Sustainable Architecture
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Lecture - 36
Energy Efficiency - I

Good morning. Welcome to this new week of lectures of this ongoing online course on Sustainable Architecture and in this week we will be talking about Energy Efficiency as part of the sustainable buildings. Now energy has become so important in our life and almost all the functions all the activities in our day to day life are dependent upon availability of energy, we cannot think of our lives going ahead with our lives without energy even for a couple of hours and we become almost paralyzed, our transportation systems, our communication systems, our food production, our life in general everything depends upon energy and its availability.

And if we look at the global trends, this dependence on energy is increasing. Our lifestyles are changing in such a manner that we are becoming more and more dependent upon this energy and that is why the entire world is discussing about how to reduce the consumption of this energy in various heads wherever it goes. We are talking about architecture, we are talking about buildings here and we are also talking about how we can conserve, how we can save energy, how we can make our buildings more and more energy efficient in today's times and why at all are we talking about energy.

Let us look at these energy consumption trends in buildings. If we look at the energy scenario of the world we can see that the per capita consumption of energy.

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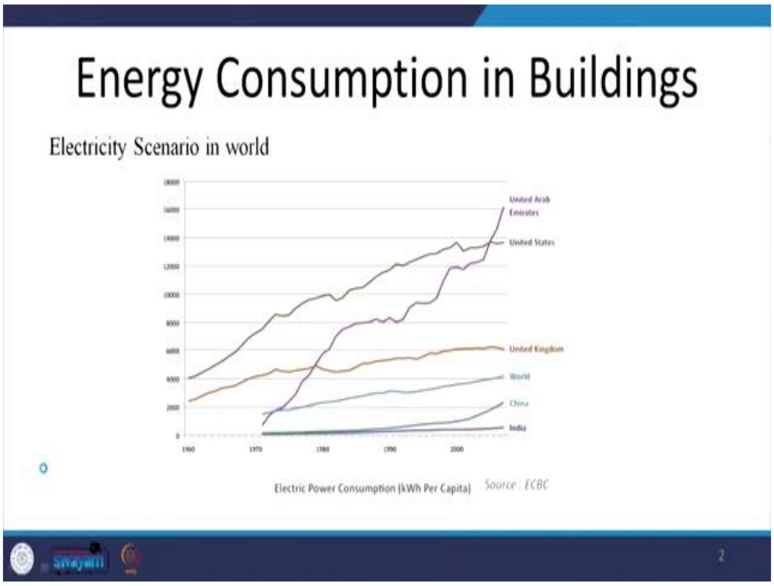

If we are looking at in kilo Watt hour per capita the developed nations have very high per capita numbers and our country has very low per capita energy usage, but if we look at the overall numbers the population and the absolute numbers, we are quite high simply because we have a huge population. And if we multiply this kilo Watt hour per capita by our population, we would see that we are quite high up there when overall energy consumption is concerned.

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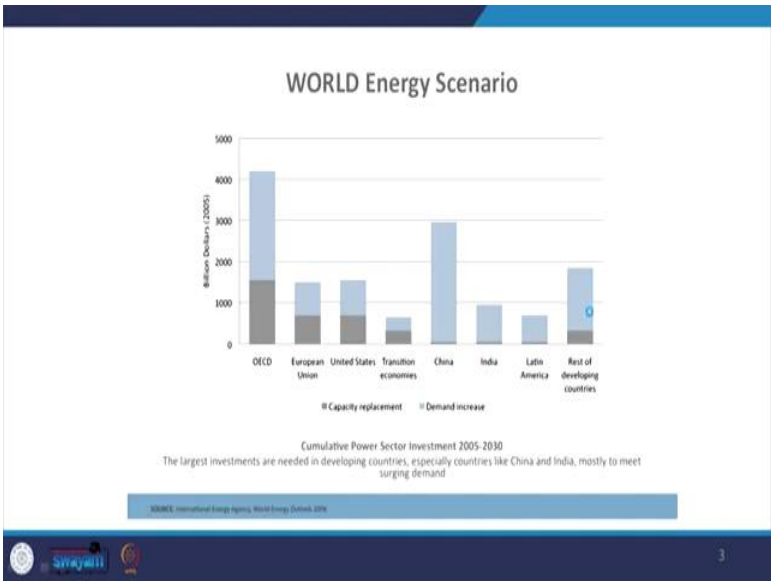

If we look at this energy scenario of the world since most of the development in nations whether they are developed nations, developing nations or underdeveloped nations is directly linked to the energy available in a country. So, every nation pays, focuses their attention towards creation of new energy sources or towards conservation of energy when simultaneous development has to happen.

So, large percentage share of GDP is actually going towards the energy resources, creation of energy resources. If we look at the electricity scenario in India and we look at how and where this electricity is going

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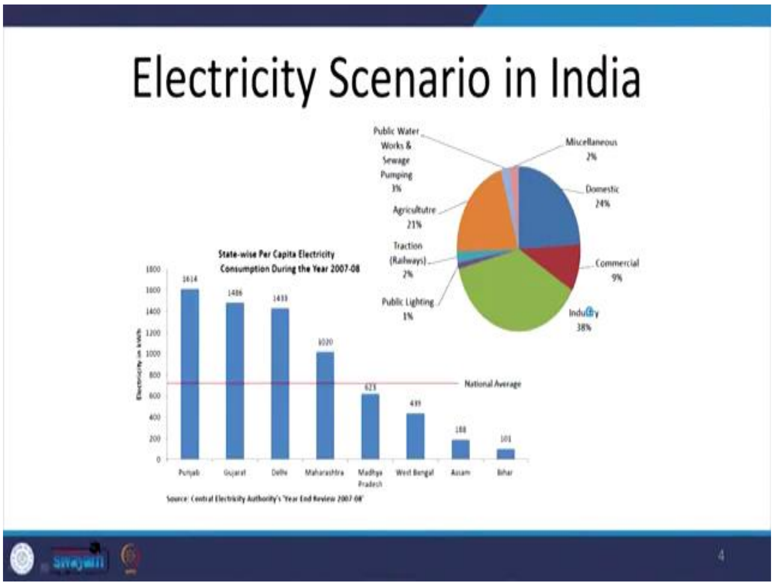

We can see that a large part of this energy is actually being consumed by industry which is around 38 percent, the rest of it is largely going towards domestic, commercial, infrastructure which is public lighting, transportation and again infrastructure here.

Also a substantial part is going towards agriculture which is towards food production, but if you look at this infrastructure: - public works, public water works and sewage pumping, public lighting, domestic and commercial all of it together comes out to be around 35 percent, that is one third of the total electricity which is consumed in our country goes towards these functions which are directly related to the buildings and built environment.

So, either building or our roads or our infrastructure or infrastructure which is required to support the buildings. So, one third of this total energy is being consumed in buildings and built environment which is a huge number.

And this number overall consumption varies from state to state in some states for example, Punjab large percentage of electricity is actually going towards the agricultural activity, while in a state like Delhi which is an urban state and a very dense state, large portion of this energy is actually going towards the built environment domestic, commercial and also industry because there are a lot of industries being set up here. So, there is a variation in the state wise per capita electricity consumption.

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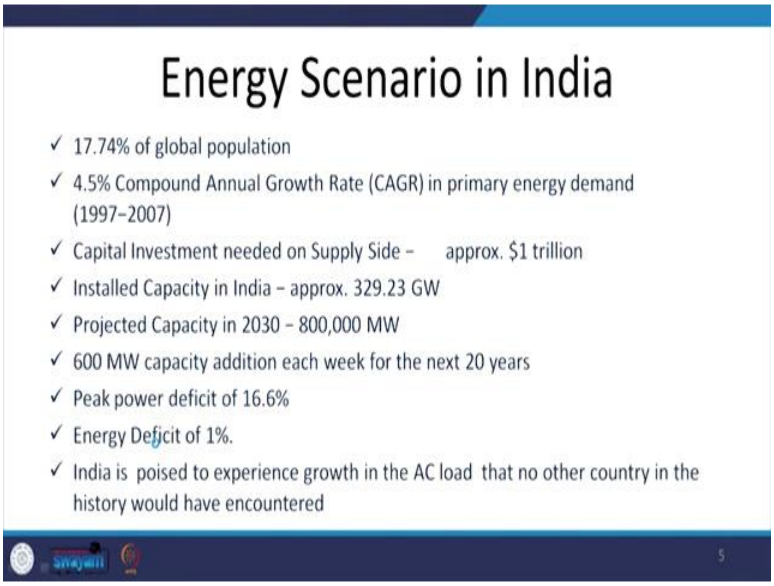

However, if we look at the overall scenario of energy in our country we see that our primary energy demand is going to increase, we are anyways, we have a huge energy demand because we have a huge population. So, even though the per capita consumption is less the overall consumption of energy of the world we still have a considerably high amount despite this per capita low energy consumption we still have power deficit, we have energy deficit.

So, we have an energy deficit of around 1 percent and peak power deficit of around 16.5 percent which is a huge percentage. So, we still have that peak power deficit and that is why a lot of our capital investment is going towards creating the supply, creating new sources of energy and gradually the focus is shifting from non renewable energy sources to renewable energy sources like solar, hydro, wind.

So, we are gradually shifting our focus to renewable energy sources supply, but on the whole there has been a huge investment towards the supply creation of energy. So, currently there is approximately 329 giga Watts of installed capacity in India and the projected capacity in 20 30 has been proposed to be has been estimated to be 800000 mega Watts, which implies that for the next 20 years we will have to add a capacity of around 600 mega Watt each week, which is a huge capital investment. And we need that energy if we want to sustain our GDP.

We cannot sustain the same growth rate if we have less amount of energy available because our industries need energy, our service industries need energy, our agricultural agriculture requires energy. So, the government already is investing a lot towards the supply side of the energy creating more and more supply of energy; however, that requires huge capital investment, it requires policy planning, it requires a long term planning from the government side from the top, the other side of it where we are talking about the demand management.

So, on one hand yes we are supplying, but on the other hand we have to manage the demand and as we have seen that around 35 percent of this energy is going to be consumed or is being consumed in buildings and built environment. We can actually reduce or keep it constant the demand towards the buildings and built environment.

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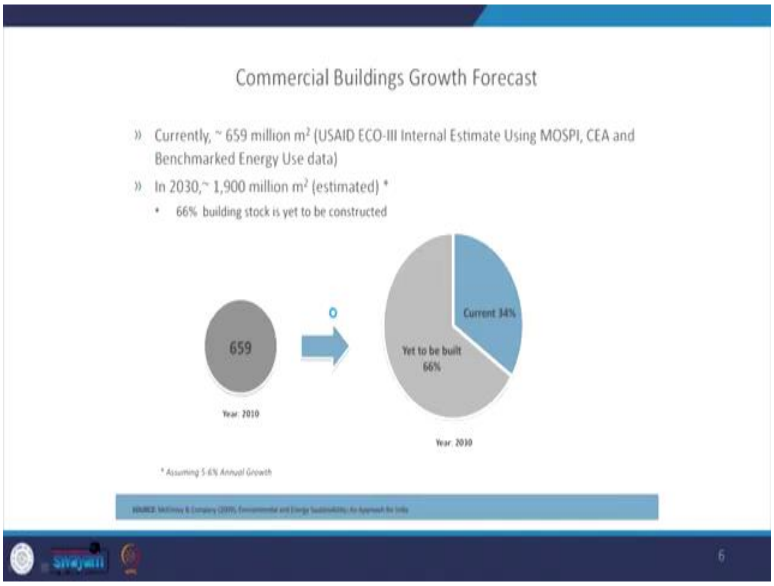

And as per the estimate, as per a study done by USAID ECO-III an estimate of the growth of commercial buildings was made. It was forecasted and it was estimated that the current building stock of commercial buildings is only one third of what it will be in 2030, which implies that around 65 percent of building stock is yet to be constructed and besides this the energy consumption because of installation of air conditioners is going to go up.

So, the percentage of electricity, the amount of energy which is currently consumed towards commercial buildings is going to rise substantially. So, even while we may be adding more and more of energy resources in our country we will still be facing a deficit if the commercial buildings continue to grow like this without taking care of the demand side. And we look at some of these buildings in different parts of our country, they look very similar.

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So, if I remove these names here if I do not talk about these buildings then more or less look the same. This is the kind of commercial buildings which are coming up in India. So, they are extremely energy intensive, they consume a lot of energy not by virtue of the design.

We are not even talking about the design some of these buildings may be highly efficient, they might be using the best of the materials, but just by virtue of the functions that are housed within them these buildings are highly energy intensive, however we can still reduce or contain the amount of energy which is being consumed in these commercial buildings. Now, if we look at the concept of energy efficiency. It is a very simple concept if we have seen how the energy is produced.

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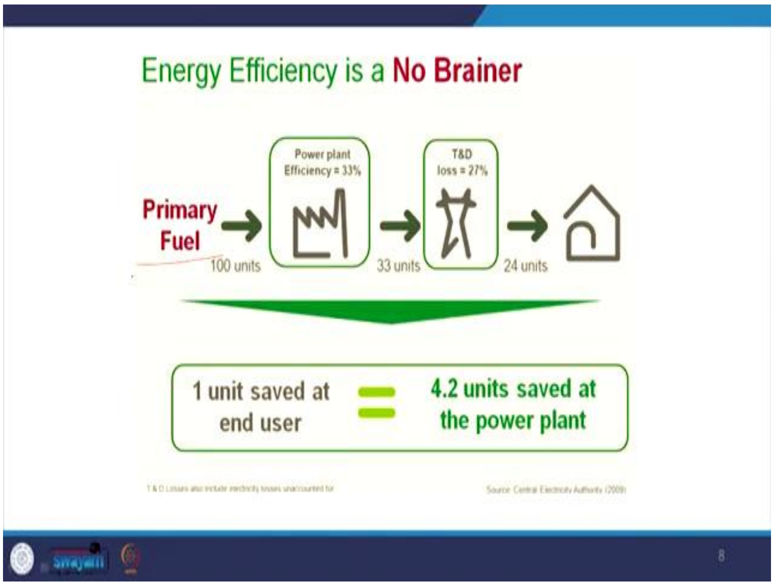

So, if around 100 units of primary fuel has been supplied, through the process of electricity generation and transmission and distribution finally, when the energy reaches our household or commercial buildings, whatever buildings.

Out of the 100 units of the primary energy only 24 units are supplied, which implies that if we save 1 unit here at the end user end around 4.2 units will be saved at the power plant end and here we are not even looking at what goes behind this, Where is this fuel coming from? So, still around 65 percent of the energy in our country is produced from thermal power plants and the coal for these thermal power plants is sourced largely from far off countries like Australia, Indonesia.

So, even before this we are taking this 100 unit of primary fuel into account, a lot of energy has already been spent to bring energy to bring the primary fuel to our power plants, power generation plants. So, if we calculated further back, probably 1 unit of energy saved at the end user end will probably become around 10 units of energy saved at the power plant it is a huge number.

So, while we are talking about adding a lot of energy sources. We should ideally, simultaneously be talking about energy conservation and energy efficiency at the demand side, where for each unit saved we are talking about at least 5 units saved at the power plant end. Hence a very simple proposition and also the investment which is required to manage the demand side is much lesser than to add more supply to the supply side. It is a low hanging fruit it can be done right away, right now and it does not require a long term planning.

It is a short term plan which is required and we can start doing it immediately. That is why we talk about buildings and conservation of energy at the building level itself. If you look at these buildings and we look at the lifecycle cost of a building.

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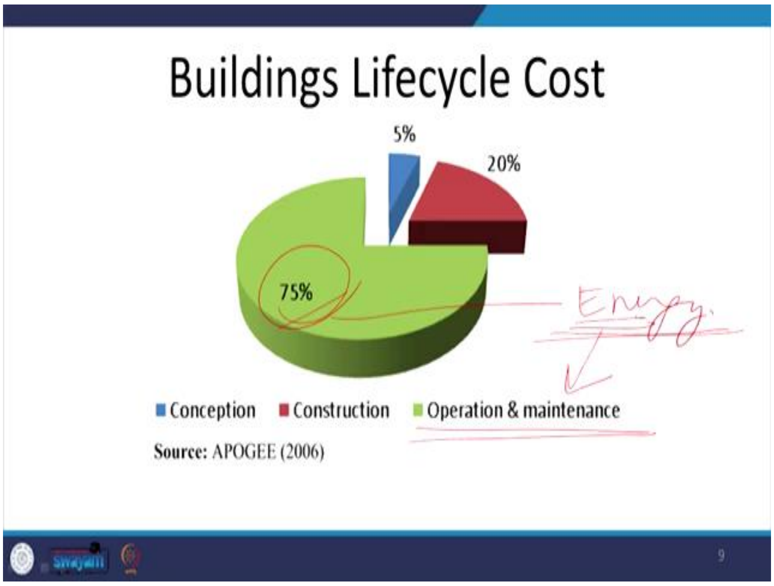

We can see that around 75 percent of the lifecycle cost of the building is during the operation and maintenance phase and of this operations and maintenance phase a large part of the cost is actually the cost of energy. Besides energy there are other resources which also inflow for example, water is there, some material is also there. But large part of the cost which goes towards this operation and maintenance is the energy cost.

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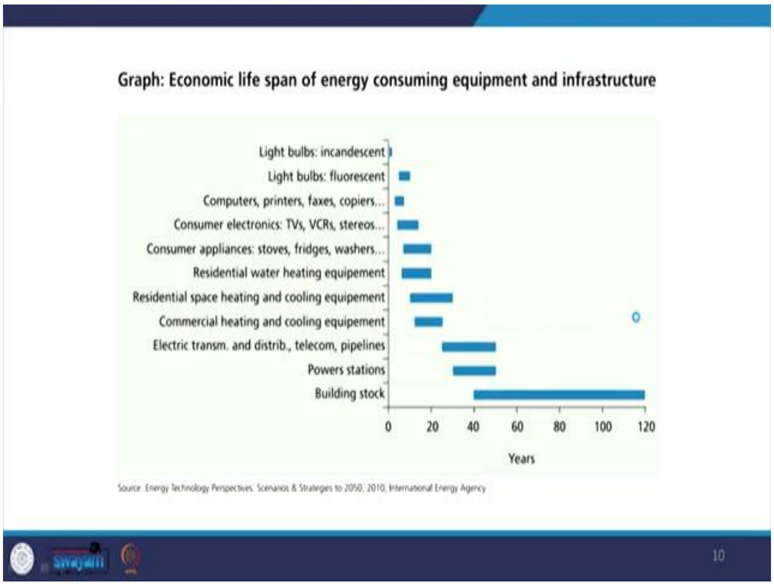

And hence we talk about conserving energy, making our buildings more and more energy efficient.

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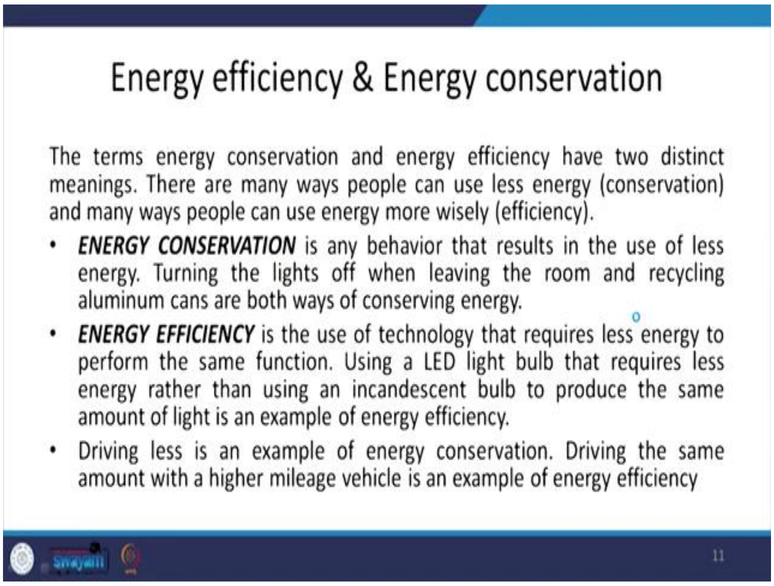

So, I have been using this energy efficiency and energy conservation quite interchangeably throughout my discussion so far. So, I use energy conservation sometime, I use energy efficiency both are the means for demand side reduction of energy use; however, they are not exactly the same things. They are two very similar, but distinct terms and processes.

So, when we talk about energy conservation. We are talking about any behavior or a process that results in the use of less energy. So, for example, turning the lights off when leaving the room or for example, making more and more of your spaces as naturally ventilated and not air conditioning them at all is an energy conservation practice.

While when we talk about energy efficiency it is the use of technology that requires less energy to perform the same function. For example, in a room, any room if we have to provide 400 lux or 300 lux of artificial lighting, after we have already reduced this demand by adding the daylight. So, during the light if I have to provide for 300 lux while I have already taken into account the energy conservation measures. Instead of providing for a CFL or an incandescent lamp, I would actually be using the LED light bulb which will be more energy efficient.

So, for the same amount of power output, for the same amount of illuminance I will be using less amount of electricity and that is what energy efficiency is. So, both energy conservation as well as energy efficiency are needed to reduce the demand for energy in buildings.

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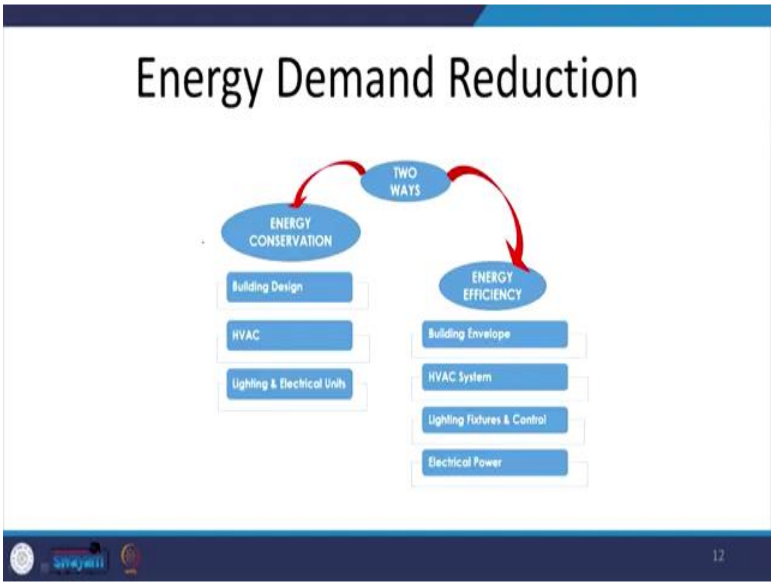

So, if you talking about energy conservation, we are talking about the design principles, we talking about how we design our HVAC, how do we design our lighting and electrical units? While when we are talking about energy efficiency we are talking about building on loop. So, what are the thermal, what kind of materials should be used and what should be their thermal properties, what kind of HVAC systems. So, again we are talking about HVAC system, but besides a design here we are talking about the efficiencies of this HVAC system.

So, maybe we have already reduced the size the tonnage of AC from 500 tons to 300 tons that is through conservation, adding different types of practices and design strategies, but that 300 tonnage of HVAC can also be installed with very high coefficient of performance or very high energy efficiency, same as with selection of lighting fixtures and their control mechanism the sensor technology and also the electrical power. So, when we are talking about the energy demand reduction. We are talking of these two ways simultaneously and not in isolation at all.

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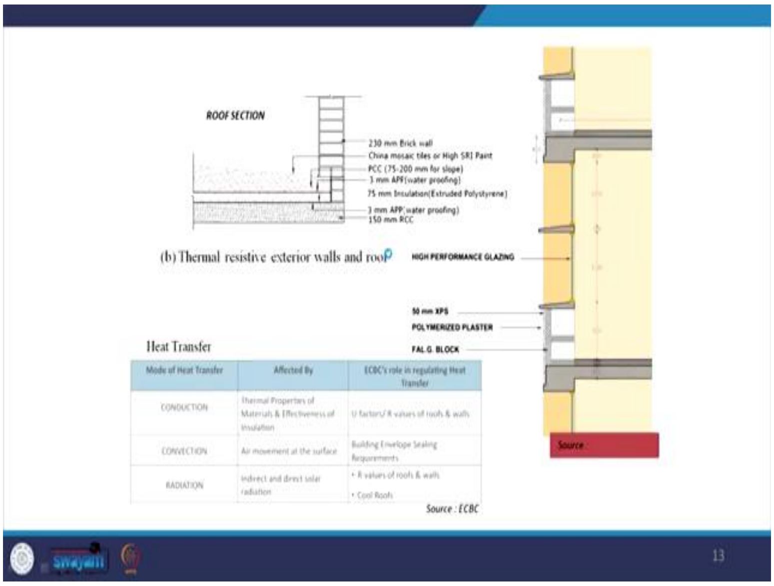

Now, when we talk about this demand side reduction, we are talking about the fundamentals of building physics. We should know how the energy is transferred and what are the different functions for which energy is consumed in a building? So, when we look at this energy consumption pattern in a building there are various functions for which energy is consumed, largely energy in a building is consumed for maintaining thermal comfort for maintaining environmental comfort inside the building that is for HVAC Heating Ventilation and Air conditioning.

So, our mechanical fans, the air conditioners they consume the maximum amount of energy besides that huge amount of energy is also consumed by lighting fixtures. So, the artificial lighting fixtures which are installed in the buildings, they also consumes substantial amount of energy. So, these two are the major guzzlers of energy besides on these two heads the equipment and tools which are anyways going to be there.

And also processes like cooking or in commercial buildings there might be processes like for computing, photo copier stationary and several such activities. So, whenever we are talking about building energy efficiency and building energy conservation. We are largely focusing on these 2 heads which is for energy consumed, for thermal comfort environmental comfort creation and for the artificial lighting purpose. Now, when we are talking about the HVAC for thermal comfort creation, we are talking about the heat exchange.

So, what happens commonly as a common sense if we have a building which is placed in a hot dry climate, where the outdoor temperatures are quite high it is very hot outside? So, what happens that a lot of heat is transferred from outside to inside and the temperature indoors goes up and we start feeling uncomfortable. So, in order to maintain the comfort cooling has to be introduced where the heat which is indoors has to be extracted and thrown out.

In another season when it is extremely cold and the outdoors are cool the heat transfer takes from indoors to outdoors and in order to maintain the comfort we have to heat the indoors. In all these different scenarios whether it is summers or winters or monsoons or a comfortable period the heat exchange is quite critical to reducing the energy consumption in a building and heat exchange takes place through the very basic 3 mechanisms and that remains the same that is the fundamental of building physics.

So, there are 3 different modes of heat transfer; one is conduction, convection and the third is radiation. So, when we talking about heat transfer through conduction in buildings specifically we are talking about the thermal properties of the materials and the effectiveness of insulation. So, what kind of materials should be selected so that they reduce the heat transfer from indoor to outdoor or outdoor to indoor? And the properties which we have to consider are the thermal properties of these materials for example, the U value or the R value of these materials.

Next we are talking about the convection. Now, this convection takes place heat transfer through convection takes place because of the air movement at this surface and also through the fenestration. So, this is how heat transfer is taking place and when we are talking about this heat exchange through convection. We will be talking about the sealing envelope sealing requirements so as to reduce this convection heat loss through convection.

And lastly when we are talking about radiation we are talking about indirect or direct solar radiation and here we will be again talking about the R values of roofs and walls. We will be talking about the S R I value the Albedo values of the materials. So, a couple of these terminologies that I have used to explain the basic concepts of heat transfer.

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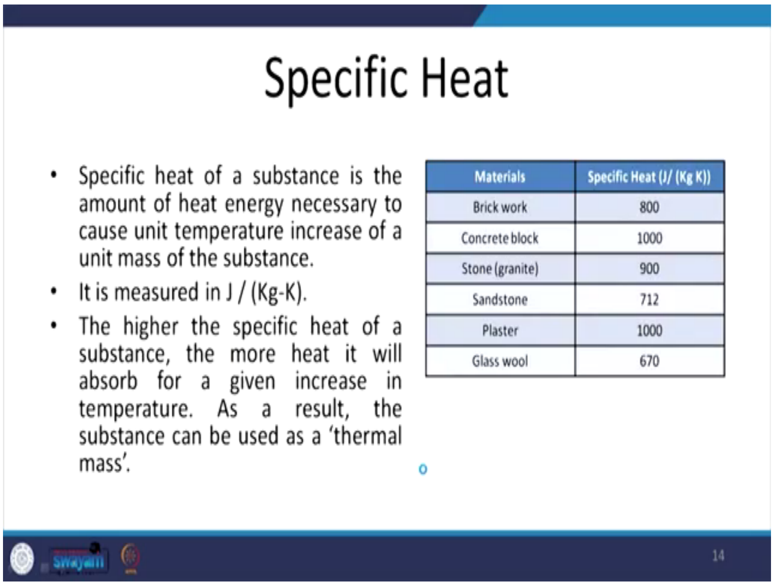

I will be covering as part of my first lecture and then gradually we will move on to more of the compliance approaches and how to select the materials, how to understand the various codes related to the energy specification when we are talking about sustainable buildings.

So, first property is specific heat all of you who are attending this course are science graduates and you very clearly know what is specific heat is. So, specific heat of a substance as we clearly understand is the amount of heat which is required to cause a unit temperature increases of a unit mass of the substance. Now, what it implies is that higher is the specific heat of the material more will be the amount of heat which it can absorb from either side of the building and gradually transfer to the other side.

So, if we have a material which has higher specific heat it means that material can store heat for a longer duration and also more amount of heat can be stored given the volume of the material.

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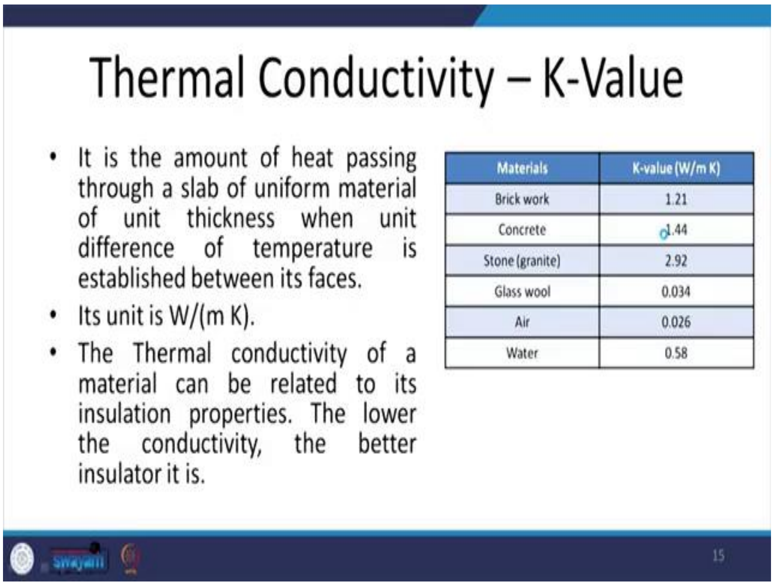

The next is thermal conductivity, now this thermal conductivity is a property where it relates it tells us that how much of the heat will be passing through the thickness of the material from one side to the other side when the difference between the temperature of its one phase to the other phase is 1 unit degree. So, it is expressed in a unit which is Watts per meter per degree Kelvin. So, which is for a unit thickness so for example, 1 meter thickness of a material how much heat can be passed from one side to the other if the difference between the two surfaces is 1 degree Kelvin.

Now, higher is the thermal conductivity, higher is the rate at which heat will be transferred from one side to the other side. So, if we look at this stone has a very high conductivity. So, though it also has very high specific heat, it also has a high conductivity which implies that it can take in more amount of heat, but it will also transfer at a much faster rate.

If we look at concrete again high specific heat, but high thermal conductivity, brick also has high thermal conductivity, metals have even much higher thermal conductivity we know that is why most of the materials are good conductors of heat. So, whatever amount is taken from one surface, almost the entire is passed to the other surface and that is why conductivity thermal conductivity is quite an important property.

On the other hand a materials such as glass wool has very low conductivity which means it makes it a good insulation material, when we talk about conductivity for a unit area of a material irrespective of its thickness then it becomes conductance.

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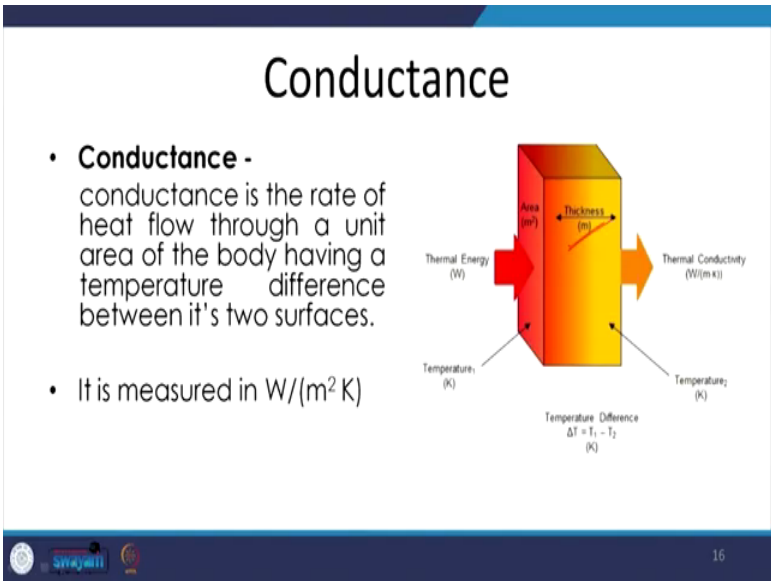

So, if we look at its unit it is Watt per meters square per degree Kelvin. So, the amount of heat which is transferred from 1 unit area of a material of a given thickness to the other side for 1 degree temperature change is what conductance is. Conductance is directly dependent upon the thermal conductivity and the thickness of the material.

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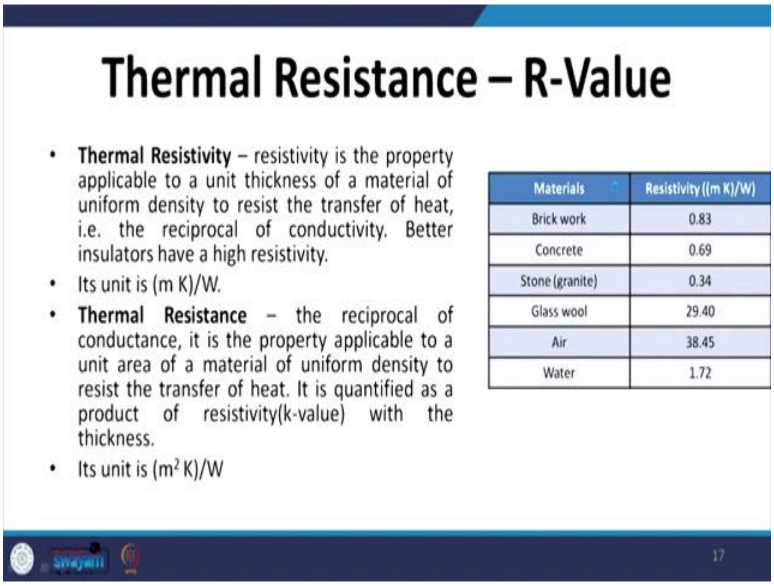

Now, we have the reciprocal values of conductivity and conductance which are called thermal resistivity and thermal resistance. Thermal resistivity is the property of the material to resist the transfer of heat and it is the reciprocal of the conductivity. So, higher is the resistivity better is the insulation property or capacity of the material. Now again resistivity is for a unit thickness of the material for a unit degree change. Thermal resistance is the reciprocal of conductance and it is the property applicable to the unit area of the material of uniform density to resist the transfer of heat.

We use R values when we are talking about the insulation properties of the materials we talked about conductivity and conductance, when we are talking about the heat transfer property of the material. So, if we have to calculate the R value which is the thermal resistance.

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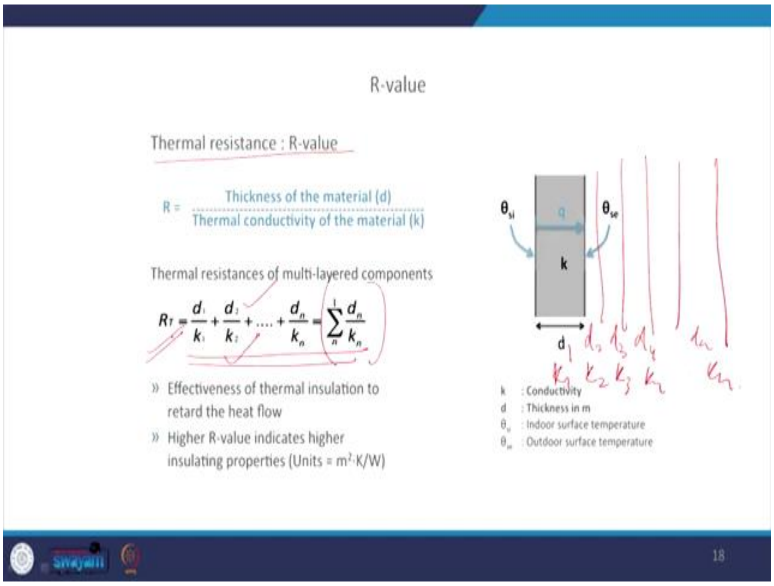

And if there are multiple layers of these material so, in case instead of this one single material if we have multiple layers where the thickness is vary from d 1 to d n and their conductivity is also vary from k 1 to k n, using this formula which is summation of the thickness of the material divided by the conductivity of the material and summing it up we get the total thermal resistance of a material.

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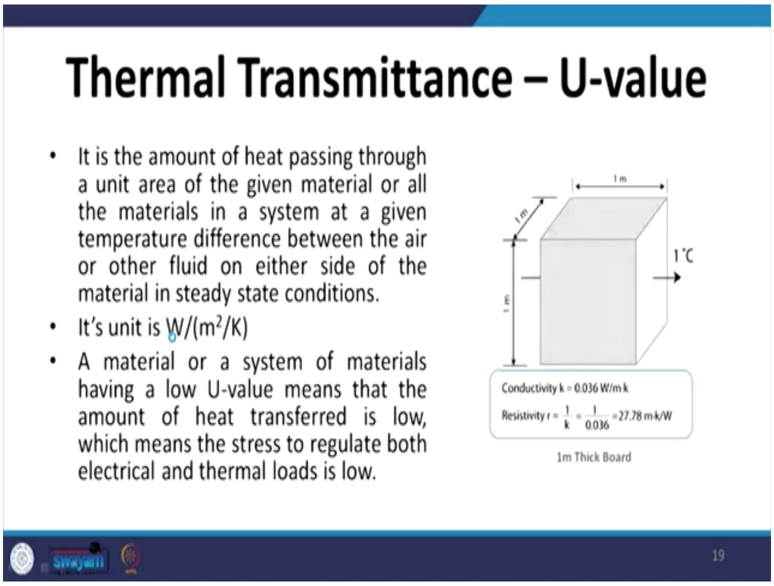

Now, we have another value which we use as thermal transmittance which is the U value. Now, this is the amount of heat which is passing through a unit area of a given material, of unit thickness, for unit degree change of temperature from one surface to the other surface. So, the unit is Watt per meter square per Kelvin. So, it has a unit which is similar to conductance, but it takes into account a unit thickness of the material and the unit area.

This is a very commonly used property which is what we will quite often come into contact and a lot of our codes talk about the U values of these materials. Now again U value could be for a uniform material which is of uniform density. It could also be for layers of materials where we would be talking about a combination of]llothese materials and the overall thermal transmittance which is the overall U value for a given assembly.

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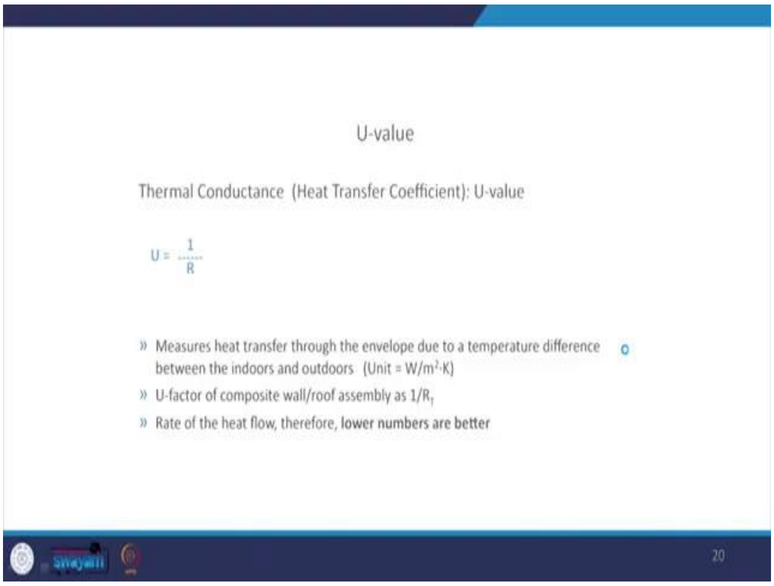

So, assembly U value or the thermal transmittance is the reciprocal of the thermal resistance.

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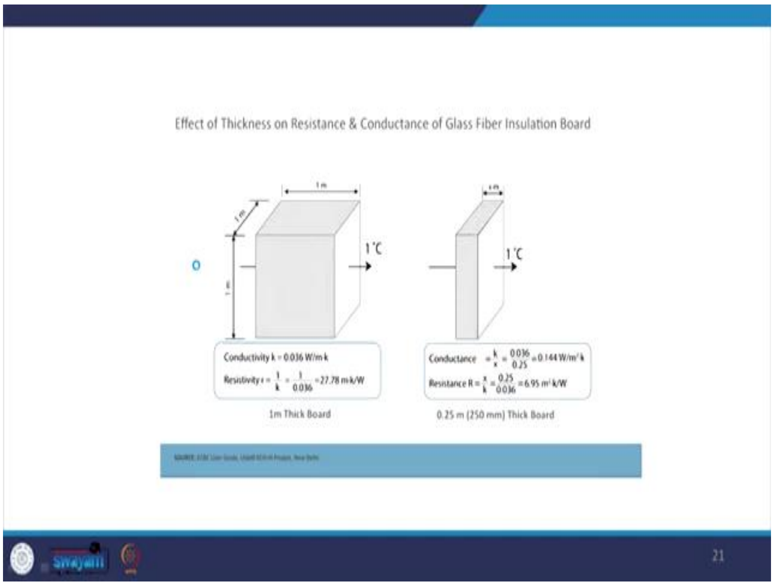

If we look at the effect of thickness on the resistance and conductance or transmittance of a material, we can clearly see as we reduce the thickness of a material its conductance increases. So, instead of a unit material say 1 meter for which the conductivity was 0.036 Watt per meter Kelvin, which is also the conductance in this case because the d is 1 the thickness of this material is 1 meter 1 unit.

And here the thickness has been reduced. So, the conductance of this material has increased which implies that more amount of heat will be passed if the thickness of the material is reduced keeping all other properties as the same. So, the specific heat remains the same, the conductivity remains the same, but the conductance changes if the thickness is reduced.

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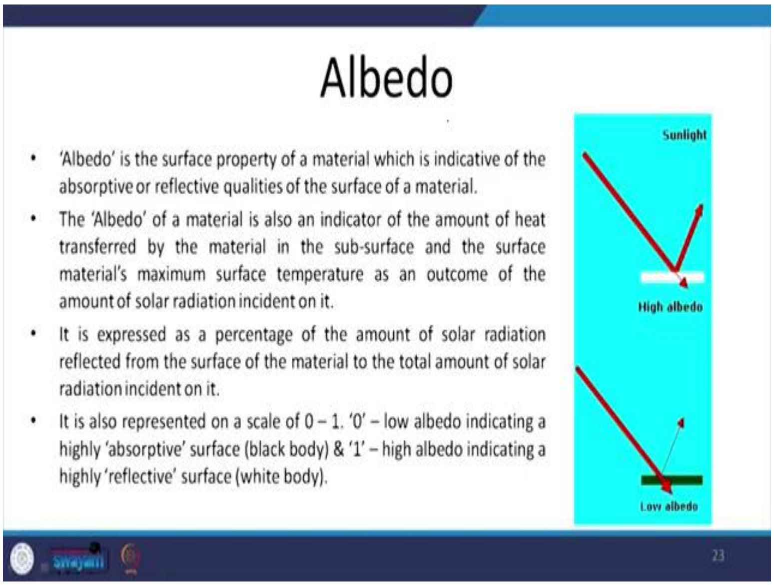

Couple of other properties, include Albedo, now Albedo is the surface property of a material which is indicative of the absorptive or reflective qualities of the surface of the material. So, it is the quality which implies how much of the heat which is incident on a material is reflected or absorbed by the material. So, higher is the amount of heat which is reflected higher is the Albedo of the material.

Higher Albedo materials imply they reflect most of the energy which falls on them, while low Albedo materials absorb most of the energy which is incident on them.

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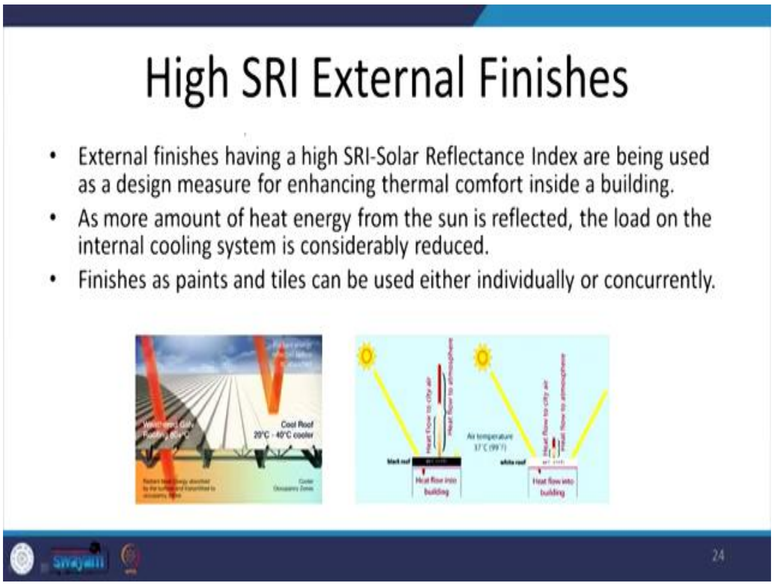

Next we also talk about high SRI external finishes I will not go in detail over this particular property here because we have already discussed it in detail when we were discussing about the urban heat island and selection of materials for reducing the urban heat island at the site level.

Now, all these properties will be used while selecting the materials for construction of building envelope or for adding the insulation layers on top of these structural members, structural materials. Here when we are choosing the insulation there are multiple properties which need to be kept in mind.

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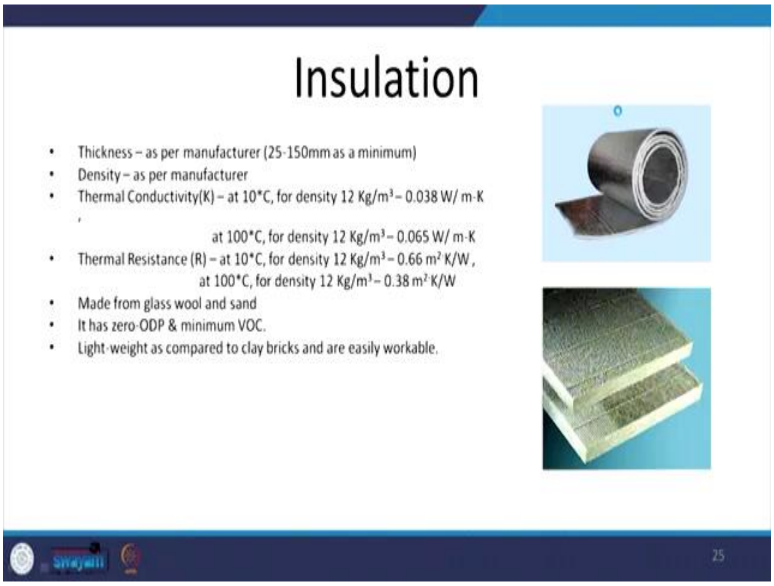

We have already discussed one is the thickness how thick the insulation has to be because we have seen lesser is the thickness more is the conductance and less will be the resistance, then its density, different materials behave differently.

So, some materials have if they have higher density and often higher density materials they transmit more heat from one side to the other side as compared to the low density materials porous materials because they have more of cavities often filled with air. Then we also talked about the thermal properties, thermal conductivity and thermal resistance or resistivity higher is the thermal resistance better is the insulation material.

Another property which is called solar heat gain coefficient and it is the property which is specific to transparent building materials which can permit transfer of heat from one side heat and light both, but mainly heat from one side to the other side.

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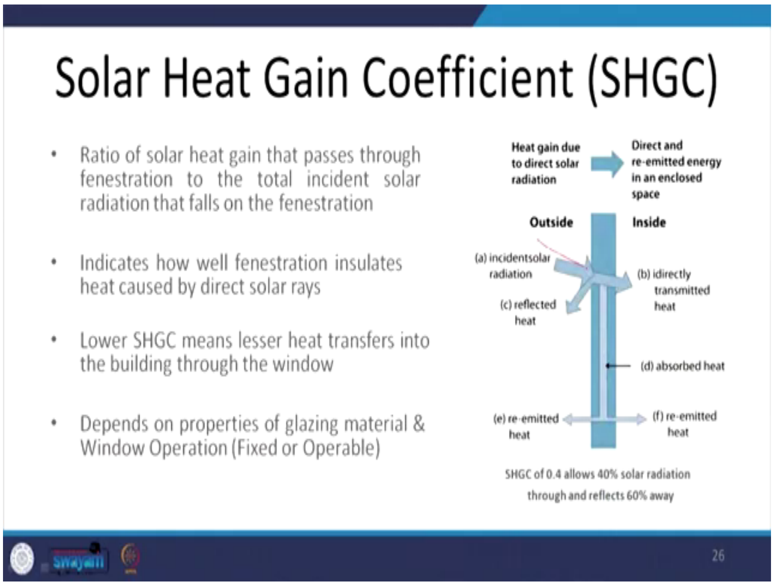

Now here whenever solar radiation is incident on a material surface from one side part of it is reflected back, part of it is absorbed by the material which is then later reemitted reradiated to both the sides of the materials depending upon the thickness and depending upon the property of the material and some is directly transmitted inside. So, SHGC is the sum total of all that is transferred from outside to the inside or vice versa, so from one side heat gaining side to the heat receiving side.

So, the total amount of energy which is percentage of it which is passed from the incident side and as a percentage of the incident solar radiation to the other side is what solar heat gain coefficient is higher is the solar heat gain coefficient implies higher is the amount of heat which is transferred from the heat gain site where the incident solar radiation is received to the indoors. Next property is visual light transmittance.

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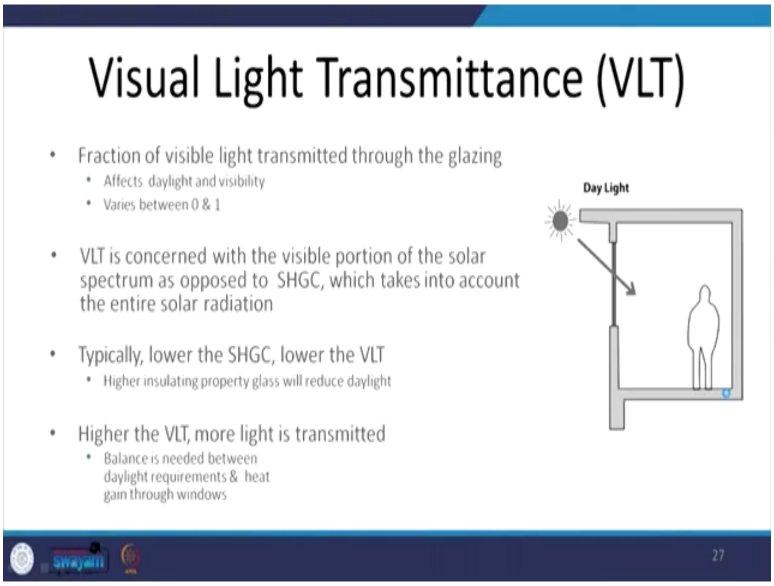

This implies what fraction of visible light? So, in SHGC we are talking about the heat component of the solar radiation through visual light transmittance, we are talking about the visible light fraction of the incident solar radiation which is transmitted through the transparent or translucent building material often glazing here.

So, this is this varies between 0 to 1, 1 implies 100 percent of the visible light is transmitted through the material to the other side. Higher is the VLT implies more will be the amount of daylight which will be penetrating indoors and thereby reducing our dependence upon artificial light.

So, with this I will stop my lecture here and we will discuss about how all these properties are utilized used in buildings design of energy efficient buildings which is an important property of sustainable buildings. So, see you in the next lecture where we will be discussing about more on energy conservation and efficiency measures and the practices for sustainable architecture and buildings.

Thank you for being with us, see you again.