Course Name: Bioclimatic Architecture: Futureproofing with Simple and Advanced Passive Strategies

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Lecture 03

Simple Graphic tools to understand climate- Climate Consultant

Hello everybody. So in the last few classes we saw what are the climate characteristics of the various climates of India. Warm and humid, hot and dry, composite, moderate and cold. But then, how do we read this climate? How do we get data on this climate of any place that you choose? How will I be able to get the climate of that place? And how will I read the climate? For that, today I am introducing to you a tool with which you can read the climate of a place. That is Climate Consultant. Now, what is Climate Consultant? Climate Consultant is a simple-to-use graphic-based computer program that helps architects and builders, contractors, homemakers, and anybody who wants to understand the local climate.

Climate consultant translates raw climate data into meaningful graphic displays. It uses 8760 hours of data in EPW format which is energy plus weather format of climate data. The purpose is not simply to plot climate data. but rather to organize and represent this information in easy-to-understand ways that show the subtle attributes of climate and its impact on built form.

The main goal is to help users create more energy-efficient and more sustainable buildings, each of which is uniquely suited to its particular spot on this planet. What happens? First is you need to download the software. Just google Climate Consultant download and then download the software, execute it, run it, then open it. Upon opening the software, the first couple of pages are instructions on how to use the software. What you need to do is press next to continue on.

Then upon opening the software, the first couple of pages are instructions on how to use this software. So, you can read the instructions. Here it says files of hourly data are available for hundreds of station around the world at the US DOE Department of Energy, Energy plus Climate data site which can be accessed through that particular website. You need to download and install your desired location of EPW file format. Select the download

EPW weather data file button when you start a new project or select change weather data from the file menu.

How to do this? I will tell you. So, you need to either read these instructions or follow what I am saying. Press next to continue on. Then here what you need to do is. After pressing next, you will get this on your screen- this image on your screen.

Here you need to start a new project. Press start a new project if you are doing using Climate Consultant for the first time. Then you select the typology of building either residential or small non-residential. I have selected residential here for the purpose of demonstration. You can select the measurement system imperial which means feet and inches or metric in meters.

I have selected metric. then select weather data. Either you open the existing EPW file weather data. If not, if you want for a very specific place which may not be there in the existing EPW file, then you have to download the new EPW weather data file. Now, here How to download? If you want to download and install the weather data file from the EnergyPlus website, select the download new EPW weather data file button.

Once the data file has been successfully downloaded and installed, it will open automatically. Here we are using the EPW file of Jaisalmer Rajasthan which we will use for demonstration. Once you click on it, you will get the EPW file of Jaisalmer. Here you can see Jaisalmer. The first slide after the EPW file is input is the summary of all the weather data in that file in a numerical format.

The later slides will be representing the same data, but in a much easier-to-understand way through graphical format. So, here you need to understand why we are—why do we even want to read the data? We want to read the data because we as architects want to understand the data to design buildings or to understand how to make the buildings thermally comfortable. Thermally comfortable, that word itself has various models. Comfortable by which standard, which model? So, here we have used the adaptive comfort model in ASHRAE. So, thermal comfort is defined primarily by dry bulb temperature, humidity and wind speed.

Although different sources have slightly different definitions or criteria or benchmarks. So, Climate Consultant will allow the user to select from one of the four comfort scenarios. Each has its own criteria screen and modifies the way comfort is shown on the different graphs. Now a brief description of what each comfort model entails is also given here below the names. And now we are choosing the adaptive comfort model.

Once you choose the adaptive comfort model, pick next. the adaptive comfort model using natural ventilation, the acceptability criteria will be defined automatically. So, this screen is different for each comfort model which you select on the preceding screen, which means If you had selected the California energy code comfort model, then the criteria would have been different. It would not be an adaptive comfort model. So, based on what you select in the previous slide, the figures will feature here on this slide.

It establishes the default criteria or decision points that are used throughout the rest of Climate Consultant, especially on the psychrometric chart. These values are different depending on whether imperial or metric was selected on a prior screen. For example, users sometimes change the upper and the lower temperature limits of the comfort zone or might increase the maximum comfortable air velocity. If you are using imperial units but later change to metric, all your values will be automatically converted appropriately. Once you press next, this chart will appear.

The first chart is the dry bulb temperature, and it is the sensible temperature typically measured by a thermometer with a dry bulb. The units are either in degrees Celsius or Fahrenheit. Whereas the second chart when diffuse radiation is higher it usually means that the sky is more overcast. You need to understand and read this. In the first chart, it shows recorded high and low temperature round dots.

Okay, then it shows design high and low temperature that is top and bottom green bars. The average high and low temperatures are shown with the top and bottom yellow charts. The mean or average temperature is shown with the slot. in between open slot. These values are calculated for each month and for the full year by Climate Consultant.

So, all you need to do is select the place and then you say have the adaptive thermal comfort model or any comfort model of your choice and press and automatically you will get these charts which are easy to read. So, you have the high and low temperatures, which are denoted by the dots. I will repeat this again for ease of understanding. The high temperature is denoted by this dot and the low temperature for the month is denoted by this dot which are the recorded temperatures. Then the high and low temperatures are shown by the green bar, and the average high and low temperature is denoted by the yellow bar, and the mean and mean or average are denoted by the slot in between the bars.

You can see in the legend it is clearly shown. Then this chart shows the monthly diurnal 24-hour average data for each hour. It shows a grey bar that represents the comfort range. So this is the comfort range of people in this climate zone and so on. It keeps You do not have to do it manually.

It is already done for this climate type. Then the average dry bulb temperature is shown by the upper red curve. Now since it is an upper red curve, I am changing the color to a violet. So this one. This upper red curve shows the average dry bulb temperature.

The average wet bulb temperature is this curve, the lower curve. Average WBT. annual hourly radiation for each month is indicated on the left-hand scale and you can change the unit and it is shown in green for global horizontal and in yellow for direct normal so you can see this green that is shown for global horizontal In yellow it is shown for direct normal and in blue for diffuse radiation. You can click on the box here that says display hourly dry bulb data temperature, and then the temperature for every hour of the day throughout the year, which will be shown in a light blue underlay behind the average dry bulb temperature curves, will also come. But it will be too confusing because too much data will be presented here on this chart.

This legend gives you the meaning of all these curves and colours in detail. So, when diffused radiation is higher, it usually means that the sky is more overcast. And so, direct normal beam radiation will probably be cut down. Thus, total or global horizontal radiation will be reduced. Global horizontal radiation is the sum of diffuse radiation from the entire sky vault plus direct normal radiation from the sun times the cosine of its angle of incidence to the ground.

All this is very difficult for us to calculate manually. The task becomes very large but then a graphical representation like this is good enough for us to extract and understand the data. Then comes the radiation range. This chart shows that for each month and for the whole year, the yellow color is the direct normal solar radiation, whereas the global or total horizontal solar radiation is in green, and then the total surface radiation is in orange. So, using the ASHRAE formula, Climate Consultant calculates the theoretical maximum hour during each month for both direct normal and global radiation and displays it as a solid black.

The meaning of all these is given here. You can see theoretical. So, the yellow bar shows the amount of solar radiation measured as if the sensor was pointed directly towards or normal to the sun. You should notice that the theoretical maximum value for direct normal solar radiation peaks in February, when the Earth's orbit brings us closest to the sun. Next, we will see the global horizontal radiation.

The green bar shows the amount of solar radiation that is recorded falling on a horizontal surface. In theory, it is composed of all the diffused radiation from the total sky vault plus the direct radiation from the sun times the cosine of the angle of incidence. Notice that the global horizontal radiation peaks in summer because that is when the sun is highest in the sky and is thus more perpendicular to a horizontal surface. Then the tilted surface radiation is the hourly radiation In this figure, you can see that for a tilt degree of 90, which is a vertical wall and the bearing degree from south is 45 degrees. It can be seen that the direct normal and global horizontal radiation remain the same, but the total surface radiation changes due to the tilt of the surface.

So, tilted surface radiation is the hourly radiation on a tilted surface and is defined as the total amount of direct, diffuse, and reflected solar radiation received on any surface during the 60 minutes preceding the hour indicated. Tilt is measured from the horizontal, which is flat, at 0 degrees; the vertical is 90 degrees. So, bearing is measured from due south. South is 0, counterclockwise is positive.

So, west is plus 90 and east is minus 90. The default ground reflectance is 20 percent for grass. All these parameters can be changed by the user in the highlighted blue box in the bottom left. So, what should be the ground reflectance? By default it has taken 20. If you are sure you want to change the value you can change the value and for that value you will get the output data. Then you press the next button again, and what will you get? You will get a chart like this.

Now in the first chart, it shows direct normal illumination. So in this hourly illumination range data is shown the yellow bar shows illumination direct normal, this yellow bar shows direct normal illumination and the green bar shows the global horizontal illumination. These units are in foot candles, also called lumens per square foot, or in lux, also called lumens per square meter. Direct normal illumination is defined as the visible light from the sun that is measured by a narrow angle meter pointed directly at the sun and that excludes the surrounding sky. The global horizontal illumination is defined as the total visible light that falls on the horizontal surface from the entire sky vault plus direct normal illumination from the sun.

This chart shows sky cover for each month and for the full year. The clear sky has 0% sky cover and a completely obscured sky has 100% sky cover. So, for Jaisalmer, what is the percentage of sky cover for various months is shown here along with the legend. Now, this chart shows for each month and for the full year. the wind velocity in either miles per hour, feet per minute, or meters per second depending on the scale you have chosen, and you can see how the wind keeps changing.

Whereas this shows the average monthly temperature of the soil at various depths And it is called as the ground temperature chart. You should notice that as the depth increases, the thermal mass of the soil causes greater time lag and more dampening. Here is a chart showing the dry bulb and the relative humidity. So these 12 charts are the average of each hour of each month of the dry bulb temperature, which was actually a yellow dot, and the concurrent relative humidity. Also shown on each monthly chart is a grey bar for the comfort zone as defined in the criteria screen.

Notice that dry bulb temperature is almost exactly the inverse of relative humidity because the capacity of air to hold water increases with increasing temperature. Then this chart is a dry bulb versus dew point chart. So, you have 12 charts for 12 months, and these are the average of each hour of each month of the dry bulb temperature, and the concurrent dew point also shown on each monthly chart is a grey bar for the comfort zone this one is the grey bar for the comfort zone as defined on the criteria screen. Notice dry bulb temperature increases sharply at sunrise and peaks around 2 to 3 in the afternoon. But then the dew point temperature is relatively stable throughout the day.

These sun shading charts show the sun's bearing along the bottom and altitude vertically for every 15 minutes during the year in colored dots. As per the comfort zone defined on the criteria screen, yellow dots indicate comfort conditions when the dry bulb temperature is within the comfort zone. So, these are the yellow dots. The red dots indicate overheat conditions when the dry bulb temperature is above the top of the comfort range. Blue dots indicate under heat conditions when the dry bulb temperature is below the bottom of the comfort zone.

Ideally, for passive heating, the window should be fully exposed wherever there are blue dots, and to prevent overheating, the window should be fully shaded wherever there are red or yellow dots. There can be two different sets of plot months, one for winter and spring that is December to June and the other for the summer and fall, June to December for the two major solstice periods. Now, this chart can be used to calculate the angle of shading devices required to efficiently shade the windows. You have to keep pressing next for each of these charts to come. By checking the display shading calculator box in the lower left corner, an overlay will be plotted on top of the chart.

To define the desired overhang, just click and drag the circle at the top of the center line of the grid vertically towards the desired profile angle measured from the center of the window sill. Here, the profile angle has been taken at 50%, and all the area in gray will be shaded by this projection. To define fins on the sides, click and drag the circles on the east and west triangle horizontally to set the bearing angle of each fin measured from the center of the window sill. Here, the angle of the west fin is taken as 45 degrees. If the window under consideration is not facing true south, the arrow at the bottom can be dragged towards the bearing angle of the window.

Here it is considered that the window is located on the southeast side. Hence, the bearing angle is changed to 45 degrees due east from south. The horizontal and vertical projection angles are also changed accordingly. Now for each tree selected, a height above the ground and a horizontal distance must be entered.

To arrive at the screen, you just have to press next. I am not repeating this for every slide. Note for trees: a default height is automatically entered, which you can change. Data for neighboring structures can be entered as height above the ground and horizontal distance or as the shading angle. For obstructions attached to the building, input the height above the sill or lower edge of the collector and horizontal distance as the shading angle measured from the sill to the top of the obstruction may be input. When data is input as height and distance, the shading angle is calculated by the program automatically.

Then press next here, and in this sun chart is like a flagpole sundial. The gnomon is like a pin or flagpole mounted vertically on the x shown as the gnomon position. It shows in plan view the shadow cast by the gnomon for every 15 minutes during the year in coloured dots. As per the comfort zone defined on the criteria screen, yellow dots indicate comfort conditions when the dry bulb temperature is within the comfort zone. The red dots indicate overheat conditions when the dry bulb temperature is above the top of the comfort range.

Blue dots indicate under heat conditions when the dry bulb temperature is below the bottom of the comfort zone. Ideally for passive heating, the window should be fully exposed wherever there are blue dots and to prevent overheating, the window should be fully shaded wherever there are red or yellow dots. Once you press next, this timeline plot will come. And this shows along the bottom the months of the year and along the side the hours of the day. The time when sunrise and sunset occur for this latitude is indicated by these curved yellow lines.

11 different variables can be plotted by selecting from the box on the lower left. See here. There is a box, and from this box you select the variables like dry bulb temperature, wet bulb temperature, depression, which is the difference between dry bulb and wet bulb temperature, relative humidity, wind speed, global horizontal radiation, direct normal radiation, tilted surface radiation, global horizontal illumination, direct normal illumination, and sky cover. In the bottom left, the plot can be changed from daily, which shows each of the 8760 hours per year, to monthly average, which shows the average for each hour of the month.

3D charts. These are the same as the timeline plots of the previous slide, but this shows along the bottom the months of the year and along the side the hours of the day. The time when sunrise and sunset occur for this latitude is again shown with the curved yellow line. and all the other data is similar to that of the previous slide. Now, this is very important.

The psychrometric chart is one of the most powerful design tools in climate consultant.

Now, reading a psychrometric chart is important. It shows dry bulb temperature across the bottom and moisture content of the air up the side. This vertical scale is also called absolute humidity and can be shown as the humidity ratio in pounds of water per pound of dry air or grams of water per kilogram of dry air or as a vapor pressure. The curved line on the far left is the saturation line, which is a 100% relative humidity line, which represents the fact that at lower temperatures air can hold less moisture than at higher temperatures. Every hour in the EPW climate data file is shown as a dot on this chart.

Some dots may represent more than one hour. For example, when a given temperature and humidity occurs more than once in any month, a given hour's dot might meet the criteria for more than one strategy zone. in which case it is counted in the percentage of hours for both the zones, which is why sometimes the percentages add up to more than 100%. The color of each dot can represent whether or not the hour is comfortable, indicated by green color, green dot, or uncomfortable, indicated by red dot, And this is according to the inputs defining the comfort on the criteria screen which we selected. We selected the adaptive thermal comfort, and this is the legend of the dots. Designed strategies like cooling, that is, air conditioning, and heating can be deselected to get a better understanding of how well other mainly passive strategies will work in that specific location and climatic condition.

Then, when you press next,. You will get a list of design guidelines for passive design strategies based on the design strategies selected in the previous slide. So, for Jaisalmer, the strategy says that, like assuming only design strategies that were selected on the psychrometric chart, 62.4 percent of the hours will be comfortable. For residential design guidelines, because if you remember, we had picked residential when there was an option of residential and non-residential. It says that good natural ventilation can reduce or eliminate air conditioning in warm weather if windows are well shaded and oriented to prevailing breezes and so on.

A list of design guidelines is given. then if you press on each of this suppose you press on this like that for each of this you will have to press you will get the strategies in graphics in a graphical form and it is this graphics that I had used. While talking of broad design considerations when I was describing the climate characteristics of each climate type. By clicking on any of the design guidelines you will get the sketch of how it shapes the building design. Then the wind wheel is another thing you will get. The outer ring shows the percentage of hours when the wind comes from each direction. On the next ring, the height and color of the bar show the average temperature of the wind coming from that direction.

Light blue is in the comfort zone; blue is cool or cold, and red is warm or hot. The next smaller ring shows average humidity. Light green is comfortable, yellow is dry, and green is humid. The innermost circle shows the wind velocities that come from each direction.

The tallest brown triangle is the maximum velocity. The tallest brown triangle is the maximum velocity for that period. Medium brown is the average velocity, and the smallest light brown triangle is the minimum velocity. Hours when there is zero wind speed do not appear on this chart.

If it is not there, it is zero. So, this brings us to the demonstration end. And the help button on the top left of the screen has a tab named User Help, which will give more in-depth information about all the graphs present in the program. So, with this, we will stop this demo on a very important software, Climate Consultant. And I hope you explore this software more. And most important, the charts will come anyway. How you interpret the psychrometric chart to arrive at what you would want as your design guideline and consideration.

I had shown you each of the components that Climate Consultant talks about, and we had looked at the characteristic features of each of the components. I will be demonstrating the software so that you understand actually how you do it. If you want, you can also work alongside me so that you will become more proficient in that software.

So first, what we will do is open the software. I have already installed the software. It's an open source software. So first, please open the software. On the right side corner here, press next. I am going to maximize it. Here you will have instructions for Climate Consultant and it talks of what you should do, how you should go back, and how you can go next.

So I will press next. Now either we can continue from the previous session or we can start a new project. Let me start a new project. So, I start a new project. I would like to work on a residential building, and I would like to work with metric units because in India we are more familiar with metric units.

So, let us work with metrics. It says open existing EPW weather data. Now if I press open existing EPW weather data, I have some weather data but these pertain to countries in the US. It does not pertain to say India. So when I open these, I have many states which are not from India.

So, I will put cancel. I want to download a new EPW weather file. Now, what should I do? I should go to install from the weather data site. So, I will go to install from the weather data site, and it takes me directly to the energyplus.net weather station library. As it opens, I will be able to feed in the data that I require.

So, now I will press download new EPW file. Then i will install from weather data site so here when i press install from weather data site, i seem to have a repository of weather data Now, let us see whether we have the weather data. You may not have weather data for all the Indian cities. Let us check.

Suppose I want to do the weather data for Vadodara. Let us check if it does not have. Maybe I should put Baroda. You see, for Vadodara or Baroda, it is not available.

So I will put for Trivandrum. Trivandrum is available. There is one match for Trivandrum. So to explain how to use Climate Consultant. So let me click Trivandrum. Let me download the EPW format. So I have downloaded, and you can see on the right corner it has gone to the downloads file.

Minimize this, close this, and now open the existing EPW file. Now probably we will have to go to the downloads and check. Yes. So if we go to downloads, we have the Trivandrum file. So this is how the Trivandrum or Thiruvanandapuram weather data file looks like. You can see you have global horizontal radiation, direct normal radiation, diffuse radiation, global and direct normal.

So, here you have a lot of radiation data for each of the month of the year for Trivandrum You also have the dry bulb temperature for all the months. You have the dew point temperature for all the months.

Relative humidity is available for all the months. Wind direction is available. Wind speed is available. Ground temperature is available. So we will now press next. Now we have already seen comfort models. So, in this Climate Consultant these four comfort models have been considered.

First is the California energy code comfort model which is default, but we would like to change. There is ASHRAE standard 55 and current handbook of fundamentals model. Then there is ASHRAE handbook of fundamentals comfort model up through 2005 and there is adaptive comfort model in ASHRAE standard 55 2010. Suppose we choose the ASHRAE standard 55 and current handbook of fundamental model. What happens? We will press next. You see, here we have data pertaining to clothing, so under comfort, if you want, you can modify the clothing.

We have already seen what clothing means in terms of its influence on thermal comfort. We have seen how it is measured in Clo. Now here the default is a Clo of 1, which is winter clothing indoors, and a Clo of 0.5 in summer, which is having shorts and light top, whereas in winter it is long pants with a sweater.

if you want, you can change the activity level, so here 1.1 met is sitting and reading. Now let suppose i make it 1.5 okay. We can. I am changing the met value. I am probably changing the winter clothing to 1.5. So here you can change, and when you change that, the comfort temperature at the lowest and highest also changes. So i will make this as 1 and please notice how the comfort also changes See, the comfort lowest now has become 16.1 and highest has become 21.8. Summer clothing -suppose from 0.5, I change it to 1.1. You see that again the comfort temperature during summer also changes. So, here this program has automatically inbuilt the relationship between clothing, metabolism and comfort range. This happens when you select ASHRAE standard 55 current handbook of fundamentals comfort model and again in this you have certain defaults. Like the minimum dry bulb temperature when need for shading begins, minimum global horizontal radiation when shading begins, then high thermal mass zone, then high thermal mass with night flushing.

So you have a number of criteria, which you can change. Say fan forced ventilation cooling, internal heat gain zone, because of lights people equipment. Based on what is happening in your design, you can change these. You have passive solar direct gain for low mass, passive solar direct gain high mass zone. Then wind protection of outdoor spaces all these can be changed if you follow the ASHRAE standard 65.

If you do not want to follow this, we can follow the adaptive comfort model. So this is applicable for naturally ventilated spaces where occupants can open and close the windows their thermal response will depend on part of the outdoor climate, like if it is very warm, they will automatically reduce the clothing level they have and this may have wider comfort range than in buildings with centralized HVAC systems. This model assumes occupants adapt their clothing to thermal conditions and are normally sedentary. That is, their met level is between 1 to 1.3 and there must be no mechanical cooling system.

But this method does not apply if a mechanical heating system is in operation. So, when you press this and go to next, you can see that none of these,- like comfort or sun shading zone, high thermal mass- none of these are activated. Only thing that is activated is percentage acceptability limit of comfort - which is 90. We had already seen, when we discussed thermal comfort, how 80 percent people and then plus or minus 3.6 from the comfort zone band 80 percent or 90 percent people feel comfortable so that is all is here.

So suppose i go back and use the ASHRAE standard 55 and current handbook of fundamental models. Move, I will not change anything here because it's only a demonstration in your design. If there is any change, you may please apply it then i will go to next. And here we will see the temperature range in a graphical format. So here we have the graphical format where the design high for residential is there 1% of hours above and so on.

And this grey is actually the thermal comfort band. Then we press next, and we get a graphical representation of the temperature, which has the dry bulb mean. See, this is the average—the red color line is the average dry bulb temperature of the place. The Dark red line is the average wet bulb temperature of the place, and the blue is the dry bulb for all hours, whereas the one in the center is only for the average. Also, we have the thermal comfort band that is marked in gray. It has global horizontal temperature and direct normal as well as diffused temperature that you can see here in sky blue color.

Then we press next. When we press next, what happens? You get radiation range. You get the direct normal radiation in yellow, global horizontal radiation, and total surface radiation. Just press next and here you get the hourly illumination values, direct normal, and global horizontal values. Press next because these are all graphical representations of all the data we already saw in the first slide. So, next And here you will see wind velocity range again in a graphical manner.

So, the wind velocity after that, we will see the soil temperature at depths of 0.5 meters, 2 meters, and 4 meters. Then we press next, and here you see the dry bulb versus relative humidity for all the 12 months using PMV. So again we press next. Here you get the dry bulb versus dew point using PMV for all 12 months of the year. Then I press next, and here you can see we get the sun shading chart. Now what does this show? That the sun shading chart between December to June is always hot, which means shade is always needed for the 2378 hours.

Sun is always hitting against the openings, and shading is needed. During summer, let us see. So during the next solstice of June to December again, you will see that shade is needed for all the hours. For 2395 hours shade is needed. Then we press next. It's again the sun chart, and then the sun chart also clearly says that shade is needed for December to June solstice and June to December solstice also. Then we press next, and here we can see the dry bulb temperature, and you can see that for 100 percent of the year the dry bulb temperature is between 22 to 38 degrees Celsius.

So, very hot or warm place. Then the same thing we will get in a three-dimensional form where what happens when it is not shaded what happens if you try to shade it. Okay, and I will press back to show that the monthly averages also show that the temperature falls between 22 to 38 degrees. So when I press next and if I press daily just see what happens again, we require shading throughout the year for 100% of the time.

Press next. So now we will see design strategies that are listed here on the left side. So? This says that you should see how many design strategies you can eliminate and still keep the maximum number of hours comfortable. In other words, try to simplify your building. To maximize the passive performance, first temporarily remove the last two design strategies. So, the last two design strategies are using active means, that is, using cooling strategies by adding dehumidification.

So I will remove this and, if necessary, heating also you remove. So and then, if you wish Climate Consultant to pick the best set of design strategies as a starting point, select the show best set of design strategies box at the bottom of the legend panel. So here we can show. For now I will press OK and I will remove all these. What happens is, when we don't have any strategy, what happens? Each of the red dot that is shown here is one hour of the year per year.

And this blue is your comfort zone; you can see that The combination of temperature, humidity etc. throughout the year does not fall within the comfort zone if you do not adapt any strategies. Now what I will do is see what happens for selected months. In January what happens? If I provide solar shading, what happens? So, if I provide solar shading in January, what happens is that 32.

4% of the year falls under sun shading of windows. So, 241 hours become comfortable if we provide solar shading only in January. If we provide air conditioning, what happens? The remaining time, 99.5%, also becomes comfortable. Now I don't want air conditioning.

So I am going to remove the air conditioning, and you can see that some part of the year becomes comfortable, which is 32.4. So 1% of the month becomes comfortable. now let us see what happens in February. What happens is 36 percent of the year becomes comfortable if i apply sun shading. What will happen if we apply high thermal mass? Nothing will happen; there is no impact of increase in comfort if we apply high thermal mass, high thermal mass night flushing or direct evaporative cooling, two-stage evaporative cooling, natural forced ventilation.

None of these strategies work here in February other than using HVAC. So the whole month you will require HVAC in order to have 100% comfort. So you see all the red dots have become green dots. Now what will happen in March? Let us see. In March again, all the hours of the month are in an uncomfortable zone. So, I will press solar shading, and I will press cooling to add dehumidification if necessary.

So, comfortable hours by using selected strategies- 744 out of 744 happen when you have HVAC. Then I will see what happens in the month of April. Again, in the month of April, it is not really that effective. You know it is not that effective to have any of the strategies other than having HVAC. HVAC is the only strategy that is making the red dots into green dots.

Okay, then next we will see May. What happens in May? In May again, there is no impact. Unless you use HVAC, there is no impact on changing the uncomfortable hours into comfortable hours by any of the strategies as per ASHRAE standard 55-2004 using PMV. Then next what we do is, so one building probably cannot incorporate all 16 strategies. So click back to return to the psychrometric chart and click Show best set of design strategies to select your own set of strategies to describe your building. To create the best passive building, remove cooling and heating from the bottom of the strategies list, then adjust the remaining strategies to maximize comfort hours, then replace cooling and heating.

So it says that you are actually trying to find out which is the best passive strategy. So why aren't you clicking put air conditioning and resolve the issue? So, it says- go back if you are not able to decide what to do. Then go back and press the 'show best set of design strategies' for all the months. So for all the months, even if I show the best set of design strategy, it still says we will have to provide air conditioning for this climate type if we have to follow ASHRAE standard 55-2004 using PMV. So, I go next, assuming only the design strategies that were selected on the psychrometric chart for 100 percent of the hours will be comfortable.

This list of residential design guidelines applies specifically to this particular climate, starting with the most important first. So, the most important is, in this climate, air conditioning will always be needed but can be greatly reduced if building design minimizes overheating. So, if I press this, I will get a graphical form of what this strategy means. So here, this strategy, which says that you will have to have air conditioner, but you can do what is necessary to reduce the overheating of the building.

So it is suggesting overhangs to protect the south glass can be used. It says use a high-mass wall with insulation. Have slab-on-grade with exterior insulation. Minimize or eliminate west glass.

Use whole house fan for night flushing. Use closed windows when the air conditioner is running. Have a north glass protected by fins. Have high-performance windows. Then it also suggests having ceiling fans for daytime air motion. Close the windows when the air conditioner is running. Have French doors or sliders with louvers and screens.

Then it says all windows shaded by porches with large overhangs have a low-mass, well-insulated construction and are then designed for cross ventilation. Also raise above grade with maximum ventilation. So in this climate, air conditioning will always be needed but can be greatly reduced if building design minimizes overheating. Suppose I click the link to know this whatever website they are saying I will eventually get some strategy which is suitable for this climate type, probably as a case study or an application.

But if they have not loaded it in the software yet we will not get it. Like it is not yet loaded now. But probably if you keep using the software, then over a period of time as they start loading the case studies, when you press the link, you will be able to see some case studies where they have applied these strategies. Suppose you press print. then you have to do what is needed to print this figure. So, we have seen this figure, I will close it. The second is raise the indoor comfort thermostat set point to reduce air conditioning energy consumption especially if occupants wear seasonally appropriate clothing.

So, I will press this and you get a graphical representation which says you need to raise the thermostat set point so that load on air conditioning is reduced. So, I will close this now. The third criteria it says is window overhangs. Now window overhangs designed for this latitude or operable sunshade, such as awnings that extend in summer, can reduce or eliminate air conditioning, and accordingly, there are graphics for this.

I will see whether they have uploaded the case study. No, see -they have not yet uploaded the case study for this strategy. I will close this. The fourth strategy is that traditional passive homes in warm-humid climate use high ceilings and tall operable or French windows which are protected by deep overhangs and veranda. So, there is a sketch of how we can have a high ceiling and openable French windows. The next strategy is that traditional passive homes in hot and humid climates use lightweight construction with openable walls and shaded porches raised above the ground.

And there is a graphic for it. Then minimize or eliminate west-facing glazing to reduce summer and fall afternoon heat gain. So, how it can be done is shown here, and again, they have still not uploaded a case study link or application link to this. The next strategy could be high-performance glazing on all orientations, which should prove cost-effective. So it talks of having low-e or insulated frames in hot, clear summers or dark overcast winters.

Then the next strategy is to have a radiant barrier or a shiny foil with an emittance of 0.5 or less with at least 1 inch clearance, and the attic must be vented. So, a radiant barrier will help reduce radiated heat gain through the roof in hot climates. The next strategy is to orient most of the glass to the north, shaded by vertical fins in very hot climates, because these are essentially no passive solar needs. The next strategy is to consider earth sheltering, occupied basements or earth air tunnels or earth tubes which reduce heat loads in very hot-dry climates because the earth stays near average annual temperature. So the next strategy is to have a high-efficiency air conditioner or heat pump with a good star rating and it should prove cost-effective in this climate.

Then the next is to keep the building small or right-sized, because excessive floor area will waste the heating and cooling energy. The next strategy is to use plant materials like bushes, trees or ivy covered walls, specially on the west, to minimize heat gain. So if summer rains support native plant growth, then all the more better- because during summer the wall will remain shaded if you have trees along the west wall. Then the next strategy is to use good natural ventilation, which can reduce or eliminate air conditioning in warm weather if windows are well shaded and oriented to prevailing breeze direction. I will press this again; they have not yet uploaded the case study but probably they will do it soon Next is to use light-colored building materials and cool roofs with high emissivity to minimize conducted heat gain.

So ensure that the heat that falls on the roof gets reflected back and does not enter inside the building. Have a long, narrow building floor plan that can help maximize cross ventilation in temperate and hot humid climate. So the image is still under construction. So for all the strategies, you may not find the graphics.

On hot days, ceiling fans or indoor air motion can make it seem cooler by 5 degrees Fahrenheit or 2.8 degrees Celsius, or more. Thus, less air conditioning is needed. So, they are saying use ceiling fans also. The next strategy talks of screened porches and patios that can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems. Then the high-mass interior surfaces like tile, slate, stone, brick, or adobe feel naturally cool on hot days and can reduce day-to-night temperature swings.

Let me see if they have any no. Again, this is not uploaded. The picture or the case study is not yet uploaded. And the last is, if the soil is moist, raise the building high above ground to minimize dampness and maximize natural ventilation under the building. So these are the strategies for Trivandrum if we consider ASHRAE standard 55-2004 using PMV. Let us, for the sake of curiosity, see what happens if we pick another thermal comfort model. So now we will pick a thermal comfort model, which is an adaptive comfort model, and we will see whether there is any difference.

So when I pick the adaptive comfort model, press next. I have already explained that only in the ASHRAE comfort model can you edit the other criteria, whereas this is adaptive-which means people will adapt or change based on what is needed. Press next again, and you will get the graphical representation of temperature, dry bulb temperature. Then you will get on illumination, sky cover range, wind velocity range, ground temperature range, dry bulb versus relative humidity for all the 12 months, and dry bulb versus dew point for all the 12 months for adaptive comfort. Again we will see this even in this model Adaptive comfort model- it is very clear that shade is needed for all the hundred percent of the hours and for 37 hours, shade could help.

But not necessary that it should not be left unshaded. Let us see what happens in December. So, in December again, 26 hours are exposed and 2352 hours are exposed where shade is needed and shade could help for 26 hours, which you can see as orange dots here. That shows that shade could help during this time. Then I will press next. Again, this shows that during the winter, some kind of shading can help during this part, whereas shade is mandatory for all the other times.

Then I will press next and here we can see the dry bulb temperature. as a graphic and now let us look at the strategies. Now I am going to remove all the strategies. So here you see that for adaptive comfort for this kind of climate, if you look at all the months, then having adaptive comfort ventilation can be a very good strategy to make 5742 hours or 65.5 percentage of the hours comfortable for the people.

So, it falls in the comfort zone. If we have Adaptive comfort ventilation. Suppose I remove the display design strategies, then the entire strategy will be removed. Okay. Now let us select only the months and see. If we select the months, then if we select the months then in January, you see,, for the month of January Adaptive comfort ventilation is the only strategy that can help, which will push the comfortable hours to 54% within the thermal comfort zone. The other part will still be uncomfortable, and you can see that in the form of red dots. Then what happens in February? In February again, 56% of the time will be comfortable if adaptive comfort ventilation is used.

What happens in March? In March, you can see it becomes 58% slightly more. 58% of the hours can become comfortable if you have adaptive comfort ventilation. Whereas if you see ASHRAE 55, what we saw before, that showed that you had to have air conditioning for all the months throughout the year. What happens in April? In April again, 54% of the hours fall in the comfort zone. What happens in May? In May, 55% of the hours can become comfortable if you follow adaptive comfort ventilation.

Then June, what happens? 70% becomes comfortable just by providing good comfort ventilation. Then July, 75% of the hours. So gradually you can see it is increasing to 75.4% in July. In August, 78% becomes comfortable just by providing this one strategy. And then in September, it starts to reduce. 69% of the hours become comfortable with adaptive comfort ventilation. In October, 76% of the time becomes comfortable just by providing adaptive comfort ventilation.

In November, 73% of the hours become comfortable if we provide adequate adaptive comfort ventilation and in December, 66% of the month becomes comfortable with adaptive comfort ventilation. So for all months of the year, providing adaptive comfort ventilation for 65.5 percentage of the year falls into the thermal comfort band according to adaptive comfort model of thermal comfort.

Now let us press next and see the strategies. So assuming only the design strategies that were selected on the psychrometric chart, 65.5% of the hours will be comfortable. And this list of residential design guidelines applies specifically to this particular climate, starting with the most important first. So let us see one by one which are in the order of importance, which is the most important criteria. So the first most important criteria is to provide good natural ventilation that can reduce or eliminate air conditioning in warm weather if windows are well shaded and oriented in prevailing breezes.

They have not yet uploaded the case study. So, the second one is to capture natural ventilation. Wind direction can be changed up to 45 degrees towards the building by exterior wing walls and planting. So, they are saying that since adaptive comfort becomes important and we need to bring in good natural ventilation for comfort ventilation, we should orient the wall in such a way that we are able to draw in more and more breeze. That can be done by changing the wall direction up to 45 degrees toward the building with the help of wing walls and planting.

The third is, long, narrow building floor plan that can maximize cross ventilation in this climate. The next strategy is to facilitate cross-ventilation. Locate door and window openings on opposite sides of the building, with larger openings facing upwind if possible. The next strategy is to have screened porches and patios that can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems. Then the next strategy is that in hot days, ceiling fans or indoor air motion can make it seem cooler by 2.8 degrees Celsius or more thus less air conditioning could be needed.

The next strategy is to have open-plan interiors to promote natural cross ventilation, use louvered doors, or instead use jump ducts if privacy is required. So, the more the building gets ventilated, you are going to enhance comfort ventilation and make the indoors comfortable. You could also try stack ventilation, but it is very difficult to have effective stack ventilation in this area because of lower diurnal variations. The next strategy is a whole house fan or natural ventilation that can store nighttime cooling in high-mass interior surfaces, causing night flush cooling to reduce or eliminate air conditioning.

The next strategy is that this is one of the more comfortable climates. So, shade to prevent overheating, open to breezes in summer, and use passive solar gain in winter. So, this is an important criteria. Traditional passive homes in temperate climates use lightweight construction with slab-on-grade and operable walls and shaded outdoor spaces. So, all outdoor spaces must be shaded. Traditional passive homes in warm-humid climates use high ceilings and tall operable French windows protected by deep overhangs and verandas.

So, the next strategy is that shaded outdoor buffer zones, such as porches and patios, oriented towards the prevailing wind breezes, can extend living and working areas in warm or humid weather. The next is to provide enough north glazing to balance daylighting as well as allowing cross ventilation. We can also have low pitched roofs with wide overhangs and this also works well because it shades the walls. We can use plant materials along the walls, especially the western wall in such a way that we are able to grow native trees during the summer. Also, in wet climates, well-ventilated attics with pitched roofs work well to shed rain and can be extended to protect entries, porches, verandas, and outdoor work areas.

If the soil is moist, raise the building high above ground to minimize dampness and maximize natural ventilation beneath the building. Also, minimize or eliminate west-facing glazing to reduce summer and fall afternoon heat gain. And then the last strategy is to have window overhangs designed for this latitude or operable sun shades like awnings that extend to summer, and this can reduce or eliminate the air conditioning. So, what we saw is that for two different models of thermal comfort, we are able to get various sets of strategies. The first model we followed was the ASHRAE comfort model, and you could see that in the ASHRAE comfort model it said that for this climate type air conditioning is the only way out. Whereas the second thermal comfort model that we saw is the adaptive comfort model, and the adaptive comfort model said that by using comfort ventilation, you can shift at least 66 percent of the total number of hours of the year into the comfort zone from discomfort you can make it comfortable, so you have to address only 34 percent of the hours which are still in discomfort band so in this manner each one provides their own strategy for example if we look at the just for the sake of comparison, if we apply the california energy Code, then the california energy code says that the best strategy would be shading the windows that will provide relief for 32 percent of the year Having adaptive comfort ventilation will provide thermal comfort for 65.5% of the year. Having fan-forced ventilation cooling will provide comfort for 3.9% of the year. However, for 29.2% of the year, you would still have to follow air conditioning. You will have to give the building air conditioning. If you want 100 percent comfortable hours throughout the year. Suppose we see the ASHRAE standard 55 model, then ASHRAE standard 55 model says that for 32% of the year, sun shading of windows is mandatory.

65% of the year can be made comfortable if we use adaptive comfort ventilation and 35.9

percent of the year can be comfortable if we are able to provide dehumidification. The humidity levels are extremely high during some part of the year and therefore, in order to reduce that for 35.8 percent of the year, we can give something for dehumidification And for 28.9% of the year you will have to provide air conditioning.

Only then will we get 100% comfortable hours. Whereas the ASHRAE Handbook 2005 says that you can provide sun shading and get 32% of the hours comfortable. Direct evaporative cooling can give 11% of the hours to become comfortable, which is 0.

1% of the year. Two-stage evaporative cooling can give you 30 hours or 0.3% hours to become comfortable. However, even in this model, adaptive comfort ventilation wins by giving 65.5 percent of the hours to be comfortable. Fan-forced ventilation cooling can give 3.8 percent to be comfortable, and 29% of course, 6.8% which is 598 hours, can become comfortable if we are able to provide dehumidification.

Also, 29% of the hours nothing can be done in terms of a passive strategy to make the indoors comfortable, and therefore air conditioning becomes important. So what we are also seeing is that the model that we use to assess is very important, and therefore I have taught you thermal comfort and thermal comfort models. So, based on the models, we will be able to arrive at strategies, each of these strategies. What each of these strategies is will be seen in detail in this course.

Every strategy and even more strategies will be seen in much detail in this course. But to arrive at the basic strategies, first is Mahoney's table. Now Mahoney's table per se is too simple, and it also has some errors, and therefore we use Climate Consultant whose base is actually Mahoney's table. Because if you actually see the initial tables, for example, I will just show you the initial table; those are all just like Mahoney's table, and the data you enter is just like Mahoney's table. So, this is just like Mahoney's table data. But how this data is interpreted and how the programming happens will depend primarily on the comfort model you choose and the comfort band that each of these comfort models assigns for a particular purpose.

Category of factor that influences thermal comfort- which is clothing level or metabolism and so on. And then based on that, the Climate Consultant software gives you various options on the psychrometric chart. The psychrometric chart decideS which strategies are best and for those strategies how many hours can be made comfortable. So this is how you use the Climate Consultant software and if you press next we have seen all the design strategies and how each of the strategy is also supported with some graphs So, some graphical format is also given for each of the strategy. For some of the strategies, the graphical format is under construction, and they are also planning to provide a link that will take us to the case study or application of the strategy in real life context or case study. And then this software culminates with the wind wheel, which we have already seen, which shows for how many hours, at what temperature, for what relative humidity, and wind speed.

So it is a combination of all the climatic elements, and then the software comes to an end. So this is how you use climate consultant software in order to understand which passive strategy must be adopted for which of the thermal comfort model and how, in some thermal comfort models, you can actually change the activity levels and the metabolism level And based on this, how do you arrive at design strategies, and by implementing each design strategy, how many hours can you push from discomfort to a comfortable zone? So this is what we saw in today's class. So with this, I will close this lecture, and we will continue with the next lecture in the coming class. So I would suggest you all should practice climate consultant for various climate types. I have selected hot and humid climate but if you take composite climate, it will be very interesting because it has some features which are hot and humid some features which are useful for hot and dry.

If you start picking month-wise, then you will notice the diverse kind of strategies you need to adapt, and that is where your creativity as a designer becomes more important. Because you need to now decide which strategy you can adapt or how can you design a building which will be able to have both these strategies So, as you use it, you will find it very interesting. Also, this is work in progress. So, what you find in Climate Consultant today, after one year or six months or two years, is bound to change because they are also developing the software.

And if you also find something which you can contribute to the software, all the more better. So, use this software and practice it so that you choose the appropriate climate-specific strategy. During the early stage of your design, you will be able to justify this to your client. So that way it's very useful software, and it also gives a graphical representation. which you can easily use to impress your client and show them how or why that strategy will help. By using that strategy, you can make so much percentage of hours to become comfortable, which would otherwise have been uncomfortable. So, with this, I stop today's class, and we will continue with another topic pertaining to simple and advanced passive strategies in the next class. Thank you.