BUILDING ENERGY SYSTEMS AND AUDITING

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Week - 06

Lecture 30

Lecture 30: Energy Audit: Case Studies

Welcome to the NPTEL course on Building Energy Systems and Auditing. This is the last lecture of module number 6. We are discussing the Life Cycle Analysis and Energy Audit. In lecture number 30, we will discuss some case studies of energy audit. So, we will see how the questionnaire survey is conducted or prepared, at least the questions and all, and how the ratings and power savings guidelines are given by the Bureau of Energy Efficiency, along with one or two case studies of the energy audit.

So, in the energy audit, one of the objectives was there quite a few years before: we should see the residential energy use and observe how different typologies, based on economic groupings like LIG, MIG, and HIG, are actually utilizing the energy. Also, we want to see what the energy expenditure is in thermal comfort systems like AC, ceiling fans, lighting, and other appliances in the residential energy sector. So, before we conducted the particular survey, it was done with some of my students—graduate students—no, sorry, not graduate, but undergraduate students in their third year. So, we conducted that particular survey. So, before the survey, we had actually fixed the objectives.

So, that is what we discussed in the last lecture: that in the pre-assessment stage, we need to discuss the objective because we have limited time, limited opportunity, and through that, how much we can get—I mean, we cannot get everything in a very elaborate way. So, first of all, we thought that we should estimate the character of the annual electricity consumption for residential households because it is very easy to get the electricity bill from them. The second objective was to see what the energy distribution is from thermal comfort, lighting, and home appliances—what I just told you—but the energy bill cannot

give you those divisions. So, we have to go to each household and ask them what their usage pattern is.

Those electrical appliances and from them with some kind of a the pre ideas we do some kind of small calculations and tentatively come down to a assessment that yes this is the bulk of amount they are going to spend for the thermal comfort and this much is for the lighting and home appliances or so. So, for the objective from the objective of the questionnaire we are first of all we have to tentatively ah the see the average monthly electricity consumptions, the the the rationals the between the electricity consumption with respect to the floor area which we have to see that ah definitely there is a we have a kind of hypothesis that a floor area increases the energy consumption is going to increase. family size if it increases it is increasing family income increases if it is increase or so. So, this three are the basic the criteria for the ah we have to we want to see that how it is changing. The second one the divisions of the electricity consumption in the following three sectors thermal, comfort, lighting and the home appliances that I just told you.

So, based on these two objectives So, we have stirred the role to play and the questionnaires and that been developed by the students and then we have start going to the house by house and see the things how it is happening. We also circulated these things in the Google the platform and we send it to the some of the people who are not in this locality, but outside also, but similar the climatic zone also and we see that how that response and from that we have analyzed that one. So, the in the component of the questionnaires are what we see the first of all the occupant and the building information said the family size and all those kind of a thing in of course, we have taken kind of the construction year of the building and the daily routine of them or whatever. So, based on that may not be very much very certainly some criteria does not have involved

But we at least want to see that the what is the economical status and the what is their day to day life the activities which should be at per normal or if there is some kind of fluctuations also. The second one we actually see the device and the occupant behavior on this three, thermal comfort, light and all those service equipment. We also see the climatic condition like what is their behavior and the energy use pattern in the time of summer, winter and the summer. a neutral month or so. And finally, we see that energy consumptions annual energy consumptions we need to see it is the daily energy consumptions, but definitely it is very hard to say because daily it is not possible ah.

So, we have a kind of a generalized idea. So, say that yes in the summer month they ah use this way in the winter month they reduce this and that like that. So, the general pattern of the questions was the name of the household, head of the household, the name of the respondent, the age of the respondent, date of interviews or so, the location of the house. that is the in the city or the it is a quarter or it is in the village areas or so or maybe it is a township. Mostly if I say it is all covered only the cities and the towns not the village areas definitely.

We have to also see the economical background of them. Mostly we went to the MIG and LIG and few of the housing of course, in the HIG categories. EWS probably we have not touched and the family size we have to seen how many peoples and the composition of the family, the occupation of the head of the household, the occupation of the other working member if any, the area of the house how much square feet or so, and the type of the house. house is rented or government quarter or whatever. And finally, the second type of data that we have asked from them that the average bill in kWh, sometimes it is a monthly bill we gave or got, sometimes it is a quarterly got suppose some of the cities or the electricity board they give the quarterly bill.

So, based on that we have estimated the electricity price of course, we need to know because that has to give by conversion. The peak the electricity bill price per kWh that need to know because that will give the conversion rate. And the peak month data that the single connection or the shared connection with somebody those the details we have to see and we actually the taken through that particular survey. So, this is the pattern of the survey. So, the same similar thing what just now we have discussed.

So, the we have just had a kind of a survey questionnaire where something has to be written and they the student has to go in a group and they have some kind of the catchment area they go there and they collect the data. So, there are some questions like the peak month data, the non-peak month data, those kinds of data, the monthly consumptions and all. So, there are other data like that what are the different type of uses of those electrical appliances like ceiling fan, air conditioner, cooler, TV, laptop. So, mostly So, they sometimes say in some hours and minute or something like that.

Even we told ask them question number 35 may be what is the hours of operation of the night lamp? How much hours you do? Some people say yes almost. hours, 7 hours or so. So, tube light, geyser everything.

So, I know that this particular answer may not be exactly the same or they use, but at least if you take maybe 500 data throughout through the household survey. So, there will be some kind of parity, some kind of parity, somebody may say little bit extra plus or minus. but that can be taken as the out layers, but there should be some kind of a parity and from that we can convert the next mathematical the calculation or the estimation system or the formulas. So, finally, what of our students got our students received the, very interesting data. So, from that I will say only 3 over here.

So, one of the groups. So, it is a kind of a group. plus, the overall kind of assessment. So, it is somewhere we say we see that yes this is obvious the HIGs are consuming more almost 531 units average per year or so monthly average of course not year. Monthly average is 531 whereas, that the EWS is 131 only.

So, it gives the hypothesis was or the kind of the what we thought is that yes the HIG population may have or definitely have more equipment run by electricity and they go for that they consume more. Even I thought sometimes this 531 is not so much I mean there may be some kind of the in their data we should look into very specifically it may be little bit more anyway. So, we also see the what is the amount of thermal comfort uses. People are still using ceiling fan; we are still using ceiling fan more with respect to the air conditioner. So, this particular analysis or the bar chart is based on the overall not only the HIG,

HIG these blocks may be look little different. So, it is actually basically summation of the all three economical categories and I told you before that we have little less percentage of the HIG, it is mostly predominant by the MYG and the LIG groups or so. This is very interesting data you see if it is said that LIG, MIG and the HIG categories in that we have seen yes from the thermal comfort kWh point of view HIG expenditure is much more 12 kind of rating it got. Whereas, the lighting is almost similar almost similar there are not so much of fluctuations. Whereas, the home appliances again there are the HIGs are more, but you see that the difference in the thermal comfort is much stiff.

With respect to the stiffness in the home appliances also. So, we may conclude that, yes, from a thermal comfort point of view, the HIG behaves a little bit more energy-consuming, but home appliances, yes, they are more, but the gap is less. So, the next one is the energy performance ratings: COP and EER. COP, we have discussed earlier, the coefficient of performance. The EER we are going to discuss today.

This COP is the coefficient of performance for any electrical appliance. It has been defined as the ratio, the kW refrigeration effect, or, in other words, how much it is going to cool or how much heat it will actually impart. So, what is the output divided by the kW energy input? The plug load: how much plug load you are taking and how much you are actually giving. So, there is a difference; there should not be the same because there are some losses in the systems themselves.

So, if these losses are encountered, then definitely the energy input is higher with respect to the energy output or the refrigeration effect. So, definitely, the COP will be a little less than 1. So, as we understand, but sometimes with the higher in the particular, it was, I think, less than 1 or so, but when it comes to some kind of efficient systems, the amount of generation of the effect of the kW effect, and the energy input is now reversed, and the COP is now greater than 1.

So, that does not mean that we are actually multiplying the energy in a particular machine or so; it is not like that. It is the efficiency of the system that determines how it will generate the cooling power. So, from that point, because there are two different action areas—I mean the potential areas of different benchmarking—they have been defined. The energy efficiency ratio, by virtue of its original definition, is given as BTUHU, which is British thermal unit per hour refrigeration effect divided by the watt energy input. So, as the BTU is equal to 1058 joules, and 1 BTU per hour is 0.293 watts.

So, we may say that the coefficient of performance is equal to 0.293 EER, the energy efficiency ratio. So, let us see in this particular scenario how this energy efficiency ratio is actually applied in different appliances. This particular sticker is made or has been provided by the Bureau of Energy Efficiency, Government of India. It has to be placed on every electrical appliance—it may be a washing machine, an air conditioner, or some kind of ceiling fan. So, it must inform the consumer about the power-saving guidelines, and based on that, they will provide the star rating for that particular appliance.

So, first of all, the brand names and all these details must be mentioned here in the first three lines: the appliance type, the brand, model, and year. Then the energy efficiency parameter EER has to be written in watt per watt format. See why watt per watt format? Because by definition, it is BTU per hour divided by the watt, but here in the BEE, it has been changed to a watt per watt unit. When it is higher, it is definitely better because the cooling effect will be high compared to the input energy. Input, not energy input—the power. So, it is actually based on the power rating system, not the energy. There may be

some loss of energy, but from a power perspective—per minute or per second—it shows how much cooling effect it will provide.

So, that benchmark is provided here. So, that is why it is more than 1 and a number is higher. So, it is always going to be beneficial. Then the the level period. So, level period is also going to mention over here.

So, it is written here it is first January 2016 to 31st December 2017. So, it may change it may level ah next after down January ah 2017 they may give you some other ah the level because they may Standardize the thing in a different way ah now in case of the new levels ah we can define this 5 star in different ah benchmark. The energy ratings there are 5 bench stars and there are some unique codes and the applicable conditions are also mentioned that as usual it has been provided in the in the sticker is provided in all the home appliances or so. So, let us do a particular small problem.

So, let us see a energy efficient ratio is mentioned as 6.7, it has to be higher in order. So, that will give you better one. So, and it is a cooling rate is rating is 4000 watts. So, the I can find out the the COP by multiplying that EER by with the 0.293

So, then the COP is 1.9631 or whatever. So, with that formula I can find out that how much is the the total average input and if this particular the the the particular unit is work for 2 hours, I have mentioned over here it is 2 hours it is 2 hours where it is where it is gone ok. So, it is 2 hours. So, this is your COP, COP is your 1.9631 and this is your refrigeration effect, why? Cooling rating is 4000.

So, I can directly find out the how much is this kW input. So, this is my input, this is my plug load that much watt. And that is working for 2 hours. So, this much watt hour, so 4.075 kWh. So, this way you can calculate, but now in India we came with a different rating system.

We call this is ISEER. What is ISEER? What is IS? IS is the Indian Seasonal What is EER?

EER is the energy efficiency ratio, almost the same ratio. There is a bit of calculation difference when I am going to give somebody as EER or ISEER. There is only a calculation difference; it is seasonal. So, the first one is straightforward if normal, and the second one It has to be computed by one season, and there are variations of the temperature in the different seasons of India. From that point of view, they calculated. So, there is again a ratio: one is CSTL, the cooling seasonal total load divided by CSEC,

sorry, cooling seasonal energy consumption. It is very similar. It is the energy expenditure or the total load expenditure divided by the consumption. What we have discussed earlier is that maybe here it is a refrigeration effect and the energy input. Very similar here also, this is very similar. It is a total load, that is the refrigeration effect or total load divided by the consumption.

So, you should not confuse with the cooling seasonal load. It is actually going to have some kind of benchmarking of the wattage of the output and the plug load, but it is not a constant one. It has some divisions for the different months or so. You have to compute that one, and then we have to keep the ISEER rating. So, I am not going to go into that complexity of how to read and how to give that particular rating on R. So, let us discuss that one in a different way. So, they are benchmarking. If the ratings are 3.1 to 3.29, it is 1 star, and if it is 4.5 and above, it is 5 stars. So, based on that, they will give the different types of ratings. So, let us discuss one of the problems which came in last year's GATE examination.

A two-tonnage of refrigeration window air conditioner of energy efficiency ratio (EER) is 3.1. I am assuming that as an ISEER, and I am assuming that as it is watt per watt. It is scattering to a room of volume 40m³, OK. In the 40m³ of the room, I am installing this particular 3.1 EER. So, 3.1 is written over here. Suppose this is 4.2.

So, in that one is 3.1 ok. So, it is 3.1 over there. So, let me erase this one. So, it is the 3.1 over there. That is for the 40 meter cube of the room the air conditioner is operational for 600 hours during the summer on cooling mode.

So, ok, it gives you some kind of a cooling. The compressor is also operating for the complete duration. I am just coming little later to this and then the total energy consumption of the air conditioner during the above mentioned period in kWh I have to find out. So, that means, I have two things I have that rated capacity is 2 tonnages of refrigeration. So, I have to use this equation which is equivalent to ISE or I am assuming that and it is what per what kind of scenario.

So, the refrigeration effect is 2 tonnage of refrigeration which has promised me that I am going to give you 2 tonnages of refrigeration. The 2 tonnage of refrigeration is almost about 703 32 7032 watts because the 1 tonnage of refrigeration is almost about 3.516 kW. So, that means, if a particular air conditioner will give me a 2 tonnage of refrigeration with the EER of 3.1 what is going to happen let us see. So, the cooling effect will be around 72 7032 watts. and my EER is 3.1.

So, the energy input must be 2268.4 watt ok. So, that will be the energy input. So, to run that particular the 2 tonnages of refrigeration of the air conditioning unit, I have to actually the plug load is my 2268.4 watt. and that will run for 600 hours in my summer. So, I have to multiply that one.

So, if I multiply, I got this big value as is kWh and then 1, 2, 3. So, it is 1361 kWh, but you see exactly the power requirement will be not. So, it will be less than that much less than that because It will not going to consume the electricity for whole 600 hours. So, there is a compressor which actually going to work.

As and when compressor is going to work inside the air conditioner unit, you require power and it will be maybe for half an hour it will work and then again 10 minutes it will not going to work. And nowadays we have some kind of the the the flexicompressor kind of a system then actually we cannot actually directly do so simply we cannot calculate that energy consumption. It is actually depend upon the some sensor and then it will cool and it will depend upon the how people will go and use it and then sometimes I may reduce the set point temperature or so the compression will stop. So, it is mentioned in that particular because it is a gate problem gate examination problem. So, it has to be understood there should not be any ambiguity.

So, it is mentioned that the compression is also operational for the complete duration. It is a very important sentence that has been mentioned over here. The total power consumption out of the 600 hours depends on how many hours the compressor is working. It may be 450 hours; I do not know. So, I have to multiply by 450 then.

And it is never going to be that the compression works for all 600 hours. So, just to remove this ambiguity, they have mentioned that the compression is working for the same period of time. So, that is why I said here that this 1361 kWh is a straightforward answer, but usually, the consumption will be much less. So, we did an audit last year for a small bank, an energy audit conducted in a bank as part of a workshop. We also conducted some small interviews; this was done by a few of the students, not the whole batch. So, it was in Midnapur town of East Bengal, which is our district headquarters next to our city.

The audit period was 3 days in March and April of this year, 2024. This type of audit is level 1, of course, and the parameters needed to be obtained from the audit were— See, that is why we need to initially determine the level of audit because if it is a level 1 audit, we need 3-4 days, even for a very small bank with almost 30 people working there. And

we needed these 4 data points: the monthly electricity bill, the number of electrical fixtures, the power rating of the electrical fixtures—of course, I must tell you that— So, all the power output or rating of the fixtures was not available; they do not have all the catalogs of their purchases. We sometimes had to assume, for example, that this might be something like that. We conducted general interviews to understand the electrical fixtures' running time during various seasons.

first of all this there have suppose there have 8 rooms and there are 2 zones in the bank for the people for queuing areas and the waiting areas lobbies kind of a thing and those TR has been calculated the I S W E R is also noted down which is more or less was obtained from the brand name and that particular ah the categories or so number of course, we know. So, we have calculated the how much kWh and all those kinds of a thing. You also note down the how many ceiling fans was there are yes there are some kinds of ceiling fan also there ah they usually go for the mixed mode type of cooling. The number of ceiling fan and kW everything has been mentioned.

So, the total power of the air conditioner was almost like 44.84 kW and the fan was almost about 1.28 kW not much. Similarly, they have student have also ah the listed down the ah number of ah fluorescent ah lamp ah CFL and the LEDs mostly CF ah the fluorescent lamp few LEDs and the CFLs mostly fluorescent lamp of course, and the total power rating of the electrical systems was 2.66 And we also note down the how many computers are there, there are many and the total rating is almost 6.8. So, based on this we calculated that particular the energy consumptions, what options by virtue of the interview we got to know that they have a kind of a Usually, the similar sort of operational period for the air conditioner, we split that into three types of operational character based on the three types of the temperature variations of the yearly variations.

Summer month, six summer month, two the spring and autumn months of February, March, October and November and two winter months here in January and December. And, we have assumed that it is 24 days in a month they work in that particular bank and the working hours varies as per the electrical. So, you see the summer they use 8 hours in the spring time they use 6 hours almost winter also they use 4 hours air conditioner. So, we get to know this by virtue of some the interviews with some of the people over there.

And also, in the last line, you see we assume that 75% of the total estimated time the compression will be operational, and less than 25% will not be. So, based on that, we got some of the values. We calculated energy values and created some small charts, which

we presented. These show that the AC consumes much more, while the fan, computer, and lights consume less. So, we came to know and provided some suggestions. We highlighted that the energy expenditure on air conditioning is too high, and they also understood that. Even the energy expenditure of the computer could be reduced because many are old.

So, we have recommended replacing around 30% of the air conditioners, as they are more than 10 years old. So, replacement is required. We also suggested installing a rooftop VRB, as they have a 44 kW requirement. So, they may reduce the requirement while maintaining the same cooling effect. Energy leakage through the windows was found because they had all-metal MS frames. So, we advised them that it would be better to switch to aluminum-frame windows.

So, that is all for this lecture on this particular module. So, we have understood the energy audit requirements at various levels, the appliances, the ratings, savings, efficiency, and the criteria taken care of by the BE. Through EER and ISEER, we have discussed some energy audit case studies. Thank you very much.