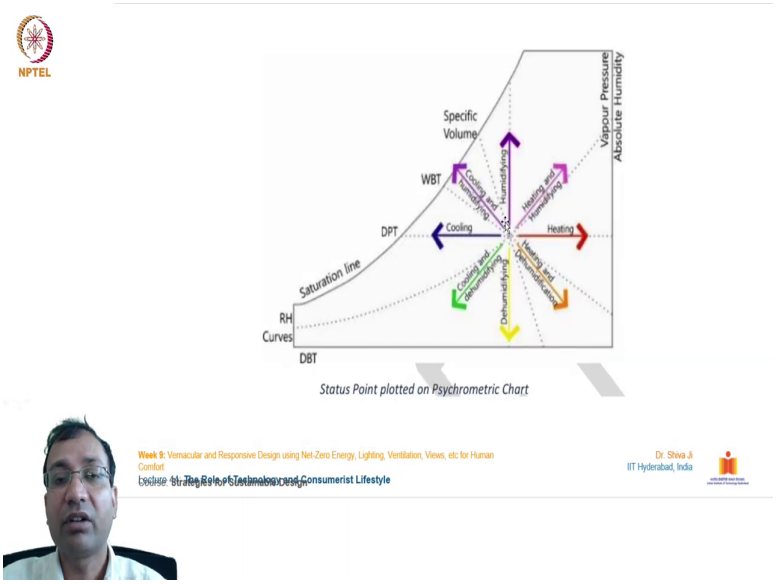

So, this is how we design for a comfort condition. So, in this slide you can see this is the status point plotted on psychometric chart. So, here it shows what kind of conditions are

required if we are moving from this standard a balanced place to these many directions. So, if you are moving up that means humidifying is an important factor. In this way heating and humidifying, in this way heating is needed, in this side cooling is needed, and this side cooling and humidification is needed this side a cooling and cooling and dehumidification is needed.

Similarly, you can understand from here when the ones temperature of any given place the relative humidity, the wind direction, the wind movement etc., once they keep on changing and fluctuating then what kind of induced phenomenon will take place are shown through this table over here.

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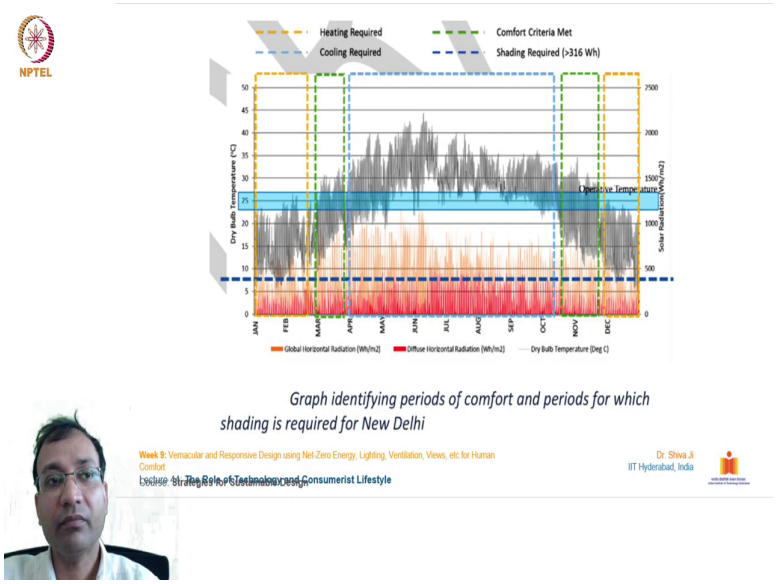

Further, this is a graph identifying periods of comfort and periods for which shading is required for the city of New Delhi. So, you can see this temperature ranges are drawn on this axis dry bulb temperature from 0 to 50. And on this scale, we have the number of months total 12 months January to December. And yeah, this side we have this solar radiation from 0 to a 2500.

So, you can see from there how this temperature keeps on increasing in these many months. So, this is shown through these dotted lines in this June heating is needed you can see over here this orange dotted line. And this is this green dotted line is a period of a comfort. So, the natural elements are at such a balance that the overall in an overall sense the outside the temperature and the combination of humidity and wind speed is at the comfort level.

And in this blue period this cooling is required. So, this is how it is mentioned over here at which time of the which month of the year what kind of conditions are prevalent and what is needed to be done. So, this is how depicted over here. This, with this dark blue dotted line it is shown the shading is needed. So, shading almost you can see once the temperature literally rises above 16 degrees centigrade under tribal temperature, it is expected that some kind of a shading is necessary in this a city of New Delhi.

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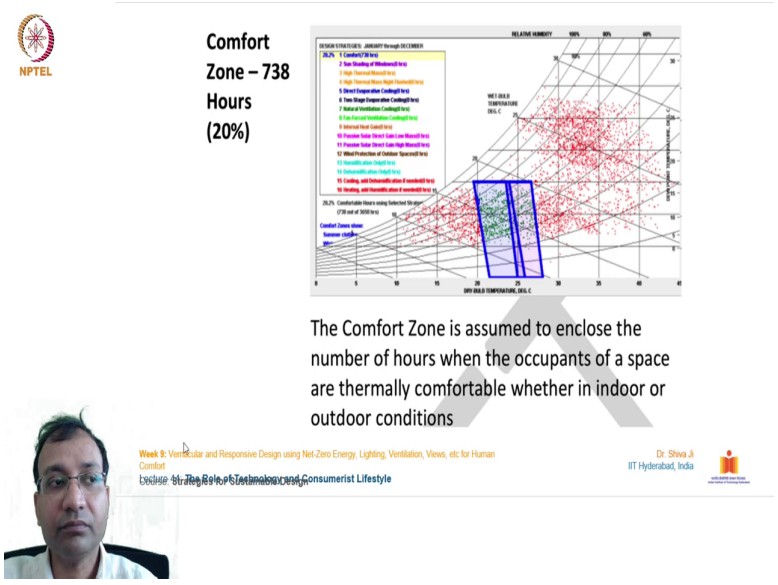

Further, we have this comfort zone. So, accordingly we can rework our designs how we can, based on these previous 2 3 slides further we can plot a region a zone where comfort conditions can be created inside any given a building premise.

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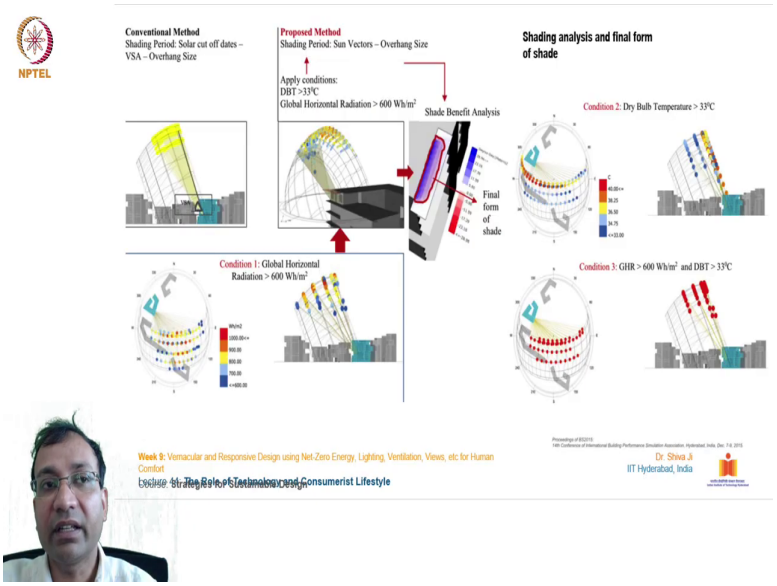

So, this is solar path diagram. So, the shading analysis and the decision of the final form of the buildings can be taken care of through this analysis. So, this is a short from this solar path diagram which shows the location and the intensity of sun at different time and different months of the year. So, you can see the temperature ranges from 33 degrees to 40 degrees in centigrade over here. I depicted with these five different colours of the sun and its location.

So similarly, in these are winter months you can see over here the temperature is below 33 degrees. So, this sun can easily penetrate deeper inside the spaces and here when the sun is shown in the red dots, so the temperature is above 40 degrees. So, how the shading will be required and all that. So, this kind of analysis can be done through this site.

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So, with this we have come to the end of this lecture. Thank you everyone.