BUILDING ENERGY SYSTEMS AND AUDITING

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Lecture 32

Lecture 32: Star Rating for Office Building

Welcome to the NPTEL course on Building Energy Systems and Auditing. In the module number 7, we are discussing on Building Operational Energy and Energy Retrofit. So, in this particular lecture number 32, we will discuss about the star rating of office buildings. In that particular module we will first discuss the star rating systems which will be the continuity which we will have we will do the continuity from the lecture number 31 itself and we will also do some kind of the step wise demonstration for energy performance index of office building. So, already you have did that one, but we will do in a little elaborate scale.

The star rating of is a band, it is a band star rating is a band and that band is created based on some of the criterias and that is depend upon three things basically. One is the energy performance index of course, and but energy performance index is seen through the two lenses. Climatic zone and the another lens is that amount of the built up area I mean the total air condition area versus the total area of the building. So, it is the as equally actually it is a the straight line equation this particular the bands are ah reflected through ah this particular table which has been provided by the Bureau of Energy Efficiency. See all the the bands 1 star, 2 star, 3, 4 and 5 star are basically subdivided into first of all 3 3 climates composite, the warm and humid and the hot dry.

Please remember last chapter last lecture we discussed about the office building at Lucknow we got 126 is the the EPI. So, Lucknow is a composite climate zone. So, I can see the first row first three rows of course, for the composite and the those ah the different three different climatic zone is further divided into ah three rows. The top one is for the the large offices, the middle one is for the medium office buildings and the last or the lower one is the small offices. How to designate this large medium and small?

We have discussed in the 21st lecture that if the building area, the built-up area, is less than 10,000m², it is small; if it is in between. So, if it is 10,000, it is small, and 30,000 or this is large, small, and this is medium. So, in between more than 10,000 and less than 30,000 is your medium; anything below 10,000 is small, and anything above 30,000 is large. So, based on that, we can again fix up which row we can go—it is a large office or a small office or whatever—and now these ratings are based on a straight-line equation.

A straight-line equation looks like y = mx + c. where y is your particular band number, and x is your AC area—how much percentage of the AC area, okay? So, based on the assumption, suppose you have 100% AC area. So, the value of x will be 100. Suppose if I say that my office is a large office in a composite climate, and then I will say that my AC area is almost like 80% or so.

So, for the first star, the 1-star, I have to use this formula. This formula I have to use. So, the y will be equal to then 0.95. So, my x is the AC area—AC percentage is, suppose, 80%. So, this will be multiplied by 80: y = mx + c, intercept 60.

So, whatever may be the value that value have to that will be the first ratings the 1 star rating or so. So, if you see particular line suppose first line if you see this is 0.95 x plus 60 the second one is 0.9 plus 50. So, reduces then it is 0.85 plus 40 both are reducing the m is reducing c is reducing then the 0.8 into 30 plus 30 sorry 0.75 plus 20. So, 60 50 40 30 and 20.

So, it is reducing by 10 the c values whereas, the m value is reducing by 0.95 to 0.9858 say so 0.5. So, definitely the value of y in the 5 star will be less with compared to the 1 star or any lower one will be the higher than the next 2 higher than 1. So, definitely your energy consumption will be low and you will get a higher rating of the star that is very well justified by this particular the table. So, if you see I have done something over here I have used three different percentage of the data 25%, 50% and 75% as the value of x and I have just taken three star and the four star in between these two I am trying to check. For all the three climates composite but the warm and humid and the hot and dry, but I have kept only the large office.

I have used all the 3 climates for the large offices. So, this 3 and also for the 3 star and the 4 star and see how it is changing. If you see now the 3 star rating building for composite climate 25% if you have a 25% of the AC area you will get a 3 star if your consumption is 61.25 or less, but if you are in warm and humid climate your building is

in warm and humid climate you will get 3 stars if you are less than 65 or so. Whereas, if your building is hot and dry climate you will get same 3 star with 48.75 less than 48.75.

So, it is a little bit challenging in the case of the hot and dry. So, to keep it below 48.75 if you want to get the 3-star rating, whereas for warm and humid, if it is 64, you will get 3-star. But if you have a PPI value of 64 for the hot and dry, you will not get 3-star; you will get 2-star, right? It is not 3-star. So, similarly, for 50% of the AC area, suppose then 82 is your EPI value for N85 here, and this is the same. So, like that, if you are having 75% of the air conditioning area, definitely your consumption is much more, and then it is 103.75 here for composite, 105 here for the warm humid, and 96.25 for hot and dry. So, similarly, I did it for the forester also, which is also similar-looking. If it is for the 75% of AC area and if your building is in a composite climate, you require 90 or less; for humid, it is required 91 or less, but for hot and dry, it is required 81 or less.

It is challenging if you compare with these three for the hot and dry. Hot and dry may not consume that much because, at other times, it may be significantly cold or so. So, the EPI values of the composite climate, and I have calculated the EPI values for the composite climate star rating systems. For the medium office, large office, and small offices, this graph is giving me the small offices, medium, and large composite climate with this 25, 40 or 50, and 75 percentage of the area. So, if I say it is a 50% air-conditioned area for a large office, I will get it with 82.5 for 3-star, but for the medium office, it is 90. For a small office, it is 67.5.

So, for the small office, the checks are much tighter. Same climatic zone, same percentage of the AC area, but your cutoff is much less: 67, whereas the medium office is 90 and the large office is 82. There is a—you may say—why the medium is more than the large. The large office sometimes consumes less because of the uniformity distributions or whatever. So, because of that, it has been devised that, or there will be statistical data that has been proven, that the large office is a little less with respect to the small offices or the medium office or so. So, those are the four-star ratings that are also showing the same: 70, 77.5, and 55 for the 50% of the AC areas or so. So, let us now go to the same problem which has been discussed in lecture number 31.

We got a total energy consumption of the building as 20,20,570 kWh for annual point of view. The total amount of built up area is 16000 meter square. So, if you have skipped the lecture number 31, please go through the lecture number 31 and see the last slide of the lecture number 31. I have just copied it in this particular slide to process or proceed to

the rating systems analysis or the star rating analysis or so. And if you remember in that particular building the first two zone that is 7000 meter square and the 3900 meter square are the AC and the air conditioned zone the rest two are non AC zone.

So, I have computed the what is the percentage of the air conditioned area which comes out to be around 68%. So, I have directly divided this two figure annual consumption of the energy and the total built up area. that gives me 162 kWh per meter square per year. So, that is my EPI of the office building as 162 kWh per meter square per year, but I need to see that was the last slide of the last lecture. Now, the next slide we will see that this is which rating which category it will be in which star.

So, I have used this one. So, first of all I have to check two three things I have to see the the building is in which climatic zone. So, it is composite climatic zone because it is in Lucknow and it is a medium office because it is 16000 meter square of the area which is more than 10000 and less than 30000 and there is a 68% of the air conditioned area. So, I have to see the composite, I have to see the medium office.

So, this is my line I have to check with. is the line I have to check with is a row that I have to check with. So, first I have checked with the first the 1 star upper limit is how much. So, 1.1 into x. So, this is the equation I am checking first 1.1 into x this is my x this is my x and plus 60 which is 134.8 my number was 126 right, 126 yes 126, 126 is my number what I got from my energy analysis or the audit.

The 2 star I have again calculate the for the 2 star this is 105 into x is 68 plus 50 plus 50, so this one. So, this is 121.4. So, this number lies in between this is the 126 which is more than 121, but less than 134. So, my building is 1 star 1 star why 1 star why not 2 stars because the upper cap of the 2 star is 121. So, if any building consuming 121.4, I will give that building as 2 stars.

If it is consuming 122 or 121.5 in fact, with 68% of the air condition, so I am not going to give. So, that will be the other the lower star that is the. So, my building consuming 126 that means, it is more than 121.4. but of course, less than 134.8. So, it is a 1 star if this building consumes almost like suppose 136 then no star then no star because this is more than the 134.8.

So, there will be no star rating it will I cannot give any star rating. So, this particular building is 1 star EPI is 126. So, it is 1 star. So, this is another small problem which was appear in the gate examination 2020. Great examination 2021, it was written that the

building is constructed on a plot measuring 70 meters by 40 meter that is plot size and it was utilized a fare of 1.5 and the energy audit team found that the average monthly bill of the building is almost like 2,94,000 rupees per month.

It is a monthly please remember monthly and the unit cost of electricity is rupees 7. What is the building energy index? Building energy index is nothing but the energy performance in EPI. BEI sometimes you may also called BEI some books or some quotes also says that is BEI So, I first found out the how much is the plot it is very simple problem just to know that I have to do two things first divided by second.

I need to know the what is the annual energy consumption that will come that will come from the energy bills average energy bill per month. So, to make it per year how much is the total requirement of the energy and total built up area. Total built up area found out like the plot area multiplied by the f here is not it. So, that is the total built up area. And next I will find out the what is the total amount of energy required for the building.

So, per month it is 2,94,000 it is indirectly given to me in this problem and one unit is 7 rupees. So, if I divide 2,94,000 by 7. So, I know that this is my electricity consumption per month. So, 42,000 kWh is the energy consumption per month. So, the

Building energy index is equal to your annual consumption of energy divided by the built up area. The annual consumption of the energy is 12 into this one this is this is per month right. So, it is per year this is the annual divided by this is the building built up area (BUA) built up area this is your built up area. So, it is 120 is the answer.

So, here will be your 120, 120 you have to answer. So, next we will go to yeah this is the same the BEE Bureau of Energy. Efficiency Government of India is also prescribed that how you will find out this percentage of the air conditioned area. Mostly it was based on 8 to 9 hours operating hours per day and 6 days a week format, but there may be some fluctuations of the working hours, there may be some fluctuations number of working day per week.

So, based on that they prescribed a method to find out the percentage of the AC area because percentage of the AC area should not be always based on the total amount of square feet, but also it may vary that how much time it is actually going for the work. So, they told to make this kind of a table where the floor wise different area A 1, A has to be first formulated, then this P 1, P 2, P 3 how much is the percentage of the air conditioned area has to be seen. Suppose this all A 1, A 2, A 3 are supposed 10000 or may be 5000m²

and there is different distribution 50, 70, 75, 80 are the P 1, P 2, P 3, P 4. But we have to check with the operational hours.

So, maybe the first floor for floor number 1 operate for 24 hours maybe it is some some some kind of ah some kind of ah the office which has to monitor 24 hours some some data maybe some meteorological office or whatever some ah some kind of the. So, that maybe a small amount of area maybe on that particular area one a small amount of the the zone is operating 24 hours and some zone may be operating for 12 hours some is 8 hours. So, based on that and also the working hours in the day some part may be work for 7 days some part may be work for 5 days or so. So, based on that we have to fill this particular table in our audit and the weighted average percentage of the AC area can be found out by the simple formula where

$$\text{Weightage Average \%age AC Area} = \frac{\sum(hi * di * Ai * pi)}{\sum(hi * di * Ai)}$$

first has to calculate the multiply these 4 numbers the row wise 4 numbers the operating hours working hours per week the area and the percentage of the area and that has to be divided by the operating hours working hours per day and the area. So, we will do a small calculation and see So, in this problem what we have mentioned here is that very similar problem with the earlier one which we have discussed in the first lecture in 31st lecture of this module. A building office building of having 11500m² of the total built up area having 3 floors that means, it is a medium scale it is more than 10000 that is number 1 having 3 floors The floor wise air conditioned distribution is mentioned below.

So, ground floor is having a total area of 2500, the first floor is 4500 and the second floor is also 4500. So, this total 3 is your 11500 right and this is the 50%, 75% and 60% is the air conditioned area for the this first ground and the second floor. Then the operating hours are having different operating hours the ground floor operates for this whatever the things are operate for 8 hours per day and 5 working days in a week. The first floor is working for a little more 10 hours per day and is having 6 week 6 days in a week program kind of a thing and the second is also like first 8 hours and 5 working days per week. we have also ah distributed 35 weeks as a summer month and 17 weeks are for the winter month and the intensity of the air conditioned is also mentioned as TR/m² just like the earlier problem and the electricity load for the lpd the electrical load as lpd the lighting load is also have different values 8 12 and 10 for three different zones

This building is situated in Jodhpur which is in hot and dry climatic zone of India and we have to find out the energy performance index and we have to assign a star rating. So,

what we did is that this is the first bare minimum data. So, from there we have calculated the requirement firstly for the winter month and for the summer month total amount of energy required and annual energy required. So, how I calculated this one? So, I have actually made some kind of hint.

So, this is the first area you see that the first row and just take the first row. The total air conditioned area I have calculated as 1250 as it is 50% of 2500. So, this comes as 50% of meter square is equal to 1250 meter square. So, this is the first step.

So, this is that. The summer month energy requirement for the air conditioning is 0.015 TR. So, this is that. So, this is TR per m², this is. And the third one, 3.5 is kW per ton. One ton of refrigeration is 3.5 kW, we know that.

So, this is I will get in kW. So, this is in kW multiplied by 8. 8 is the hours of operation, the 5 is the days of operation, and 35 is the weeks for that particular summer month, 35 weeks. This is the days of operation, this is the hours of operation, that gives me 91875. Similarly, see the winter month of the same row, this remains the same.

Winter is 0.005, this one is the summer. 0.385 and this is 17. Where is the 17? This is the 17 winter weeks; this is the weeks. So, it is 14875, 14875. So, if you add this to this plus this. Is equal to this.

Similarly, I did it for all the 3 zones with the help of Excel. So, the annual energy consumption for air conditioning load is 711,786, and I have also calculated for the electrical load. So, it is nothing but this: the total area is 2,500. There is no question of AC area or non-AC area; the total area will be illuminated by the lights. This is the area. This 8 is the LPD; LPD is in the form of watt per meter square. This is your meter square. So, this is watt.

So, this is divided by 1,000, which means this is kW. This is hours, this is your days per week, and this is weeks for 52 weeks, which is the total annual. Per rows is that if there is a change of LPD. So, 3 times calculations are required. So, the first one is 41,600, and all those things have been calculated. So, this is your annual lighting load: 2,96,94,320.

So, these 2 are added together: building load, a building energy requirement for annual, air-conditioned load as 7800, 11, 7 lakhs, 11,000, and this is 2 lakhs, 94,000 for the lighting. So, the total is 10 lakh something; built-up area is 11,000 something. So, this is now I am going to calculate the percentage of the AC area: same table, and this is the multiplication of the H, D, A, and P is here, and summation of that.

So, this is the multiplication of H, D, and A in the second row. And the summation is 55 lakhs or something. So, that gives me 65.5% as the equivalent or the weighted percentage of the AC area. So, you can use it for calculations in an Excel sheet because this is required to find out the BEI cutoff or the star rating. So, we will do that in the next line or next stage.

So, we have to calculate these two values, which are very important: 10,00,000 something divided by 11,500 gives me 8. This 10,00,000 is the total annual energy requirement, and 11,500 is the built-up area. So, that is 87.5, the square foot—the footprint of the energy, the EPI. So, the EPI—this is my EPI. Of the building, and this is a medium office, as I mentioned, because this is more than 10,000 and less than 30,000, and this is in Jodhpur. So, I have to check the star rating for the hot and dry climate in Jodhpur, and this is a medium office.

So, this has to be checked, and this is the AC area, which is this much. So, the x value is 65.5. So, based on that, I have calculated. So, this is my row. I have calculated all the star categories.

So, if it is 83 or more then it is 4 stars, if it is 83 or less it is 5 stars, if it is 97 less than 97, so it is a 4 star, if it is more than 97 it is 3 stars, so like that. if it is less than 136 in between 136 and whatever may be here. So, it is a 2 star if it is more than 136 no star no star. So, my value is 87.5. So, it is more than 83.

So, it is not going to get the 5 stars, but it is less than 97.5. So, it is going to get the 4 star rating is it clear? So, it is less than 97.5, but more than 83. So, it is in between the 4 star or 5 stars.

So, it is going to get the the 4 stars rating. Suppose this building is in Bhubaneswar same building is Bhubaneswar same EPI 87.5 Bhubaneswar is the warm and humid. So, you have to take different set of the equations this So, here I have again calculated these 3 values based on this equation this this the medium ah scale building equation. And now you see it is 87 is coming over here because the 4 star says that if it is anything anything which is ah less than 84.

It is going to be the 5-star. So, it is more than 84, but less than 97.5 in between. So, it is going to get the 3-star rating, isn't it? So, it is more than 84. So, it is not going to get the 4-star; it is going to get the 3-star.

So, its star rating is reduced. Again, if I go back to some other zones of Amritsar, which is a composite zone. Amritsar is a composite climatic zone. So, I have taken the composite climatic zone and the same medium-scale office, and again I have calculated those. Now, I see this again come back to the 4-star, even though it is performing better in that sense. So, hot and dry and the composite—the same building, same parameters—actually give me 4-star. If you see, this is composite, and this is hot and dry Jodhpur, 4-star, but warm and humid gives me 3-star.

So, it is a little bit challenging in the warm and humid climate. So, we have discussed this one. So, that is all for this lecture. We have discussed the EPI and star rating, how it is proposed by the BEE, and we have discussed the corresponding way of calculating the percentage of the AC area and the climatic zone. Based on that, we have discussed the EPI. Thank you very much.