Principles and Applications of Building Science
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Lecture – 12
Energy Efficiency and Simulation

In the previous modules we have been talking more about the climate responsive building, building envelopes, we talked about the heat transfer, we talked about thermal comfort, and we also talked about thermal adaptation, design of shading system, properties of glazing systems. Now we will take a look at energy efficiency, then we touch upon what building simulation is all about.

As a part of this particular course I may not be able to exhaustively gives you hands on tutorial on simulations, but I will introduce you to the concept of energy efficiency and how do we compute energy efficiency and simulate; what is the basic concept behind building simulation, what are the various tools available, where to apply and how to apply. You will be getting a basic idea about these things.

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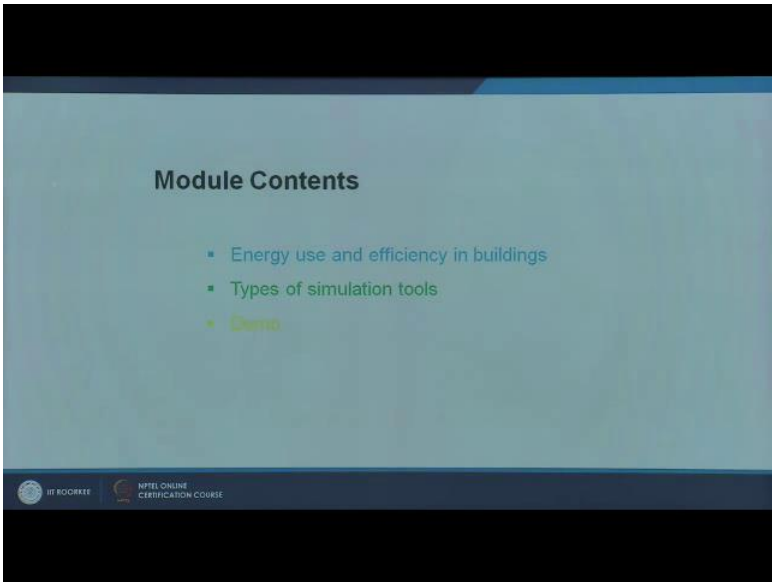

Primarily I will be covering energy use and energy efficiency in buildings, type of simulation tools and I will be giving you demonstration of one of the leading energy simulation tools. We will be looking at it the quick demonstration provided. Before getting in to energy and energy simulation we use energy primarily for comfort

conditioning, that is first thing it can be the use of fans or it can be the use of air conditioners or heaters depends on the climate and the indoor requirements of indoor conditions thermal conditions. So, first is for comfort conditioning then for appliances. So, typically when you will look at the energy load in building we talk about appliance load or connected loads; it can be from your laptop, computers to household kitchen equipment like, ovens and microwaves or refrigerators.

So, two major things go in; one is appliance, load second is a comfort conditioning load. As a climate and climate responsive designers we are more interested in the comfort conditioning part of it, how much really we are spending energy to condition the whole building to be thermally comfortable. As I said we have been talking about thermal comfort, but there is a threshold beyond which the building cannot offer much say, we saw some climate example where even with all passive strategies put in place 20 to 30 percent of the occupied hours you will need conditioning even a best possible design would need some more, at least minimum use of the fan ceiling fans.

In these cases we have to really look at where to start optimizing, is there further any optimization method. One goes with directly the efficiency of the system itself say when you buy an air conditioner what is the EERN you know efficiency ratio of the system itself whether it is three star rated whether it is five star rated and what is the efficiency it has to offer. It is like how much power it is taking and how much amount of cooling energy it is producing, same with the heaters as well. Then as a designer we are concerned about how do we make our building envelop itself; do we need insulated, do we need to provide more thermally sealed envelopes or do we have to enhance ventilation in some cases what is that we need to do.

Now let us look at the context of simulation. There are lot of benchmarks now even benchmarks are being developed say for commercial buildings for example, there are standard benchmark available different standards provide different benchmarks, different building typology say for a 24 hour operated building versus 8 hour operational building. Like for example, bureau of energy efficiency provides a interesting case of baseline for health care building, say if you want to find out what is the efficiency you need to provide for an hospital building you can choose the number of beds. There are certain criteria you can look online based on that it says this is the baseline criteria and how do you improve it. Likewise, for residential building it is a very challenging thing to define

baselines for residential building energy, performance baselines there are lots of research and projects going around evolving certain baselines for this.

Coming to the simulation part of it; simulation is primarily mimicking the actual performance of building so that you can derive quick and cost effective solutions, rather than doing a field test and trial and pilot monitoring. Before all that you minimize your effort instead of doing 10 different tests you do the whole thing in your system virtually model it let it behave the same way or at least closely mimic what the actual building is doing. Then test all the options here chose two or three tested in field and then take the right one.

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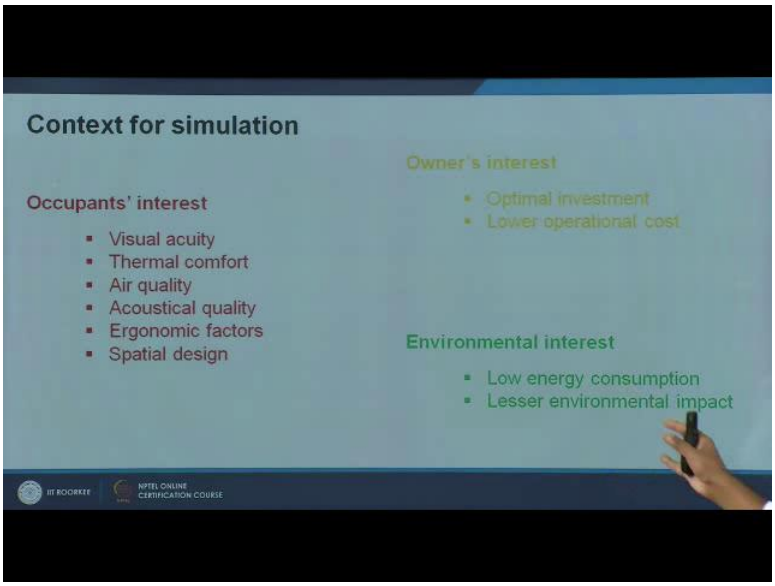

So, what is the context for simulation? You can do simulations for three different parties; first let us say occupants' interest as a building occupant you will need a good visual comfort; visual activity is needed, you need thermal comfort, you need a good air quality, you need acoustical quality, ergonomic factors are there, spatial design factors are there. Out of all these primarily we do simulations for visual performance, we can do day light or artificial lighting simulation, you do simulation for thermal comfort, yes air quality also simulations are done, acoustical quality lot of simulations are done.

Then next perspective is owner's interest, say if you are simulation consultant you are working for a building's owner, the owner will be interested in an optimum investment versus lower operational cost. So, the result of your simulation will vary or the way you

have to present your result will vary. What kind of results you have to look for? For example, building owner may not be really interested to know what is the actual temperature and its variations and the space, he will be interested in what is the system you are asking me to buy, what is the investment I have to make and what is the minimization or reduction and operational cost and what is my payback period, will be more commercial for a building's owner.

Whereas, if you are trying to specify or trying to convince the building standard or building occupant you will have to talk in terms of this will improve your visual comfort this will improve your thermal comfort this will also have to talk about energy efficiency. Of course, it is not exclusive, but the primary thing would be about comfort inside the building. Owners interest yes of course owners are interested in comfort, but the primary interest is what else is needed. We have done this now I have to invest this much and this many years I will be getting the payback.

Then the primary area today where lots of simulations are happening is for these environmental things, where we have to prove energy efficiency. You take any code like (Refer Time: 06:53) lead any international code as well ECBC, any complaints is you want to say you want to prove the building is efficient by say 20 percent 30 percent relating to the baseline building. So, I really have a base case or you generate a base case, you put your building now compare this with the base case, try to prove that this is 20 percent efficient 30 percent efficient. You talk more about energy efficiency and partly about comfort as well.

Then there are also simulations which are done for environmental impact like CO 2 emissions. You can simulate what is the overall life cycle energy, life cycle assessment is separate then life cycle energy can be totally estimated, tools are getting more and more capabilities. Earlier tools with just had simple comfort simulations, now have energy as a dimension. Apart from energy they also predict the CO 2 emissions; you can enter input lot of values with which you will be also able to predict environmental impact. And they also have a cost dimension where you can do the cost benefit assessment can also be done. Before getting hands on with the simulation you should understand the context and the party for which you are simulating.

The process remains the same; there is no change in the methodology. The kind of input output remains the same, but the way you express it and what you derive out of the results that is considerably going to vary depending on who you do the work for.

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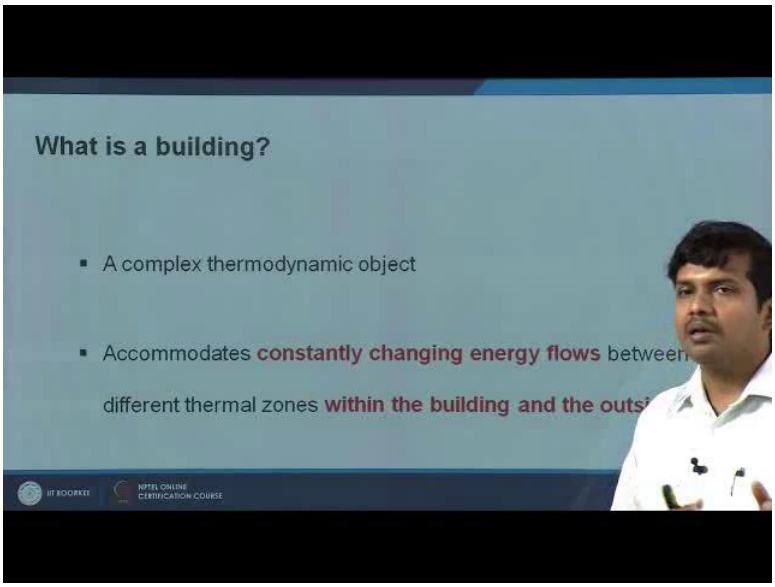

As for building simulation, building means it is a thermodynamic object. Heat exchanges are happening. Movement you put a window there is a heat exchange which is happening, from the opaque wall you are taking 10 percent and you are calling this as a transparent or translucent fenestration, then the heat exchanges are going to vary. Apart from the window then you are providing a frame, you are changing certain things, you are providing shading to the window to thermo dynamic balance is considerably getting affected.

Essentially you are changing an equation you have to look at the whole building as a long stretch of equation with which any single modification is going to change a variable in the equation. It accommodates a constantly changing set of energy flows between different thermal zones, when you say thermal zone each room or each space in a building be refer to as thermal zones as I said it is a thermo dynamic object each room means a zone which is a thermal zone. There are two types; thermal as well as non-thermal zones. Say if you are defining a specific shading system or something like that it does not have to be a zone by itself. We will look at some of these things in the demonstrations.

There will be a constant set of changing energy flows. It is not static you are talking about dynamic every minute every hour there is going to be change in external condition change in internal condition and the gradient of heat flow is also going to vary.

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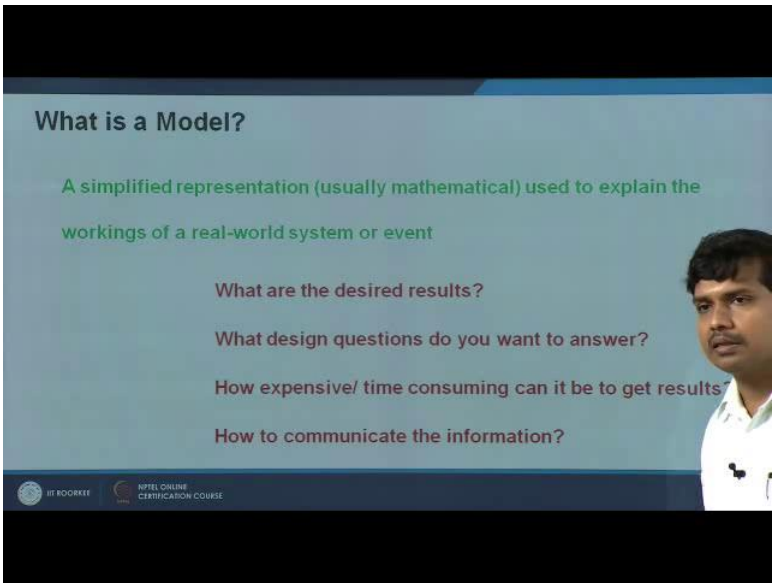

What is a model? As I said it is a simplified representation of a mathematical expression, it is representing a real world system or an event. As I said we have to keep in mind 4 important things. What are the desired results? Are we looking for comfort, are we looking for detailed assessment of air flow or are we looking for energy estimate or are we interested in the costing. So, what are our primary results which are essential? Then what design questions we want to answer? It can be lot of what if questions; what if there are shading, what if there is insulated glass, what if the wall is insulated. So, there is lots of what if question's you can answer using simulations.

But specific to the question your choice of simulation tool will vary and the type of analysis you do with the same tool itself can vary. Now tools are capable of various different aspects, they are in module. So, if you want to use, say for example you want to find out what is the efficiency of the window in terms of ventilation the tool choice itself can be different and the type of analysis you do with the tool it will be different and the presentations of the results will be different.

How expensive and time consuming can it get? This is a crucial question especially if you are in the field if somebody asks you for a quick energy estimate versus a detailed

energy simulation results, whether you want a calibrated simulations or you just need a validated simulations or you do not even need to validate it. As I said there are 3 steps here; first is a very rough way of estimate of energy. If somebody is asking I have a thousand square foot building, single storey building there is a large space office space I need to find out what is the efficiency of a particular system insulating it not insulating it. So, you do not have much estimate you just know the climate location, you know the space and the type of occupancy. With that you can derive a very rough estimate, but it will not be any closer to the actual performance data, but still it is an apple to apple comparison you have the base case you have the predicted case more or less you can say there is 5 percent efficiency 10 percent efficiency.

The next level is a validated simulation. You will need an actual number of same building or a similar building type then you can say the predictions are more or less valid. If the actual number is 1000 I am getting somewhere between 900 to 1100, so there is a little bit of say 10 percent variation in the prediction accuracy. You are kind of validating the trend summer to winter to monsoon how the trend in energy consumption are comfort or temperatures vary, so validated simulations.

The third is calibrated simulations, where you have an actual building this is running, you are trying to help the facility manager to improve the efficiency of the building, you are getting real time data continuously it is getting feed fed in to the system, now you run the simulation, you kind of tune the simulation tool to predict as closely as possible the actual results. This is a process called calibration. So, you are calibrating the whole model to predict as closely as possible to the actual system. Then you alter various possibilities; it can be building insulation, it can be changing of operation procedures anything like that addition introduction, deletion of certain features, then you find out what is the impact of it.

The last thing how to communicate the information? Lot of people does simulation; there are lots of software tools and each tool also customize and give you a report. If you say print report, any leading tool you take you can finally after simulating you can say print a report it will customize and give you a standard format template in which all the results are sequentially presented. But is that exhaustive thing what we need or we just need one or two aspects of it which needs to be highlighted.

So, what information you pick from the whole simulation? After you simulate you will be having an ocean of data. So, what kind of information you pick from that and how do you communicate it. You have two certain post processing. The thing called post processing is very crucial in the success of simulation results.

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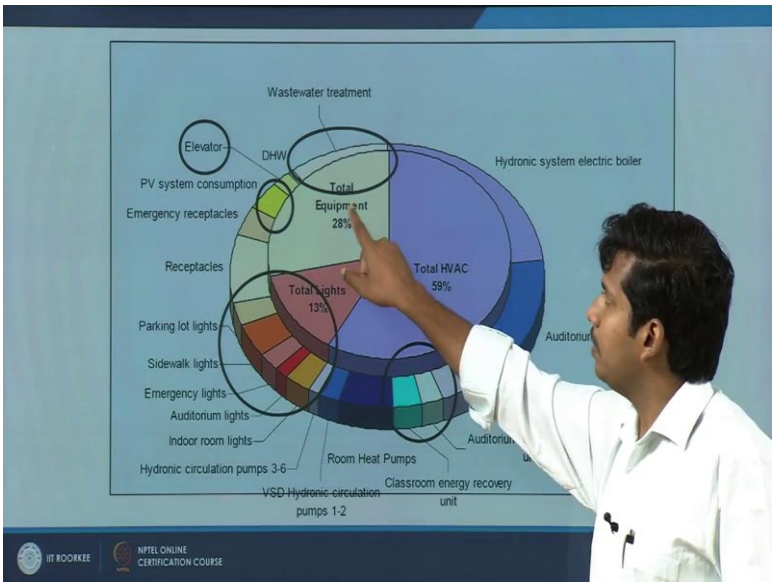

Typically you will get certain breakups. You know what a HVAC is, load this is like comfort conditioning load, then what is the lighting load, then what is the equipment load and within that you can get certain segments. If you want to do energy efficiency first thing you need to do is find out in which area you are working on. Say let me give you an example, total equipment load is this, imagine this is an office building you have computers plus printing and reprography machines. If it is around 30 percentages you may not have very big control on this internal loads or kind of connector loads. Yes, to certain extent you can advise that you can minimize it, but this is not the field where you have a direct control on.

You will have control on two things; one you will have control on the comfort conditioning site, number two on the lighting loads. For example, change of one light to the other light. Say from a florescent light or to CFL or to sorry two LED light then you will say 5 percent reduction in the lighting load, 10 percent reduction in the lighting load or introduction of a censor an occupancy censor or a light censor you know day light

censor; where it controls on off or dimming control is provided. Then you will say I have minimize the lighting load in this kind of you know into this much amount of magnitude.

Then you take a look at the HVAC load. HVAC load is partly due to the building envelope, partly due to the internal occupancy internal loads we call. Then it also depends on the efficiency of the system. So, in three contexts you can do. In case you are working on building envelope you have to optimize the envelope itself the choice of software and the kind of results you need to pick from the same tool can be different. While, if you are interested in the internal loads the choice can be different, if you are interested in the equipment side of it you want to model the fans and pumps component to component the choice of tool or the level of detail you work in the same tool could be considerably different.

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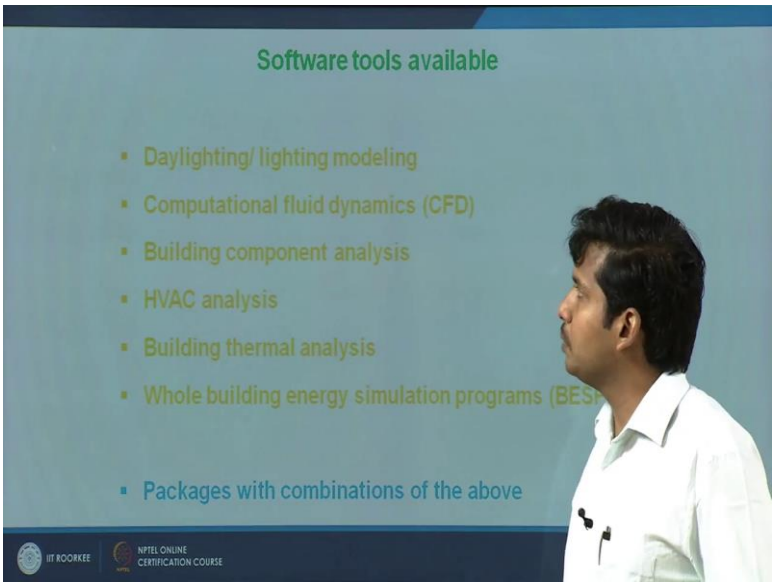

There are different software tools available you have; today it is pretty nice that you have exhaustive tools for day light and artificial lighting modeling, you have CFD tools fluid dynamic tools for air flow modeling both air conditioned spaces as well as naturally ventilated spaces. Then you have tools for building component level analysis, for example if you want to estimate the u value or heat transfer for example through a frame then you have a specific component tool through which you can assess how much heat gets transferred through a buildings frame or you want to access what is the air flow distribution through a particular diffuser. So, specific component level you can analysis.

Overall HVAC analysis you have lot of tools today. Then building thermal analysis heat exchanges 1 dimensions, 2 dimensions, 3 dimensional or whole building simulations tool are also available. If you are leading packages which give you combination of these modules, you can buy certain modules or they will give you all the modules you can use or do not have to use certain modules some of them are custom made.

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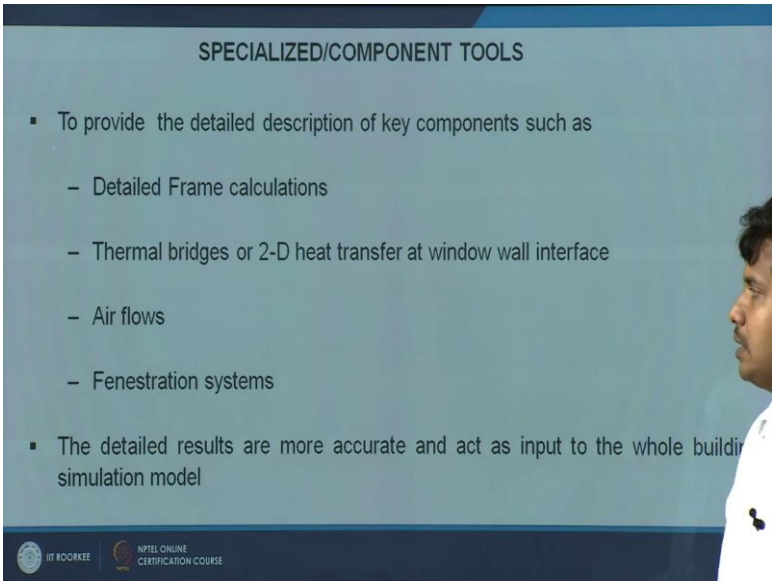

As I said there are specialized components tool we have to quickly take a look at them. For example, as I said calculation of heat flow through frames. The crucial thing it is a weaker link we have things for the whole building whole wall thing, but again if you want to get in to the details of the frames for example, you can have a specific set of tools are available through which commonly used this is tool called Therm; t h e r m where detailed frame model can be made indoor outdoor conditions can be set. It is not a whole building thing it is just an element or component modeling tool. Then you can also model thermal bridges 2-D heat transfer through window wall interfaces, the junctions joints can be model. Air flow models can be built fenestration system can be model. So, it depends on the level to which you have to work on.

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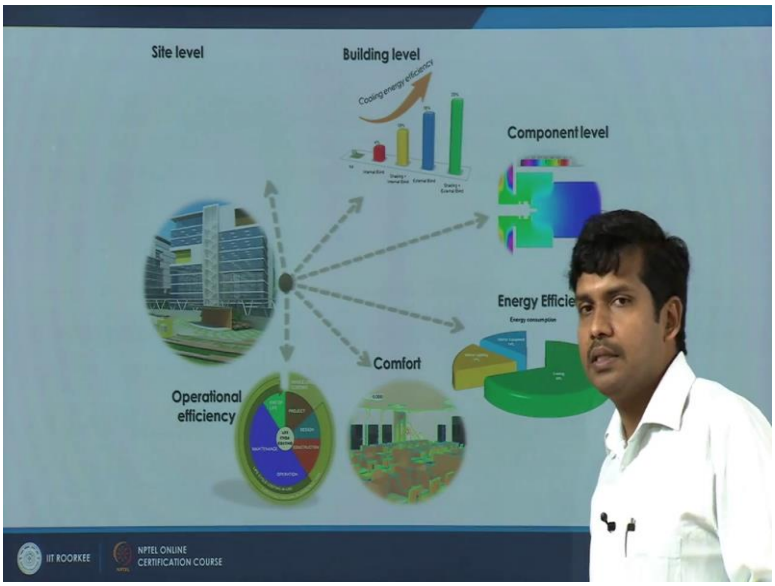

To give overall picture, in the site level you have certain tools then in the building level you have cooling efficiency and quick estimate can be made. Component level, to the level of glass frame specifics assemblies you can model. You can have tools for energy efficiency overall split up can be given or indoor comfort modeling in terms of air flow in terms of thermal distribution radiation or lighting levels or costing calculations anything can be model or overall operational efficiency and environmental impact. You can choose pick and choose tool that you actually need.

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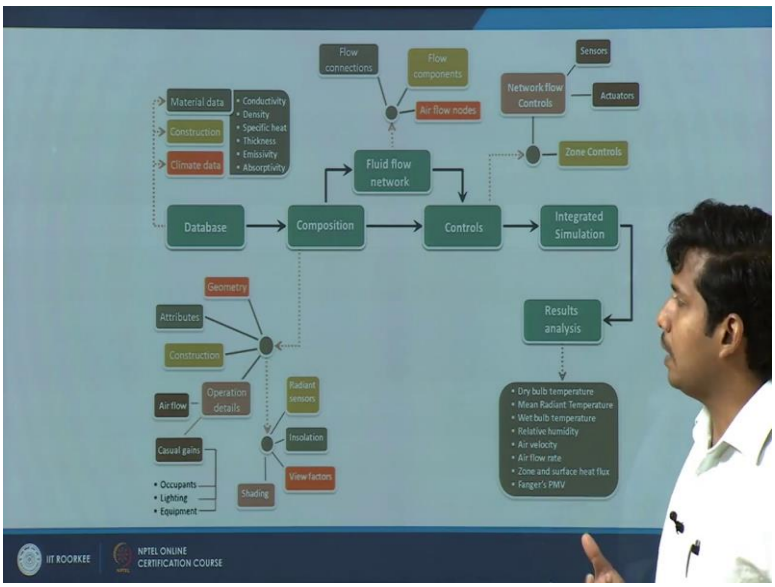

The general overview of the process associated the first thing start with the database. If you have to do good modeling the best practice is to first develop a data set. You need 3 different types of data; first is a material data, you will need thermo physical properties, what is the density of the material, what is its conductivity specific heat, MECVT, observity, surface properties this basic material data is a primary requirement.

Next is the construction data. How do you construct wall system, which wall systems you will primarily use, what is the thickness, what are the different layers associated, what insulations you are using, where are you putting it. So, you can kind of make a library which we call the construction systems, wall system, and window system. You can model the frame separately then you can constitute the whole window glass frame assembling.

Next crucial thing is a climate data. You can generate your own climate data or for standard specific major locations in any country. Say if you take India around 30 to 35 locations you have weather data easily available. Weather data I mean a climate data I mean an hourly data most of the detail software tool will require an hour to hour weather data 8 7 6 0 hours for the whole year, the weather data is required. Some standard data's are available or you can also develop your own weather data sets.

The next step is, so once you have the database you have a library from which you can pick next will be the composition of the model. So, first you need the basics drawing, physical dimensions and drawings are needed. Some tools allow you to import the drawings some of the tools you will have to model it from scratch, from coordinates you have to start modeling. So, you need a basic geometry, you need the attributes which size is exposed which is used which is not used. Then the construction details can be picked from here.

Important thing is the operational details, how many people are there when are they using the building whether they are opening closing the windows they are operating the shades, what is the set point temperature is it remaining whole through the day is it remaining the same or they modifying it. So, you are starting to put in equipment you are starting to put in equipments in the virtual model. So, occupancy lighting and equipment and how things get modulated with time. You can feed the schedules very clearly. Then it goes to developing shading systems, then putting censors if there are certain censors

where things will be controlled. Is there are lighting censor, is there are a temperature control, it can be modeled.

After this there is an option if you are really going for an air flow modeling or specific software where you are also taking a natural ventilated air flow, then you have to define something called a flow connection. It will involve nodes and connections connected through components. Say you have a room, one single room you are modeling there will be for example I will call it a node in the center of the room there will be one more node in the outside it will be connected through a component which is window in this case; an open window can be a component, open door can be a component a crack which is a infiltration connection can be a component.

So there are two nodes; internal node and external node which are connected through a component. This modeling happens fluid flow network modeling, some of the tools allow you to skip this, some of them if you do not need an air flow thing it is a sealed air conditioned building you can avoid this. Then the controls, how people use it what are the censors actuators what time AC turns on turns off, occupancy censor light censor it involves modeling this things. Then you do an integrated simulation.

Now you have virtually modeled the whole system. You are letting the whole machine run, it will be giving you results. As I said the major challenge is taking these results picking the right information from the large repository of results available and then post processing it. Post processing is a crucial step in this whole process. It is a complex interaction, as we said building envelope it interacts with the whole lot of thing external environmental is there, rules regulations are there, plus internal operational patterns are there. So, it is a complex intervening thing which most of the tools today available leading tools are able to take care of.

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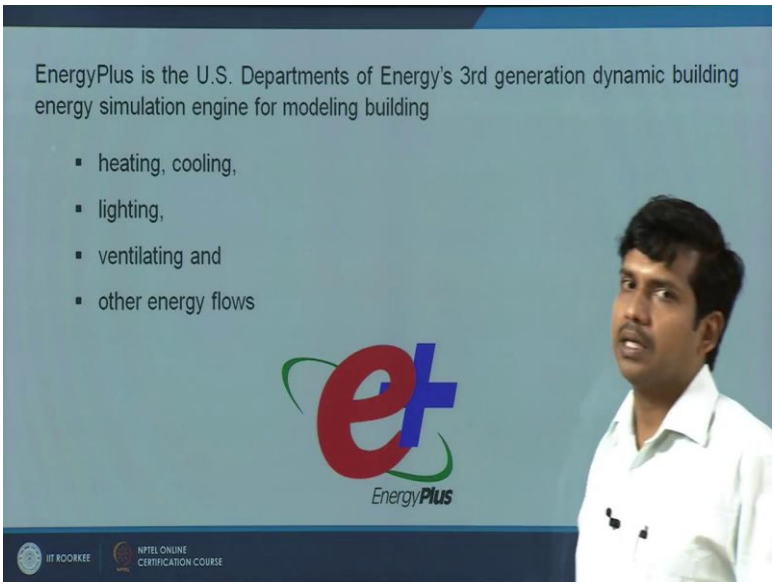

We will be mainly focusing on one tool today which is energy plus, which is a called engine. This functions as engine or the core for lot of leading commercial software tools. The tools available today are front ends of energy plus energy is a core engine I will be showing you in the demo the screen of energy plus how it looks. You can either do direct modeling in energy plus which is a freeware it gets updated very constantly you know 5 to 6 times a year you gets updates it is a very frequently updated tool it has come a long way.

It helps you model heating cooling loads, lighting loads, ventilation model and other energy flows can also be model. Newer version of it allows you for cost based modeling. You can also get certain environmental quantities CO 2 emissions etcetera can be obtained. This is a basic core, lot of leading front commercial softwares take this energy plus as a core either it can be stand alone or there are cloud based tools, but the commercial front end is sold to you.

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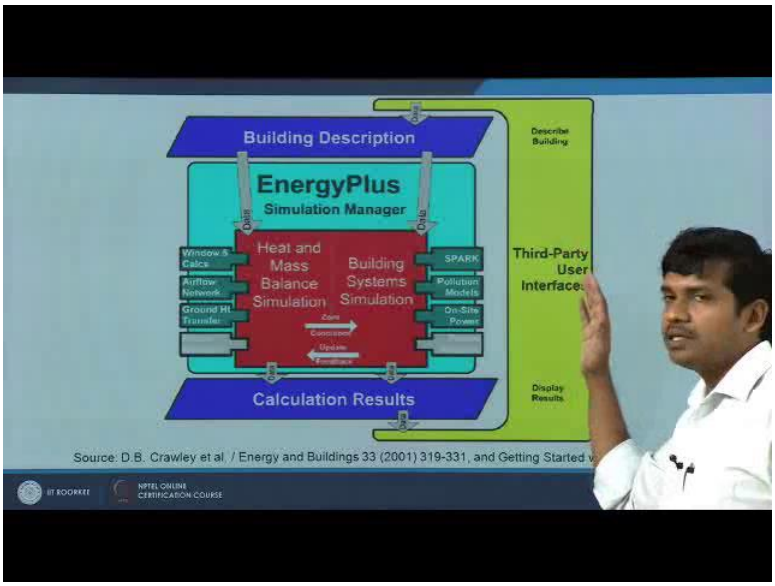

It has a simulation manager; it has a basic heat mass balance simulation. Then you have a building description, and then you have the calculation result. This is a core engine. You have commercial front ends which will interface with it. The basic advantage you get is energy plus does not have a very good graphic interface you have to go with numerical inputs one by one. Whereas, this third party tools have graphic interfaces where they kind of pre built libraries are available, so you can pick and choose it is very simple more or less simplified approaches that is what actually you are paying for.

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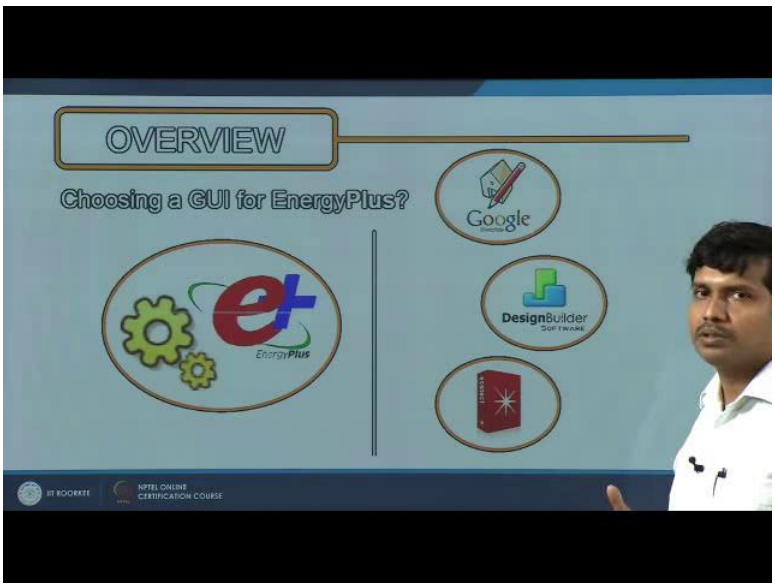

Lot of tools are available, starting from sketch up you have open studio. If you have sketch up you can directly use energy plus or there is a tool called open studio with which it tags energy plus along, so you do not have to spend really lot of money to model or to do energy simulation. Then you have leading tool design builder which is available which is also getting revise quite often. Lot of templates libraries are available it interfaces well with energy plus. Then ecotect also interfaces, but you do not find much updates for recent energy plus version. Every time there is a upgrade in energy plus this tools also update themselves so as to tag with it more accurately.

We will now go to the demo of this software tools couple of them I will be demonstrating I will be primarily looking at energy plus I will show you what is the interface looking like, then I will be showing you how design builder software tool looks like and what are the major components and what is the interface and how to work along with this design builder.

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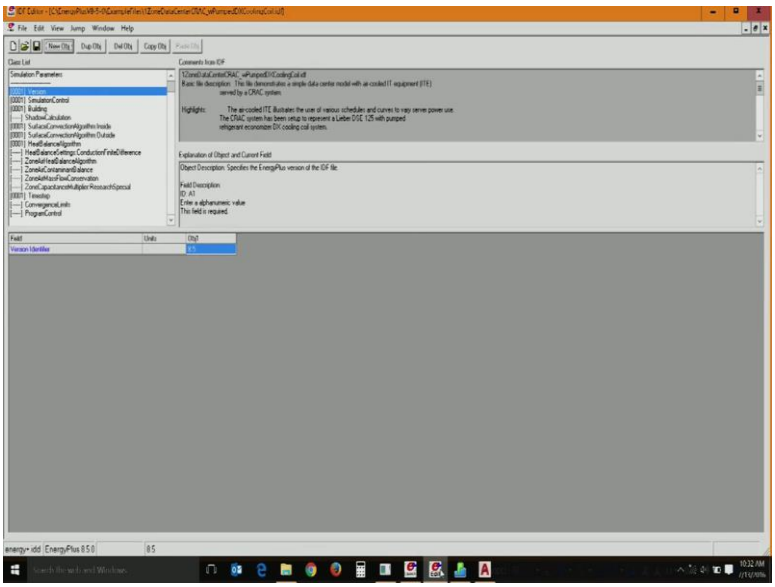

Now, we will take a look at energy plus which is one of the core engines that I was mentioning about. There are two three other things or the other commonly used you know core engine in the CSPR; it is environmental system performance by research. It forms the basis core for software tools like (Refer Time: 25:48). Now we are looking at energy plus which forms the core engine for open studio which tags with sketch up are design builder this things run on or auto desk green building studio. This primarily runs

on energy plus as their core. Moment this is freely available for download the current version is 8.7 it gets updated quite frequently minor to major updates are happening versions update like 7 to 8, 8 to 9 there will be a major migration in the certain coding patterns also, You know kind of data exchanges will slightly differ, but then minor variations and bugs fixing will happen within the same revisions among the same version itself; say 8.1 to 8.2. There will be minimum variations.

So, once you download install it you will get a screen like this, once you launch it this is called energy plus launch this is like a launch pad you can run simulations on this. Essentially you have to choose input file if you have one already or you can create a new one. You can also do group simulations say you have hundred files together you can tag them together and simulate it; you can simulate one file with 10 different weather locations. Like you know you also have few other utilities we will look at them, but before this how to create a simulation thing itself, how to virtually model the building.

There is something called IDF editor, click on this will open a screen, this is what we call IDF editor. Here I am opening IDF for an existing file so have you are finding certain inputs which are already there, you know certain things are already built in. If you open a blank file say if you want a new IDF file this will be an empty file here you will find a series of inputs starting from simulation parameters like building shadow calculation and what is that you need what time if you need the calculations at.

Then you also have location and climate, you can define the sites location, you can start doing latitude and longitude. So, here if you want to input say take an example here location and climate I want to input the location, I will say new object more objects get added up say I can start typing New Delhi then I will give the latitude longitude here I will start entering the values one by one time zone I have to enter elevation I have to enter, everything manually you have to be feeding it.

Similarly, the next thing would be the schedule what type of schedule, when people are coming, what is the day daily morning to evening hourly schedule, how many days of week people are working, how many weeks in a year, what are the holidays, what is the working pattern basically, so you define this is like defining library. Like we discussed in the earlier methodology first we are start of defining the whole set up, we are saying this

is algorithm I want to use what is a kind of heat transfer algorithm. There are different types here, you can choose whichever is more appropriate.

Then comes defining the library in terms of location and climate the site conditions basically including the ground reflections what is the (Refer Time: 29:08) and all that. Then you can define the schedule library, then the construction element library you can start defining the material. So, you can say the name of the material. Let us say it is brick what is the roughness, what is the thickness of the material, what is the conductivity density, specific heat, thermal observe some numbers you will find are pre built you can modify them as you want. Then you have window components you can define roof vegetation, you can define air gap.

Each and everything as you look at it goes by defining in terms of numbers, it is like filling up huge excel sheet. Then you can define your construction. You have a pre-built set up material I have brick I have plaster I have insulation layer. Then, now you can define construction saying layer one is say external finish then there is a plaster then there is say insulation, then there is brick, then there is internal plaster. So, I can define it layer by layer you do not have to calculate the overall property that it will do, what you will be defining layer to layer.

Then comes to defining the geometry; you will be defining zone by zone. If you look at this you will have to define the x origin y origin z origin. So, it is essentially like a coordinate system. In very old graphic editing tool kind of thing where if you are more comfortable if you have the coordinates of the buildings relatively simple you can simply get typing this numbers you will still have a full proof system software which is giving you good results.

Element by element you can define. Then shading definitions can be done. It goes all the way up to defining the whole HVAC system itself, starting from coil, starting from fan pump motors everything can be defined here heat recovery system what types. It does not mean you have to fill all this parameters. Like we saw the earlier example which I had opened not all the blocks are filled, some of them are left empty the software still allows you to leave certain things which you do not need to be unfilled. You do not have to fill anything they have filled a few things they have left certain things open. This is where you have to act smart saying what is my required or desired result and what am I

really modeling, where am I detailing. If certain detail is not required I would suggest you leave that blank do not attempt to it. Certain things are essential only do that and what is relevant to you. Accordingly even in HVAC system some of them are left blank here they have some more settings they have a connection loop.

Then finally, you define what your output variables that you are requiring are, what are the sets of output? Say here they have asked for outdoor air summary, zone temperature summary; mean radiant, temperature system, sensible cooling energy, heating energy like you know they have asked for seven different results. You can also have energy meters, how much is energy consumption. You can also do costing you can do life cycle cost assessment here, you can input, you know the currency variables, you can include the tariff, you can include certain LCC related terms. Then you will be able to get what is a payback period as well, this computes thing. It also has parametric things. You can define a logic, you can set a define set of condition then it will be doing a parametric iterative simulation. Now this is energy plus once you are done with modeling it you can chose a weather data I am not modifying it much can simply say simulates to close this, I am not saving any changes just saving simulate.

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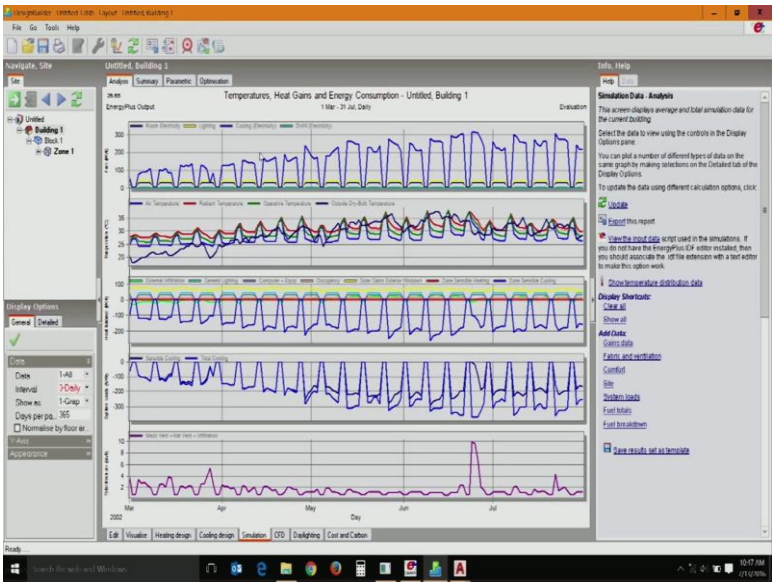

It will quickly run it just took four seconds to simulate it, but you will find the results like this ESO is a common result folder where it is all text data; t e x t files you can open it in excel you can do analysis if you are comfortable with, but this is what essentially

you will get result. You can look at the graphic of the model that you have built; it will be showing you a d x f file where you can take a view of what model actually you have made because you have inputted in terms of coordinates, so it will give you the model here. You can look at the model, this is what is the model that we were simulating 4 zones are there certain fenestration components. And you will be able to see here results.

Now let us take a look at design builder which I said is a commercial front end of energy plus. Now this gives you the much more flexibility and ease of use in terms of modeling. I quickly create a new file I have taken Delhi as a weather file, there are lots of built in templates you can chose one of the templates or you can go for a blank template, you can do types of analysis it can vary. So, let me quickly create a file and show you what is inside this tool. This essentially gives you a graphic user interface where you can start building your thermal model or a building model virtual building model. It is not as flexible as sketch up because this is not a graphic model this is a thermal model, so there are certain restrictions available in case of the shape, form, the type of modeling that you do.

And one more thing you have to keep in mind the more complex you make your model you start doing integrate detailing its a thermo dynamic object, there will be more and more heat exchanges which are happening and your modeling time will be drastically increase; some of the models the tool cannot even handle. So, that would be that large kind of a mathematically equation or expression to be handled by the software. Here actually you have a basic thing. If you want to start modeling a building you simply say I had a new building, again it will take you through a series of template what type of considerations, what are the default data, what is it an office building or is it something else, what type of construction. Everything as I said is a prebuilt template. You can actually build your own template before starting to model or you can start the model then tweak around with the templates.

It will customize and give me a quick a template on which I can do further modeling. It is preparing the building data, assembling all the libraries, because as such I have chosen the building type what is the construction type etcetera. So here I have the height, it is a extruded shape I can simply draw model finish the edges. So, it has already put in certain window and other elements here. I am not going to detail it out further. So, this is a model for your information, different levels are available; first is a site level then this is a

building level this is where we are then if you go the block level there will be different zones. Now, there is only one zone, so the zone level this is in further in detail. If you click on the zone further you can access the roof, now this is a floor, this is a roof, and wall if you want to edit further in the wall you can reach out for the window accordingly.

Now it has taken a template it has fixed the windows, it has predict through, now you can start editing the libraries which you have already defined. You can have the activity library where you can edit, you can have the construction library where you can edit materials this is construction then the materials can be edited. Then there is a opening library in which the glazing frame systems can be edited, either you can input a whole u value or you can model it component to component. Say take a look at this construction template, if I want to model the external wall I can edit it here first it shows the wall has four numbers of layers, brick layer, and insulation, concrete block and gypsum plastering.

Further if I want to edit these things I can further get in to it, the next window will appear. Here I can model or modulate the conductivity specific heat or density, I can modify the surface property, I can define whether there are some green elements, I can input embedded data I can input whether it is a face change material it is a type of you know capacity of insulation which changes face to observe heat.

Then you can input cost data. Instead you can define the wall definition itself in a simplified way whether you want to define layers or the whole thing you can define in terms of setting a u value for the whole wall. You can just say the whole u value of the wall is something say it may u value is 0.9 I can simply say it is 0.9 watts per meter squared Kelvin, you do not have to get in to defining this layers. But of course, you cannot get a precise account of what is a heat transfer heat exchanges happening through the envelope. If you want that detail then go for layer based approach. If you want a quick estimate go for a simple setting up of u value and defining with it do not get in to details of modeling it and everything.

You can model infiltration, we saw the openings you can define shading separately, frames and dividers can be modeled you can model shading system whether it is window shading or local shading. Window shading is blinds louvers etcetera. Local shading means it is like overhang fins can be modeled. Each and every change you make will get

updated in the graphic part of it, then comes the lighting load. You can change the type of lighting; you can also define certain light you know lighting like. But if you have enough data sheets you can define your own light fixtures, but more or less it has a exhaustive library which is already available.

HVAC is another exhaustive you know section which design builder has. Different types of prebuilt HVAC's are available. Starting from generic like CAV system VAV system fan coil units, it goes on to. Even you can model the specific system up to fan and pump level motor level you can do the modeling if you want or you can choose from one of the existing template. Say if you want air cool CAV system constant air volume system you can simply say right now it is fan coil unit. Let us choose say constant air volume, air cooled chiller, and just say click on it the whole thing would change.

You can set your operational efficiency you can set the efficiency of the pumps heating cooling system coefficient of performance CO 2 can be set. You can define an operational schedule; you have a series of schedules which are already available. If you want to modify you can modify again, there are different types of modifying it. You can modify it like a detailed schedule or a day schedule or a compact schedule it depends. You know the kind of level of detailing varies. You can also define set temperature at what temperature AC is on AC is off. If you want natural ventilation you can define natural ventilation. Passive things like air tubes, you can also input certain cost variables. Is there some renewable generation, it takes care of photo old type generation at the moment.

Then at last you have to define what kind of results you are expecting. Do you want surface level details, like do you want surface temperature. Then instead of two to three minutes the simulation is going to take further more time. If you want specific component level heat flow modeling it is going to take lot of time. Then if you want to define air flow you go to the next sections CFD it again demands you to kind of model it much more in detail. This is with heating and then cooling. Then what are the specific simulation outputs. Do you want environmental factor HVAC energy, you want comfort.

We looked and Fanger's model, we took at looked at pierce two node model, adaptive comfort model. It will give you summary of comfort as well. So, movement you are done you know picking and choosing this things you can do the heating cooling design. It will

give you a quick estimate. This is like your single number calculation, this is not a dynamic simulations it is a quick estimate of what is a heating cooling load. It will take a particular heating day where you do the calculations for heat loads, cooling loads and the heating loads. You will see a quick result; you can also see a summary what is the design capacity, what is the floor rate, total cooling load sensible latent loads.

Lots of estimate is given. This is as I said it is not hour to hour simulation, but it is a quick quantitative estimate like were HVAC engineers do it, like a one number estimate you estimate the cooling quantity UA delta t plus certain other factors radiations are taken in to consideration. Once you want detail simulation go to the next tab, similarly you can do heating design cooling design then comes a simulation tab. Here also you have flexibility, you can do month wise simulation. If you want for 12 months or just for 2 months just 1 monthly data like you get your energy bills if that enough you will get that alone. The simulation is pretty faster. If you want daily number energy consumption per day, average temperature inside temperature per day, then you will get daily simulation maximum minimum average you get. Or you can go for hourly simulation hour to hour it will give you data. If you say sub hourly, how many divisions you want? Do you want it for 5 minute interval 15 minute interval the more you go in to detail the more simulation time and machine capacity computer simulation the engine capacity is needed machine capacity is needed.

You can also choose specific month say if you want only for say March to July. Specific set of month and you only want monthly and daily data you can be fine with it. You have a still an option of choosing or deleting certain additional outputs which you may want you may not want. Slightly it is slower than energy plus because there is a data exchange which is happening between the core and the front end, but once the simulation is done this is something what you will get. You can see the interval you have simulated for annual data, monthly data, as well as daily. But if you choose hourly simulation is not done it will ask do you want to re stimulate right now I am not simulating it daily data is enough.

Per day, what is a variation in fuel consumption temperature, heat balance, loads typically, fresh air intake parameters. Then it will give you a summary this can be taken in to HTML tables is useful information is presented here. If you want to run parametric simulation you can define condition I am not going to get in to these things right now,

but essentially what you get out of design builder it is like a graphic user interface plus a simplification system which is available to you. Say if you are a designer if you are a student who do not want to go in to the (Refer Time: 46:00) of energy plus you do not know which section to choose which section to ignore this is a quick fix solution.

Similarly, open studio also gives you flexibility. It does not have this many template built in, but it is like a freeware you can build in your own things, takes little bit more time but still you will have a free to use thing. Whereas, design builder though it is commercial it gives you customize templates much seamlessly you can done simulations the results are reliable because energy plus is a core engine it has been validated quite significantly validated tool. Predictions are more or less closer.

Before closing the whole discussion about the demonstration and things, you have to note that whatever accuracy and whatever precision rather we are trying to predict the buildings energy simulation energy consumptions. First let us talk about energy consumption alone the maximum accuracy you will be able to expect is of the order of 50 to 60 percentages maximum, more or less most of the simulation results are 30 to 40 percent accuracy they are only one third to around 40 percent maximum accuracy you will get the data which you are on getting on field.

I am saying say if you are simulating a room and you are building the room running the air conditioner or heater and finding out what is the similarity you will find around 40 to 50 percent similarity. There are taller uncertainties, because the exact material performance can only be proved or found out when it is actually built and actually let to interact with the climate. Whereas, when you are simulating it virtually there are lot of control conditions boundary conditions which are very static you do not allow them everything to modulate dynamically.

With that sense this things are little more or little less representative of the actual scenario, but base case versus predicted proposed case apple to apple comparison as I said it gives you a very good fair estimate of what the actual system is going to do. If the (Refer Time: 48:06) effect of changing certain materials strategies this is pretty much easier to do.

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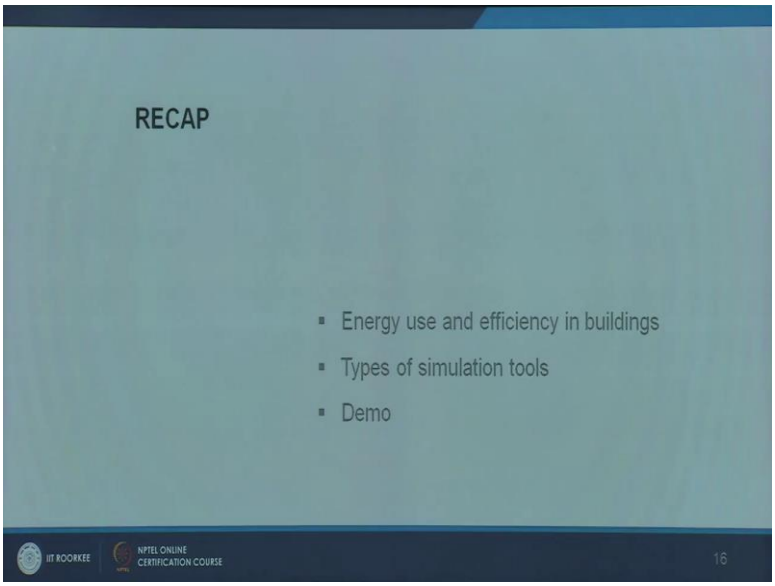

So, as a part of this course we looked at the basics of energy used where energy is used in the building what is energy efficiency, what are the type of simulation tools available or basically simulation and what do we try to get out of simulation tools. And we also looked at demonstration of energy plus as well as design builder software tool.

Thank you.