Sustainable Architecture
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Lecture – 38
Energy Efficiency – III

Good morning. Welcome back to the third lecture on Energy Efficiency for this ongoing online course on Sustainable Architecture. In the previous lectures on Energy Efficiency, we have discussed about the various terminologies related to energy efficiency and we have seen what are the different components of a building envelope, which contribute towards heat gain. We have also seen the different factors of the indoor environment inside a building which contribute towards the heat gain.

So, in the previous lecture, we talked about how the different building components should be optimized through design, through material selection in order to optimize the heat gain from outdoor to indoor through the building envelope. In today's lecture, we will be talking about the equipments which are installed inside the building or are required to keep the building cool.

Now, one of the most important systems in today's building specially the commercial building which a coming up is the HVAC system; Heating Ventilation and Air Conditioning system.

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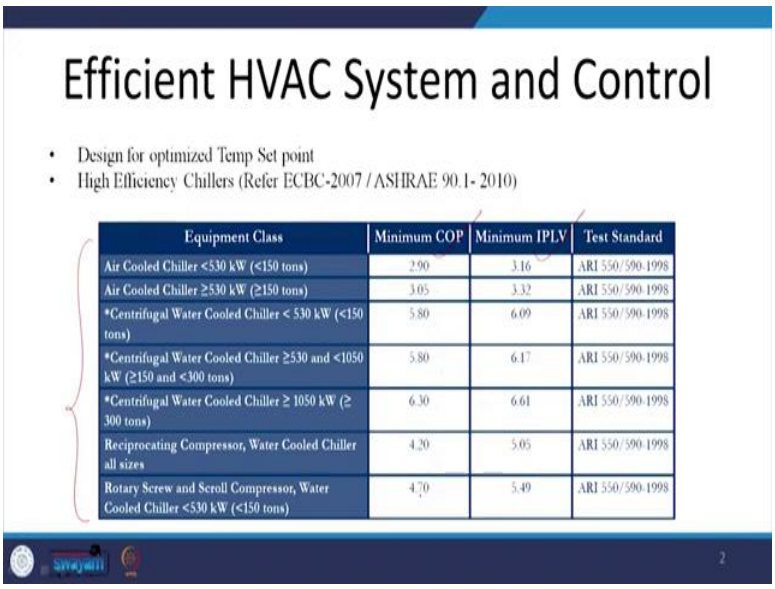

So, when we talk about the efficiency of these systems, we talk about the coefficient of performance and we also talk about the integrated part load values. Now, for different types of these air conditioning systems, different coefficient of performances are specified. So, higher is the coefficient of performance, higher is the efficiency of the HVAC system. Depending upon the tonnage of the building, the highly efficient HVAC system is preferred to be used.

However, we have to look at the cost payback; what is the capital investment which is going into the particular HVAC system and then, we look at the corresponding efficiencies and calculate the overall energy savings.

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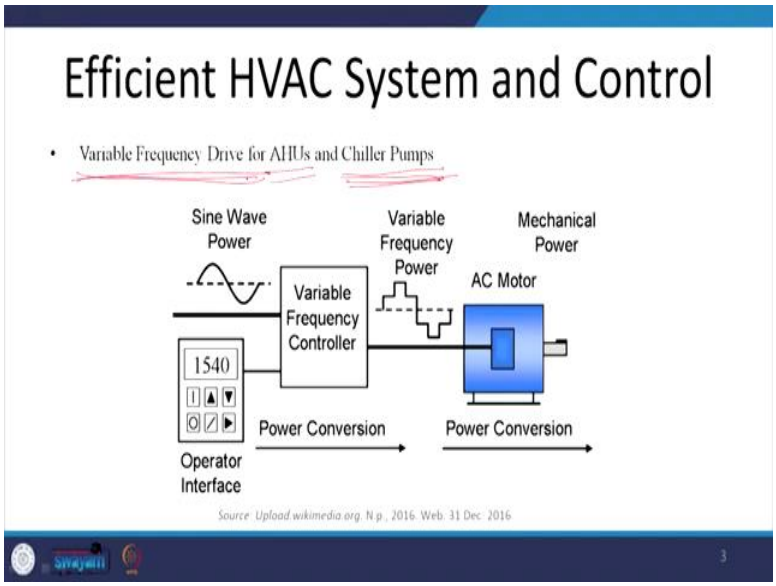

So, when we are talking about different types of efficient HVAC systems and controls, there are different strategies. One very important type of equipment is a variable frequency drive. It is called VFD commonly. What VFD does is it varies the frequency of the controller. So, the first and very important and also commonly used equipment part of the system is variable frequency drive.

Now, what variable frequency drive does is it varies the frequency at which these chiller pumps work. So, it varies the flow of the coolant into the U. So, by varying the amount of this coolant which is going into the U that is dependent upon the loading; if there is less load, the frequency required is less. So, if we reduce this frequency of the chiller pumps, we are able to save a lot on the energy.

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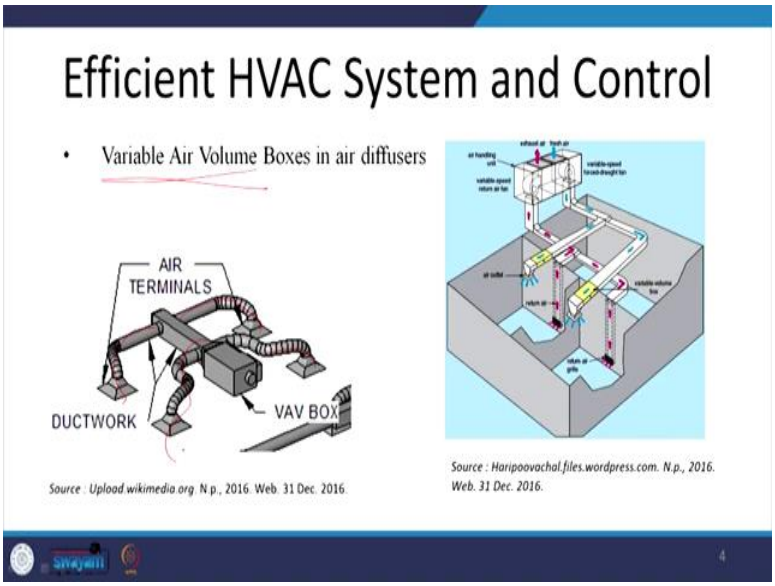

So, besides the efficiency coefficient of performance of the HVAC system, there are additional devices which we use for example, this VFD. Another one is VAV which is Variable Air Volume. So, in any building not just commercial building, but in any building, different amounts of cooling or heating is required at different times of the day. So, during say the office hours in an office building which is say 9 a.m. to 6 p.m. which is at 75 percent occupancy, while from 6 p.m. to 10 p.m. it may be only at 25 percent occupancy.

So, the same amount of cooling is not required; same amount of air flow is not required because the number of people have reduced. So, what is this VAV does is that it reduces the amount of air which is supplied through the ducts and sent into the space. The moment we reduce this amount of air which is supplied, we reduce all the back work and reduce the amount of air which is getting cooled or heated in the AHUs; thereby, reducing the energy consumption, the power consumption.

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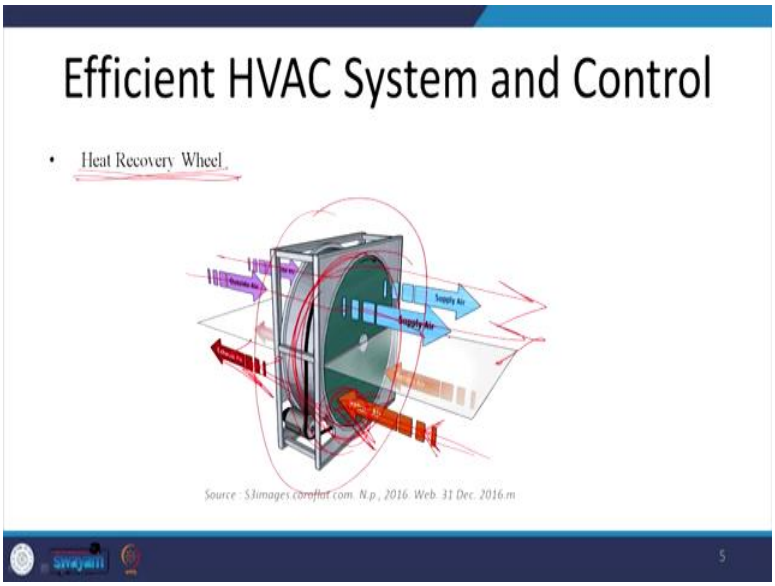

Another very important device is this heat recovery wheel. What heat recovery wheel does is that when the air when the return air which is going back through the returned duct. So, this is installed in the ductwork. This return air is already reasonably cooled. So, instead of exhausting it directly, this heat recovery wheel recovers the amount of coolth and it allows the cool to be taken from this return air to the supply air so that lesser amount of cooling is required for the supply air. This is what heat recovery wheel is.

Now, this heat recovery wheel derives its name because in cold countries, in cold regions, this return air is actually the heated air. It is the hot air and the supply air is also heated up to a certain degrees temperatures. So, while this return air is going out it is being exhausted. The heat which is contained by this return air is taken up by supply air and it is supplied inside. The reverse phenomena is applicable where the buildings have been cooled. This is what the concept of heat recovery wheel is.

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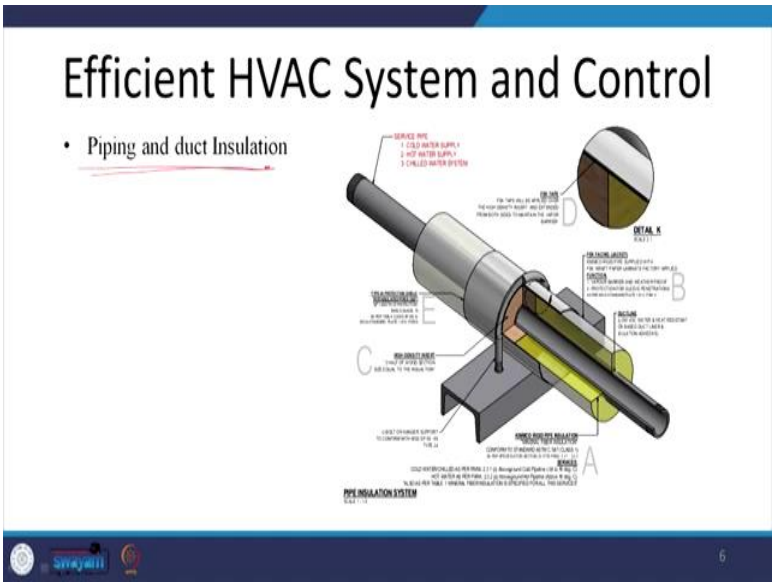

Another important system component is piping and duct insulation. So, while all this air is being supplied, while all the coolants are being supplied to the AHUs and then from AHUs to the spaces, conditioned spaces. The ducts the pipes which carry these coolants and these air, they themselves need to be insulated properly. There has to be proper insulation on them which is usually done, but that has to be done properly in order to ensure that there is no heat loss, heat transfer while the coolant or air is being supplied.

Now all these different components and systems which we have just seen. So, there are chillers, there are condensers, there are pumps, VAVs, VFDs and fans and all this thing, individually they may be working at very high efficiency; but all these components need to be balanced as a system. So, if one component is working at a very high efficiency, but all others are working at low efficiencies or they are not simultaneously working at high efficiency, the system efficiency will still remain low.

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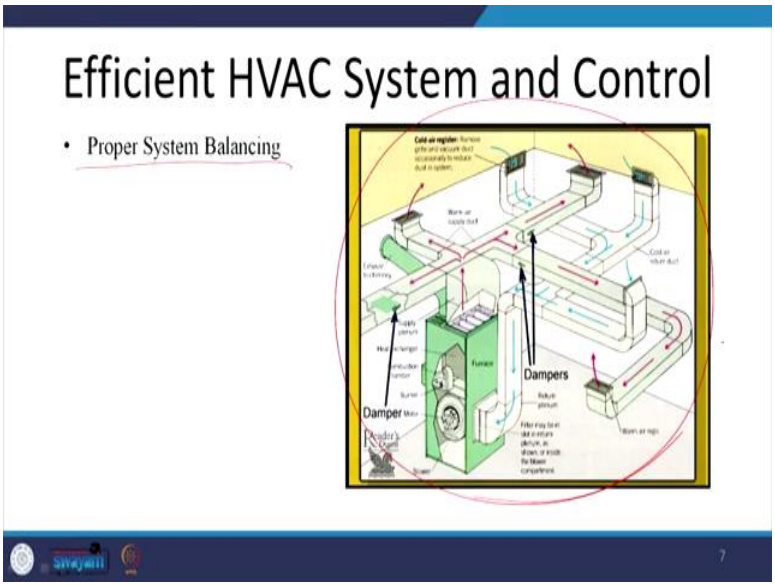

So, for that purpose proper system balancing has to be done in order to integrate all the different components of this HVAC system to deliver the desired efficiency levels.

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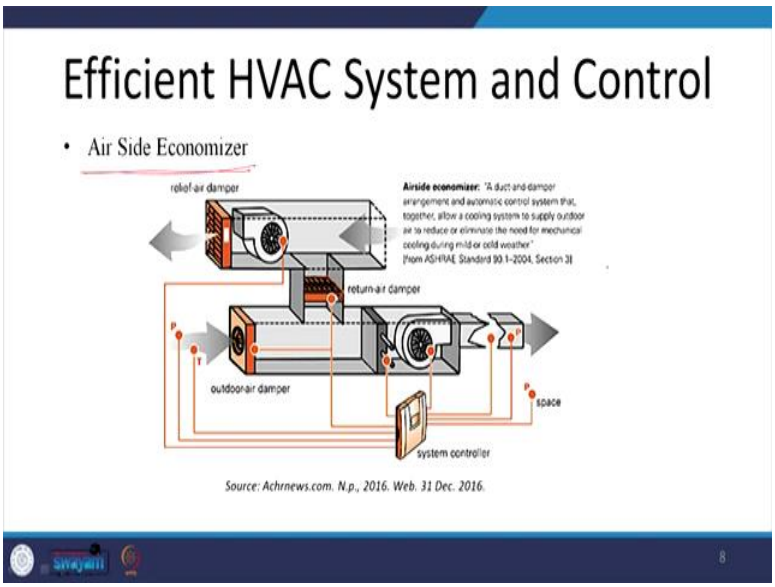

Another component within efficient HVAC system is the economizer; economizer could be air side economizer or water side economizer. So, what an air side economizer does is that if the outdoor air temperature is within the comfort limit, it will automatically shut off the air from being cooled and it will directly supply the outdoor air and allow it to be

treated and supplied indoors without getting cooled. So, no energy will be consumed in cooling or heating the air, if the outdoor air is within the comfortable range.

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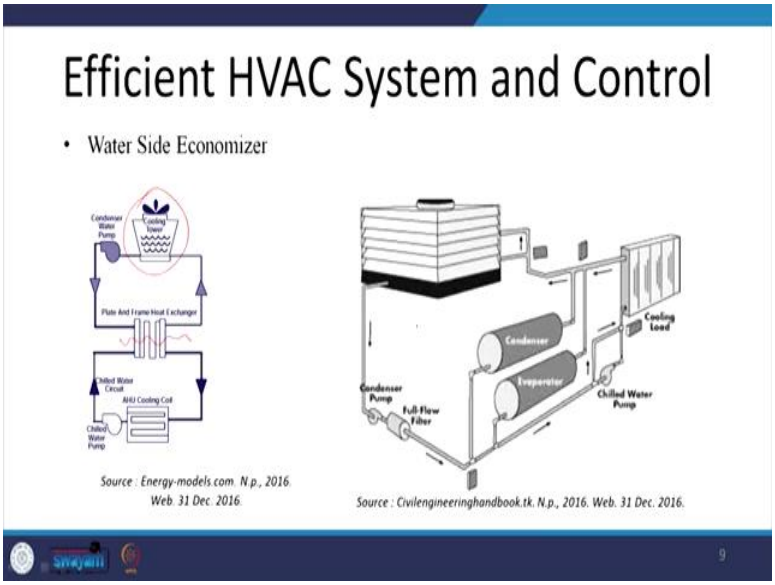

Through the waterside economizer, so if in the chilled water circuit, the water is at a temperature which is within the desired range, then it will automatically cut off from sending the chilled water to the cooling tower unit and thereby, saving on the energy for this through the circulation of this water through the pump. In addition to the back end of the HVAC system, where all the chill one plant and AHUs, piping and everything is there, there is a front end control, where the occupants are.

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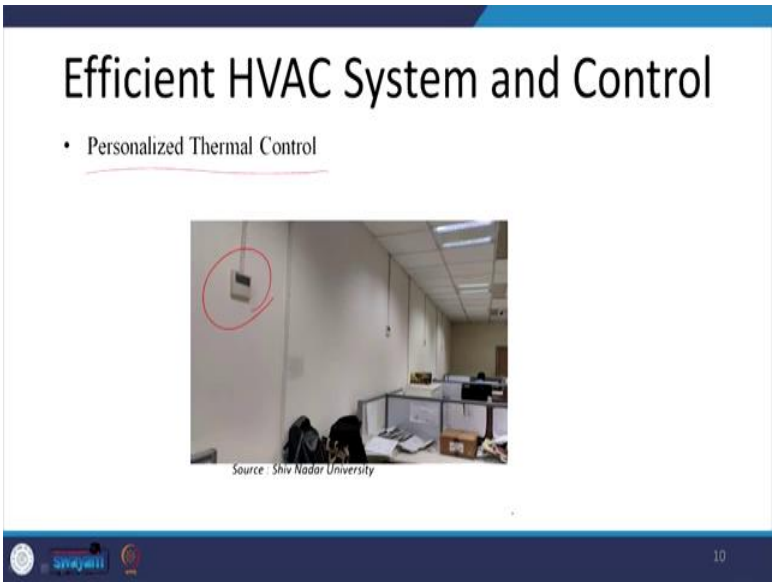

So, there we may have personalized thermal control. So, what personalized thermal control means that not every occupant feels comfortable at the same temperature. They may increase the temperature, thereby reducing the amount of cooling which is required and individually, the amount of air which is flowing into their space, the temperature will be varied. Collectively, this increases the occupancy comfort and the number of people, percentage of people, who feel comfortable who are satisfied with their environment; at the same time, reducing the amount of energy which is required.

Besides HVAC which is the major component of energy consumption in a building, the second most important system equipment system is lighting system and the control. Now, lighting is a major energy consumer specially in commercial buildings and it accounts for approximately 15 percent of the total energy consumption in India.

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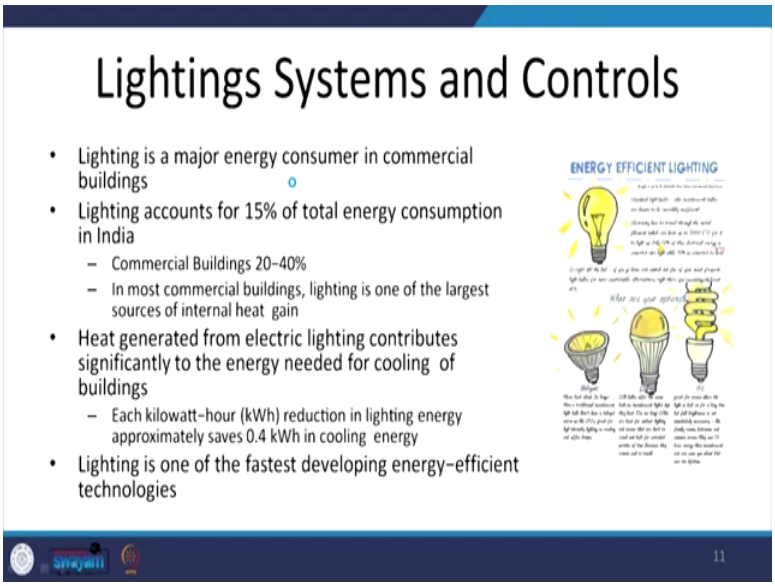

In commercial buildings, it can go as high as up to 40 percent because a lot of artificial lighting is added into commercial buildings. Now, besides the energy which is required for lighting up these lamps, these lamps they generate a lot of heat when they are burning, when they're on.

So, the efficiency of the luminary depends upon how much of the power is supplied to the luminary and what percentage of this power is released converted in the form of light energy and what percentage of it gets converted in the form of heat energy.

For any luminary, the maximum output of illumination as a percentage of the wattage of energy which is supplied higher is this number more efficient is this lighting system.

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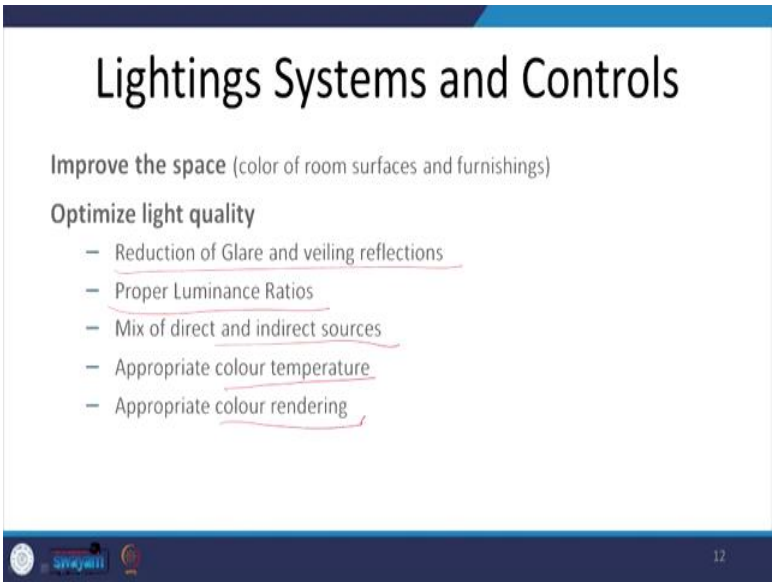

So, when we are talking about the lighting system, we are talking about the qualitative aspects as well as the quantitative aspects. To quickly summarize, the qualitative aspects the first is reduction of glare and reflections from the luminaries; proper luminance ratios in the space; a mix of direct and indirect sources; appropriate colour temperature and colour rendering. So, it has to be a mix of all these qualities when we are selecting the luminary.

Besides this, we are also talking about the quantitative aspects, where we are talking largely about the energy consumption of these luminary lighting systems. One very important approach when we are designing buildings for reduced energy consumption for lighting is by providing the day lighting.

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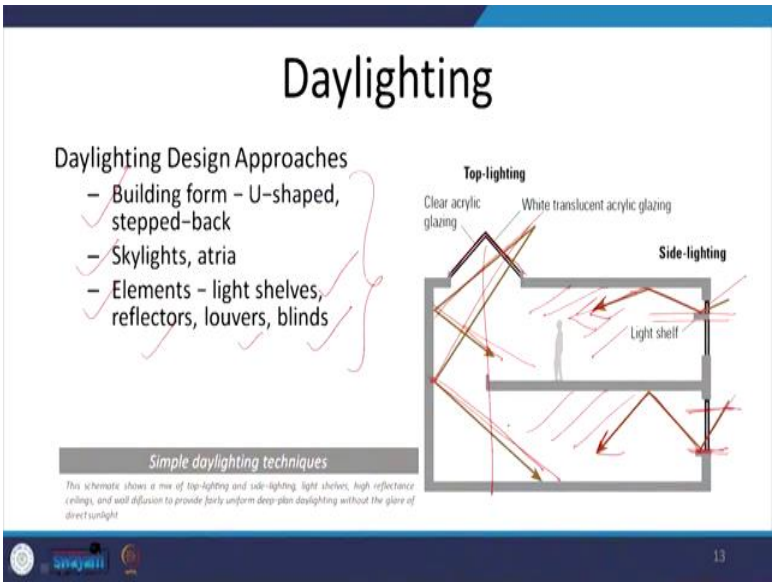

So, there are several day lighting approaches through the design of the building form, through the incorporation of skylights and atriums and through several different elements such as light shelves, reflectors, louvers and blinds. All these together will help in reducing the dependence on artificial lighting and thereby, reducing the amount of energy which is consumed.

So, here we can see how different elements have been used. For example, light shelves which reflects the daylight to the ceiling and helps it penetrate deeper into the building and that is also the diffused lighting. The sky lighting with appropriate choice of the material such that the light is penetrated deeper and with the help of this atrium, the light is penetrated into the deep areas of the building.

Also, the shelves. So, light shelves. So, light shelves is at the top, but also the shelves which reflect the building such that there is deeper penetration of direct light, daylight into the building. So, with the help of such passive strategies, the building can be day lit and artificial lighting can be reduced.

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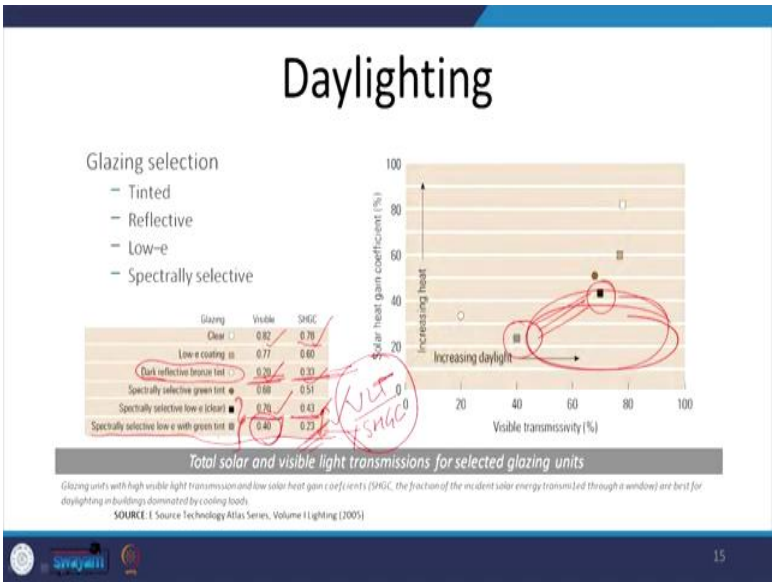

Next, we look at the type of luminary which can be chosen, which has to be selected. So, next we talk about the type of glazing which has to be used on the windows which will allow for more day lighting, but less of the heat penetration. We were talking about it as part of the building envelope, but with a greater emphasis on the heat transfers. So, we talked about the SHGC and U value for the glass. Here, we are also looking at the VLT, the visible light transmittance for glass.

So, if we look at these different types of glass for clear glass, the visible light transmittance is 0.82 which means it allows 82 percent of the natural light falling on to it to transfer inside and 0.78 of SHGC which implies at 78 percent of the heat which is falling on the glass will be transmitted inside. If we look at all these glasses, probably a reflective dark reflected bronze tint glass which has a very low VLT 0.2, but also a low SHGC. So, it will reduce the amount of heat which is transferred inside; but at the same time, it will block almost all the light which is penetrating in might not be a good idea.

While if we to look at the spectrally selective low-e with the green tint, we see that 40 percent off the light will be transferred inside, while 23 percent of the heat gain heat incident will be transferred inside. So, higher is this ratio of VLT to SHGC. So, if we look at this VLT to SHGC higher is this ratio, better is the glass. Because higher ratio implies more light is penetrated while less of the heat is transmitted inside. If we place it here glass

which is in this range is a good glass, when we are talking about a balance between daylight and heat penetration.

So, higher of VLT and low on SHGC is what is preferred. So, here a glass which is somewhere here and here both may perform equally good. So, spectrally selective low-e clear or spectrally selective low-e with green tint both could perform and result in almost the same amount of energy consumption. Because if we will look at the spectrally selective low-e clear, it has a very high VLT 70 percent and SHGC is 0.43.

So, slightly higher than this, but this increase in the heat gain may be compensated because of penetration of daylight and reduction in the energy required for artificial lighting. So, a judicious choice has to be made and which can be helped through different tools which are available, which we will see subsequently.

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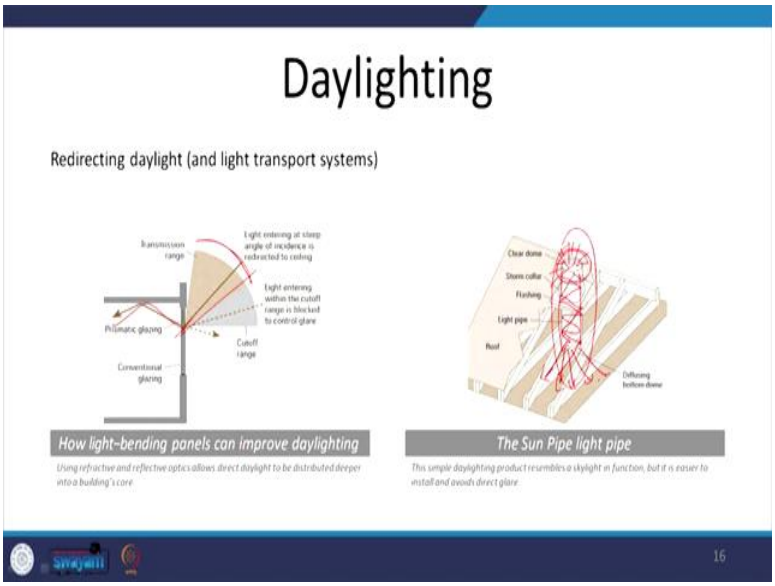

Other systems include the redirecting systems, the light transport systems. For example, a light tunnel; this light tunnel, this light pipe actually has a cleared dome on the top which allows penetration of light from all the sides because it is a domicalstructure and then, inside it is a reflective surface. So, the light is reflected multiple times and from all the directions and it allows for the penetration of light down into the habitable area. This is quite useful, where the light cannot be brought in from the fenestrations on the walls or the sky light cannot be provided because there are multiple stories here.

In addition to that we also have prismatic glazing. Now, this prismatic glazing allows selective cutoff based upon the angle of incidence. So, depending upon when is the light coming in. So, the light entering at a low angle may be cut off because that may be causing glare that may cause glare. So, there are different cutoff rangers which may be by virtue, which is by virtue of the design of the prismatic glazing, but the high angles of incidence are allowed to penetrate inside.

So, these are some improvised and little high-tech systems, where the light can be brought inside and it can be directed to certain areas and depend based upon certain conditions. Other than this we talking about the energy efficient lighting system.

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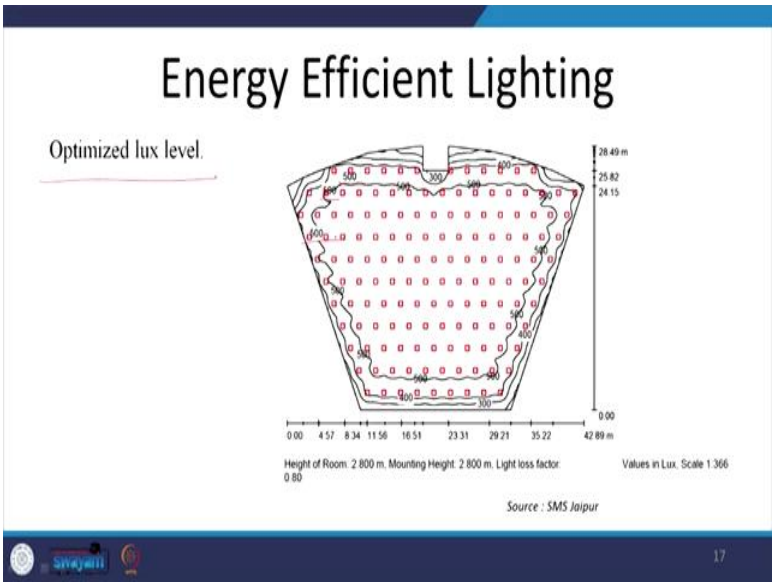

So, when we are talking about the optimized lux levels. So, as per the codes, it is defined how much of the illuminance is required in a given space for a given function. So, based upon that requirement from NBC, we would know that how much is the optimized lux level which has to be achieved in a given space and to achieve that proper lighting design has to be done, uniformly distributed lighting in order to achieve this given illuminance level, the lux levels.

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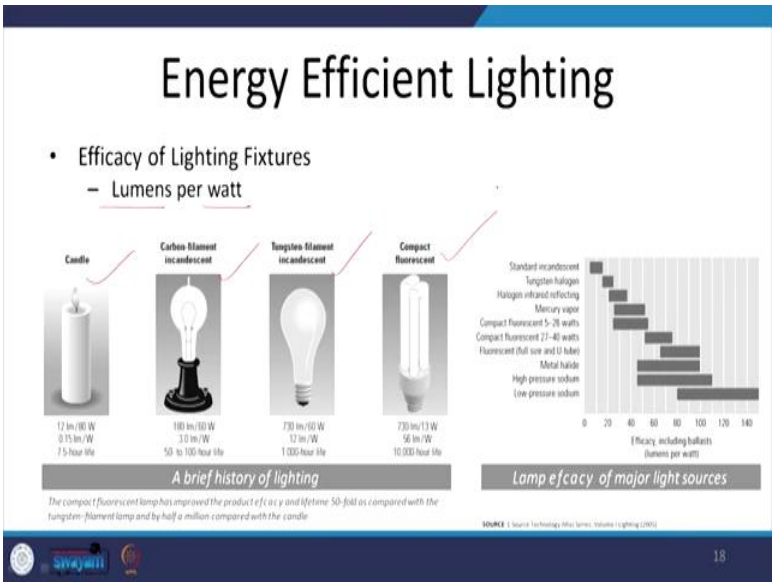

Besides the design which is the uniformly distributed illumination level, we are talking about the efficacy of the lighting fixtures which implies the amount of light measured in terms of lumens which are produced per watt of the energy supply to the luminary, the lighting fixture.

So, if you are look at the different luminaries starting from candle to the incandescent bulb to the tungsten filament incandescent bulb to the CFL which is the compact fluorescent and then, we also have the LEDs.

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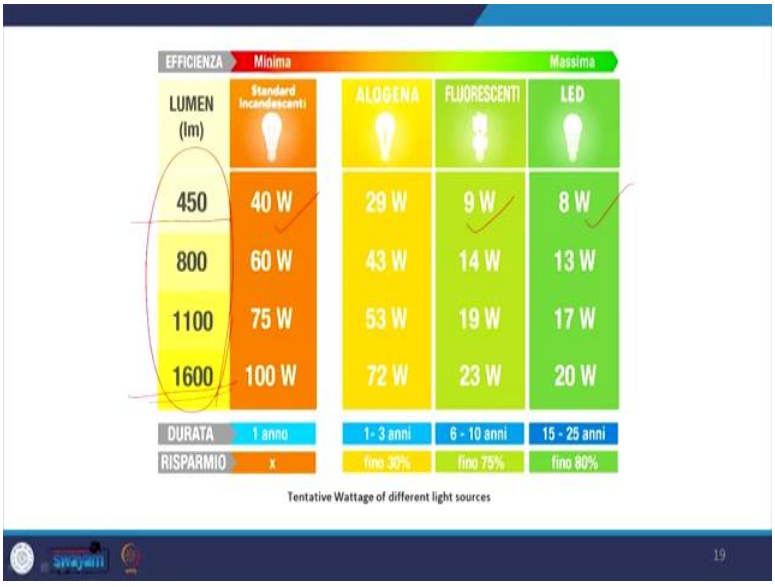

we see for the same given luminance level in terms of lumens, the amount of light which is amount of energy which is consumed by these different types of luminaries lesser is this energy consumed for the given lumen output, better, more efficient is the luminary which we say it has higher efficacy.

So, if we see here for 450 lumens, the standard incandescent bulb would require 40 Watts, while an LED would require only 8 Watts. A fluorescent, a CFL may also require very less amount of energy. LED is have revolutionized the lighting industry, you know it has just leapfrog. So, we today consume very less amount of light for producing the same amount of luminance in our buildings these days.

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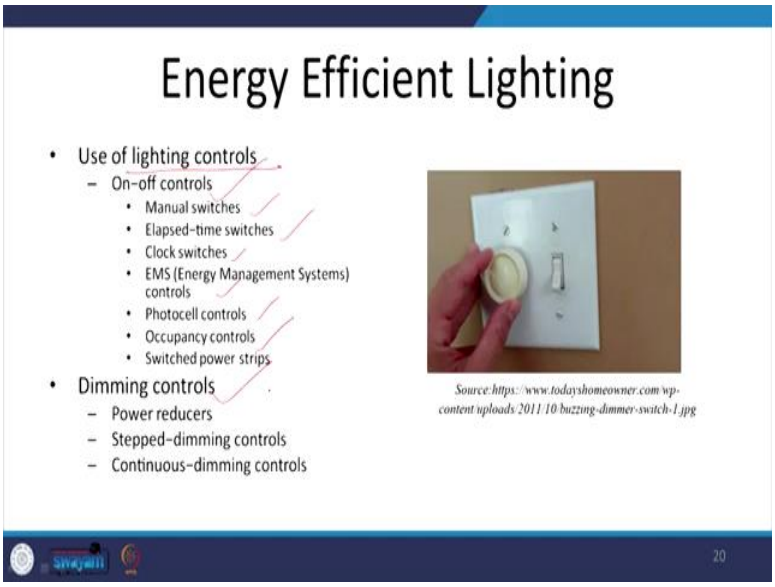

So, highly efficient luminary should be used, high efficacy luminaries should be used and that is why you would see that almost the entire a market is now moving towards the production and sale of LED lights and it comes us no brainer because they consume less amount of energy while giving the same amount of lumen output. In addition to the luminaries, the lighting fixtures, we also have to add the lighting controls. Now, these lighting controls could be of two types; they would be on and off type of controls and they would also be the dimming controls.

So, we have manual switches, the elapsed time switches, clock switches, energy management systems, photocell controls and occupancy controls as part of the on off controls. We will quickly see each one of these what do they do and how do the function

and in dimming controls, we have the dimmers. So, where just like we reduce the speed of the fans, we can reduce the luminous the lumen output of the luminary by reducing the amount of energy which is supplied to it.

So thereby, reducing the energy demand. Less amount of light is required instead of turning off the light and making certain portions of the building certain portions of the space dark, we just dim; we just reduce the amount of luminous which is being produced.

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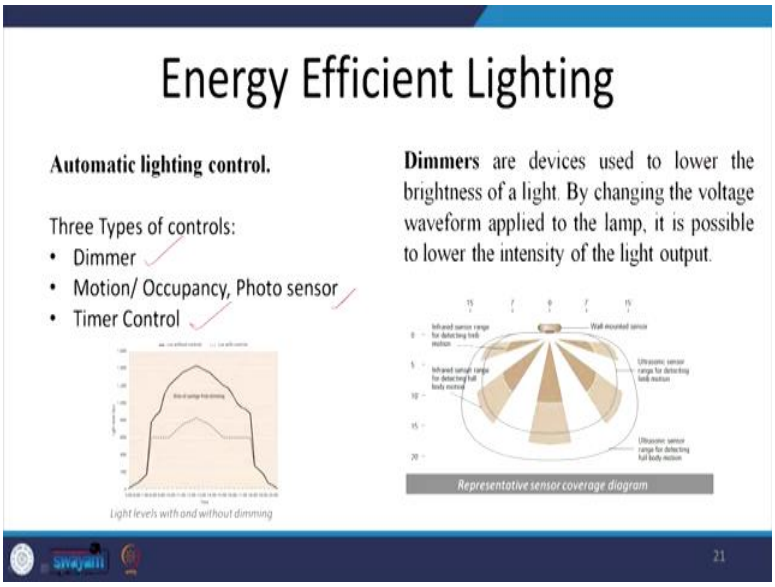

So, what we have is we have three different types of controls, the dimmer controls, the motion or occupancy sensors of photo sensors and timer control. So, dimmers are the devices which are used to lower the brightness of a light by changing the voltage which is supplied to it and thereby, reducing the amount of energy which is consumed.

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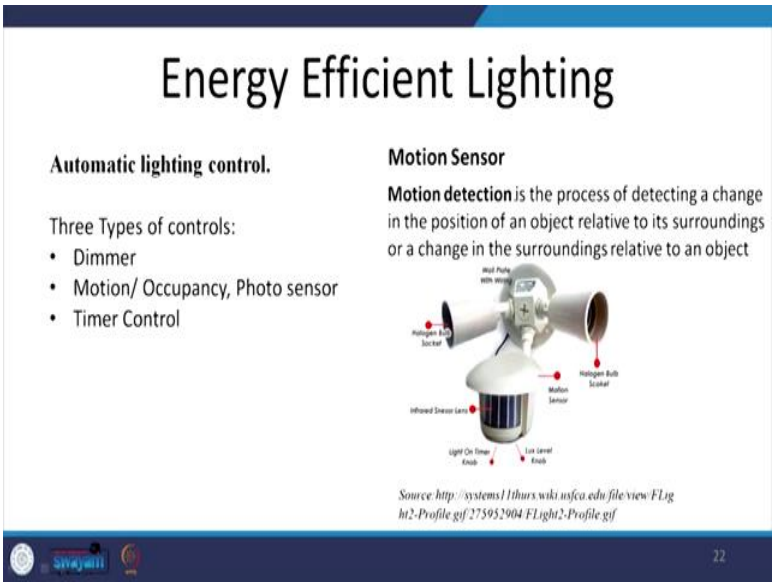

The motion sensors or the occupancy sensor, they sense the motion, movement of people and it is through the infrared sensing. So, the moment there is movement, the lightest turned on in all other times the light would be just turned off.

So, the moment somebody passes where the sensor is placed, the subsequent light which follows, it will be turned on. So, when there is no movement in the corridor or certain areas of the building which may remain empty most of the time, the lights could just be turned off their by saving the energy.

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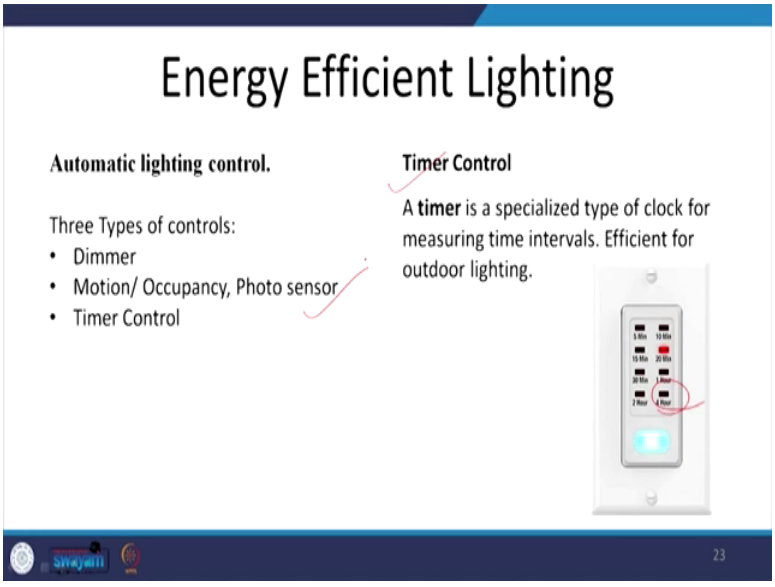

The next is a timer control. So, it is a kind of a clock for measuring time intervals and it is efficient for outdoor lighting. So, for example, in commercial buildings after 7 p.m. for example, when it is getting dark, the building outdoors have to be maintained lit for up to say 10 p.m. for certain types of lights; but beyond 10 p.m. only very few lights are required. So, for this series of light which needs to be turned on only from 7 to 10, a timer control is installed where the timer is set for a say 4 hour duration from 6 to 10. So, for after this 4 hour, automatically all the time all the lights will be turned off.

The other types are photo sensors. So, in photo sensors which all of you might have seen, it measures the daylight levels and after the daylight levels have dropped to a certain level, the lights would automatically turn off. Besides HVAC and lighting systems, we also have several other equipments which are required in the buildings and we need to install efficient equipment and appliances in our buildings. The bureau of energy efficiency has come up with a star rating scheme for different appliances, for different equipments.

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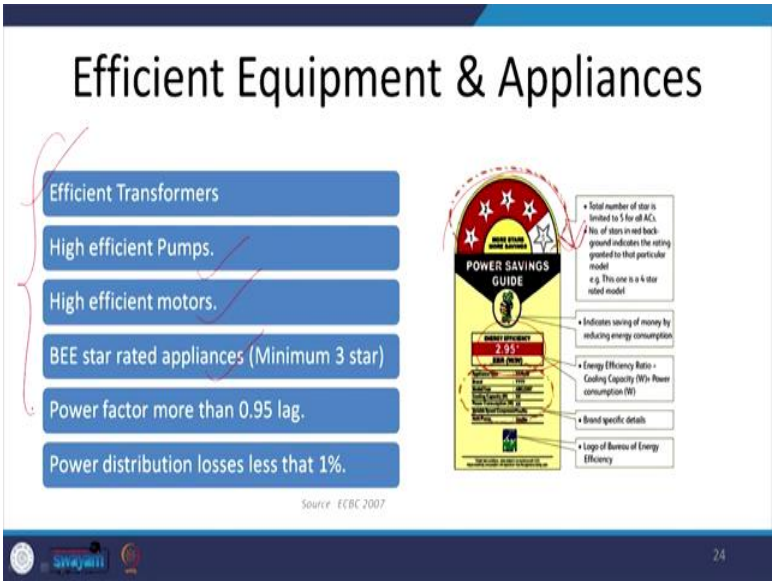

Now, higher is this star rating, I am sure all of you would already know because this is available out in the market. Higher is this star rating implies higher is the energy efficiency of the equipment or appliance that you are buying and lesser is the amount of energy which is consumed for the same amount of output.

So, the different equipments which are required in the building include the transformers, pumps, motors and appliances which include refrigerators and air conditioners. So, all

these are available with very high efficiency in the market and we must choose the highly energy efficient equipments and appliances to be used in the buildings.

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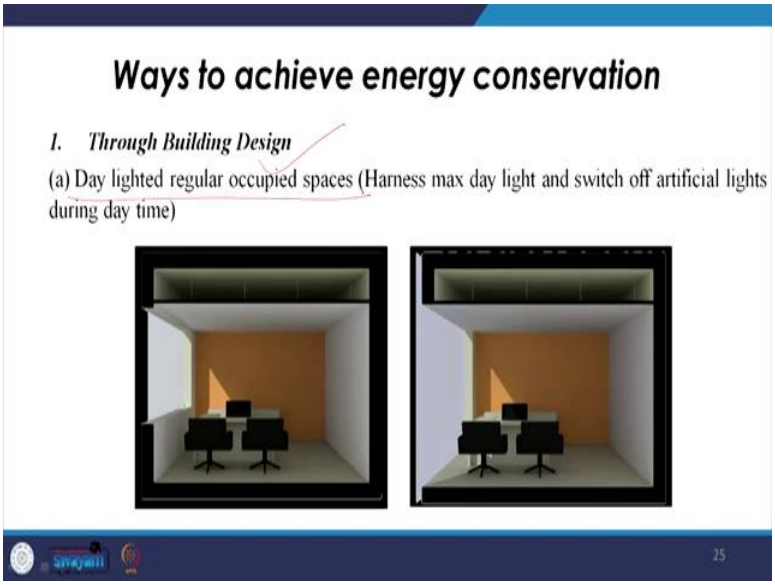

Now, that would collectively reduce the amount of energy which is consumed in the building both for comfort creation and day lighting and also through the regular equipment usage. So, to summarize this generalized discussion about energy efficiency of buildings, let me quickly go through the steps.

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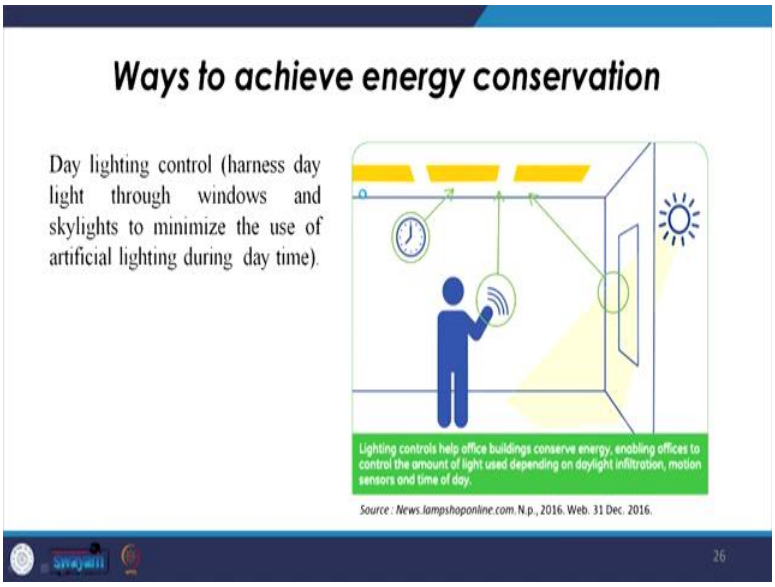

The first and foremost is to optimize the building design and improve the energy efficiency that is through day lighting the regularly occupied areas in order to harness more and more of day light through windows and skylights and minimize the use of artificial light.

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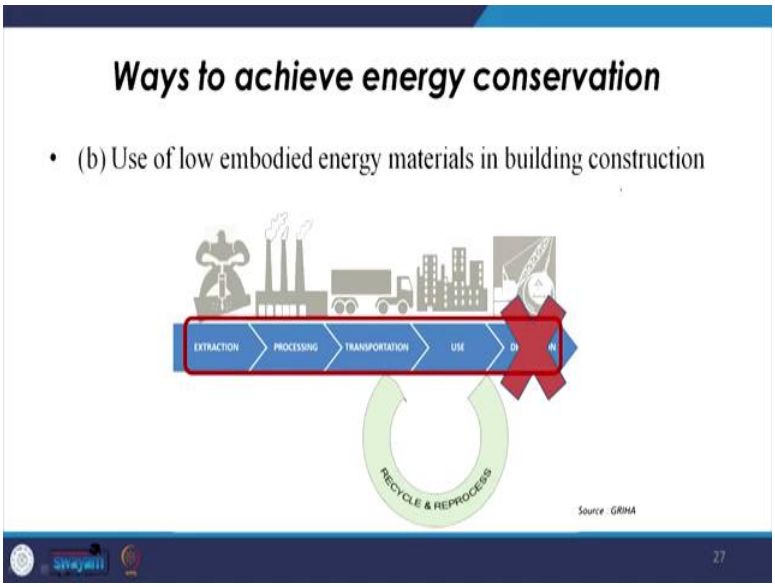

Second is through the use of low embodied energy materials in building construction. Preferring natural ventilation wherever possible.

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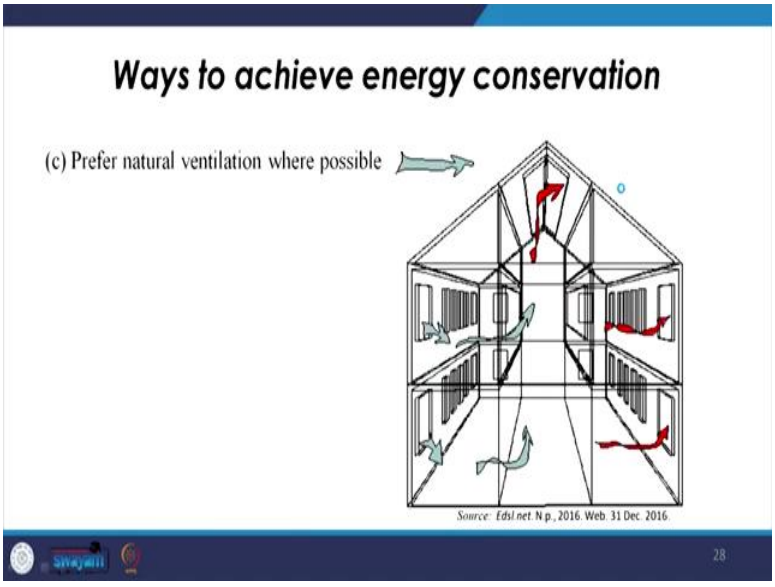

So, the first is to address the thermal comfort and the visual comfort issues to passive design. So, designing the building and building envelop properly in order to reduce the energy consumption of the building.

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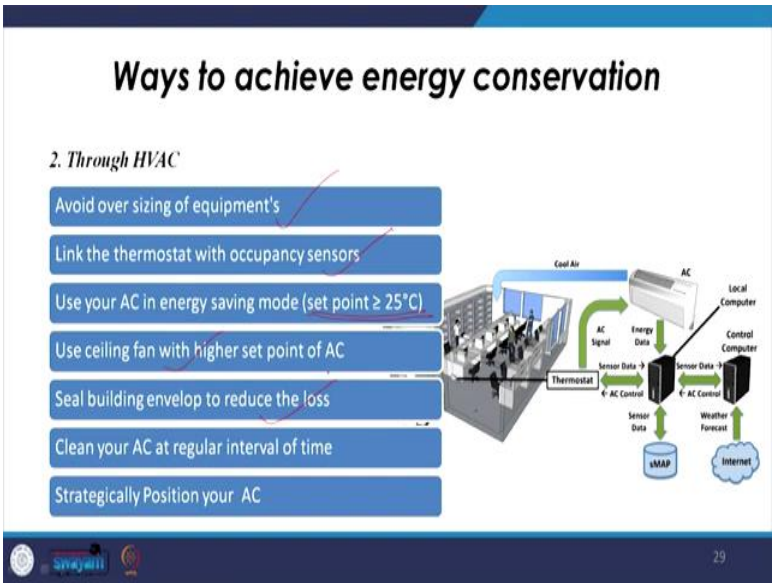

Next step would be through HVAC by avoiding the over sizing of equipments which is what is a usual practice because we always take a very high safety factor. Linking the thermostat with the occupancy sensors so that the thermostat and occupancy sensor are in sync and it is not that even when the occupancy is less, the thermostat is still allowing for a lot of cooling. Use the air conditioner in energy saving mode which is setting it at 25 degree centigrade or higher that is specially for Indian subcontinent, the region in which we are in.

Using the ceiling fans along with the higher set point of AC. Now, these are the operation, these are the operation mechanisms, these are the practices which we can use when we are operating the buildings to achieve a higher energy efficiency. Seal the building envelop to reduce the loss. So, that the coolth, when the building has been cooled is retain inside or the heat is retain inside of the building is being heated.

Maintaining the equipments at regular intervals of time and strategically positioning the air conditioners. This is for individual buildings, but when we are talking about large buildings, then also strategically positioning the ducts, the supply ducts and also the return

ducts, return air ducts in order to increase the area which is cooled by the same supply duct.

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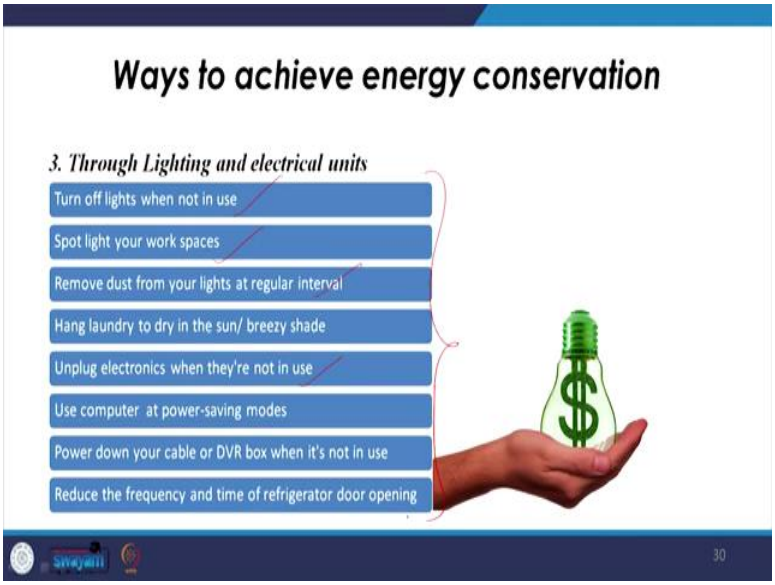

Next will be through lighting and electrical units so, the practices such as turning off the lights, using spotlight, maintaining the lights at regular intervals using sun to drying instead of dryers. So, using computers in power saving modes and not plugging in the electronics when they are not in use. So, some of these are the practices which will lead to saving of energy through lighting and electrical units.

Besides this, selecting the luminaries properly, designing the illumination system such that uniform lighting illuminance is provided and also using sensors and controls such that turning them off automatically when the illumination is not required.

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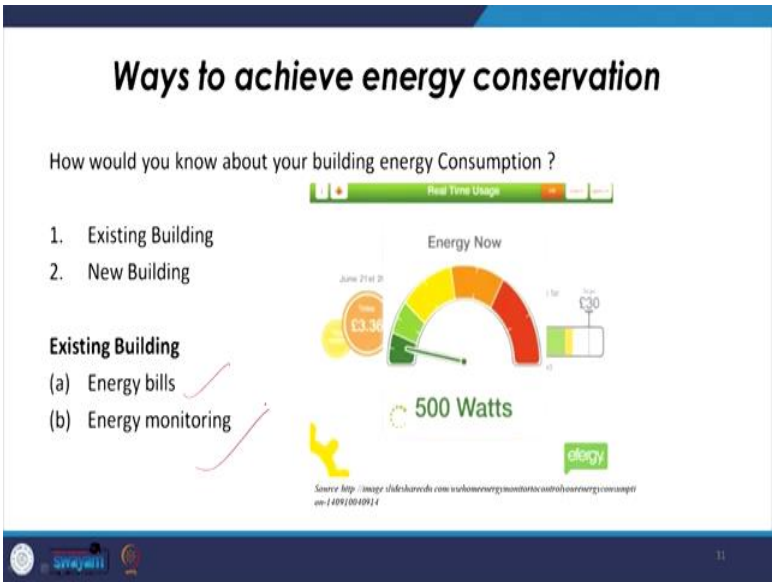

So, what do we do; how do we know that where is our building consumption? We can do that by monitoring our energy consumption and regularly comparing our energy bills. So, if we see that our energy consumption is going high, we can immediately adopt some practices which will help us reduce the energy conservation. Now, this was from a user perspective, from an occupant perspective.

But from a designer's perspective our first aim should be to design the building passively in order to bring in thermal comfort and once that energy demand has been reduced by ensuring thermal comfort, we would then go on to add the HVAC systems and lighting systems.

When we are talking about the new buildings, as at different intervals I have been talking about the different tools which are available. So, there are energy modeling tools which use simulation, computer based simulation to actually simulate how the design is going to affect.

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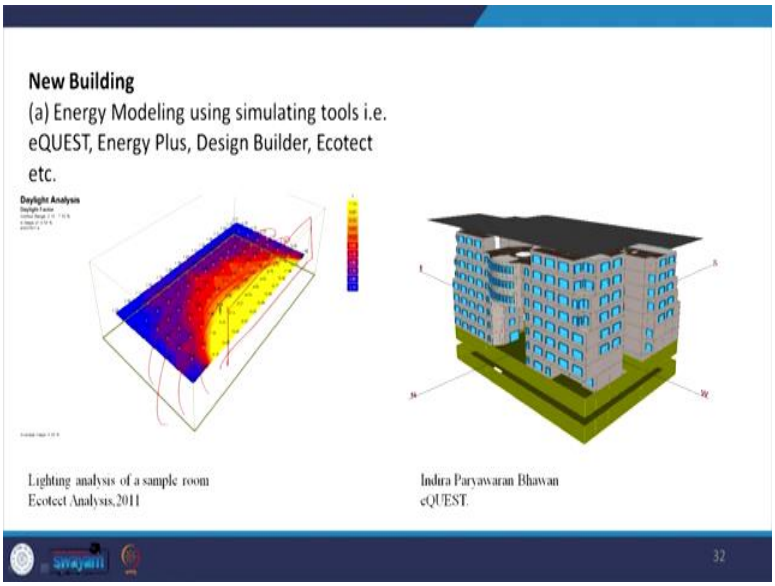

So, how the daylight is going to be when we are talking about a particular design of the fenestration or what will be the overall energy consumption for one alternative versus the other alternative in a proposed new building.

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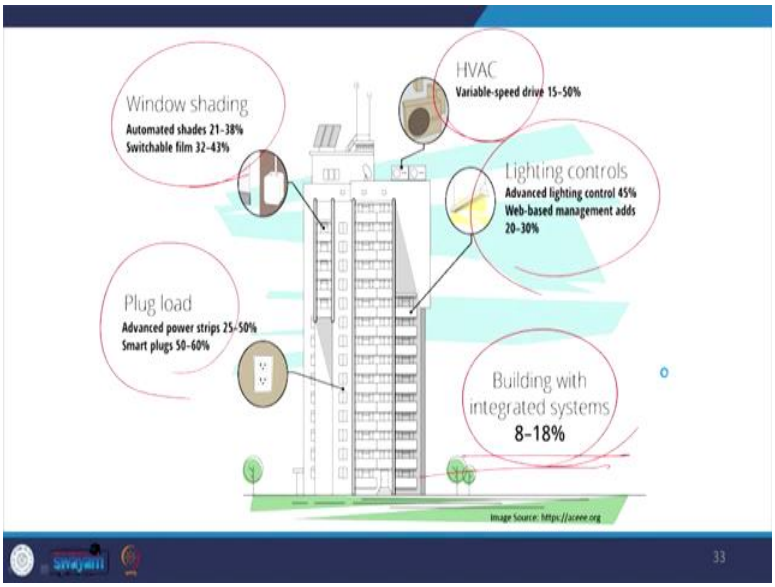

So, what we would do is when we're stimulating this building, we would incorporate all these different components of lighting, HVAC, window shading which is the passive design and also the plug load and calculate and also integrate it with the building integrated

systems of energy generation and calculate the overall total energy consumption and how we can optimize on each of these systems.

So, I was stop here for this and in next lecture, we will look at the compliance criteria for the green building rating programs, rating systems and how to comply with them what are the calculations we have to do and how can we go ahead with the compliance criteria.

In addition, to that in subsequent lectures which will be towards the end of the course, we will be looking at use of one of the simulation tools for this energy compliance how to simulate the building for energy compliance. So, we will also look at that towards the end of this course.

So, thank you very much for being with us today. See you in the next lecture.