BUILDING ENERGY SYSTEMS AND AUDITING

Dr. Shankar Pratim Bhattacharya

Department of Architecture and Regional Planning

IIT Kharagpur

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Lecture 31

Lecture 31 : Introduction to Energy Performance Index

Welcome to the NPTEL course on Building Energy Systems and Auditing. Today we will discuss the module number 7, we will start the module number 7. The module number 7 is basically on the building operational and the energy retrofit. In the lecture 31, the first lecture of module 7, we will start with the introduction to the energy performance index. So, in this particular lecture we will going to cover two concepts basically we will start with the building operational energy.

We have discussed these things a little bit earlier we will elaborate it in this particular chapter. We will also discuss the schedule of star rating of office buildings here. So, as you know that the building has three phase of energy consumption initially it called as the initial stage is called as the embodied energy the middle phase the the the maxima the of of of the phase which the the building is running in condition is called the operational energy. So, in the last module we have seen that how to calculate the calculate the the the the embodied energy of a building.

In this particular lecture we will discuss that how to understand and how to actually methodically through some kind of energy audit we can find out the the operational energy demand of a building. So, for the day to day running expenses for the running expenses in the sense of the the energy expenses and maintaining a particular building to perform the the the the functionality of the building we required energy. And that energy will be actually calculated based on the lifespan of the building multiplied by the energy footprint of the per year or per month or something like that. In the particular stage of operation when we actually see a building and we see the how much is the energy requirement of the building. So, that particular the operational energy footprint of the building is calculated by virtue of one unit $kWh/m^2/year$.

So, we will discuss that elaborately in the next slide. This particular slide is borrowed from our lecture number 28. If you can see lecture 28, we have discussed this one in detail. So, let us introduce this energy performance index. Energy performance index of a building is a kind of indicator that shows how much energy is consumed by this building through its operations and functionality.

This is an estimation of the yearly consumption of the building based on it being normalized, normalized based on the square foot or the m^2 of the area. So, basically EPI is estimated as kW-hour per m^2 per year. So, the kW-hour gives you a particular indicator of the total amount of energy because kW-hour is the unit of the electricity bill. We pay electricity bills based on the kW-hour unit also. We actually convert, if you want to convert, the kW-hour will get the megajoule or joule as an energy expenditure.

Plus, we can easily see what the different other parts of the energy systems the building utilizes and that was also converted to this kW-hour. That particular amount of energy expenditure has to be calculated for the whole year. There is a seasonal variation of the energy because of the air conditioning and all. There may be a diurnal variation of the energy because of the daylight and the artificial light utilization. So, based on all the variations and all.

have to calculate the the the total energy expenditure for year and that has to be divided by the per m^2 or so that that much is the footprint the per m^2 that much energy is going to utilize for this building. Definitely the number should be little less or maybe we will see that through the retrofitting or some other techniques the how to minimize that one or that will be the challenge. So, this particular the EPI so, you should not confuse with this EPI and the we have discussed earlier the envelope performance index that is the performance index of the envelope which is ECBC has given us. So, this is EPI some of the countries also say it is a EUI energy utility index. So, this EPI or EUI is a value of the total energy electricity purchased or generated.

Please remember that one it is electricity purchased or generated in form of the annual kind of energy and consumed per m^2 of the area of the building. it will exclude the electricity generated from the the renewable source renewable sources. So, renewable sources if I want to my building is actually generated some kind of energy that will not going to take part in this EPI calculation. So, Bureau of Energy Efficiency BEE government of India has proposed rating systems for those buildings, hospitals, office

building, shopping malls, IT buildings also. So, we will discuss the office building today and next lecture we can discuss the the shopping malls and other buildings.

This targeting of the office building is based on three climatic zone warm and humid climate, composite climate and hot and dry climate. And this building specified I mean the building can appeal for this kind of the star rating system when the building is connected a load which is more than the 100 kW or more. And this building these buildings are also classified into three categories large offices which are having building having the built up area the more than 30,000 m^2 or so. In between 30,000 to 10,000 m^2 the build the offices are called as a medium scale building or medium office buildings.

And if it is less than 10,000 m^2 or so, this is a small office building, but the catch point is that the building should have a connected load of 100 kW or above to get that certification. but there is no bar actually as per the as per the square foot area or the m^2 of area building the footprint area built up area is concerned. So, for this particular estimation of EPI the energy performance index we have to do a survey or minimum what we have to do we have to actually know about the electricity bill per month any kind of extra purchase like diesel or petrol or any kind of LPG that is going to purchase to utilize in the building. Please remember that other than the electricity used for the air conditioning and the lighting purpose.

other type of energy used in a building is also going to take care of this particular calculation. Suppose there are pumps for the water supply, there may be some kind of the electricity required for the lift and escalators, there may be there is a if there is a mall maybe there is a food court or maybe if there is a office also there may be a small canteen or hospital may have a a kitchen. So, for that you may require some kind of a fuel LPG or something. So, everything has to be considered to find out the the footprint.

It is not only the electricity required for the HVAC and the lighting. So, sometimes if a building does not have those type of the extra the activities and the purchase of cement purchase of diesel or the petrols or so, then normally we can directly take the electricity bill and we can check otherwise you have to take everything. So, here there are the list we have to see the connected load because that is very important whether the building will qualify or not. we have to see the installed capacity of the diesel generator or gas generator set it is in terms of kW the annual electricity consumption purchased from the utilities may be from the grid and the annual electricity consumption through the diesel or

any gas generator so some building may have additional electricity requirement for the diesel through the diesel generator or the gas generator.

Sometimes we can check the installed capacity of the air conditioning system TR value or the per m^2 of the TR values or so. Installed lighting load in LPD form and the fuel that is LPG and all these other things has utilized for the building. Other than that also we can actually see the area of the building which may exclude the parking, lawns, roads. So, here we have categorically said that it is does not going to include the parking areas or the areas which does not come under the direct F air. The air conditioning area, how much m^2 and what is the non air conditioning area, what is the percentage of that.

The working days, how many working days per week, it is 5 days working day of this building or 7 days or whatever. Total number of employees, total number of beds in terms of if it is a hospital building or maybe if it is a hospitality like hotels or so. average number of persons any at any time. So, those are extra the data may require to just to justify some of the excess or some potential amount of energy use, but moderately we can actually take some minimal data and to find out the EPI. So, as per the BEE this is that the office building standard the format of take care of those data or the values.

So, whatever you have discussed it is almost the same. So, you can go visit this the Government of India Bureau of Energy Efficiency website and get down those things. I have actually prepared this particular lecture based on that guideline only. So, the EPI is a kind of the indicator you may say that it is an energy performance indicator which is a ratio between the electricity purchase and generated except excluding the generated onsite renewable energy source divided by the the built up area of the building excluding the basement parking lawns etcetera.

So, and that has to be the expressed in $kWhm^2$/year format. So, let us discuss this the small example of office building suppose I have I have an office building breakup data. This data consists of different floors, the ground first, second and third. There are four floors and there are four zones of the building.

Suppose in time of the energy audit, the auditors found that there are four zones basically and the zone wise distribution zone wise distribution in each floor are given. So, zone 1, zone 2, zone 3 and there is a service zone. So, why these 3 zones? So, we can see why it is 3 zone because there is different type of utilization.

So, we can see that the zone 1 and zone 2 there are there are some amounts of air conditioning. is not it and the zone 3 and zone service zone does not have any kind of the air conditioning. So, that is why it has bifurcated zone 1 and zone 2, but why zone 1 and zone 2 why they do not have a single zone because the and the air conditioning the footprint or the air conditioning load footprint per m^2 TR per m^2 is also not same in zone 1 and zone 2. Zone 1 is thrice with respect to the zone 2.

Maybe it required more amount of air conditioning because of some reason or other maybe it is some area where it may be the south and west facing rooms or so whereas the zone 2 may be the east facing and the west east facing and the northern facing rooms maybe or maybe because of the requirement because of the zone 1 may have more populations more occupancy because of that latent heat is more. So, basically based on that also we can we can actually devise or estimate the tonnage of refrigeration. So, anyway there is a difference between them whereas, zone 1 and zone 2 is a is having the LPD the light power density W/m^2 same 10 whereas, the zone 3 is 8 and service zone is 6.

So, based on this available these two things I have to calculate the the overall the requirement of the air conditioning electricity and the lighting electricity. This building is also having lot of other things that during the audit it has been found out it has been found out that the equipment load was found 50 kW hour per day per floor. So, there are 4 floors. So, there are 200 kW per hour is consumed by the equipment like may be computer, may be some instruments, may be some machines or something may be printer or something like that.

It has a lift. The building is having the power rating of the lift is 30 kW and it works almost about 3 hours average per day. It was also found that the in the energy audit is that a 200 litre diesel per month is required to operate a DG set for additional power that may be required for may be may be for some requirement may be additional extra requirement of sometimes there may be a power failure. Sometimes maybe there is a some one phase has been having some kind of a voltage problems or so. looking after your all the landscaping part, the pumping and all these things and the water supply to that part may be through the generator set or so.

There are 2 pumps of 15 HP which works for 2 hours for water for pumping. So, that is also another requirement or findings. There is a canteen I told you in fact, for the canteen also you require some kind of energy or power. The canteen in the building requires 20

liter LPG per day and those are the in the last line I have found out some standard to convert all the diesel, HP and the LPG to the kW hour because finally, the unit has to be in kW hour. So, let us find out.

So, what I did is that I found out the column wise addition and find out the total area of each zone. So, after finding that total area I first try to calculate the how much is the air conditioning load. So, I found out that the air conditioning is applicable for the zone 1 and zone 2. So, the zone 1 is having suppose if I take the first line. So, this 7000 is the area right and the

zone 1 has 0.03 TR per m². So, I have multiplied with 0.03. So, that means, 7000 into 0.03 is the total tonnage of refrigeration liquid for zone 1 to for air conditioned and I have multiplied with 3.5 because I know that 1 TR. is equal to 3.5 kW hour sorry not kW hour it is kW. So, I have found out finally, the how much is the kW required for the zone 1 and similarly for the zone 2.

So, in the next I have calculated for the electricity required for the lighting purpose. Now, there are 4 all the 4 the blocks or the zones including the service zone required electricity. 3 lines because the zone 1 and zone 2 have the similar requirement of the 10 LPD W/m². So, I have added the area of the zone 1 and zone 2 that is 7000 and the 3900 and I multiplied by 10 and then again divide that by 1000. So, make that in kW.

Similarly, the third zone 2700 m² is multiplied with 8. So, this has to be multiplied with 8. Here these two are added together and multiplied with 10. and that has been divided by 1000. So, I got 21.6 kW is required for the zone 2.

Similarly, 14.4 kW this is a small mistake it should not be hour its is should be kW. So, 14.4 kW is the requirement for the service zone. so basically, I have first this two slide i have calculated the energy requirement for the electricity for uh air conditioning and the and this thing that the lighting now other for five Equipment load 4 floors per floor it is 50 kW hour. So, total 200 kW hours is the electricity required for the equipment and that is per day.

This is very important. We have to see which is per day, which is per week, which is per month or so. The lift will be operated for 3 hours per day on average with a 30-kW rating. So, almost 90 kW-hours. That is also per day. Whereas the DG set requires almost about 200 liters of diesel per month to operate the diesel generator.

So, I have converted this 200 with 7.5 to make it 1 liter equal to 7.5 kWh. So, that I have taken into account. So, this is required here. To convert, it is almost 1500 kW-hours required for the DG set operation, and that is per month, that is per month. The pump is operated for 2 hours per day, and there are 2 pumps of 15 HP each.

So, first of all, the 15 HP is multiplied by 0.7457. So, this is here, and that is converted to kWs, and there are two numbers and two hours of operation. So, finally, 44.7 kW-hours, that is also per day. And the canteen requires 20 liters of petrol.

So, sorry, 20 liters of the LPG. So, the LPG conversion rate is 1 liter of LPG is 10.75 kWh. So, that is here. So, this is going to be here, and then your 215 kWh, and that is per day. So, what we have done is we have converted everything—it may be LPG, it may be

it may be diesel, it may be some horsepower or whatever—converted to kW-hours first of all, and that is now something per day and something per month. So, per day, I have down equipment, lift pump, and canteen—those are per day estimations. So, the total energy use for the service per day is 549.7—almost 550 kWh—whereas the monthly consumption is for the diesel sets, that is 1500. So, I have four figures with me now. The first two figures come from the electricity required for the AC and the lighting, and these two figures—one is per day and one is per month.

So, now in this, I will calculate that. So, I need a little more data. I need the operation data of the office—how many hours it operates, how many days per week it operates or whatever. And it is written that this office is located in Lucknow, Uttar Pradesh, which is a composite climatic zone. It is the office building. The working hours vary a little bit between Zone 1 and Zone 2, which are the air conditioning zones.

It is operated for 8 hours per day whereas, zone 3 is operating for 10 hours per day. hours daily whereas service zone is operated for 12 hours per day maybe for some extra hours for some cleaning and all these things that is one of the points. and air conditioning requirement reduces 50% during 4 winter month that is 16 weeks. So, there are winter month there is a less half requirement and the summer month or other month which is full requirement whatever we have calculated which is a full. And this particular office works as 5 days in a week and we have to calculate the or estimate this energy weekly basis and we will assume that there is 52 weeks there are 52 weeks

in a year. So, out of the 52 weeks, 16 weeks there is a little less amount of the air conditioning load and rest of the weeks is more. So, based on that we will see that what

are my requirements. So, this is the energy used for the air conditioning system. So, we have calculated the zone 1 and zone 2 as per the energy or the tier requirement.

So, already already we have discussed that one. So, now, we see that what is the total amount of energy required for the annual energy required for the operating this air conditioning. So, you see the first one. The first one we have calculated for the summer weeks. How many are the summer weeks?

Summer weeks will be total number of weeks is 52 minus 16 weeks are for designated for the winter. So, that is that means 36 weeks that is first I have to understand and the winter weeks are how much that is 16. So, those two gives me that total 52. So, the first you see the air conditioning energy for the summer weeks 735 + 136.5 here comes this 2 for these 2 different zones that is in kW right I have written down kW.

Those 2 offices 2 zones are working for 8 hours it is mentioned here zone 1 and zone hours right 5 days 5 days per week how many weeks 36 week this is the 36 because this is summer ok. So, if I multiply all if I add this to and multiply all you will get 12 lakhs 52,960 kW hour. See it is kW hour and this is annual summer only not the winter annual summer only Similarly, I can find out the winter only thing is that I have multiplied 0.5 because it reduces winter that is 50% energy demand is reduces.

So, whichever I have calculated 735 plus 136.5 has to be reduced down by 50%. I multiplied with 8 hours because winter also it will be working as 8 hours. In winter also it is 5 days per week, but in winter there are 16 weeks of operation. So, it is 2,78,880 kW. Now, if you add up, add both, it is almost like 15, 15,31,840.

So, 15,31,840 kW hour is a total energy expenditure based for because expenditure for air conditioning. Similarly, I can find out for the lighting. Lighting I have calculated for all the four zones. First two zones are similar type of lighting distribution LPD 10. So, the total again there is a small this has to be not hour it will be kW.

I will rectify this 109 for the first two zones, 21.6 for the third zone and 14.4 kW for the fourth zone, but the calculation is very straightforward. So, first zone which is 109 kW which is for the zone 1 and zone 2 see the zone 1 and zone 2 works for 8 hours. So, that is multiplied with the 8 hours. The zone 3 which is 21.6 That zone 3 works for 10 hours, so this is multiplied with 10 and zone 4, 14.4 which works for 12 hours, 14.4 for 12 hours.

So, total this per day 1260.8 multiplied by 5 multiplied by 52 because there is no change in the winter hours and the winter month or winter weeks and summer weeks. So, total is

the total energy required for the electrical energy required for the lighting is 3,27,808 kW hour. Next, we have calculated the air conditioning energy 15 lakh something, we have calculated just now the lighting energy 3 lakh something. We have services also the third port equipment lift pump and canteen which was if you just go back a little bit. So, it is 549.7 per day please remember this per day.

So, per day means per day and that 5 days per week and 52 weeks per week 52 weeks per year annual. So, it is 1 lakh something 142922 and DG set which is 1500 kW please remember that was per month. So, I multiplied with by 12 months in a year. So, it is 18000 kW hour. So, now, I add up all those add up all those means all 4 15 lakh something for the air conditioned loading requirement.

and 3 lakh something for your the lighting for the building for per year 1,42,922 is the services one part of the services and to running the DG set is 18,000. So, total 20,20,570 kW hour is the total annual energy consumption of the building through purchase or generated. Purchase generated means I am purchasing something electricity I am going to purchase. I have to purchase the LPG and sometimes I am generating through DG set or those things I am going to generate. So, but it does not consider any kind of the solar or any kind of RE renewable energy.

So, now this has to be divided by this is the whole sole amount of requirement annual requirement has divided by the built up area the total built up area all the 4 zones which has red marked calculations in the column wise if you add up it is 16000 m^2. Now things are very easy this I also calculated how much percentage is the air conditioning zone. So, that will discuss in the next lecture.

So, if I divide this number, these 20 lakhs something, by this 16,000, I will get to know about the EPI of the buildings, which is almost about 126 kWh/m^2. Per year. So, that is the Energy Performance Index of the building. So, that is 162 is the number, which means per m^2 of the building per year, that is the average energy use. It is an indicator of the building; it is a

normalized indicator of the building because I am dividing it by the total area of the building. You may not say that, 'My building is large, so I have more consumption.' No, I am finally dividing this by the m^2s, the total built-up area. But whether this 166 is a 1-star or 5-star or whatever, we will discuss in the next lecture. So, what we did here is that we discussed the Energy Performance Index; it is a measure of annual operational energy consumption by any building. EPI is obtained from the monthly electricity bill or a full-

scale energy audit. EPI is defined as a ratio of the energy consumption of the building and the built-up area.

Thank you very much.