

Glass in buildings : Design and Application
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Lecture - 23
Fundamentals of Daylighting

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Now, moving down to Performance Matrix.

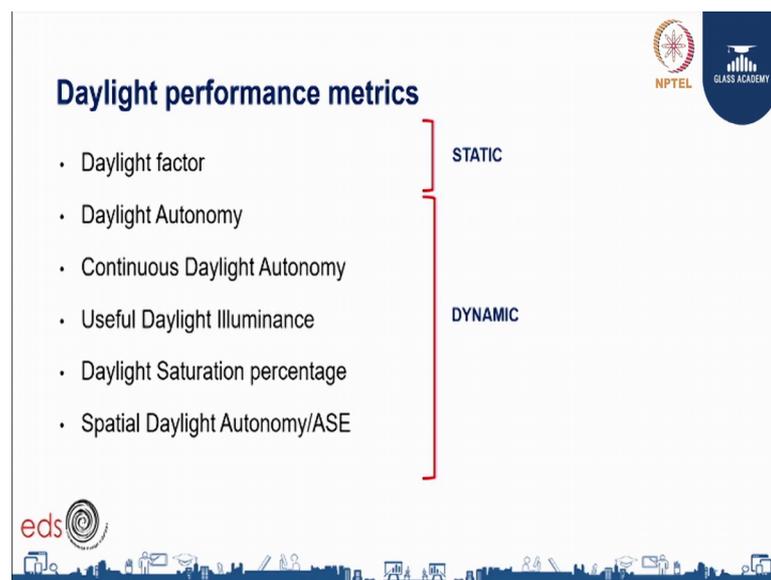
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So, performance matrix is basically a terminology used or a set of criteria used to measure the conduct or health of any project or building organization etcetera. So, it is a generic term. In the same similar terms there are daylight performance matrix which basically takes into consideration, the quality and the quantity of daylight, helps the designers to evaluate, compare, and optimize different design options of a daylight space. And basically it helps them to meet the statics part, the energy savings part and it is not just the measurement of daylighting that you are getting 300 lux is not the criteria it also takes into account, the statics, the energy savings part due to electrical energy and also the quality of daylight that is known, whether your space is overlet, underlet, glare free.

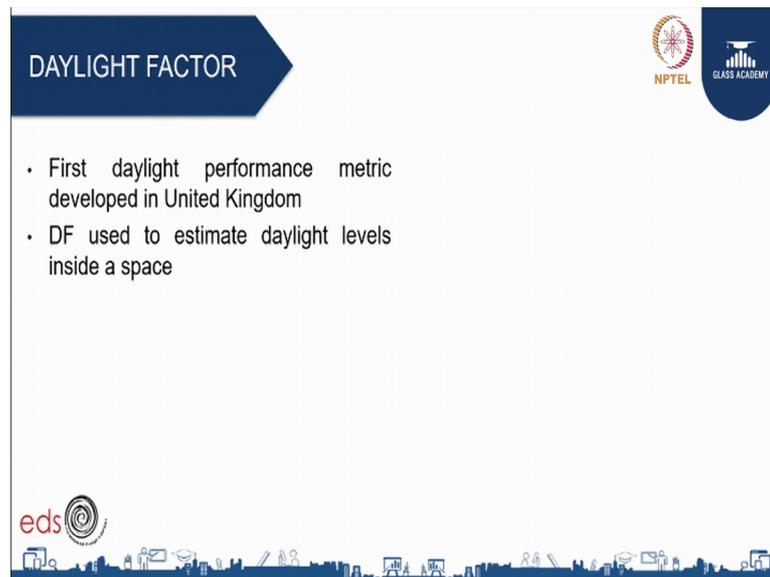
So, these concepts are now gain importance and in order to evaluate or put a or compare these things this daylight performance matrix have been developed.

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There are different daylight performance matrix, the oldest one is daylight factor, then daylight autonomy, continuous daylight autonomy, useful daylight illuminance, daylight saturation percentage, and the last one is special daylight autonomy and ASE. The daylight factor is can be called as a static daylight performance matrix, whereas the rest of them can be categorized as dynamic daylight performance matrix, because they change with every hour throughout the day.

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DAYLIGHT FACTOR

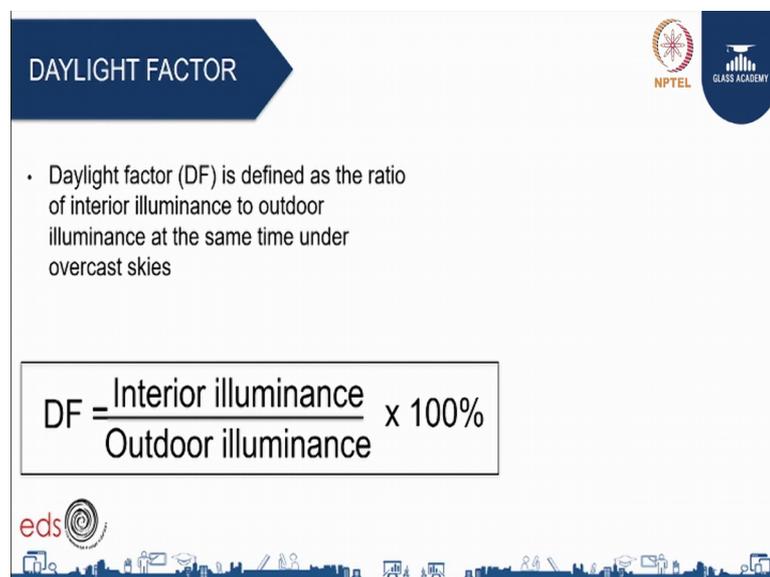
- First daylight performance metric developed in United Kingdom
- DF used to estimate daylight levels inside a space

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To start with, let us start with the first and the oldest performance matrix which is daylight factor. It was first daylight performance matrix developed in United Kingdom; it was used to estimate daylight levels inside a space.

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DAYLIGHT FACTOR

- Daylight factor (DF) is defined as the ratio of interior illuminance to outdoor illuminance at the same time under overcast skies

$$DF = \frac{\text{Interior illuminance}}{\text{Outdoor illuminance}} \times 100\%$$

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It is a simple factor; I mean it is simple formula; daylight factor is equal to Interior illuminance divided by Outdoor illuminance percentage, you calculate the percentage of that. So, it is from the equation its clear it is a ratio.

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DAYLIGHT FACTOR

NPTEL GLASS ACADEMY

- Daylight factor (DF) is defined as the ratio of interior illuminance to outdoor illuminance at the same time under overcast skies

$$DF = \frac{\text{Interior illuminance}}{10,000 \text{ lux}} \times 100\%$$

eds

The slide features a blue header with the title 'DAYLIGHT FACTOR'. In the top right corner, there are logos for NPTEL and GLASS ACADEMY. The main content includes a bullet point defining the daylight factor and a boxed equation showing the general formula. At the bottom left, there is an 'eds' logo and a decorative city skyline graphic.

So, let us just say. So, if you have 10000 lux; if you if you take your light sensor outside the building and you measure it is if it is 10000 lux and, if you take the same sensor inside the building at your work plane and you get 300 lux.

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DAYLIGHT FACTOR

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- Daylight factor (DF) is defined as the ratio of interior illuminance to outdoor illuminance at the same time under overcast skies

$$DF = \frac{300 \text{ lux}}{10,000 \text{ lux}} \times 100\%$$

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This slide is identical in layout to the previous one, but the boxed equation now shows a specific calculation: $DF = \frac{300 \text{ lux}}{10,000 \text{ lux}} \times 100\%$. The rest of the slide content, including the title, logos, and definition, remains the same.

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DAYLIGHT FACTOR

- Daylight factor (DF) is defined as the ratio of interior illuminance to outdoor illuminance at the same time under overcast skies

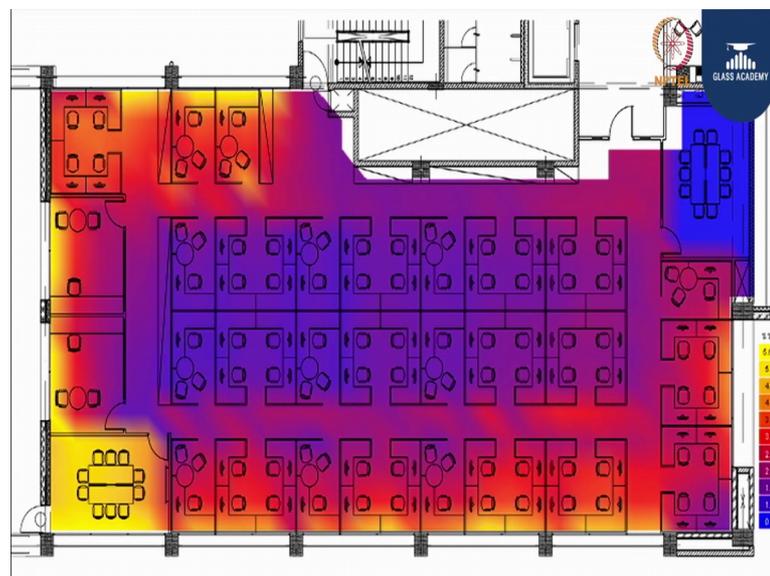
$$3 = \frac{300 \text{ lux}}{10,000 \text{ lux}} \times 100\%$$

eds



So, you get a daylight factor of 3 percent.

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This is a image of the simulation output. One can clearly see there is a legend over here, one can clearly see that this conference room is getting 0 percent daylight factor, whereas this corner conference room is getting somewhere around in the range of 5 to 8 percent of daylight factor. That means, if I take a 10000 lux, my conference room is getting somewhere around 500 lux, whereas the internal conference room is getting 0 lux as the illuminance value.

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Few things to note about day light factor, the as per the definition they say that daylight factor is calculated for the overcast sky condition; that is it is the calculated for the worst case scenario. Because, they believe I mean when it is started they thought that you know if it will work for the worst case scenario then it will work for all conditions.

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Daylight factor is simple, point in time metric, it is done for 1 hour of a day, regardless of the day and the year. So, it is point in time metric.

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It was very useful and it is in fact is useful in making design choices in comparing different design options starting from different building forms to other thing understanding surface colour reflectances, seeing their impact on the daylight factor.

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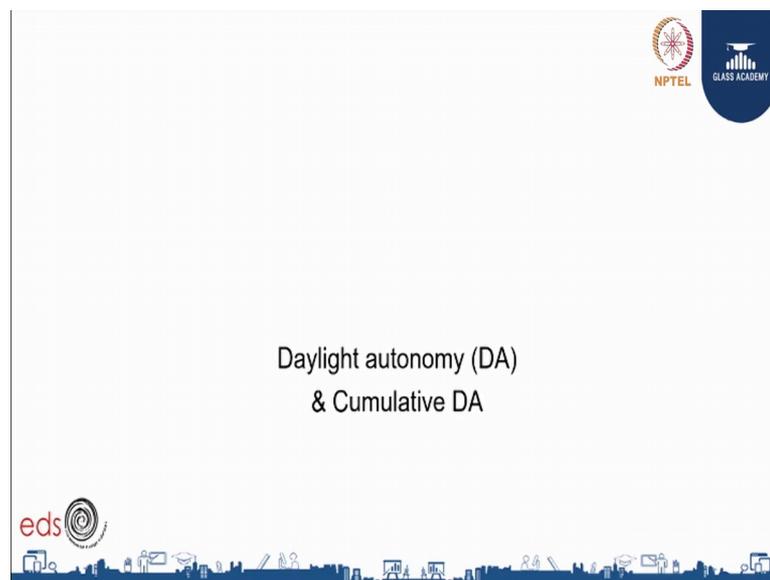
But, as we know nothing is interesting or have a complete one sided, so let us see the other side of the coin. So, there were certain benefits of daylight factor.

Now, just let us see what are the cons of the same? So yes, overcast sky condition helps you design for the worst case, but it also results in overdesigning. Because if and again it

was primarily developed in UK which has got more of cloudy sky condition than a sunny sky condition, if I replicate that for an Indian climate, where I have got a more days more sunny days compared to a cloudy sky. I might if I take daylight factor as my performance matrix, I would be kind of it you know overdesigning which will find the results in result in glare.

So, that is one of the cons of daylight factor. Again it, since it is point in time matrix it cannot predict the interior light savings, in case because that is for 1 hour; the annual savings cannot be predicted. Since it is done for over cast sky, it is in dependent of location and orientation, because overcast sky whether you are in India or UK or near the equator, if it is overcast sky you will have a standard illuminance outside which will range between 8000 to 10000 lux via UK. But in terms of location it will be independent and orientation. So, your requirement for the North facade would be same as the South facade, because it is the overcast sky.

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Because of those factor the next daylight performance matrix came into picture which was called day light autonomy and cumulative daylight autonomy. Also because the simulation capability is improved and that there were simulation tools available, weather data available, slowly this static daylight factor has transformed to this dynamic daylight performance matrix which I have talked about.

So, the first dynamic daylight performance matrix developed was daylight autonomy and cumulative daylight autonomy.

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It was originally proposed by the **Association Suisse des Electriciens** in 1989 & improved between 2001-2004 by **Christoph Reinhart**.



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In a simple it was originally proposed by Association of Suisse des Electriciens in 1989 and improved between 2001 and 2004 by Christoph Reinhart.

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DAYLIGHT AUTONOMY

- Daylight Autonomy is represented as a percentage of annual daytime hours that a given point in a space is above a specified illumination level.

$$DA_{300} = \frac{\text{Compliant Hours}}{\text{Annual Daytime Hours}} \times 100\%$$

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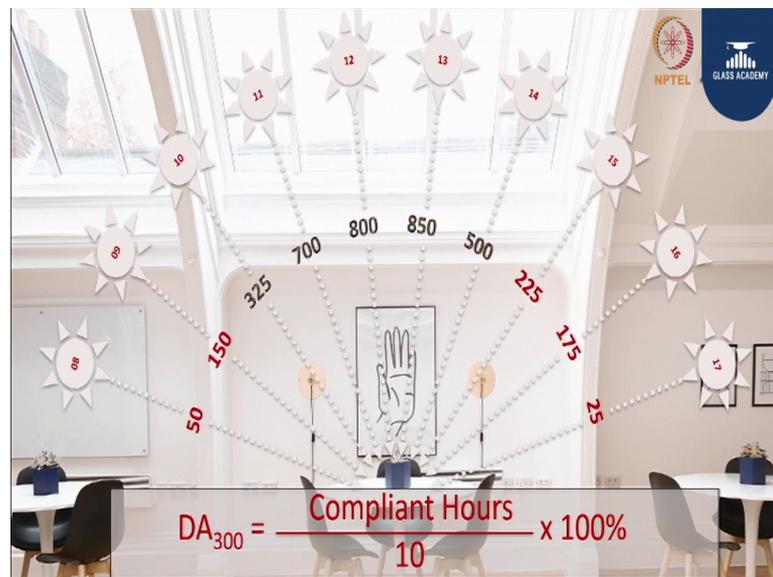
NPTEL GLASS ACADEMY

As a definition, Daylight Autonomy is represented as a percentage of annual daylight hours that a given point in a space is above a specified illumination level. So now, this is resulted in annual day time hours. So, you take the total day time hours and you calculate

that your sensor point or your given point in that space is above a certain illumination level. So, you count that.

So, the it is generally represented as DA with the illumination level as a subscript. So, here the DA is 300. So, they are talking about that this the point in question how many hours it will be above 300 lux? So, you have compliant hours which are above 300 lux and the annual daytime hours, so you calculate the percentage that gives you the daylight autonomy.

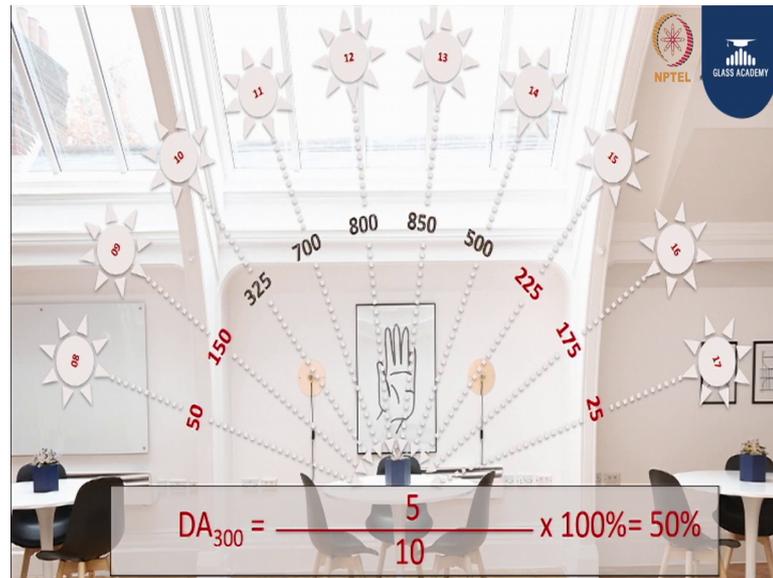
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Now, let us take this through a simple small example. So, let us see if we are we are interested in finding the daylight autonomy at this point right. So, just to make it simple in calculation I have taken it for a day. So, formula we note the daylight autonomy 300 compliant hours by annual daytime hours. So, let us take per day 8 in the morning till 5 PM. So, there are 10 hours; so we have got. So, in this case we will take a annual day time hours as 10 and, so around 8 AM we are getting at this point 50 lux then 9-150, 325, and 700, then 800, 850. So, this is generally the profile of the day lux level at this point.

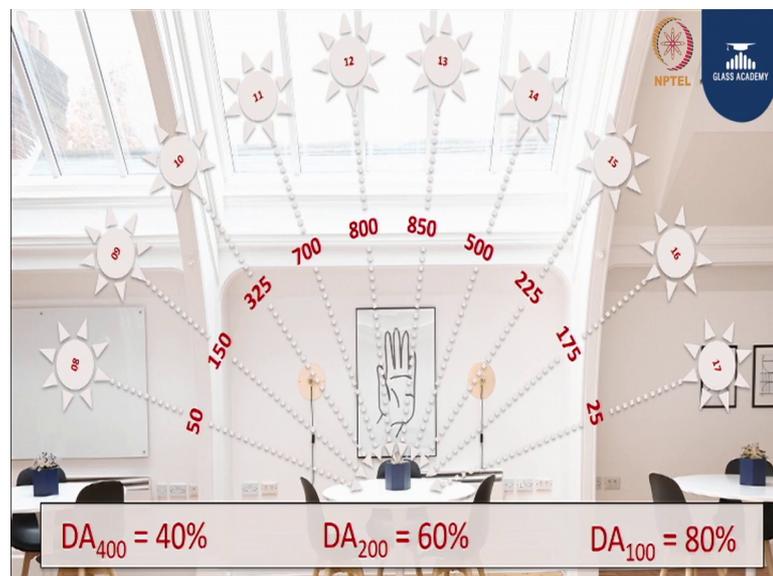
Now, let us try to identify how many points out of this 10 points? Are above 300 lux. So, we can easily count that they are 5 points which are above 300 lux.

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So, that gives me the daylight autonomy or 300 for this point as 50 percent.

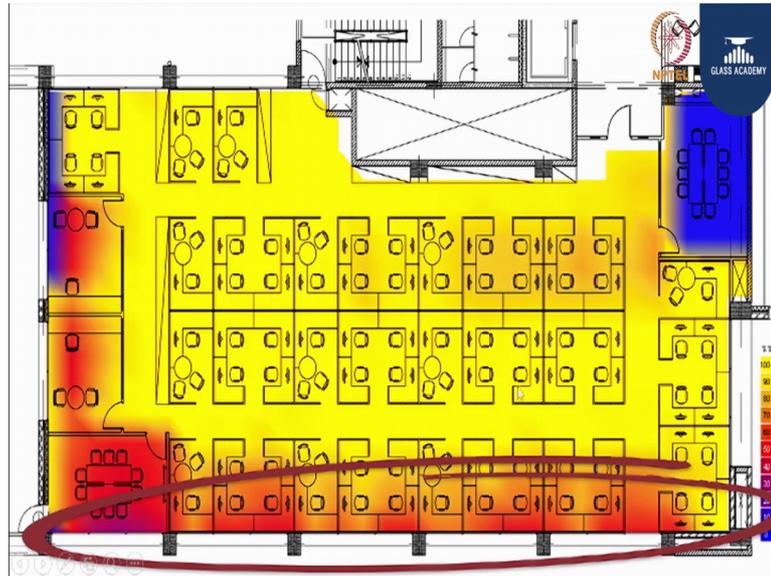
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So, let us just quickly see that calculate the daylight autonomy with 400 lux, daylight autonomy for 200 and daylight autonomy 400, right. So, above 400 we have got around 40 percent of the point, above 200 we have got 60 percent, and above 100 we have got 80 percent of the time.

So, this calculation is done; is generally done by the simulation tool for every hour for every daylight hour throughout the year and then this percentage is calculated.

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This is the same example; now we have represented the daylight autonomy. So, one can easily see that you have a daylight autonomy of above 300 lux for 60 to 40 percent of the time; that is the yellow point. And this blue is less than 10 percent of the time.

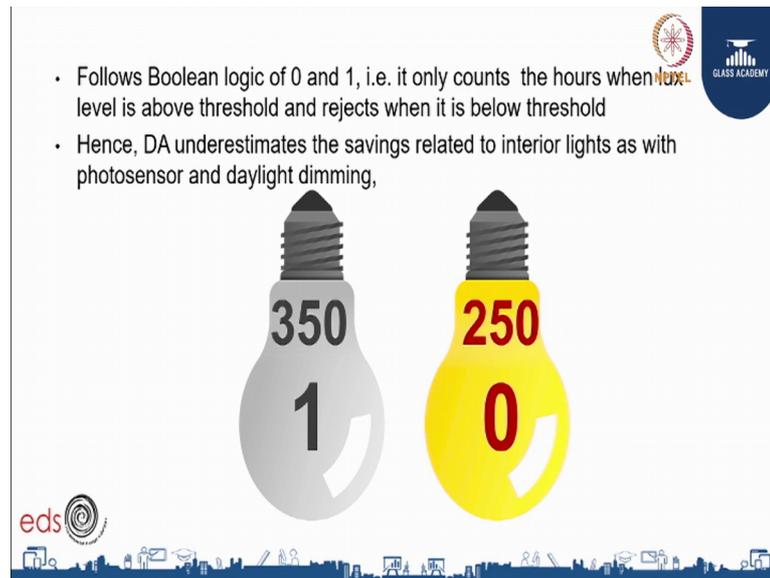
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Daylight autonomy also helps in estimating energy savings due to electrical lighting savings. So, from the daylight autonomy output, I will get back for x percentage of hours I am getting more than 300 lux.

So, as a calculation I can I can assume that that point for that point we do not need electrical lighting for that percentage number of hours. So, based on the voltage and other thing we can deduct the electrical energy used from our internal lighting energy used, and we can calculate the energy savings due to electrical light savings.

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The slide contains the following text and graphics:

- Follows Boolean logic of 0 and 1, i.e. it only counts the hours when lux level is above threshold and rejects when it is below threshold
- Hence, DA underestimates the savings related to interior lights as with photosensor and daylight dimming,

Below the text are two light bulb icons. The left bulb is grey and labeled with '350' and '1'. The right bulb is yellow and labeled with '250' and '0'. The slide also features logos for 'eds' and 'GLASS ACADEMY'.

So, from daylight autonomy the next term came which was cumulative daylight autonomy. So, I will just explain why they stressed to cumulative daylight autonomy. As we have observed that daylight autonomy follows the Boolean logic that is 0 or 1; that is it counts only the hours and the lux level is above threshold and rejects the hours when it is below threshold. Hence, a if I see in realistic world we dimming sensors and light dims the daylight autonomy underestimates the savings related to interior lighting as with photo sensors we can we can easily achieve daylight dimming.

So, above 300 or 350 you get one and even if you have 250 lux daylight autonomy will assign a 0 thing to that, it will not count that hour towards daylight autonomy factor, right though 250 is also good. And I just need around 50 lux to supplement from the interior lighting to achieve a 300 lux level.

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CONTINUOUS DAYLIGHT AUTONOMY

- Continuous Daylight Autonomy is a basic modification of Daylight Autonomy. Continuous Daylight Autonomy awards partial credit in a linear fashion to values below the user defined threshold.

$$cDA_{300} = \frac{\text{Compliant Hours (Full + Partial)}}{\text{Annual Daytime Hours}} \times 100\%$$

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Because of that they came up with the next daylight performance matrix, it was continuous daylight autonomy. It is represented as small c and DA, cDA and then the lux level in the subscript. The compliant hours are now full and partial. So, the continuous daylight autonomy is basically give wording some partial credits in a linear fashion to those vale which are below threshold, right.

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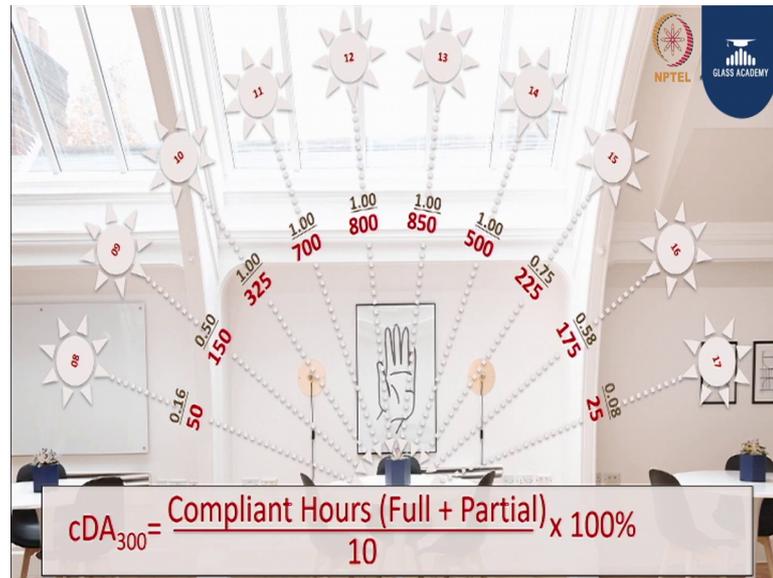
NPTEL GLASS ACADEMY

50 150 325 700 800 850 500 225 175 25

$$cDA_{300} = \frac{\text{Compliant Hours (Full + Partial)}}{\text{Annual Daytime Hours}} \times 100\%$$

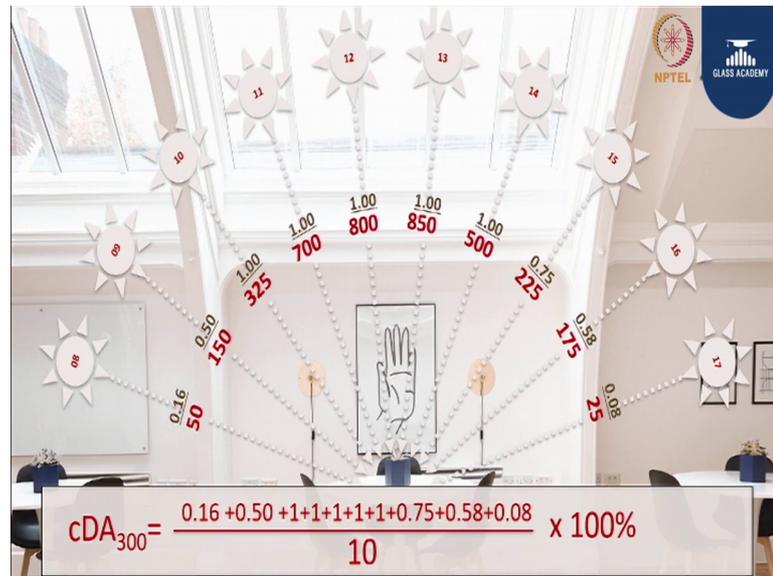
So, now let us just visit the same example we have thing: so full and partial.

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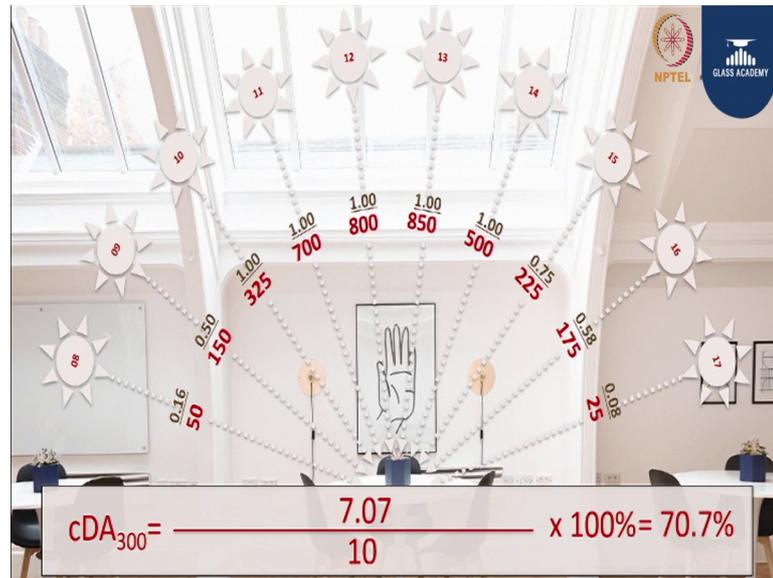
So, the annual daytime hours in the same case remains the 10, but if I take the ratio 50 will become 0.16; 150 will become 50 percent of 300 lux, then 325 is taken as 1, 700 again 1, anything above that threshold is considered as 1, and anything below of the threshold a partial credit is given.

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So, now if I calculate my overall cDA comes down to 70 percent; 70.7 percent in this case right.

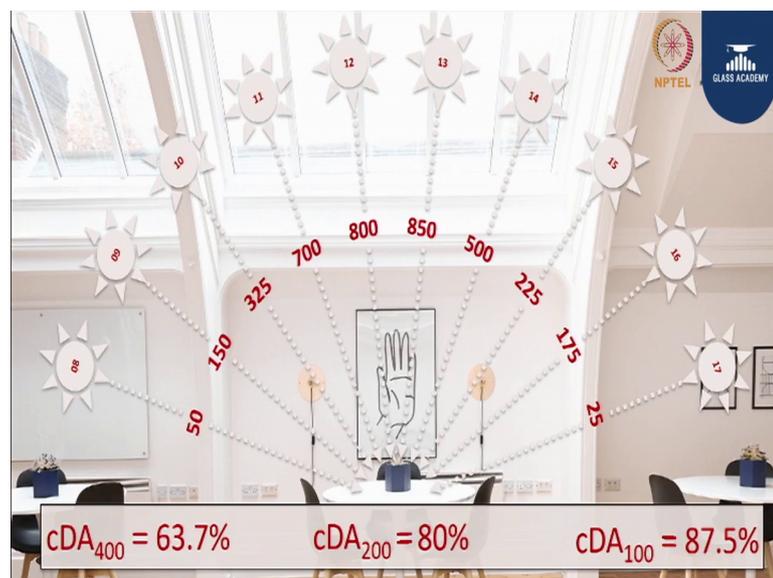
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And now this is a more accurate and then you know with this you can have a more accurate estimate of the interior lighting saving. So, in actual also you will have 70 percent of the time when you will not requiring your artificial lighting.

So, again let us do the same thing with example with 400, 200, and 100.

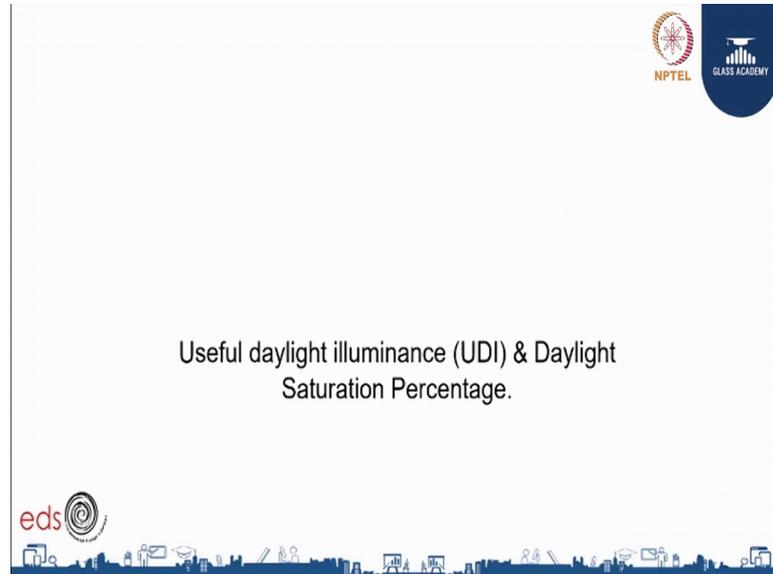
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So, you can do it, but the results are like 63 percent, 80 percent, and 87, you can see an improvement from daylight autonomy. In this figure; this above upper left corner is the

daylight autonomy figure, and then you can see in this cumulative daylight autonomy the yellow area has increased compared to the daylight autonomy.

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Now, coming down to the useful daylight illuminance and daylight saturation percentage.

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We all know more is better, more money is better, but we also know that you know access of everything is bad.

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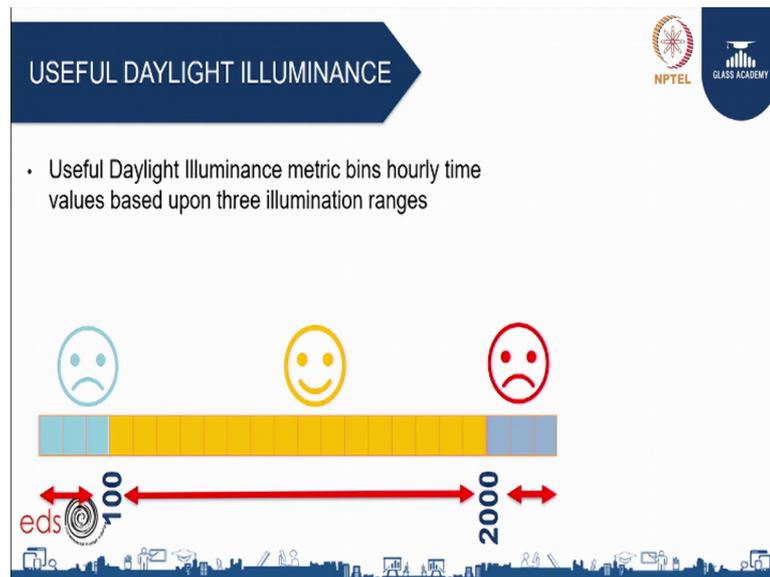
So, that because of that thing they have arrived on the useful daylight autonomy. Similar case is for daylight. So, if I got more daylighting it will result in glare. So, the earlier daylight autonomy or daylight factor they did not consider the over lit spaces or excess lighting.

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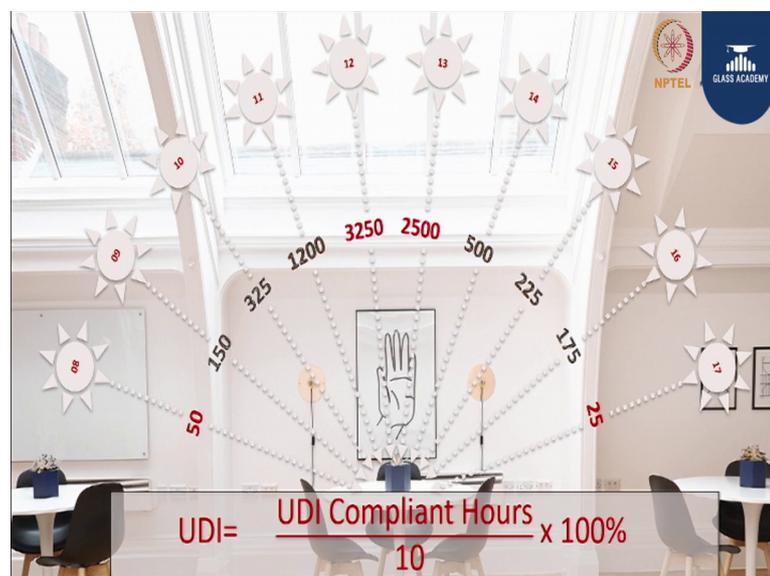
So, that is why the daylight useful daylight performance matrix came into picture. So, you can clearly see the glare impact in this image right.

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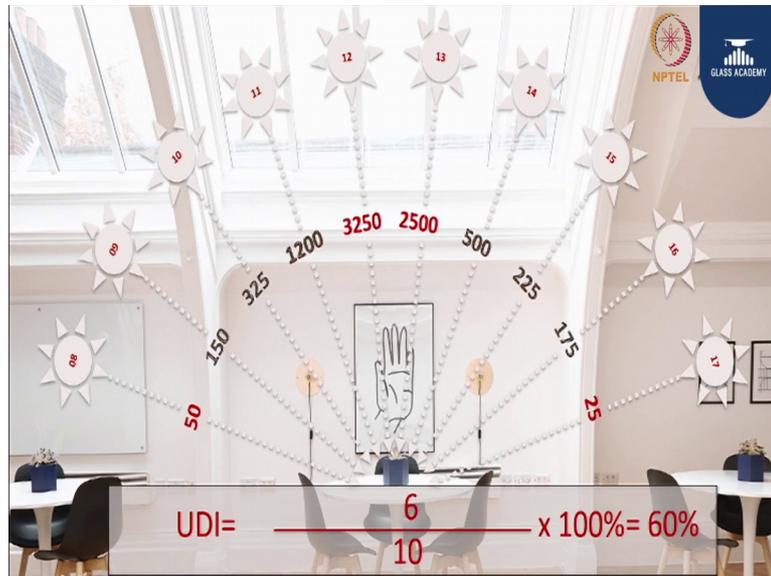
So, in terms of definition: useful daylight illuminance matrix bins hourly time values based upon three illuminance range. So, it bins the ranges into 0 lux to 100 lux which it call is at again not as useful to daylight illuminance its called underlet, than 100 lux to 2000 lux, and above 2000 lux. So, what it says is 0 to 100 is again not desirable, because it is its low lighting, above 2000 is again not desirable because it will result in glare, anything between 100 to 2000 is considered or is taken in favor of the useful daylight illuminance. So, it gives full credit to anything between 100 to 2000 and 0 credits for anything below 100 or above 2000 lux.

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Same example if we calculate in this case. So, if we see.

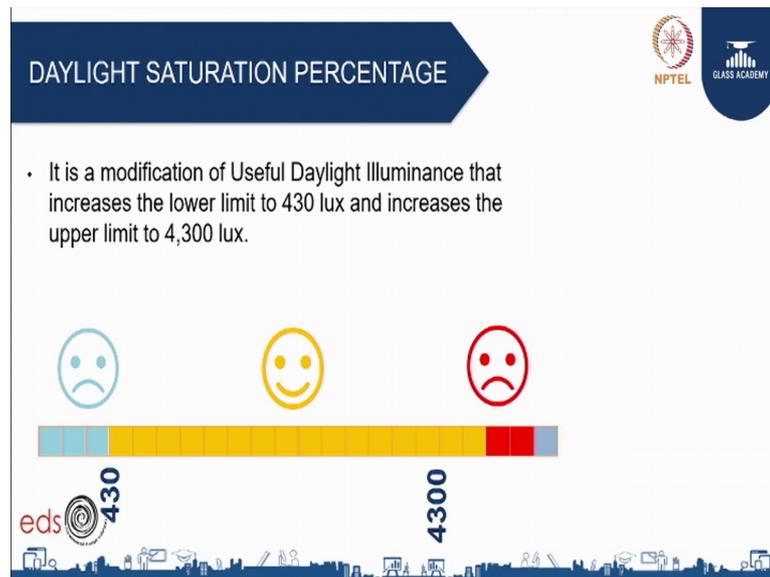
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The total UDI complaint hours are 6. So, here the threshold is 100 to 2000. So, 150, 325, 1200; this will not qualify 3000 because it is above this thing then 500, 225, 175. So, out of 100 10 hours we have got 6 hours where we can say that; yes, this is useful daylight illuminance, so that gives us around 60 percent of UDI number.

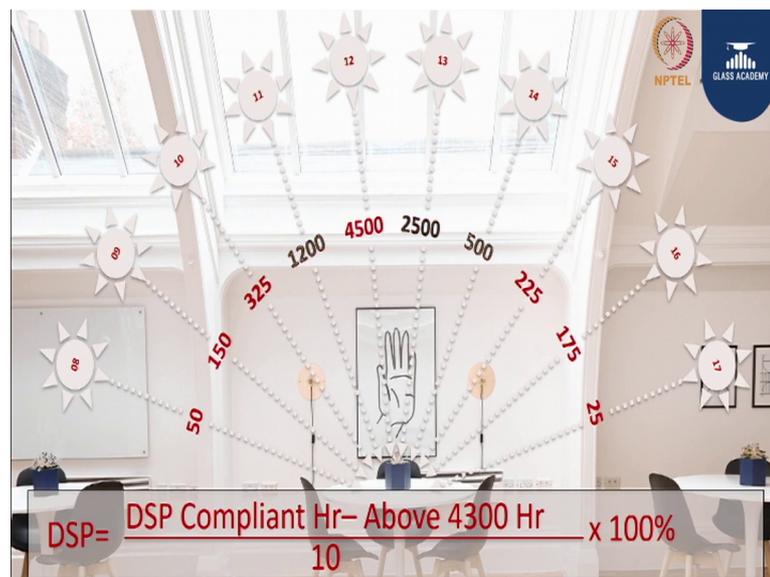
You can see the simulation output, you can easily observe the areas which are close to the perimeter. They are they are get less of number of hours, they are achieving useful daylight, whereas the areas that are inside are getting more number of hours as a UDI complaint.

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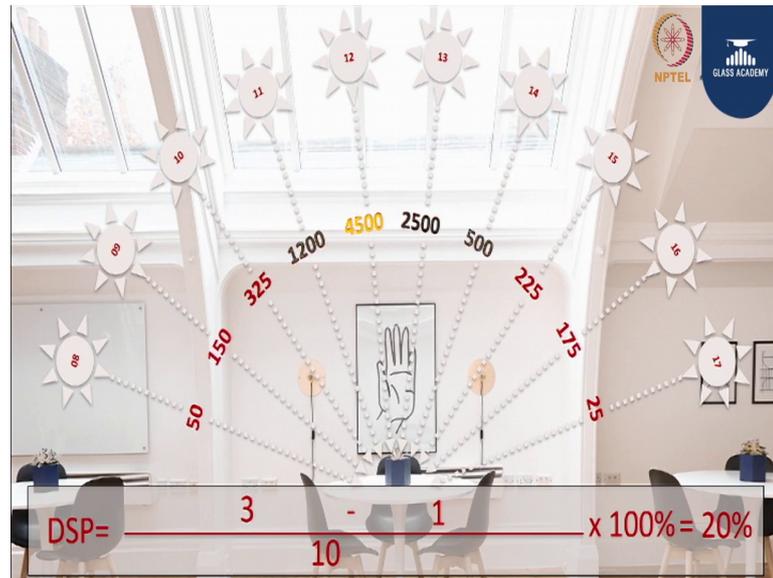
The daylight saturation percentage is kind of a modification of useful daylight illuminance. The only thing is it has increased the lower limit to 430 lux and the upper limit to 4000 lux. It has also introduced a concept of penalizing anything that is going above 4300 lux. So, if you have got 2 hours above 4300 you have to deduct them for your overall calculation.

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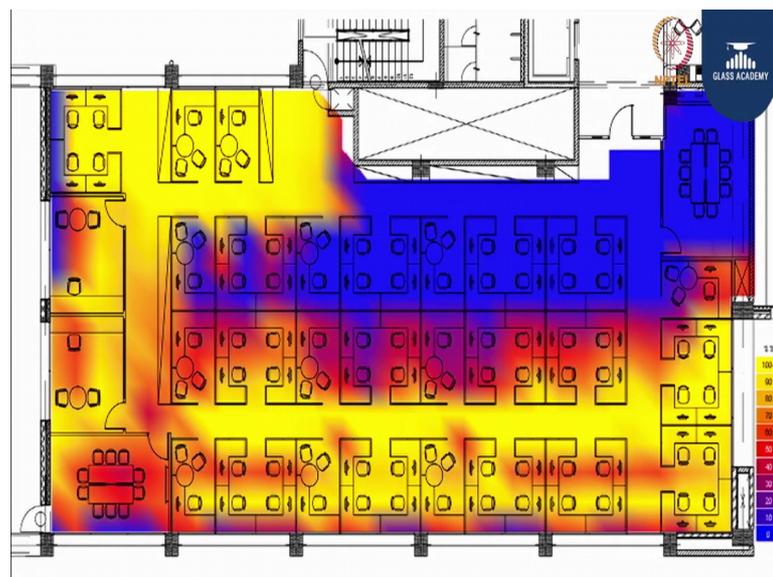
So, taking the same example: so the my formula changes now it selects saturation percentage complaint hours minus above anything that is going above 4300 hours. So.

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So, the same example: I have got 2 hours which are complaining with the daylight saturation percentage. So, 1200 2500 and 500; and I have got 1 hour which is above 4000 500. So, effectively the DSP for this point is 20 percent right, because I have been analyzed for excessive light that is I am allowing excessive light to come in above; that is above 4300 lux.

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Again as simulation output showing the distributions; so you can see these areas are low because now the low threshold has increased from 100 lux to 430 lux. And in this areas also, there are few points which are above 4300 lux.

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SPATIAL DAYLIGHT AUTONOMY

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⌘ Spatial Daylight Autonomy defines the percentage of floor area that receives at least 300 lux for at least 50% of the annual occupied hours.

$sDA_{(300,50\%)} > 50\%$ $sDA_{(300,50\%)} > 75\%$

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Coming to the last daylight performance matrix which is the spatial daylight autonomy, this is also lead version, they also take into count the spatial daylight autonomy. As per definition it is the percentage of the floor area that receives at least 300 lux, for at least 50 percent of the annual occupied hours. As per the study that they have done they have came to a conclusion that the SDA value, but means 50 percent to 74 percent indicates percentage of time if you get 300 lux indicates a preferred or good space.

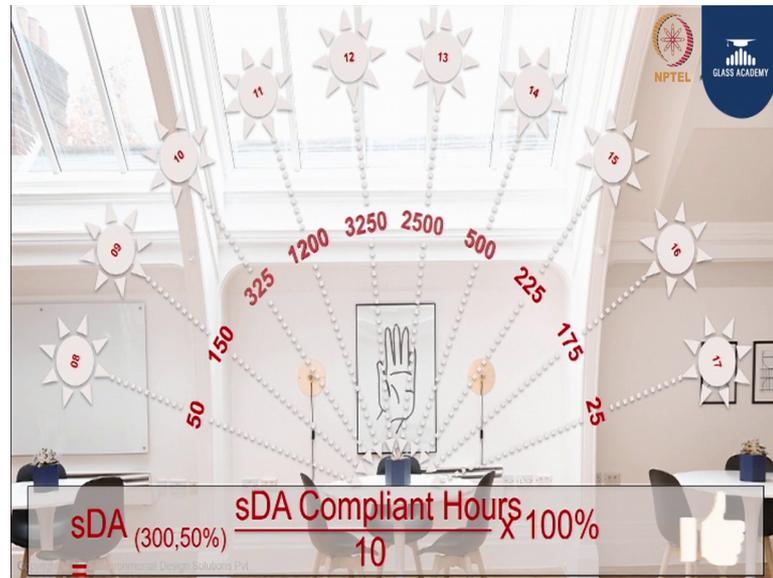
So, basically an SDA if you have more than 50 percent of the annual occupied hours then you are getting 300 lux, then its preferred its accepted and more than 75 percentage of the area is getting 300 lux for 50 percent of the time is the preferred one.

Now coming down to the last daylight performance matrix it is the spatial daylight autonomy spatial daylight autonomy defines the percentage of the floor area that receives at least 300 lux for at least 50 percent of the annual occupied. You must have observed that they have now all along with the lux level they have also introduced the time factor into this matrix. So, along with 300 lux; that means, that sensor that space has to achieve 300 lux, but they have also specified that at least for 50 percent of the time they should

achieve 300 lux. So, any point which is getting 300 lux, but is not getting for 50 percent of the time or less time is not counted towards as a good daylight point right.

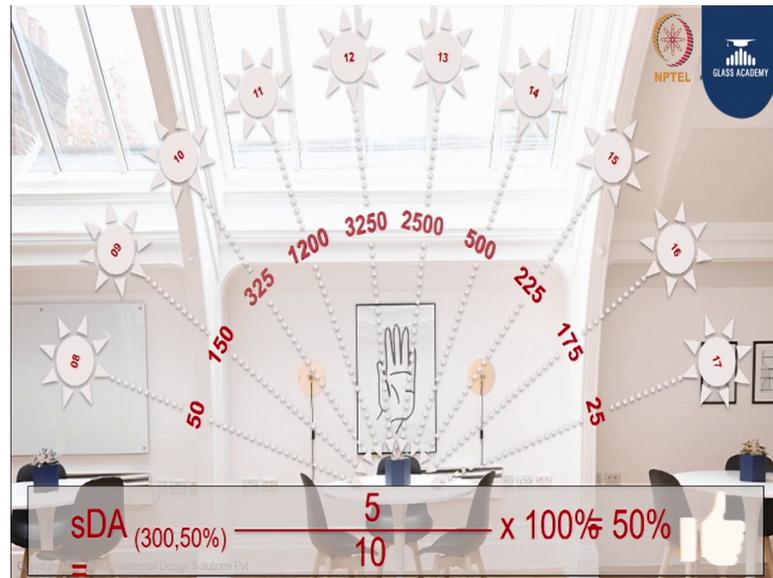
So, just for reference SDA value anything between 50 percent: so if more than 50 percent of your room is getting 300 lux for 50 percent of the time is considered as accept acceptable. And, but if 75 percent of your room is getting 300 lux for more than 50 percent of the time is the preferred one.

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So taking the same example, on this case let us just quickly calculate the SDA for this space. So, I have got I have to see the points which are above 300 lux.

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So, over here there are a 5 points: 325, 1200, 3250, 2500, and 500 and so that gives around to 50 percent; that means, 50 percent of the time this point is getting more than 300 lux which meets the SDA requirements.

Thank you. Along with SDA they have also another performance matrix to cater to the glare respect is the annual solar exposure which states that that any space should not have more than 10 percent of the area receiving 1000 lux for more than 250 hours. So, they have they have they have clearly say that yes certain percentage of direct sun or high illuminance is acceptable, but if any space or more than 10 percentage of the area of the space is getting 1000 lux for more than 250 hours then that is that is not acceptable.

So, SDA and ASC are two parameter are two performance matrix that goes hand in hand. And, SDA talks about takes into account the daylight availability or the illuminance the minimum value, and ASC takes care of the glare part or excessive illuminance part of the daylighting.

Thank you.

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Summary:

By the end of this video, you have learnt about the:

- Daylight performance metrics
 - Static
 - ✓ Daylight factor
 - Dynamic
 - ✓ Daylight autonomy
 - ✓ Continuous daylight autonomy
 - ✓ Useful daylight illuminance
 - ✓ Daylight saturation percentage
 - ✓ Spatial daylight autonomy/ASE