

BUILDING ENERGY SYSTEMS AND AUDITING

Dr. Shankar Pratim Bhattacharya

Department of Architecture and Regional Planning

IIT Kharagpur

Week - 06

Lecture 29

Lecture 29 : Introduction to Energy Audit

Welcome to the NPTEL course on Building Energy Systems and Auditing. In the sixth module, we will discuss life cycle analysis and energy audits. In Lecture 29, we will begin the energy audit. In the energy audit, we will see the types of audits and some measurement criteria for the audit. So, we will see that.

First, let's look at the definition of an energy audit. It is very much required in today's world to audit buildings from an energy perspective. Because it will give us an idea of how much energy is being used in a particular building, and if there is a benchmark, we can see if the building is consuming more energy or is at par with the benchmark. From that point of view, we can decide whether energy management is required for the particular building. In the second stage, we can see that if I implement energy management or retrofitting for energy utilization, what should be my capital cost and how quickly I will recover that cost.

If I look at the stages of the energy audit and assessment, it has three stages. A pre-assessment stage, the assessment stage, and the post-assessment stage. In the pre-assessment stage, we examine the building in a very overall way. We can see the different functions of the building, the different areas that require energy, the monthly energy bill, the age of the building, and we can set some kind of performance benchmark or target.

And, we can also do some kind of the assessment and through some kind of the committees where we can create a small group or maybe a two layer subgroup the of the committees or so. So, those are the initial process of that audit which includes the as a pre assessment stage or so. As a whole it is look like a very easy stage or the easy step very early stage or so, but it has a long term impact. If I do not take the target appropriately

with the age of the building and the amount of cost I can involve or invest in the retrofitting or so. So, there is no use of the next stage assessment stage or the pre or post assessment stage or so.

So, initially this germination stage of the pre we can say it is a very first stage of the germination. So, you have to very much cautious about our in the what is our target, what is our actual, what is I am going to look into? Should I look into only the HVAC systems? Or should I look into the only a particular area where I may feel that that particular laboratory or that particular some kind of the operation theater for a hospital or maybe some kind of the IT office some segment of the IT office is taking care of much higher energies or so. So, target oriented the target oriented strategies have to be taken in the this pre assessment stage.

Let us go forward. to the assessment stage. This is the main the part of the assessment stage where we will be going to assess the whole building from the energy conservation and the energy utilization point of view that is a the straightforward the definition of the assessment stage also. But again, it is not so straightforward we may have three levels of assessment. First level is called the primary energy use through the walk through analysis also we have a detailed on that.

The second is the energy analysis part, and the third is the detail of the capital investment measurement also. So, let us go to the next slide and discuss the post-assessment, and then again come back to this assessment stage and go one by one through those three levels. In the post-assessment stage, suppose we did the assessment stage, any one of the layers, any one of the levels. Other levels are defined by the pre-assessment, that I am going to have a look into, only the walk-through and normal kind of the audit, or I have to investigate very thoroughly in that. So, I have to go for the third level of assessment also.

Whatever may be the level of assessment, we need to have a post-assessment also. I have written down the four points over here. How are these particular strategies implemented? So, you have to come back after maybe 6 months or maybe after 1 year to see what the change is—noticeable change or what we thought that is not coming up, maybe only 30, 40% is coming up, not the full 100%. So, where is the gap?

We have to see the operation and the management guidelines also. So, suppose we retrofit with some kind of a system, but the workers and the staff are not very much aware of the maintenance of the system also. So, definitely that will not give any benefit

or may not give the effective benefit out—we cannot get the effective benefit out of it. Whatever be our stages of the level of the assessment, based on that, we need to have post-assessment criteria, and then again, we have to look back, and then again, we have to maybe sometimes rectify that one. Now, let us go to those levels of energy audit.

So, we have just now discussed that level one is called the walkthrough audit. Let us go to the three levels of the energy audit. The first level is called the walkthrough audit. The second level is called energy survey analysis. So, definitely we need to do some kind of survey and also analysis work. This is the very preliminary stage of the analysis, but sometimes we do that. We will have a small briefing of that in the next lecture. The walkthrough audit in this particular module itself will be covered.

The level 3 is the detailed survey analysis. So, you can ask what is the difference between the energy survey analysis and the detailed survey analysis. So, we will come to that. So, in between the walkthrough audit and the energy survey analysis, we can sometimes say target energy audit. So, target energy audit is that it may be a walkthrough, but

Some of the strategic areas or the targets I may have—I may only look into the HVAC systems, nothing else, or sometimes I may only look into the heat gain from the outside by changing the windows, the glasses, and all those kinds of things. So, a particular target-oriented kind of analysis or audit we can go for. In that case, it is a walkthrough plus a particular type of energy survey analysis. Now, again, the point we are discussing is why level 2 is energy survey and the second one is the detailed survey. What is the difference between them?

Yeah, detailed survey analysis actually going to produce the investment grade audit. That means, in the energy survey analysis we will just stop that yes this is the your performance of the building and you can perform well if you do this if you do that or if you do these 3 4 points or whatever this choice up to is up to you, but if I now go for the detailed one. Then I have to go with some kind of simulations and then I have to represent that work with some kind of a scenario generations and all and I can say if you take these options, it will be your benefit, if you take the second options it will be further benefit or whatever that we have to detail out. So, definitely the level 3 analysis is much more tedious, much more elaborate and of course, required much more manpower and the money to execute that one. In the work through analysis the there are certain points we have let us discuss the level 1 analysis we will have to actually go for the energy efficiency measure EEM.

So, it is a roughly it is rough order of the magnitude because we do not want to invest that much amount of time and the manpower in it. So, we can actually include the summary of utility data. that what does it mean that the utility services the electrical services or the illuminations and the machines or the HVAC systems data. So, you can generate that how much power consumptions and how much daily running operation time those utility data for each and everything we can collect. We can maybe collect like the most the preferable way to collect those data is the monthly electricity bill of a company or maybe a building or so that is all I mean that will give you some kind of idea that yes this particular building is generating the requiring this much of energy.

We also can sometimes estimate the saving associated with this rate of change the some of the energy calculation index benchmarking and targeting. So, that may be come under some kind of the secondary kind of the analysis in in connections with the level 1 walkthrough analysis also. So, we can say for a small building suppose a small guest house. Maybe a small office building, maybe a very small institute school buildings, a residential tower or something like that small that tower maybe again we can define the tower is a big building category or the small building category.

I am talking about the walkable kind of the tower or the mid-rise kind of a building or so. So, those can become under that. And, I must say that those small buildings should be actually they should go for the level 1, because very detailed analysis because the consumption of the energy in the small buildings are less. So, why should they go for the detailed analysis or the level 2 analysis or so. Next, in that particular audit we can actually give some kind of the solutions that some repair of the the broken glass in the window, the lowering the preset temperature of HV system.

HVAC systems may have some some some kind of issues. So, running issues, they can ah take some default kind of a values or the set point temperature also. So, we can actually see and prescribe that you can change also. So, we are not going to say that we change the whole HVAC systems also, but we can say some of the the conditional time changes or maybe some kind of a set point temperature changes those can be the the outcome of the walkthrough. The adjusting the boiler and air foil unit or those kinds of a things we can actually say.

The level 2 survey that is the energy survey and analysis will take some kind of the detailed and the proficiency in creating the quality of the audit. So, it will little bit up. So, we can now one on each point has to be detailed way we have to investigate we may have

to survey for couple of days or maybe one or two weeks. And also, we have to interact with the people, we have to take some of the opinion of the people, we have to discuss with them, we may have a survey format and from that we can actually go some of the selected people and then we can actually talk to them and take and fill the survey form. So, in that particular survey on this particular analysis the we have to look into the inventory

the inventory, equipment inventory, the energy balance criteria, energy balance is that how much actually the input energy is coming from the plug load and what is the output. So, what is the total efficiency of the building the equipment or so. So, those has to be checked a proper way. I may not say that you have to check the whole lot of the instruments or so, but at least some sample of the instruments and the systems instrument can be actually checked. So, this will actually lead to a little bit of the other detailed understanding of the how the energy is being used in that particular scenario.

So, we also need some kind of we have to give some kind of solutions after this particular survey. So, we have to give some kind of a financial analysis also at the end of the survey. And a rough estimate of the how the project capital cost or so. So, maybe an auditor or group of auditors who has vast experience on this particular area, they can actually give some kind of a genuine suggestions, options and also and then from that the client can take any one of them. And, they may also give some kinds of the hint that what should be the capital cost involvement of that and what will be the at the end what will be the savings from this particular the investment.

So, level 2 audit is most likely to be the use for the large building. So, large building I may say that it is a large building maybe it is a it is a it is a building which is higher floor areas or in the complexity higher floor area, but it may not should not have the complexity of the functionality ok. So, it maybe it may be office building of a large area, it may be IT building of a large area, it may be hospital of a large area, but it main should not have that operational and the functional complexity. That means, it should not have some kind of the advanced equipment in it or maybe some kind of the suppose I may mean to say if it is a kind of the industrial unit or so or maybe some kind of.

or that kind of a building which actually have different kind of complexity. So, from that point of view because other buildings suppose it is a large office building or a large hospital, a large the IT building. Similar kind of the work culture or maybe the footprint and also the footfall and also the occupancy, it will be more or less same throughout the

year or so. But the industry has different type of equipment or so, the airport has different type of footfall, different type of systems and that has created that may create some kind of the it if you say it is the railway stations or maybe a kind of the the the the the traffic in interchange stations or so, it is difficult it may not be this second level of survey will serve you. well interaction between the outdoor and the indoor the conditions are so.

So, from that point of view the complexity may arise in the large or small building then we have to shift it to the level 3. So, in the level 3 we have to see the checking of utility services, the analysis of the peak demand, when is the peak demand major. So, whatever we are actually going to checking and all probably it will be remains constant in the in a in a particular season. Suppose in the the winter season is some peak demand and whatever and the summer seasons the demand may increase the peak may increase, but there is a systematic way of the changes also. Where in the complex building it may not be the same, it may in the same period of the time maybe the weekend there is a different scenario in the weekdays there may be a different scenario or maybe it is because of some kind of interaction with the outside inside there may be some kind of scenario changes also.

So, in the level 3 of the detail analysis is more expensive capital projects. So, where my capital investment or the project is very large on the capital investment point of view, if I can actually use any this detailed method and saving a very small amount of 10 percentage of the energy also. That is a great saving for me because it is a huge capital investment. So, in that We trained to put into logs that are data loggers and all.

So, a constant monitoring is required. Sometimes it happened to be it is a year long auditing. year long auditing for the buildings also. So, it is a constant monitoring is required, we actually go for some kind of a sensors and all. So, that data will be actually generated and at the other end some kind of the transmissions has to be taken place transmission in the sense of some kind of action has to be taken place.

So, so this is a one of the very extensive types of the survey. So, perhaps now you understand what is the difference between the normal level 2 and the level 3 survey. In the level 3 survey we need the hourly simulations In fact, we need to know the peak demand if there is any kind of a peak in a some hours, we need to know the what is happening half an hour before and half an hour after that, what is the set point temperature, how the steady state temperature is coming or maintaining in a particular

building, how long it is required, whereas the personalized ventilation will going to help it or not.

So, those are the some of the decisions we have to take. And finally, this audit will lead to the investment criteria, the investment grade audits it is called IGA and it is typically done for the buildings which high capital investment and also building with the high complexity. So, in detail survey also we should look into the life cycle cost LCC, what is the total life cycle cost, energy life cycle cost of the building. If I invest some more, so is there is any benefit, so what will be my payback period and all these things are has to be taken care of. We have to actually see lot of the economical parameters in it in the interest rate, inflations and tax rates also.

So, mostly the auditors have a huge team where some of the accounts the people will be there, there are some kinds of the engineers will be there and maybe some kind of the auditors who have this kind of the experience and all will be there to do this kind of a general survey. The other one the level 2 one it can be done by some trained people for maybe you can take them for one week training or one and half week training and then you can they can actually do that, but here you need a very expert people to actually do the detailed survey and analysis. So, next let us go to the the energy audit measurements. So, sometimes we measure something in the walk through may not be the walk through, but the next level or so, if I want to have a target oriented kind of a audit. So, we can go for some kind of

the energy audit measurement. So, in that measurement the SP 41 code talks about the U max, the maximum U value, thermal performance index, thermal time constant, thermal damping or so. So, those are the typical values that they have prescribed for the hot and humid climate and the warm and humid climate. So, if the thermal damping has to be taken into account, so we have to actually find out the T_o and the T_i . So, that is the outside and the inside temperature. of a wall or of a ceiling.

So, you just go and in the top of the roof and see the what is the top temperature outside top and also the ceiling soffit temperature or so, then I can measure how much damping is possible is happening. So, similarly we can actually see the thermal performance index the TPI, we have actually talked about that in the earlier lecture probably. In the TPI has two types, one is for the non air conditioned building which is defined as the TIS minus 30 into 100 by 8, where TIS is the peak inside surface temperature. So, in a particular space in a room there may be 6 surfaces ok. In the 6 surfaces we take the temperature and

the peak temperature we can take out of those 6 temperatures and deduct that from that we can deduct 30 and then these equations.

Thermal Damping

$$\text{Thermal Damping} = \left(\frac{T_o - T_i}{T_o} \right) \times 100\%$$

T_o & T_i = Outside & Inside Temperature Range in °C

But for the air conditioning room we have to actually find out the q is. that is the peak inside heat gain watt per meter square. So, that can be easily done if I know the U value of the material and if I know the outside and the inside temperature, I can find out that. So, I have taken example of a building where we have found out the temperature for outside temperature, wall temperature and the roof temperature for 24 hours. have taken a building where we have taken the outside temperature and the inside temperature.

In the inside temperature we have taken the wall temperature and the roof temperature and for 24 hours and we see that 38° at around 12, 14 hours is the highest in the outdoor, but the indoor surface temperature of 28 and 32 for wall and roof respectively. From that we can actually generate some graph that we know that is a kind of a time lag or so, but we can find out the thermal damping of the wall and the roof. Because, outside temperature is 38 for both, but the inside temperature is 28 and 32 of wall and roof. So, finally, it come down to 26% damping for the wall and 15% damping for the roof, but we have to actually match with this particular SP 41 table the where it has told that D minimum D is the damping sorry.

So, D minimum for suppose it is a hot and red is should be 75 and 60% also. So, definitely this is your data it is not going to be the very good data I must say. Similarly, we can find out the thermal performance index. So, here the thermal performance index is 32 minus 30 because the top temperature the inside surface temperature highest inside surface temperature is 32° at roof. So, it is 25 let us see with the code 25 thermal performance index, but TPI is should be something like that 100, 125 or something like that.

Also, if I know the U-values of the wall and the roof, and then if I know the indoor temperature, and so on. So, I can find out the QIS of the wall and roof, what is the total QIS, and then from there I can find out the TPI for the room for the air-conditioned case. So, here it is going to come to be 73, which is also not very promising. So, we have done an energy audit of a case study of a small house, which is on the ground floor. So, this was a residential building on the ground floor with 2 rooms.

It is a naturally ventilated building; it does not have any air conditioning. The south and east walls are exposed to the outside; the roof is not exposed. The wall thickness is traditional brickwork with 15 mm plaster. It was in Kharagpur, near our institute, not inside our campus but outside. There are two occupancies, and we took the data on the 25th and 27th of May, 2023. The target measurement was to measure the thermal damping. TPI for a non-air-conditioned kind of scenario.

So, we have taken hourly data from morning 9 to night 11, not the whole day, of course. The first row gives the outdoor temperature, then the indoor ambient temperature. TSI is the highest surface temperature of the indoor surface, of course. The relative humidity is also measured, then with that formula, the thermal damping and the TPI are measured. So, the red boxes are shown as it is not functioning very well. So, the amount of damping of the wall or roof, whichever may be the highest, is not good, and also, of course, the roof is not taken care of because the roof is not exposed here. So, only the two walls have been taken care of.

So, even though the thermal damping is around 14% or so, which is not good enough to say the TPI is also better in that sense. Sometimes, the maximum TPI can reach almost 100, 110, 120, or even 150. So, it may be said that it performs better from the thermal performance index point of view, but not from the damping point of view. So, in this particular lecture, we have come across the three levels of the audit, which are very important to understand in the assessment process. We have also discussed some of the measurement techniques, particularly in the very first stage of the energy audit. Thank you very much.