Sustainable Architecture
Prof. Avlokita Agrawal
Department of Architecture and Planning
Indian Institute of Technology, Roorkee

Lecture – 40
Energy Efficiency - V

Good morning. Welcome back to this last lecture on Energy Efficiency in sustainable buildings as part of this online ongoing course on Sustainable Architecture and I am your instructor Dr. Avlokita Agrawal, Assistant Professor at Department of Architecture and Planning, IIT Roorkee.

So, in the previous lecture we looked at the compliance approach for meeting up with various criteria set for energy efficiency in buildings and most of these criteria we followed from ECBC when we are talking about energy efficient buildings in Indian context. One aspect of the compliance which was left was interior lighting power.

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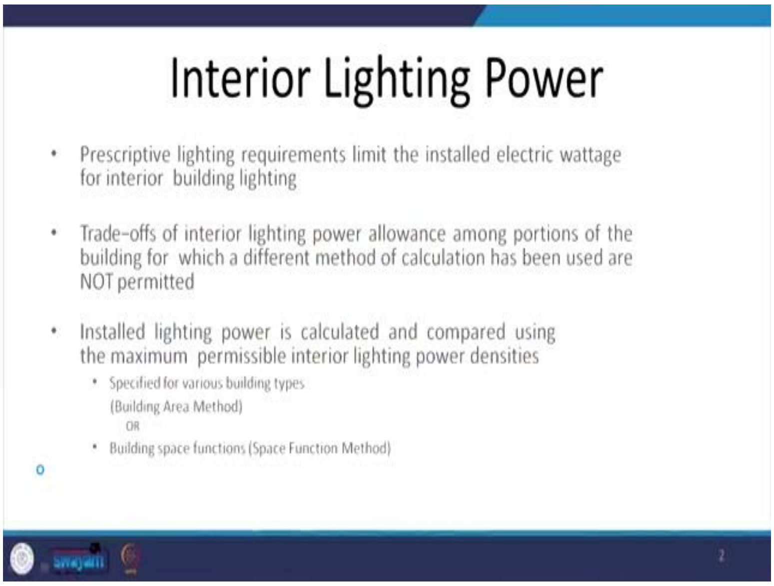

So, continuing from the previous lecture we will quickly look at what are the compliance criteria for meeting up with interior lighting power. So, whenever we are talking about the interior lighting power we are talking about the prescriptive requirements for the installed electric wattage for interior building lighting. Now, this implies that to achieve the desired illuminance levels how much of the power electric power will be consumed and that is what we call as if the lighting power density.

So, the LPD of an overall interior lighting system is calculated. When we are talking about the compliance approach we have 2 types of compliance approach.

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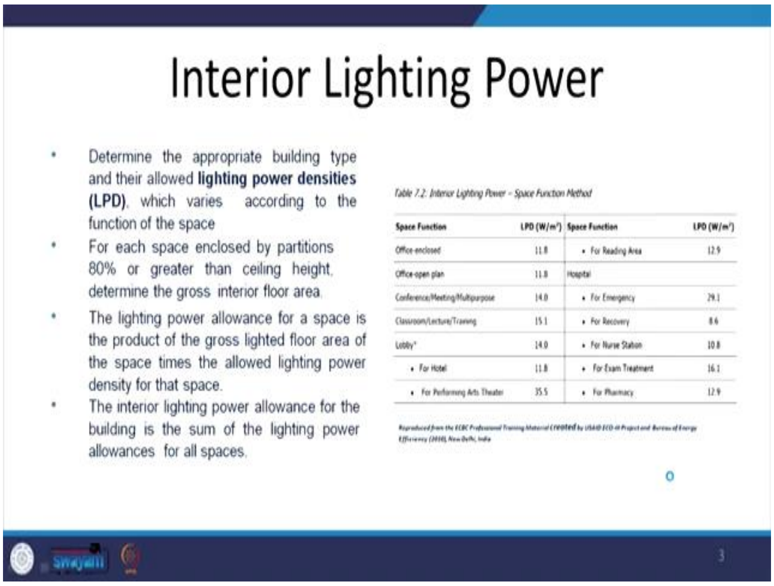

One we have for different spaces within a building. So, we call it a space function method. Now, in this space function method we have different functions assigned to the spaces. For example, an enclosed office area, an open plan office area or some conference or multi purpose hall or a classroom or a lecture room, for the lobby of a hotel, for emergency in a hospital for recovery and like that. So there is a long table and for each of these spaces for each of these space and function lighting power density has been prescribed.

So, if you are looking at an open plan office and LPD which is 11.8 Watts per meter only for meeting up with the interior lighting requirement is prescribed. So, whenever we are talking about the offices the open plan area of the office will have to meet up with the LPD given as this. Now, when we would. So, there are 2 compliance approaches; one is the space function method and in this method all areas in a building specifically will have to meet up with the lighting power density requirement as prescribed here for each area.

So, there is different LPD for the circulation in different LPD for the open plan office different LPD for this enclosed office, for toilets, for the common areas and like that and we have to meet up with them individually. So, this is quite rigid. So, in the space function method for each space in the building the desired LPD will have to be achieved.

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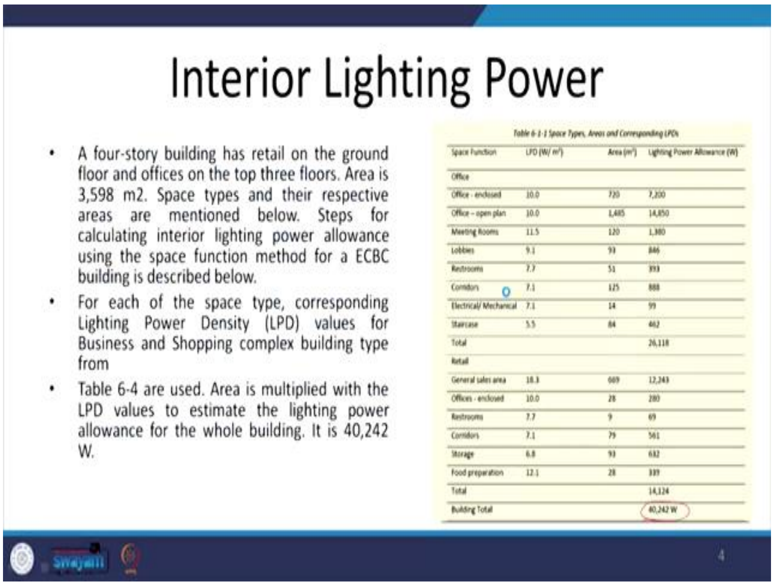

When we do that so, suppose this is for a particular building. These are the different types of areas which are there and the total area for each of these spaces and based upon the LPD requirements which are taken from the ECBA we calculate the total lighting power allowance which can be taken for each space and based upon this the lighting system will have to be designed, the luminaries will have to be picked up. Now, here the LPD of each space will have to be met individually.

However, if we calculate the if we know the total lighting power allowance for the building we can also go to the building area method where instead of meeting up with the LPDs individually while maintaining the given illuminance levels as per NBC, The total LPD of the building which is also as per the function of the building the type of the building the LPD can be met.

So, instead of meeting up with the individual spaces we can achieve the LPD as desired as prescribed for the total building. So, within the interior lighting power there are these 2 approaches space function method and building area method. Now, when we are talking about lighting power this was for interior lighting, artificial lighting. We also have compliance approach for the exterior lighting power.

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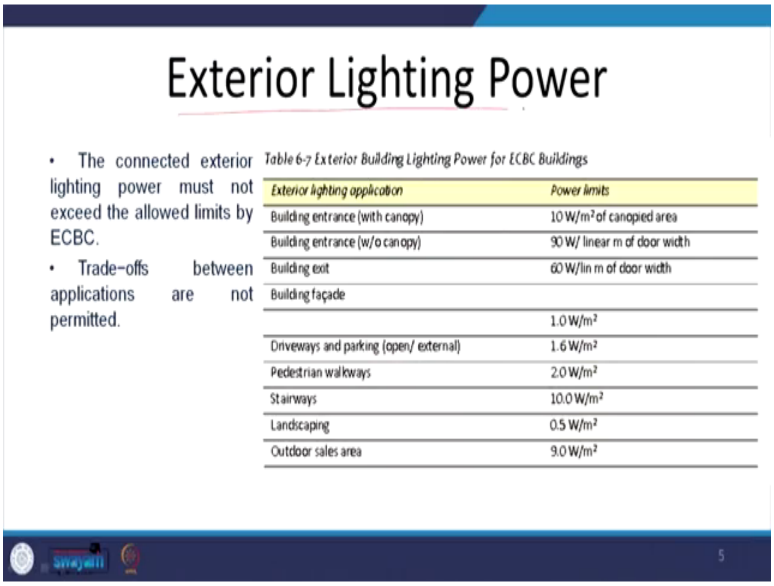

Exactly, in the same manner as we have for interior lighting power we have the prescriptions for the exterior lighting applications. For example, building entrance with canopy, building entrance without canopy exit, building facade, driveways and parking pedestrians and like that and then we have the power limits the LPDs. So, this is 10 Watt per meter square of the canopied area. For driveways and parkings we have 1.6 Watts per meter square which is which we can clearly see that it is much lesser than that of the interior lighting power because more lighting is required.

And just as the compliance for interior lighting is shown we will show the compliance for the exterior lighting. Based upon the total area of say the driveway or the parking and the wattage the power consumed to light up the entire driveway up and parking and calculating the LPD. So, again we have to meet up the LPD requirement the lighting power requirement for each of the spaces in the exterior of the building to comply with the exterior lighting power requirement as per ECBC.

So, when we are looking at this ECBC compliance as I had briefly explained in the previous lecture there are 3 compliance approaches so, far we have seen the prescriptive approach.

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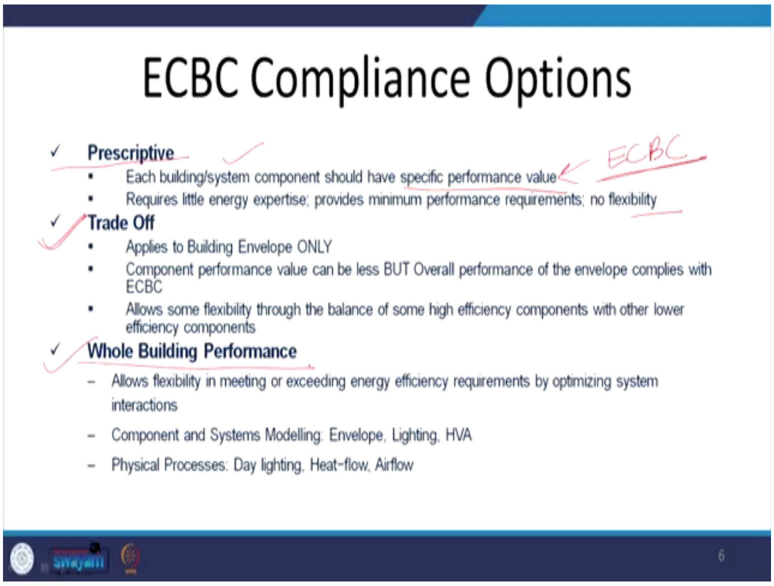

Where each building system or component should have a specific performance value which comes from directly from the prescriptive tables of ECBC. For this one it requires very little energy expertise you do not need to perform simulations or much calculation and all we have to do is select the right kind of material which meets up with the prescriptive requirements of the ECBC and our job is done.

But often to meet up with the prescriptive requirements of ECBC we have to select the high performance materials. So, for example if you want to have a fenestration which has a u value of 0.3 and then shgc of 0.27 it would directly imply that we have to select a double glazed window with a Low-e coating or with selective coating. Now, that will prove to be a little costlier as compared to say a single clear glass building where we can provide proper shading.

So, the second approach in the compliance as per ECBC was trade off method where we can trade off the performance of one component of envelope with the other component of the envelope. So, just as I was explaining here that in case we do not want to select a very high efficiency material as in the case of fenestration as I was just talking about. Instead of investing in the performance of fenestration I may improve the performance of the roof if I know that there is more amount of heat which is going to be transferred through the roof as compared to the fenestration based upon my design.

In certain other design it may be the other way around that the fenestrations become more important and the roof is not as important. So, I decide this trade off based upon my design and then using the equations the calculations which are given for the trade off we prove that the performance the on low performance factor of the proposed building is better than the that of the base case building.

The third approach is whole building performance approach where we will use the simulation tools whole building simulation tools. So, that there are different tools which are available one of such simulation tool we will learn at length in subsequent lectures in the last 2 weeks of our course here. In this type of compliance approach whole building performance approach we create a computer model, a simulation model of the proposed building and then we input the properties of all the materials which are proposed all the on loop systems HVAC systems, lighting systems, the electrical power systems, pumps everything.

So, all the energy consuming components will be input in this whole building performance method. And the overall performance factor for the proposed building will be calculated and for compliance it will be shown that the proposed building performs at least equal or better than that of the base case building. So, in this case it is not necessary that only the performance of the envelope of the building is considered.

Here, all the energy components both passive as well as active components are collectively taken into account and the overall performance of the building is proved to be better. So, we will look at this whole buildings performance method in the last 2 weeks through the details of assimilation tool how to use a simulation tool.

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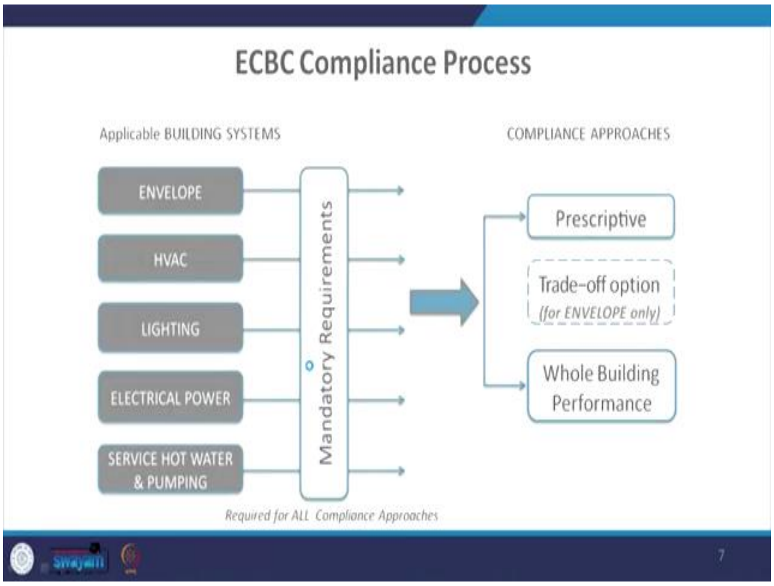

So, this is to summarize the ECBC compliance process. We have looked at the different applicable building systems envelope, HVAC, lighting, electrical power and service hot water and pumping. So, we have minimum mandatory requirements for each one of these. After complying after following these mandatory requirements we can choose any of the compliance approaches we can go ahead with the prescriptive approach or for envelope we can go for the trade of option.

In case of trade off the mandatory requirements and the prescriptive requirements for all other components will be kept as the same. They will have to be met using the mandatory and prescriptive approach only. The third one is this whole building performance approach where all the components of building systems energy systems and buildings they can be changed, but the overall performance of the building needs to be complied with.

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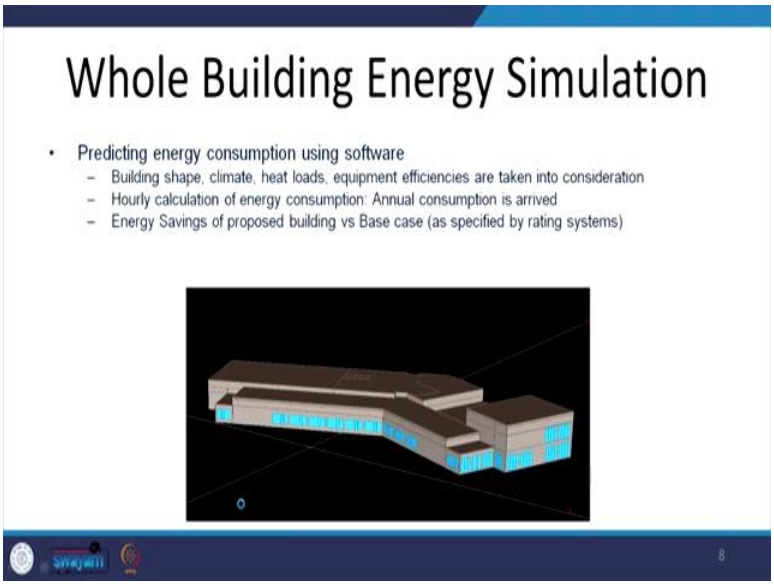

So, in the last 2 lectures we will be looking at the whole building energy simulation where the tool takes into account the building shape and geometry climate, heat loads, equipment efficiencies and it calculates the hourly energy consumption and based on that the annual energy consumption is arrived at and then we compare the performance of the proposed case versus the base case.

In addition to the energy efficient building the concept of reducing the demand of energy in buildings the new concept and it is the concept which is quite relevant today. So, when we were looking at the energy scenario of the world and we looked at how the future scenario for energy is going to be. We saw that in order to contain to or contain the global warming at the industrial levels of the global temperatures we will have to construct all our new buildings as net 0 energy buildings. Now, what is a net 0 building?

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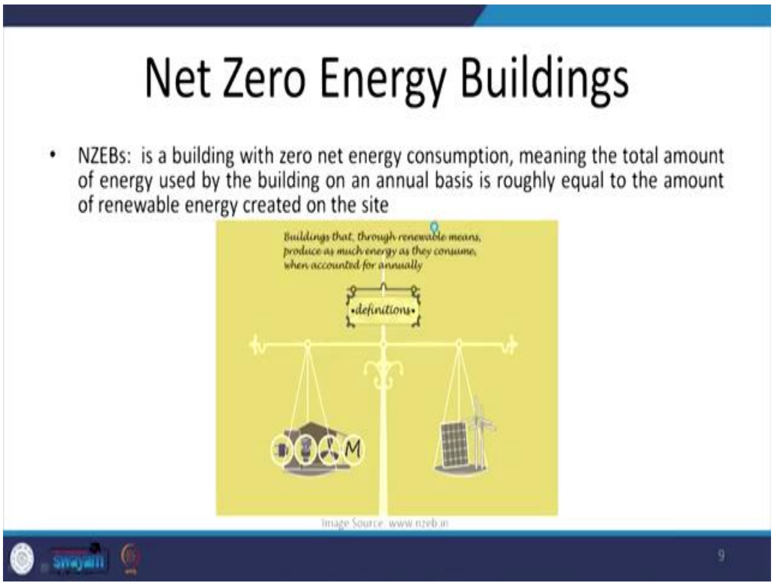

A net zero energy building is a building which has zero net energy consumption which implies that whatever energy is going to be consumed in the building, the same amount of renewable energy will have to be created on site. So, we do not take any energy from outside the site and all of it is created on the site itself. Now there are multiple variations within this net zero energy building.

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So, we have a net zero site energy. We have a net zero source energy. We have a net zero energy cost and we have net zero energy emissions. Let us quickly look at each of these definitions. The first one is net zero site energy building.

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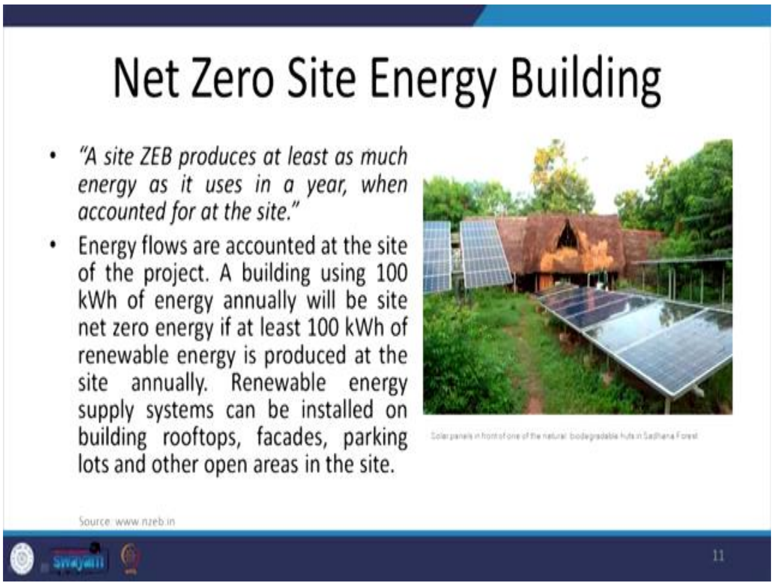

Now, here in this type of a building all the energy which is consumed in the building is produced on site itself. So, this particular picture is in front of a natural biodegradable heart in Sadhana forest which is part of the Oroville township. So, in this forest whatever they consume in these buildings which are also organic they produce them on the site itself. So, there is no transmission of energy from outside the site to the site and the site at the site the building is net zero energy.

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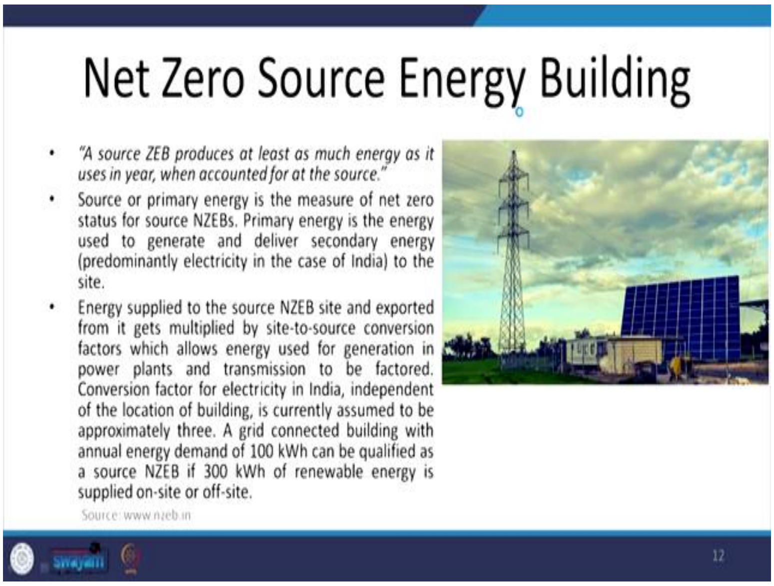

The next is net zero source energy building. So, when we talk about this a source zero energy building, it produces at least as much energy as it uses inner year when accounted for at the source. What it implies is that it will still remain grid connected.

It may draw energy from the grid at certain points of their time, but if we calculate it over the energy use in an year it will produce the same amount of energy at the site, at the source itself. So, it will still draw energy during certain periods and certain seasons while it will be giving back to the grid at certain other seasons and times of the year and times of the day. That is what net zero source energy building is.

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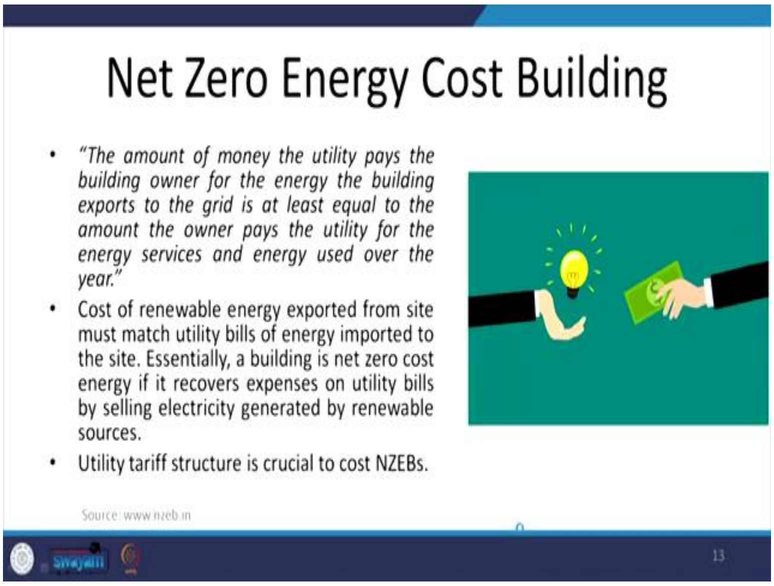

A net zero energy cost building is a building where the net cost of the energy of the money that the building owner pays to the utility for procuring the energy or vice versa is. Now, that happens in a case when the building consumes or produces energy at other times of the day which are off peak and supplies it back to the grid when it is the peak demand.

There by selling the energy generated on site at a higher tariff and drawing more amount of energy which is supplied at a lower tariff. So, here we are not only looking at the total amount of energy which is consumed and produced we are also looking at the tariffs of it and so overall the energy cost of the building comes out to be net zero. So, we are mainly concerned about the cost of the energy which is consumed in the building.

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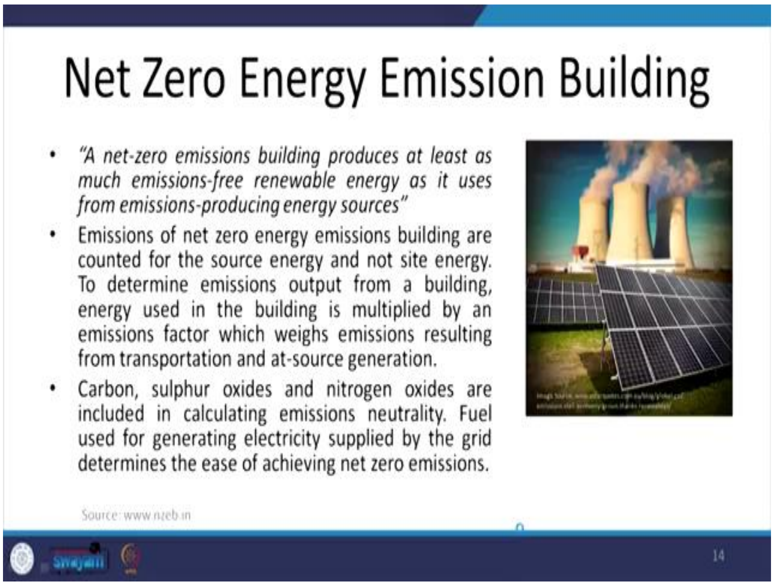

And the last one of these terminologies associated terminologies is a net zero energy emission building. Now a net zero energy emission building produces at least as much emissions free renewable energy as it uses from emissions producing energy sources. So, for example, the building is situated in a place where it is dependent upon the energy which is generated through the thermal power plant.

So, the amount of energy which it is consuming from the energy obtained from the grid which is largely the energy generated through thermal power it produces the same amount of energy using the renewable sources. So, this has to be equated and then it becomes a net zero energy emission building.

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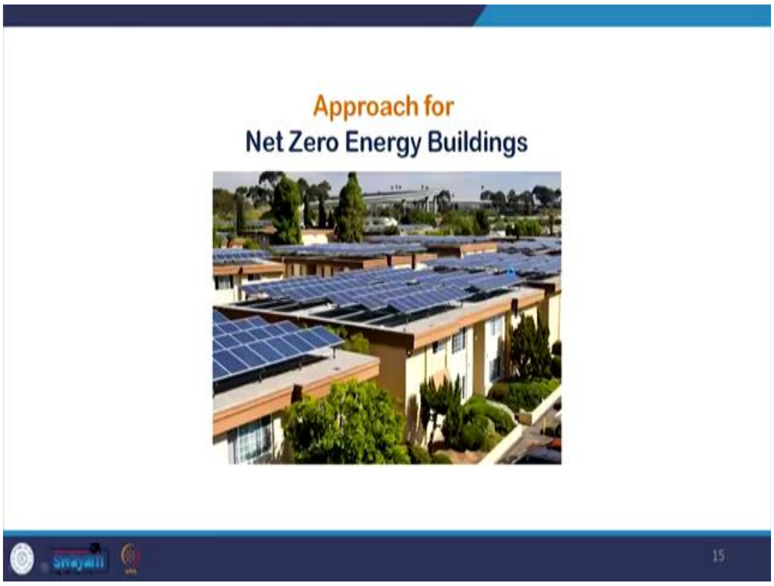

So, what is the approach for a net zero energy building. Now before I go into that for all these various definitions the fundamental understanding for us for a net zero energy building is that the amount of energy which is consumed in the building an equal amount is produced somewhere either on the site itself or off the site or somewhere. So, that the overall balance of the energy consumed and produced remains equal.

So, when we are talking about this net zero building and the approach for it we will first have to look at the different components energy consuming components in a building. So, we have HVAC.

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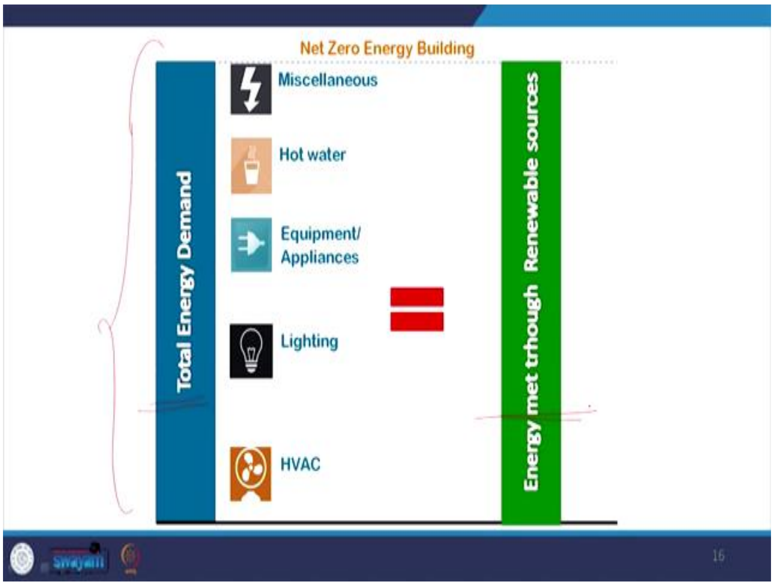

We have lighting load. We have equipments and appliances. We have hot water requirement and we have nice miscellaneous energy consumption. So, this is what comprises the total of this entire energy consumption in a building. For a building to be net zero we have to produce the same amount of energy using renewable energy sources. Once this total energy demand is equal to the amount of energy generated using renewable sources that is when the building qualifies to be called as a net zero energy building.

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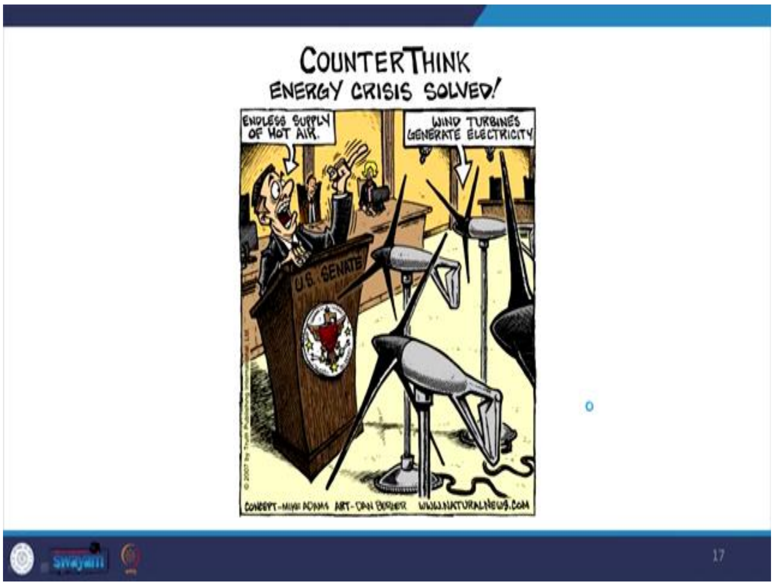

However, it does not mean that we continue to increase our demand and also continue to increase the amount of energy which is generated using renewables. Because renewable energy is also coming at a cost. It consumed natural resources, it is consuming huge amount of metal and glass and a lot of transportation is required installation is required. So, the intent should be to reduce the energy demand first and how do we do that we have seen it enough. First of all using the passive energy conservation measures which are integrated in their design.

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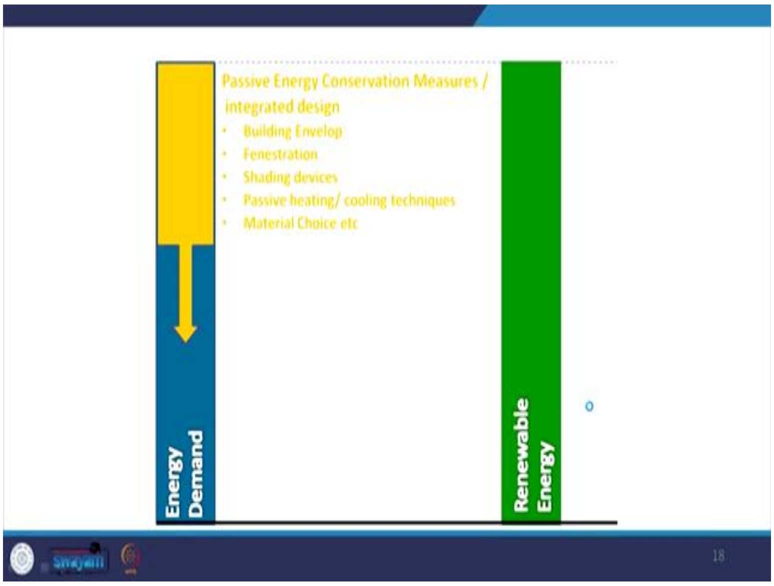

So, we talked about the building envelope, fenestration, shading devices, the passive heating and cooling techniques, material choice etcetera. So, all of this we have seen in our discussions so far. So, we reduce the amount of energy which is consumed we reduce the energy demand.

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Next, we employ the active energy conservation measures that is by using efficient lighting efficient appliances and we reduced our energy demand further. As we go on reducing our energy demand the amount of energy the equivalent amount of renewable energy which needs to be produced also keeps going down.

So, once we have reduced the energy demand substantially a small amount of renewable energy will need to be produced and the overall concept and proposition of net zero energy becomes much more feasible. So, it is a 2 step process. First of all reduce the energy demand and whatever that reduced energy demand is we substituted using the renewable energy.

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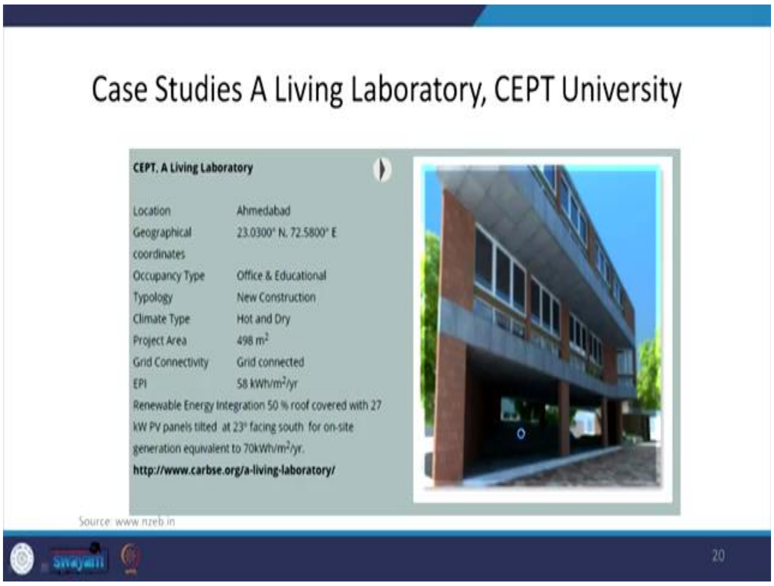

This concept of net zero energy is picking momentum across the world and also in India. So, Bureau of Energy Efficiency launched the net zero energy buildings portal NZEB portal which is live and a lot of information is available on NZEB portal and a lot of information on how to achieve this net zero energy status using what are the different passive design strategies, what are the different active strategies.

So, all of that is a properly summarized and integrated on this NZEB portal you can go to Bureau of Energy Efficiency and NZEB portal to look for more information on regarding this. So, there are some buildings in our country which have a net zero energy status. I am picking up some of the case studies relevant case studies more you can find out on net. So, the first case study is the living laboratory accept university it is in Ahmedabad and it is an office and an educational building. It is a new construction building it was constructed new and Ahmedabad is actually a hot dry climate.

The total area is approximately 500 square meter and it has a grid connectivity it is not off grid. So, the first thing that they did was to reduce the EPI Energy Performance Index of the building and they brought it as low as 58 kilo Watt hour per meter square per year. So, if you remember the numbers when we were talking about the standard buildings in India and we saw that air conditioned building have an EPI of as high as 250 kilo Watt hour per meter square per year that was the average.

This is a substantially low number. This is a very low EPI the moment we have a low EPI it implies that the amount of renewable energy which needs to be generated on site is also less. And after reducing the EPI the demand energy demand they have generated the renewable energy with 50 percent of the roof which is covered with solar photovoltaics and the generation is equivalent to 70 kilo Watt hour per meter square per year effectively compensating for all the energy demand in this building.

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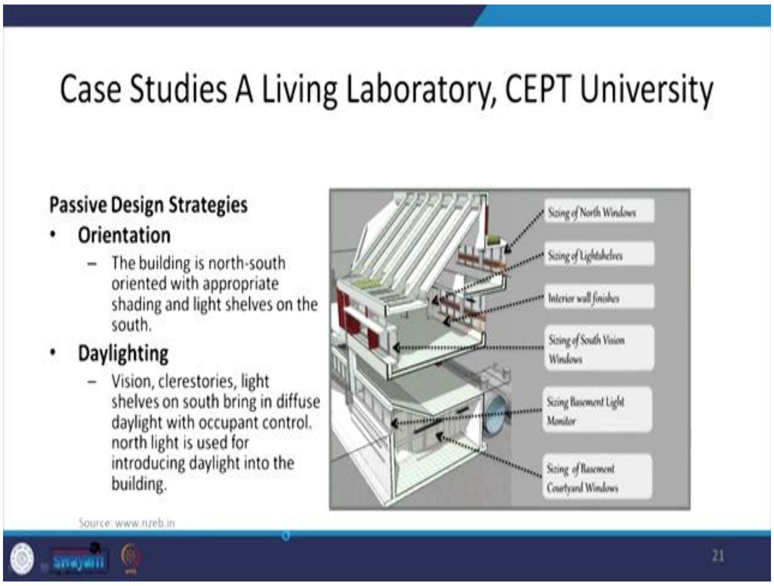

So, the approach was first of all the first step was passive design strategies incorporation of that. So, they talked about the orientation of the building which we have seen as north south being the most appropriate and the best orientation, incorporating daylight strategies, adding vision windows, adding clear stories and light shelfs on south to bring in diffused light along with the occupant control so, that there is no requirement for artificial lighting during the day. Using these passive design strategies first level of energy demand reduction has been achieved.

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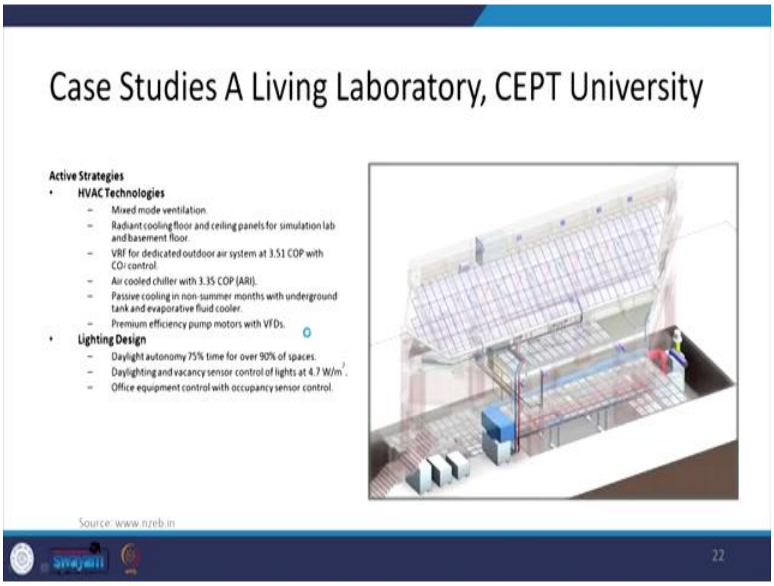

The second was thinking about the active strategies. So, first one was HVAC where instead of just air conditioning the entire building throughout the year mixed mode ventilation worked out where during the comfortable seasons when the outdoor temperatures and the environment is quite comfortable the mixed mode ventilation was implemented incorporated.

In addition to that radiant cooling floor and ceiling panels were used added a variable refrigerant flow device was used for dedicated outdoor air conditioning system which also had a very high COP and in it was inbuilt with the carbon dioxide sensors and controls high efficiency air cooled chillers was used and passive cooling in non summer months with underground tank and evaporate evaporative a fluid cooler were used. All of these together reduced the amount of energy which was required to create indoor environmental thermal comfort.

And the light the energy requirement was substantially reduced for the HVAC. The same was done for daylight for lighting design where first of all most of the spaces were able to achieve daylight autonomy for 75 percent of the time over 90 percent of the spaces which is practically making the requirement for artificial lighting to be close to 0 and then in addition to that occupancy sensor control of lights was also installed and overall the demand for energy through the active strategies was further reduced.

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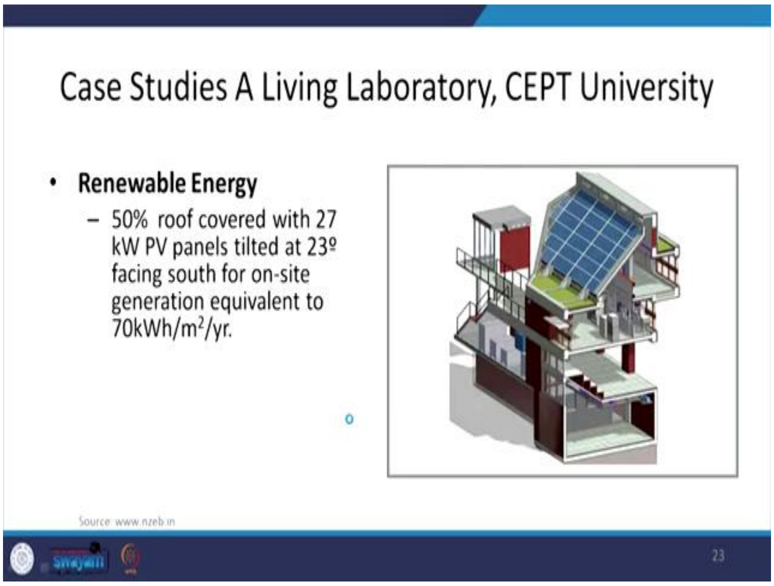

Once this passive and active strategies were incorporated into the building and the EPI was reduced to 58 kilo Watt hour per meter square per year renewable energy was further added where the 50 percent of roof was covered with these photovoltaic panels and they were able to generate the equivalent amount of energy which was consumed in the building thereby making this entire building as a net zero energy building.

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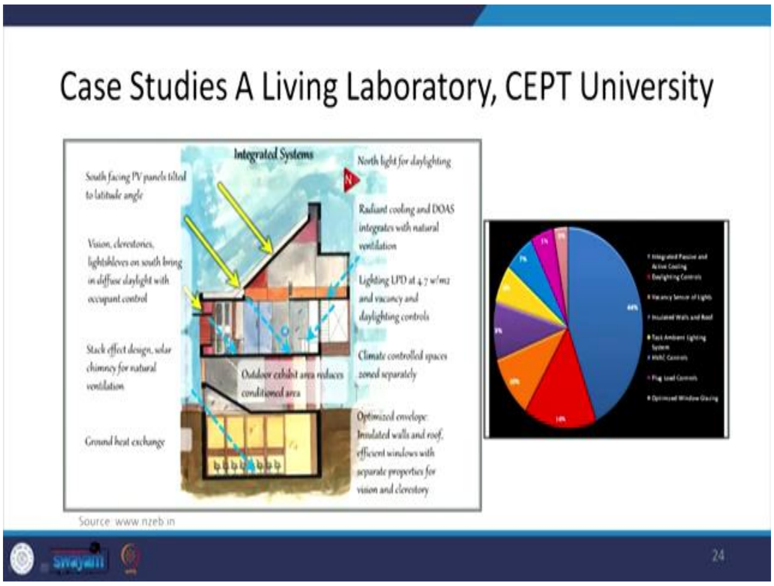

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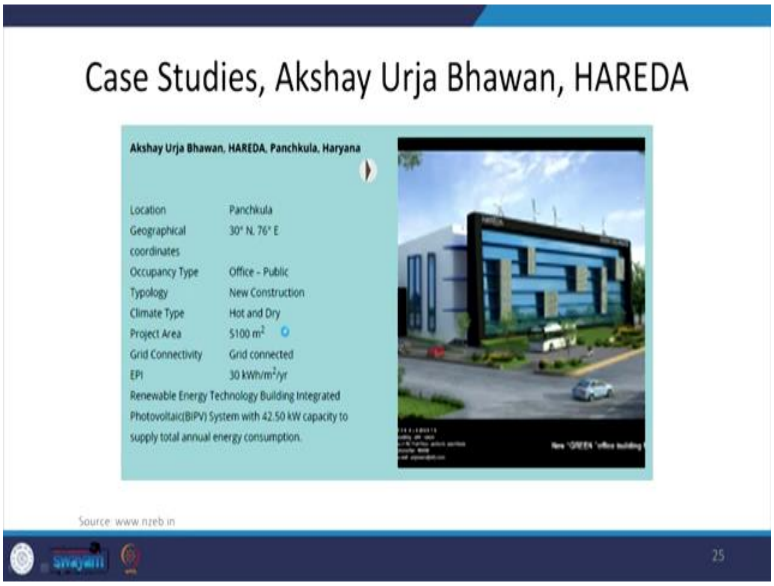

Next case study that we have here is Akshay Urja Bhawan at Panchkula. This is a public building an office building. Again Panchkula is classified to be a hot dry climate. So, the next building that we have is Akshay Urja Bhawan at Panchkula. This is an office building again a new construction and the overall area for the project is around 5,000 square meter.

It is again a grid connected and here if you look at this EPI number it is really impressive it is it has been reduced to 30 kilo Watt hour per meter square per year in this building that is very low and the rest of the energy the this energy was supplied using the renewable energy systems which was generated using the building integrated photovoltaics.

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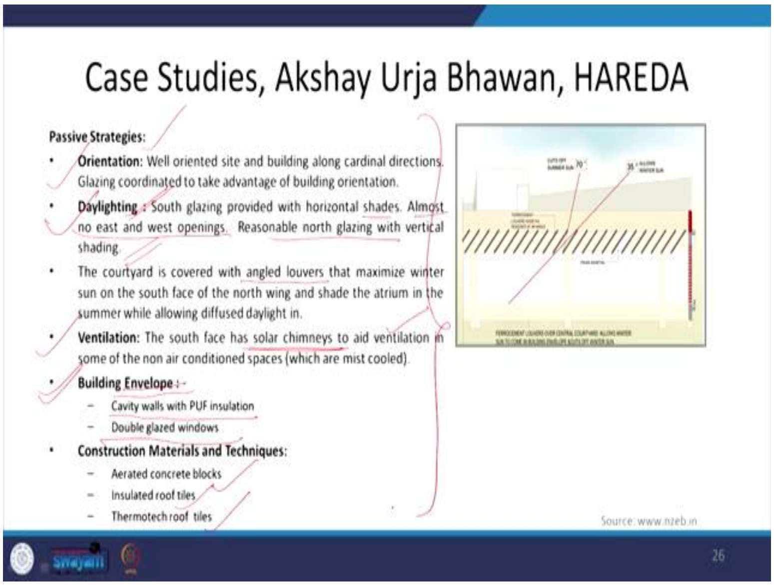

So, how they have done. The first step as we have always discussed is the passive strategies they have considered orienting the building properly, day lighting allowing for day lighting in most of the areas. So, the south blazing was provided with horizontal shades and there were almost no east and west openings and there were reasonable amount of north glazing with vertical shading provided.

Doing this almost the all the areas indoors they were they had sufficient amount of daylight available. And the courtyard the building has courtyard which is covered with angle which can maximize the winter sun on the south for south face while reducing the diffused daylight during summers. Another passive design strategy was that of ventilation where the south face was added with solar chimneys to aid the ventilation in some of the non air conditioned space.

So, this entire building was not air conditioned which was the most impactful strategy in reducing the EPI of the building. In addition to that the construction of the building and the components of the building envelope. So, it had cavity walls with insulation and also double glazed windows and aerated concrete blocks were used for walls insulated roof tiles and thermo tech roof tiles were used. Incorporating all these passive design strategies the energy demand in this building for thermal comfort was reduced in went.

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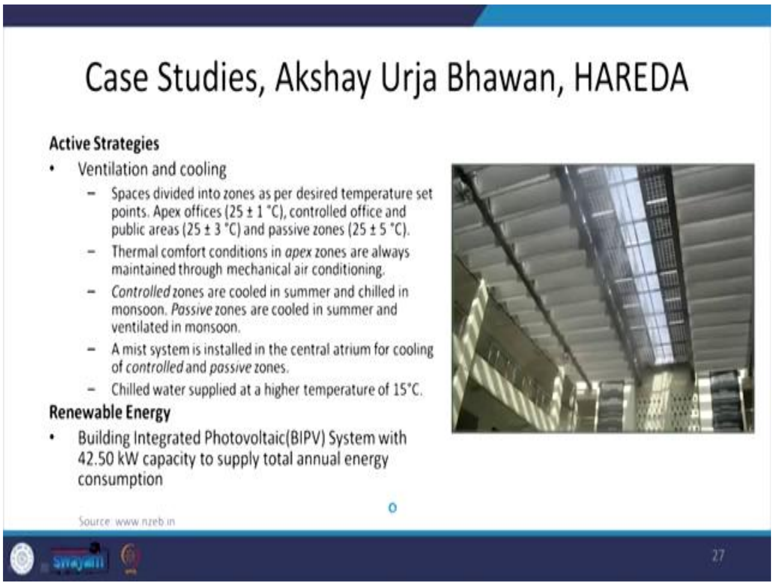

In active strategies they placed a lot of importance on ventilation and cooling. So, the entire space was divided into 3 distinct zones. And the first strategy that they used was maintaining proper set point temperatures as we have seen. So, at 25 degrees plus minus 1 degree in the apex offices and controlled offices and public areas were maintained at 25 plus 3 degree centigrade and passive zones were maintained at 25 plus minus 5 degree centigrade.

And in different zones which is the apex offices, the controlled offices and the passive zones they had different strategies. So, in pass in control zones they were cool in summer and chill in monsoon, passive zones were cool in summer and ventilated in monsoons. In the atrium a mist system was installed which was which would control with the cooling of the control and passive zones and the chilled supply chilled waters was supplied at a much higher temperature of 15 degrees while normally it is supplied at a temperature of around 8 degree centigrade.

Once these passive and active strategies were incorporated, the EPI which was brought down substantially to 30 kilo Watt hour per meter square per year the rest of it was generated using the BIPV which was installed on top of the roof in the atrium and it was able to generate the same amount of energy which was consumed by the building thereby making this building as a net zero energy building.

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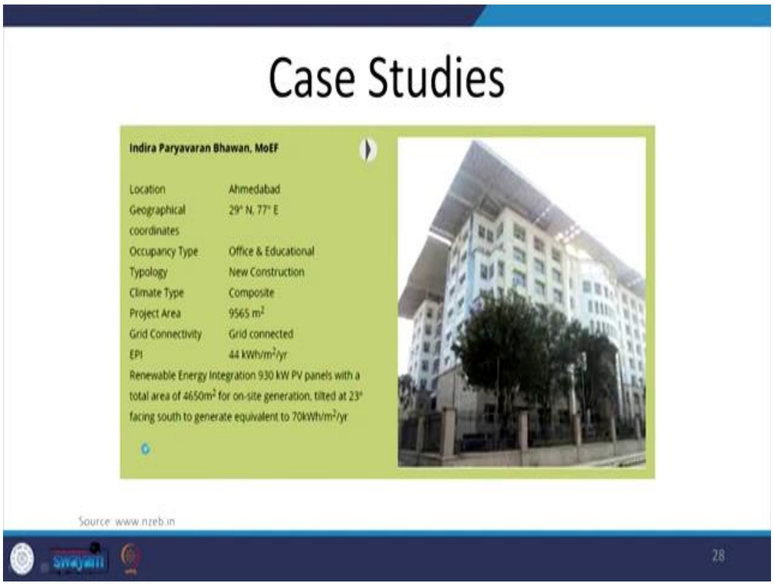

Couple of more buildings are available as case studies and you can learn more about it from the NZEB portal, but the approach for all the net zero energy buildings remains the same. First of all we use the passive strategies to reduce the amount of heat gain into the building and also to reduce the amount of energy consumed for artificial lighting and heating and cooling.

And then we add on the active efficient active strategies to further reduce the amount of energy which is required and lastly whatever reduced energy demand is it is offset by installing renewable energy. So, Indira Paryavaran Bhawan which is in Delhi it is an office building and it has a project area of around 10,000 square meter. Here also the EPI has been substantially reduced and the entire roof of this building is covered with huge rooftop PV and it generates an equivalent amount of energy which it consumes. Another building which is an eco commercial building of a Baers material science.

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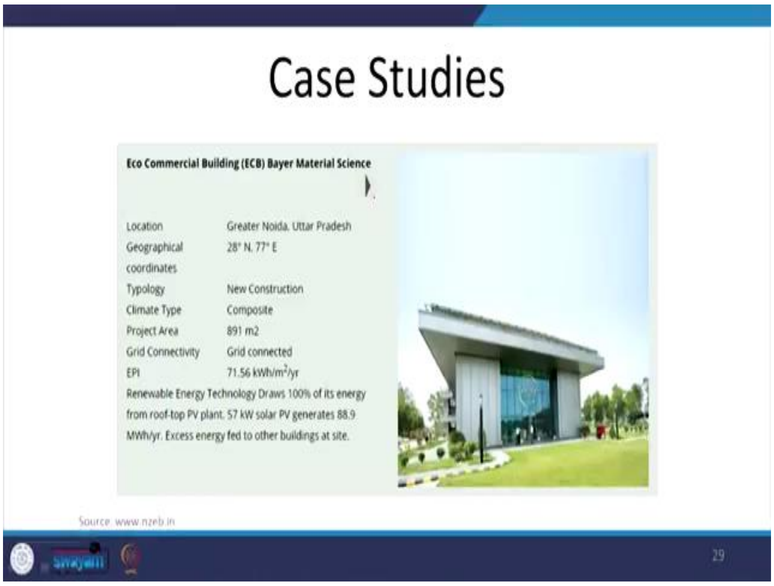

It is in Greater Noida. It has an API of around 72 kilo Watt hour per meter square per year, but with the help of the photovoltaic rooftop photovoltaic which is installed on it is roof it generates these equivalent amount of energy and much higher amount of energy than what it consumes. So, it general and this excess energy it gives back to the other is it gives to the other buildings on site.

So, it is not just a net zero energy, but it is an energy positive building where it generates more amount of energy than it consumes. So, there are a couple of other case studies which you can see on the NZEB portal and with this we conclude the discussion on a Energy Efficiency in Sustainable Buildings and we also conclude the lectures of this week. From next week onwards we will start discussion on another head related to sustainable buildings and towards the end of this course we will be learning a software for whole building energy simulation.

So, thank you very much for being with us this week. See you next week with a new series of lectures till then bye bye.

Thank you.