Sustainable Materials and Green Buildings
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Lecture 06 - Case study for energy in building

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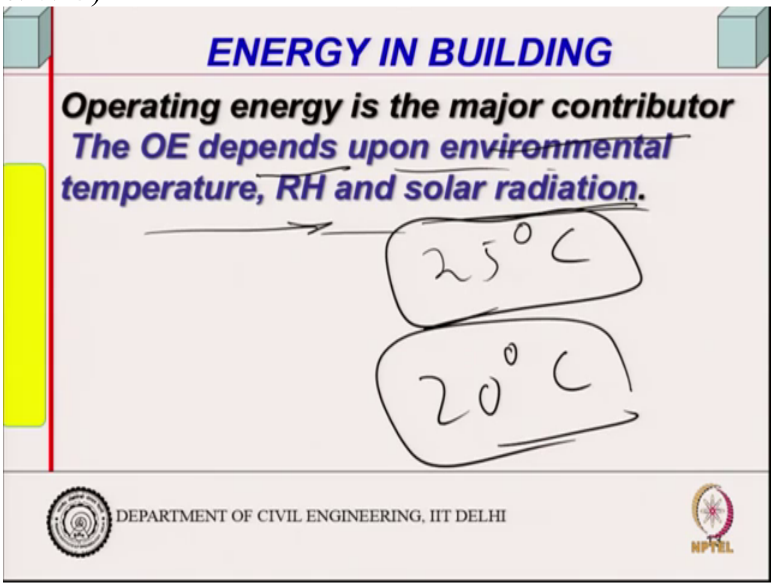

Ok, so let us look at energy in building. Now they are the operating, in building operating energy is the major contributor. Operating energy is the major contributor.

How? Let us see. This depends upon environmental temperature, relative humidity, solar radiation that is what we have seen. Some of you may not have taken that course but you know generally it would depend upon the environment, thermal comfort of people, for example, this room is maintained maybe at 25 degree Centigrade or something like that, 25 degree Centigrade, you know that is what it should be normally. Some other places, it might be 20 degree Centigrade. So today of course outside is all cool but in summer time it will have higher temperature outside, solar radiation falling onto it.

So you have ways and means of calculating this, we might look into some of them or may not. We will see that. So, operating energy depends upon environmental temperature, outside relative humidity and solar radiation. Because relative humidity is important. Thermal comfort depends upon relative humidity. If you can recollect, we have seen that there are four factors which governs the thermal comfort.

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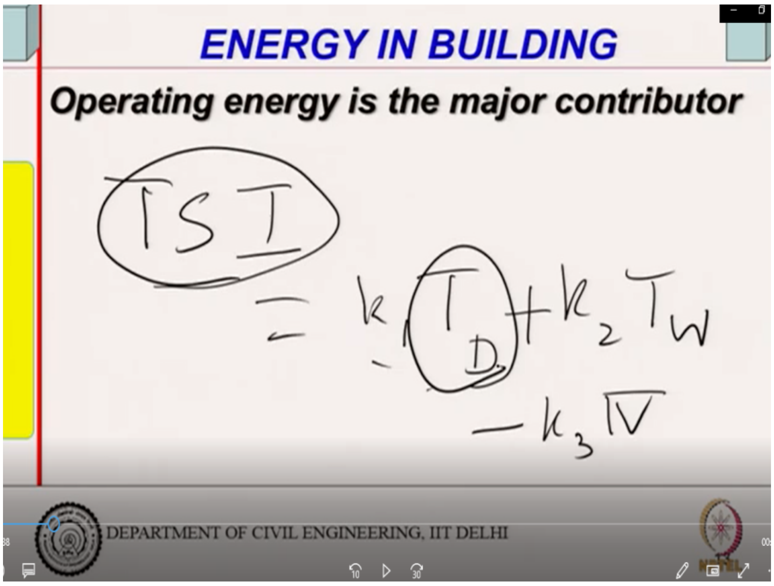

If you recollect something like TSI, tropical summer index just for your recollection those who have done a course on building science would know that this is one of the comfort index and comfort index means what you do? I club temperature, relative humidity, air velocity and of course if there is a radiation coming from wall etc., that also I take into account.

So, tropical summer index is given by some K1, temperature, what you call dry bulb temperature plus K2, wet bulb temperature minus some K3 into root over velocity right, something like this. I have just delivered it; I did not give the equations, this is three-fourth, this is one-third, et cetera, et cetera and this is 2. So, roughly some of those who have done those course, they would remember, this is the point that I am trying to make is it is a function of temperature.

Now, dry bulb temperature is the temperature of the normal thermometer as you understand. In the room if I put a thermometer or some sensing devices, heat sensing devices, second thing is if in a thermometer if its bulb is kept wet by gunny bags I mean jutes or something of that kind, then temperature will come down because of the evaporation. That we call as wet bulb temperature. That we call as wet bulb temperature, right.

So that depends upon relative humidity. If the relative humidity is 100 percent there will be dry bulb temperature and wet bulb temperature will be same because there will be no evaporation. And if relative humidity is very low, lot of evaporation, so difference between TD and TW will be large. The point I am trying to make is and if air passes through your body, some heat will be taken away.

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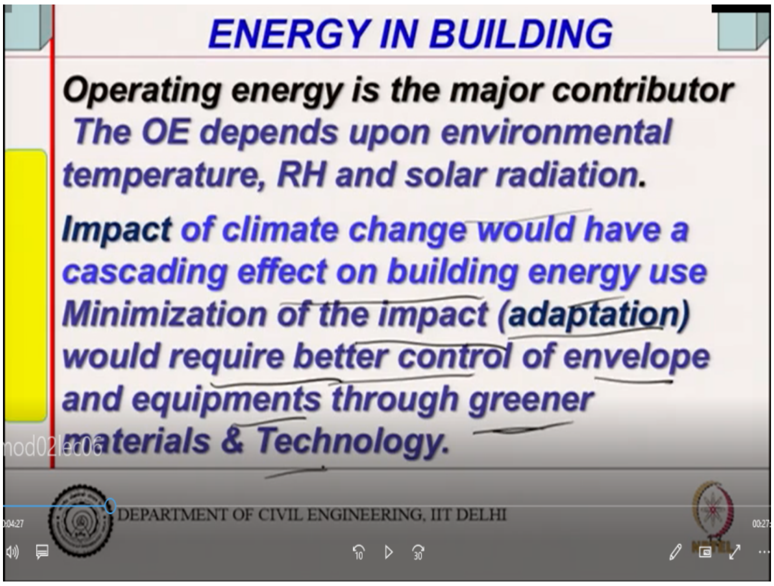

So, in summer, tropical summer index as I am calling it, this is the function of dry bulb temperature, wet bulb temperature, that is relative humidity and air velocity as well. So this will depend upon those situations. You know, this will depend upon all that. So, if you have change in temperature supposing there is a change in global warming and change in temperature, this will in fact you will have a cascading effect on the energy use, would have a cascading effect on building energy use because higher temperature particularly in tropical countries where temperature is higher, so therefore you would need more energy to be removed. So, this we call as kind of cascading effect, you know vicious effect in fact.

So, therefore minimizing of this impact would better, so therefore you need to control this as well. Minimization of the impact would require better control of envelope and equipment through greener materials and technology.

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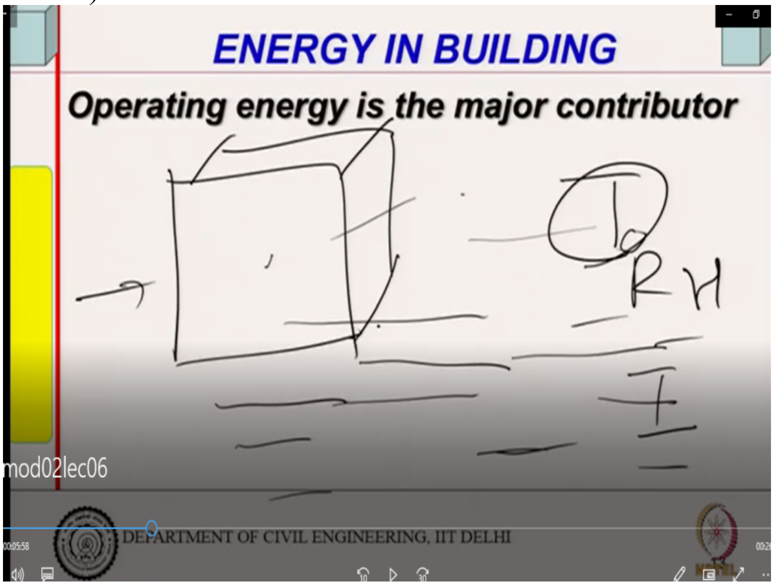

So, basically which is responsible, what is responsible for this energy? We have seen this relative humidity, temperature, and air velocity within the room but if outside scenario if I look at it I will have some temperature, of course, some relative humidity and RH outside RH outside and if I put a notation T O, RH outside, and solar radiation that is received, intensity of solar radiation that is received into the building.

Now, if this is my building, outside conditions are this, then heat flows, in summer conditions heat flows. So higher this temperature, more heat will come inside. So, thermal component will be disturbed and if I am keeping and doing, if it is conditioned building I am trying to maintain it, comfortable temperature more energy need to be withdrawn, more energy need to be withdrawn.

So, this and who controls this? The passive part, the active part is one which in a building even in structural engineering we talk of active and passive part, earthquake engineering. Active part is one where I give some energy. Passive part is which is the part of the building itself. Passive part is the part of the building itself, in the of course transportation system most of it is passive. The example is say structural system, you have active systems for earthquake engineering.

In buildings, a sprinkler is an active system partly active system, not fully although energy consumption is less, so we do not really take it. Sprinkler means what it will do? As soon as the fire is there it will be detected and it will start sprinkling the water onto it. So therefore, that is more of a kind of, like energy is depending upon how much energy. Air conditioner is an active system because it actively withdraws but then passive ones are the walls, the envelope that is what I am mentioning. The envelope of the building, envelope is just surrounding building and its surrounding area. Maybe I will have a formal definition in the next class.

So, envelope is the one which controls the, is a passive part which controls the energy coming in. So, your first thing is envelope design should be such that and as we shall see, look into rating, envelope plays a big role there, also it is possibly one of the major things. Then, the machines that you would be using, right so that is what being said here.

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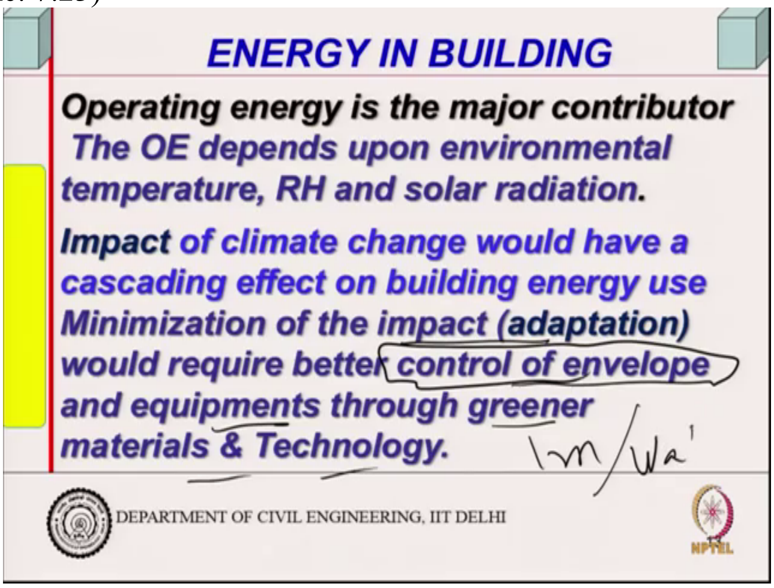

Minimization of, you know control of envelope in building, design it in such a manner that heat flow is minimum and equipments, air conditioning equipment, active systems, active ones through greener materials and technology. For example, the simple thing is the lamps today. If you look at incandescent lamp which you were using earlier, you know maybe almost from the time of Thomas Alva Edison who invented that, so those lamps were consuming very high amount of energy. The lumen output was much less. Lumen is a unit of light and lumen output per watt was for much less.

So, you would have needed a 40-watt lamp, then the technology improved in over last 10-15 years and the kind of LED light which you use the same lumen output you are getting from a 40-watt lamp, you might get from simply 5 watt or 12 watt, 7 watt or 8 watt or something of that kind. So, the equipment efficient, I mean this is just an example. Equipment efficiency you must see that equipment becomes efficient and use more efficient one. So that is what it is.

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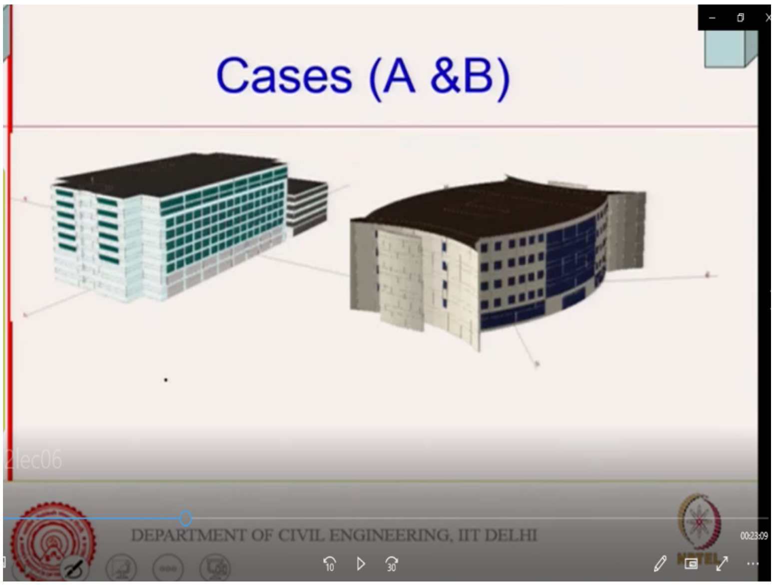

So two cases, you can see this is some case studies. Real building in Chennai. Now, these two cases I suppose this is one of those Ascendas building or something of that kind close to ITM. Two buildings, one can model them.

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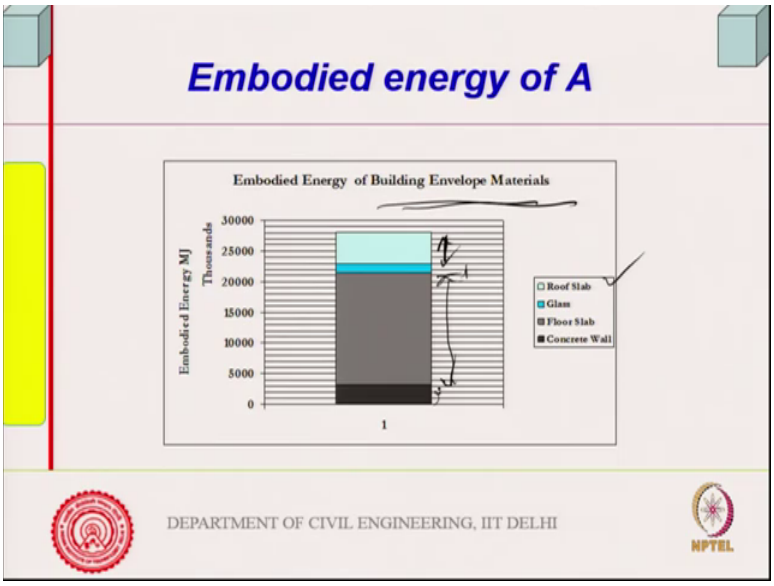

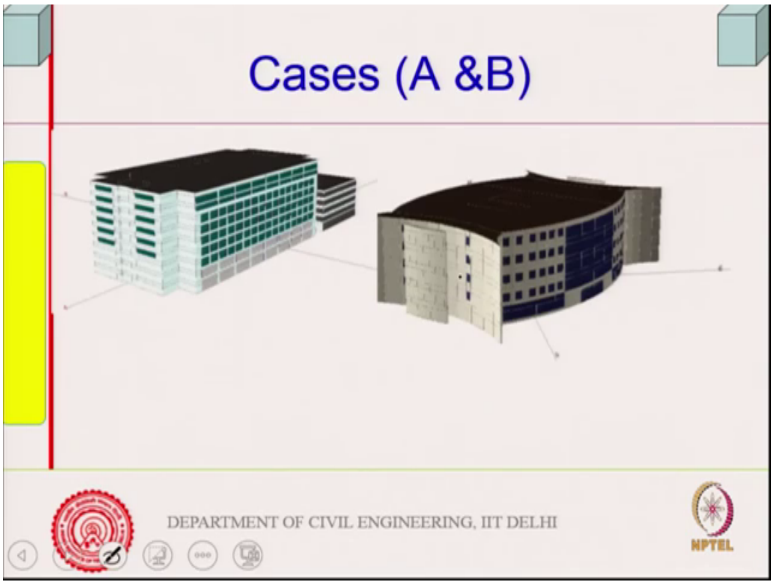

Look at the one can calculate out the embodied energy of the building. Some guidelines I will give you how to calculate but unfortunate part is we do not have data available in Indian scenario. Data of embodied energy of materials because the transportation energy will differ from country to country. Production energy depending upon efficiency of production it will differ from country to country. UK, they have complete data has been given there in the website, possibly some extract from that I have, so one has to go to the site actually, do an accounting of the energy being used up in production of everything and that is how you should be able to find out, there is no other way.

So, the original raw data in India is very limited. There is small data; I will give you that later on. But, based on that or whatever is available one can calculate for the whole building envelope material, embodied energy. So roof slab you can see it contributes this much, glass that contributes this much, floor slabs because number of storeys in the building, you can see that the storeys in the building, so number of floors are more so, therefore totally on the floor slabs it is only looking into building envelope material, floor slab and concrete wall. So this is the concrete wall, so component-wise it is seen embodied energy in megajoules is something like this.

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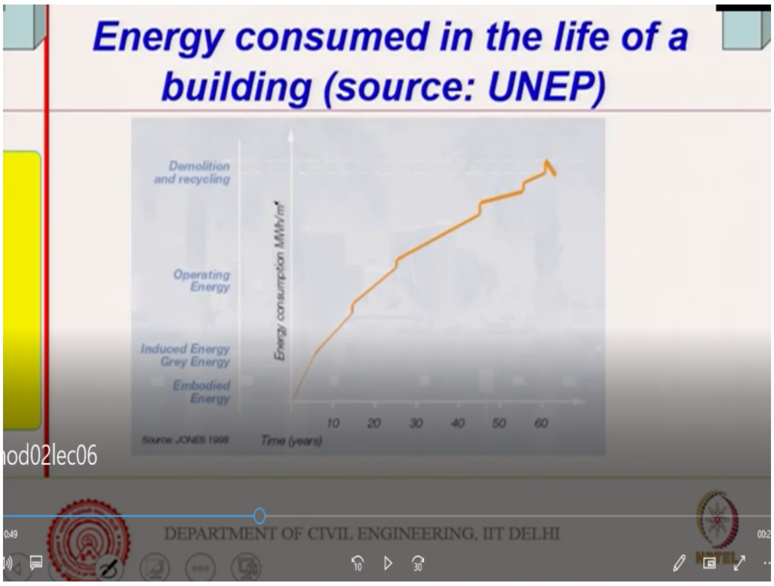

If you see the second building, well second building will have a similar sort of thing and if you see their operational energy that will be much less. I will come to this later on.

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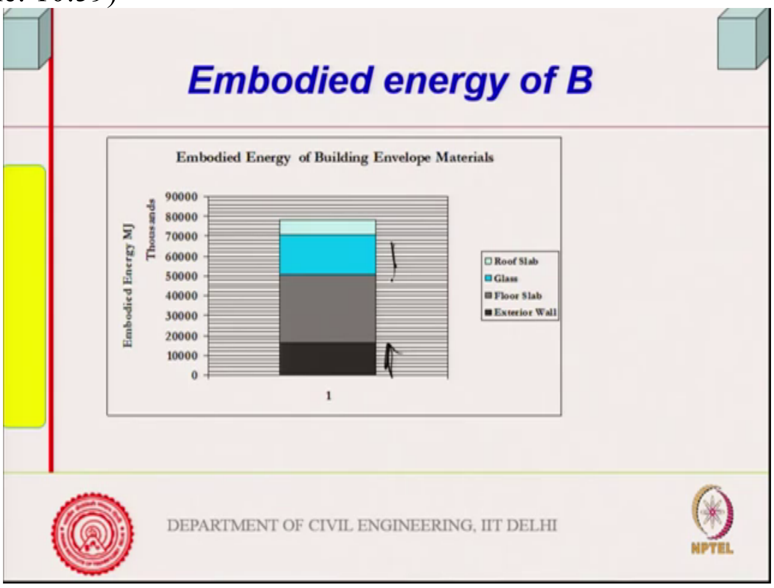

Yeah, embodied energy of the building B again something like this. So the floors those are there because there the if you look at the concrete system that would be majority, roof, et cetera, et cetera, depending upon how much glass you have, glass can contribute to them, exterior wall can contribute to them.

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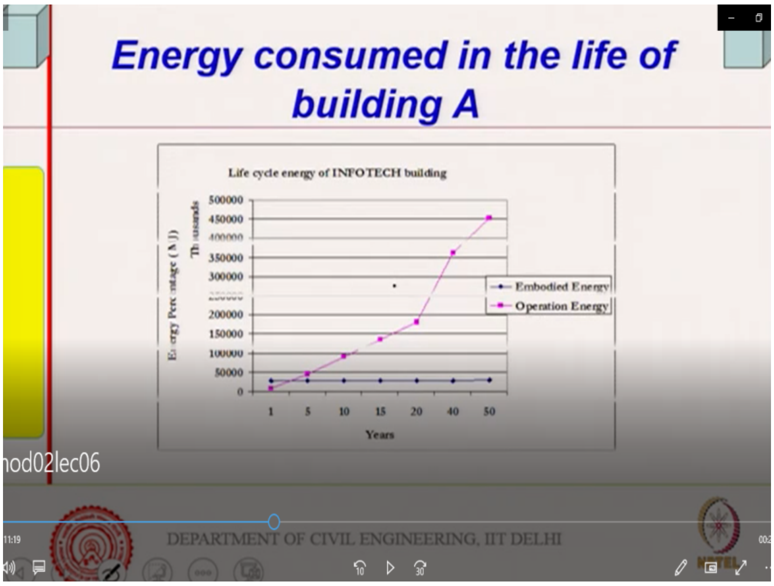

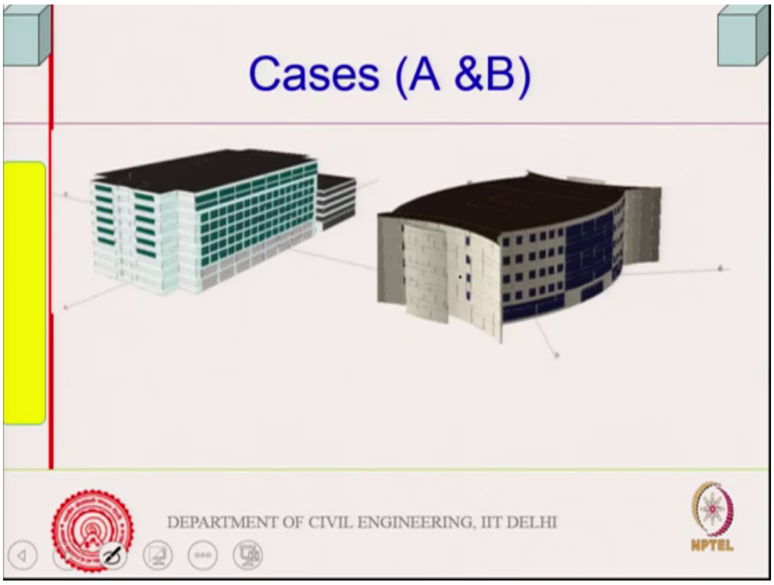

Now, energy consumed during the life of the building one can calculate it out this way because this can be stimulated in, this you can simulate in software like eQUEST. Some of you might be familiar with this name. There are open source software available for calculating building energy right, so you can model them, model the building. In fact, this building was modeled for, you know these are models for using eQUEST. These are models for using eQUEST, EnergyPlus which is of course not open source but there are Ecotect, there are several such softwares available today which one can use for calculating out the energy consumption.

Of course, we have in one of earlier courses we discussed about the methodology, the equations and things like that, heat transfer in building and so on. Those who have taken that course they will know the basics, fundamentals behind this. But softwares are very robust, they can calculate for any building.

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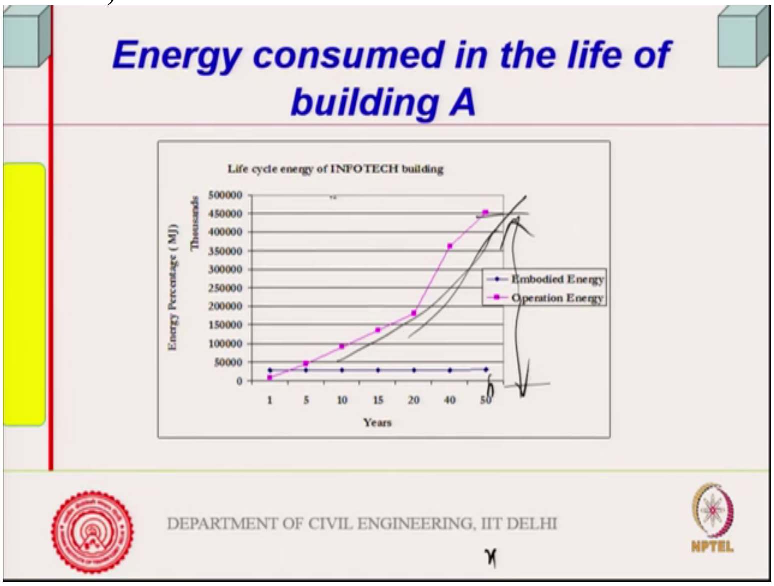

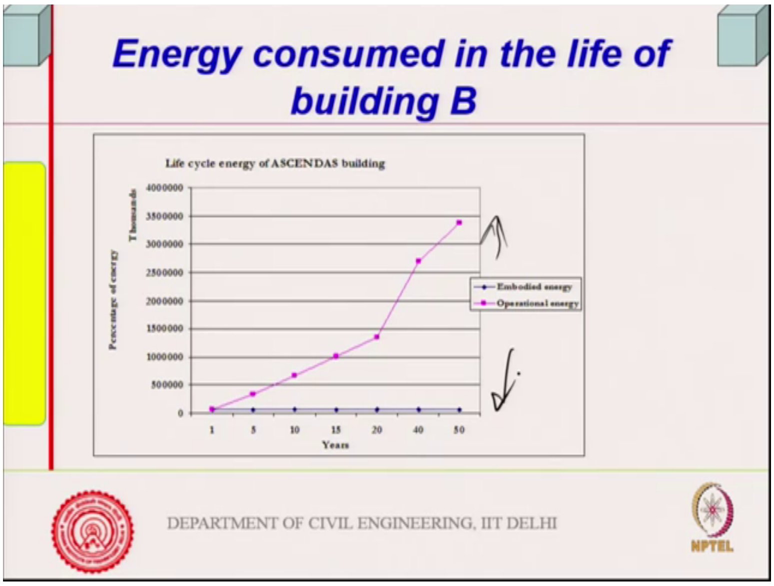

So using those softwares one can calculate out the energy and this is the cumulative energy, operational energy for building A. So you can see since it is over the large number during the 50 years cycle, complete 50 years, total quantity of operational energy is much higher. Embodied energy is once you have done without assuming any repair, in this work repair was not assumed, it remained same, this is in Infotech building actually in Chennai and Ascendas building in Chennai, both are close to ITM. And embodied energy is fixed because it is not going to change unless you take the repair. So this is a major component and if you are trying to make your building green then you must address this issue in much bigger way.

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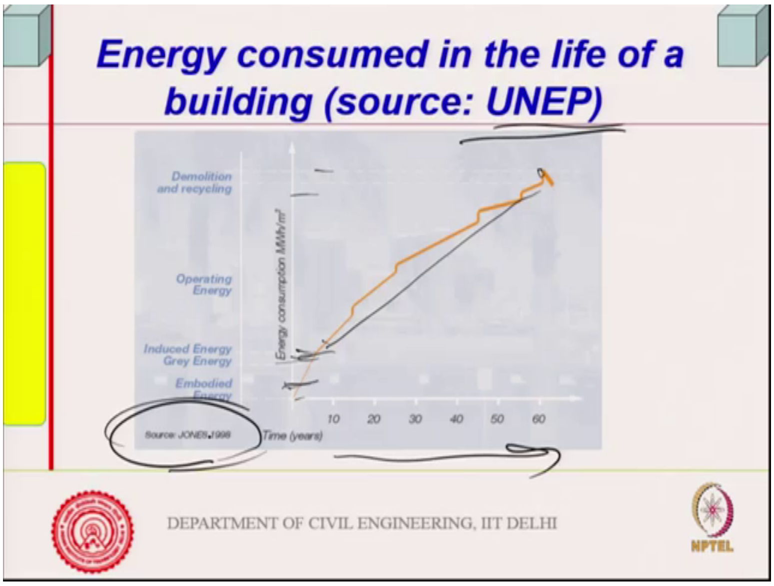

So let us go over to, this is a UN, United Nations I think it comes from JONES 1998. This is from UNEP source. This gives you years and this gives you the embodied energy, total energy, so embodied energy is somewhere here. There is some amount of grey energy. The grey energy is related to energy of repair. It is not easy to quantify but some idea, so other sources of energy which are not measured. But, look at the operating energy which is going from here to straight up to this, so these lines are actually demarcating, this line is demarcating and after demolition you might recover something. After demolition also you might recover demolition. So demolition, because recycled so accounting if you are doing that if you have recycled the energy that you would have used in producing that, so operating energy is significantly large.

Operating energy is significantly large. So you should, this is global I mean from this source, sources. So, therefore, this is true for any place. So both embodied energy and that is what I was talking of life cycle energy. So one should actually address the question of life cycle energy and if you are able to address even the question of grey energy, for example if you do less maintenance, no repair, if you do not replace let us say you have used an insulation system and it lasts for 60 years, obviously grey energy contribution will be less. But if it lasts for 20 years then you have to replace it three times, that means embodied energy now you added two more times, first time you added, second time, third time because you have replaced it twice in between and 60 years maybe, you cannot plan for more than that planning horizon.

You would have in engineering economics you would have come across when you have two projects you want to compare you have what is called planning horizons. So buildings normally have planning horizon is 60 years. So if you are doing twice repair, your grey energy is more and so on. So that is what the importance of this one is.

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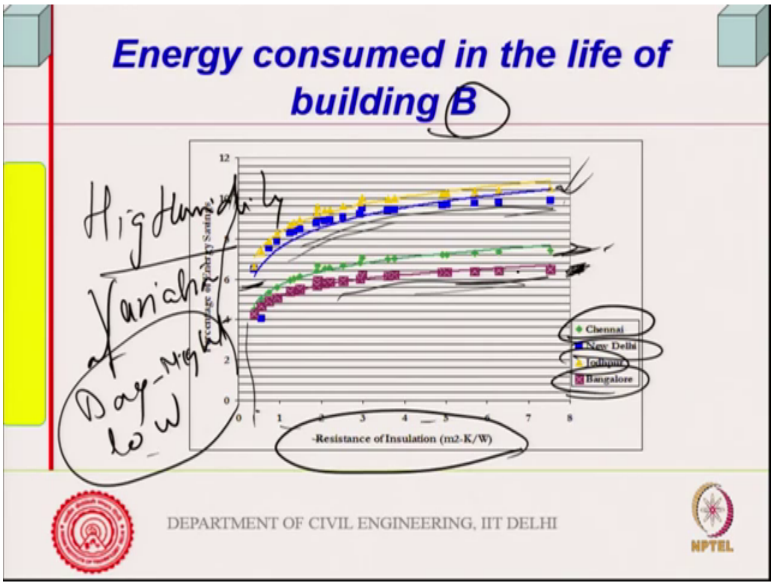

Yeah, so typically if you see that when we look at the lead rating or similar sort of rating like lead rating is one of the which we will discuss somewhat at slightly more length. It started in United States actually leadership in energy and environmental design, right. So they give rating depending upon your features, various features of building starting from site to everything else.

Insulation plays a big role there. So what we see is these two buildings if you see, if you take at different climates Chennai, New Delhi, Jodhpur, and Bangalore same buildings, those two buildings right, it is one building B which was that Ascendas building, second building I talked about. If the same building was to be built in let us say New Delhi, it is actually in Chennai, its percentage of energy-saving that you get from the base case if you improve the insulation from whatever was existing, so you see that it improves. Blue one is New Delhi. Higher the insulation, energy-saving increases but does not increase beyond a point of course to a higher rate.

Now, purpose of selecting these four cities, there is a purpose. What was the purpose? The green is Chennai where it is. Now that climate, we call it warm humid climate. So, some of you are familiar with this because already we talked about this. Now, what is warm humid climate? A warm humid climate is classified by high humidity, so without going into details of this because then it will be a repetition of another course. So I am not doing that but those who have not gone for them a little bit.

High humidity is characterized by high humidity throughout the year, less low diurnal variation means temperature day and night temperature variation is lower. So variation of, variation of day and night temperature, day-night temperature, you know diurnal temperature variation is low. Delhi if you see or Jodhpur if you see, in summer Delhi minimum temperature goes to around 25 or so, maximum will be 45 or could be even higher. Kabul is all low; it is lower temperature, subtropical.

Student: It goes to minus also.

Professor: Yeah. So this wind is like Bengaluru, it does not change much temperature; they are in the equatorial plane and some at altitude, so therefore that does not change. But, so warm humid climate is where humidity is high, humidity is high and diurnal variation is low. Maximum temperature is also, annual maximum is also low, annual maximum is also low. So Chennai is that kind of climate while Bengaluru is one where temperature variation is more or less much low variation, it is almost like subtropical climate. You know it is all different climate basically, so you do not have to, here the temperature variation is low, humidity variation is low, relatively comfortable scenario all the time and if you look at Jodhpur which is hot, dry, desert climate. What is the latitude of Kabul?

It is almost like Srinagar, so this is you know along that almost along that line, therefore that summer temperature also goes higher relatively. So anyway, Jodhpur is desert land where the temperature variation is very high. Winter temperature also relatively goes low. So that is why these four cities were selected and in all cases what you find is that as you increase the insulation obviously Bengaluru have less effect because there is more or less comfortable scenario. So as you increase, there is an increase beyond this point really it may not have much of a benefit but that is what the point.

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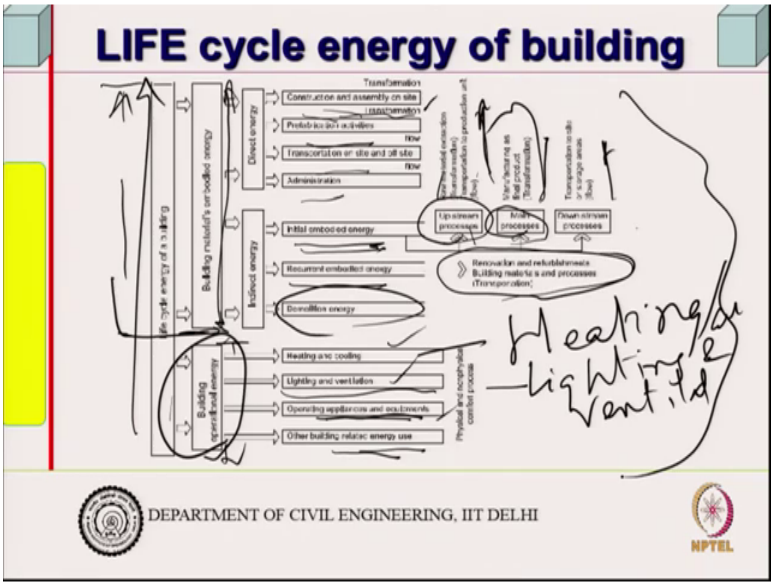

So, let us look at the life cycle energy of the building. Maybe we will see it a little bit more elaborately later on sometime again. So if you see up to this portion, there is a life cycle energy in building, whole thing is I think visible properly. This is the whole thing, we are looking at life cycle energy of the building. This is building materials embodied energy and building materials embodied energy and this is operational energy, this is operational energy. It is only showing the component of embodied energy and component of operational energy. This is not percentage. It is not percentage. It is not that embodied energy is much more than operational energy.

Now, what does building operational energy constitute of? Heating and cooling; heating, cooling, lighting and ventilation, lighting and ventilation; then appliances, operating appliances, right, for example lift, right lift or any other household commodity everything, other building-related energy use. So main is obviously heating, cooling, lighting, ventilation, and then all appliances and so on and if you come to this, this will have some direct energy. For example, if I start from here not the demolition, construction, and assembly at site, first is the material, then construction and assembly at the site, prefabrication activities if it is required, you know transportation to site and off-site and some energy might be spent in administration and things like that.

So initial embodied energy then upstream processes, if you look at it, raw material production, then main processes, and then downstream processes. So, for example, upstream processes like I was talking about cement production, so raw material to handling the raw material, processing them, that would, that raw material extraction, that is basically upstream processes. And then transformation, this material from raw material to cement, this will be one, and then cement to concrete and to building element, everything has to be there. So that is what it is.

Then main processes: making concrete, then transporting, transportation. So, some of them, then additional will be removed, renovation, refurbishment, maintenance etc, that kind of energy is also involved, that forms the grey energy kind of thing. So, then initial embodied energy is this, recurrent embodied energy from the renovation and refurbishment and demolition is there and things like that, and if some energy is spent on demolition, that is what it is. So, this is actually this shows the total life cycle energy in building and one has to address this.

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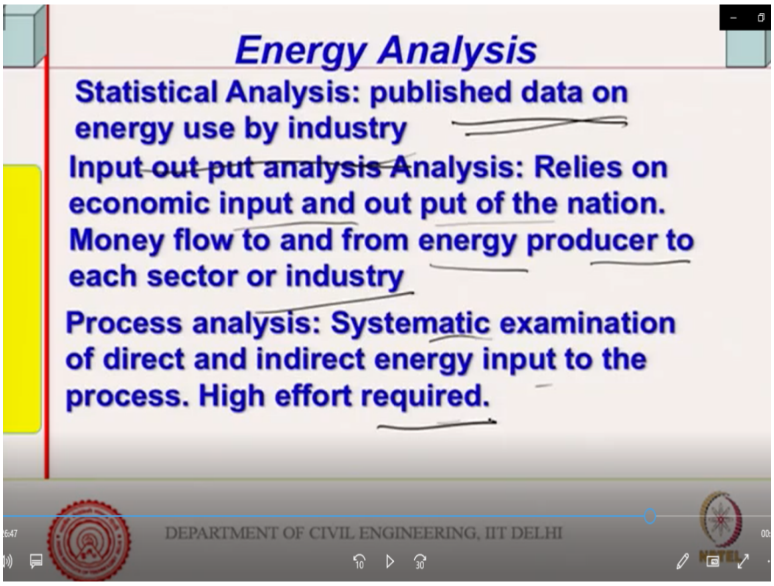

How can you do this analysis? It is not easy to do. Not a very complicated mathematics or anything of that kind but it is a laborious process. So, if you have, for example, if I want to find out how much is the energy, embodied energy of the cement? Then first, the steps are too many. So, possibly you have to find out the machinery which actually crushes the rock at the site. How much energy it consumes? Fuel it consumes per day and produces how much tonnes? Then there will be dumper trucks which you bring this crude material to the crusher. So a dumper's capacity and how much distance it traveled which you may take average of or if it has gone for hominization, somewhere it is being placed and scraper or cranes they have used to homogenize this, take raw material from one place to another place, mix them together to make it all homogenous raw material.

So you have to actually take those, data has to be generated in that manner. So it is not going to be easy and then it comes to the crusher, so as the sizes increases, sizes becomes finer and finer and energy required is more. We will see that sometime later on. Grinding energy, or crushing energy. So, calculating this out, how you can calculate? You have to find out the fuel consumed, if it is electricity how much electricity consumed in the crusher? Any other, somewhere the fuel that will be used by truck, so this becomes a very laborious process but some people have done it anyway.

So statistical analysis, the industry might have done it. The total energy you have used in fuel, for this much tonne of cement production in the year is this because this accounting would be available. So, without going to each individual ones and I mean individual ones will be important if they are trying to reduce it, trying to find out where it is high and you want to cut it down. But overall if they want to find out for the third party's purpose, then from the published data of the industry one can look into. One can look into.

Then input analysis that is what I am saying, relies on the economic input and output of the nation. For the nation also one can look into money flow from the energy producer to the each sector of energy. That is bulk way and from that also one can get into how much is the energy.

Then process systematic examination of direct and indirect energy input energy to the process, this is high effort, that is what I was saying in the beginning first, then statistical, then third is the nation-wise electricity boards or similar authorities which supply the electricity. How much energy they have supplied to a particular plant per annum? So, there are different ways one can actually look into this to find out what type of energy is given to what type of production, how much cement they have produced and so on. So that one can find out and actually one can use combination also. This is not, this definitely effort required and it is not a very great work but a lot of hard work is required.

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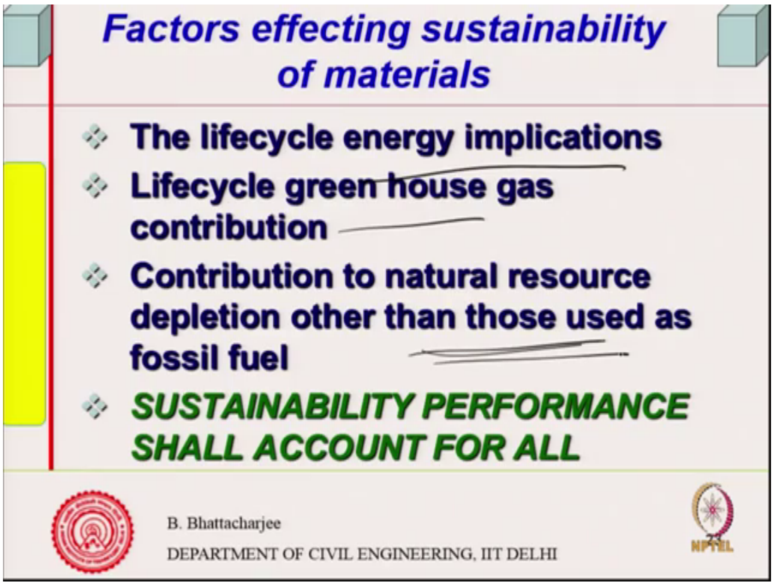

So life cycle energy implication is very important, greenhouse gas contribution is very important, contribution to natural resources and depletion of other than depletion of natural resources other than those used in fossil fuel. So natural resources, fossil fuel is already we will be taking into account separately but other than like he was talking about recycling, aggregates in cement concrete or if you are using alluvial clay for production of clay bricks, so you are using those resources, so how much is that one can find out.

So sustainability performance shall account for all. It should take account of all these issues and in terms of life cycle right in terms of life cycle. So that is what it is.

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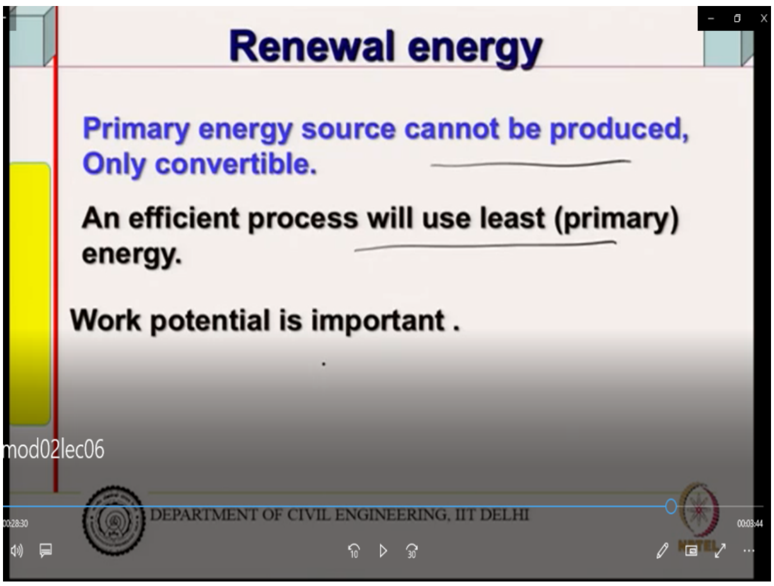

So, primary energy source you cannot produce. It is convertible, efficient process will least primary energy, work ok, this is fine. This I will not talk.

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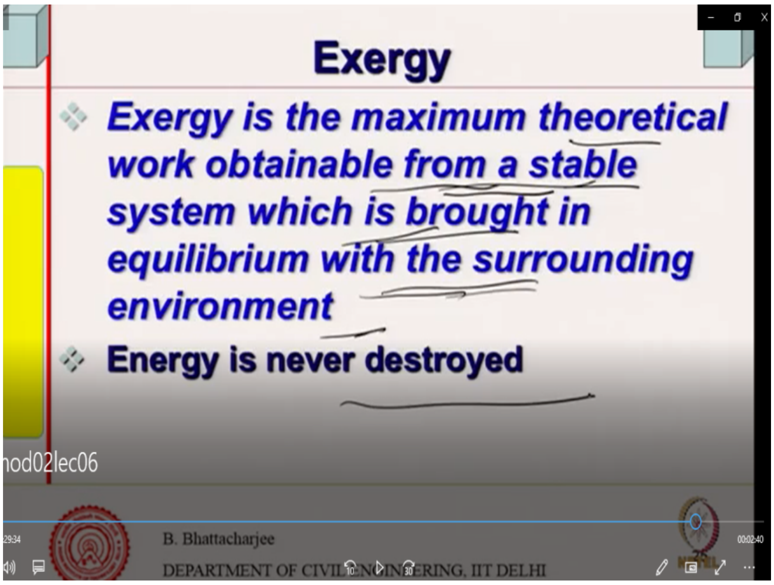

So, work potential is measured in terms of something called exergy which we might touch up on sometime. It is the theoretical work obtainable from a stable system which is brought to equilibrium with the surrounding environment. This is the terminology used in thermodynamics. This is the maximum theoretical work you can get. Energy is one issue but energy, whenever you are converting or using into work does not loss. This looks into the actual work that you are able to do, the theoretical work that is possible from which is brought to equilibrium with the surrounding environment. So that is what the work potential. That is what it looks into and when one is trying to make the process efficient, let us say cement plants for them it will be very very useful.

They should see that how they improve the exergetic efficiency as we call it, as opposed to energetic efficiency. We may not discuss this too much. Energy is never destroyed but work potential is destroyed, work potential is lost, right. Energy is never destroyed, this is irreversible, exergy is destroyed. Yeah, we will be little bit fast, more fast.

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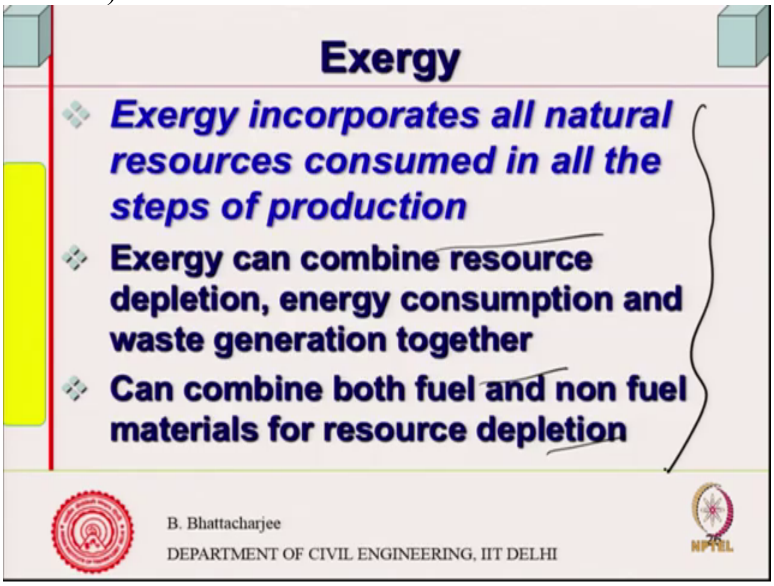

Energy incorporates all natural resources. Exergy incorporates all natural resources consumed and can combine resource depletion, energy consumption etc. But I do not think at the moment we have a theoretical model to that. So can combine both fuel and non-fuel materials. So using exergy, the work potential, you can actually combine or all the processes can be combined.

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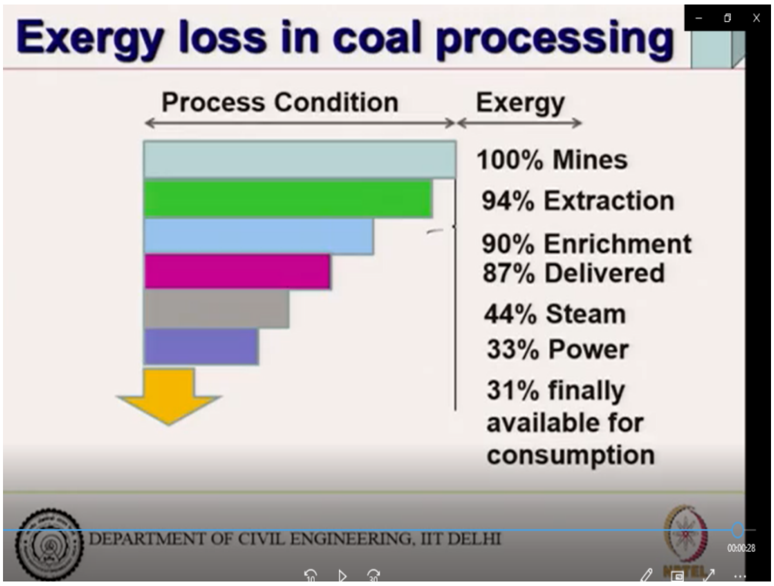

So, look at this for coal. Mines have got 100 percent work potential, right 100 percent. Then I have extracted it. I spent some energy onto it. So this much energy I spent, now effectively accounting wise 94 percent after extraction and then I might have done some enrichment that means I might have washed it to remove the clay, some enrichment I have done, so another 10 percent gone. And 87 percent because I have transport it, delivered somewhere and then they produce steam. The effective work potential of steam is 44 percent right, turbines, steam turbines I will be using and then power generation from the steam; some amount of loss is here.

So what that power can do? Power that I have generated can do only 33 percent of the that was available with the coal and then finally available for consumption. So, therefore, there are lot of work potential loss every time and final I get much smaller than what I should be actually you know originally was there in the mine or so whatever resource it is. So I think we finishes the discussion. We can take some questions if you have.