System Design for Sustainability
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Week- 04
Lecture - 01
Product Life Cycle Assessment

Hello everyone let us start with the second part of the Product Life Cycle Assessment lecture.

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So, this is where we left last week with a question is a coffee machine for a restaurant equivalent to a personal coffee machine. So, the first machine that you see is a coffee machine from a restaurant and the second one is from a personal use coffee machine.

So, here comes a third important aspect of life cycle assessment is functionality, we of course, cannot compare apples versus oranges there is no way to compare them. So, we have to ensure that the functionality is same. So, setting the functional unit or something which is called as a declare unit there is a difference between the two the meaning of the two, but they are used in a similar context. So, let us first understand functional unit.

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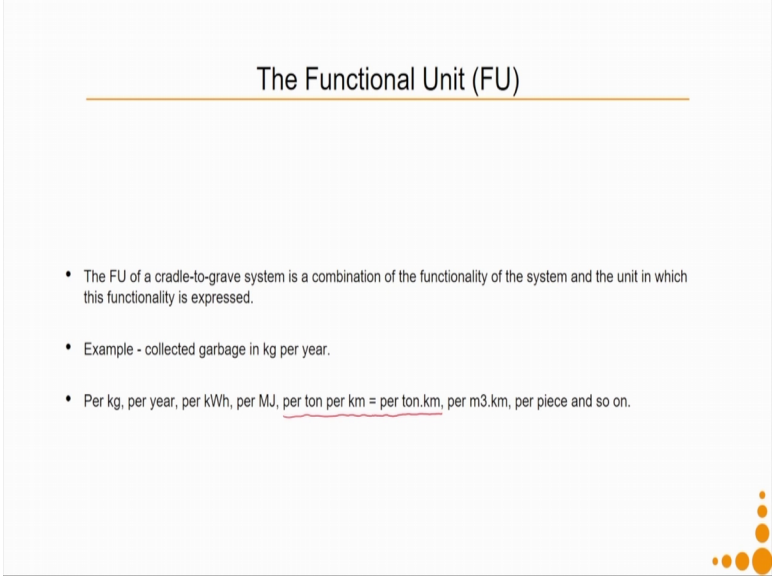

So, the functional unit of a cradle to grave system is a combination of the functionality of the system and the unit in which the functionality is expressed. Example so, when I am talking about cradle - to - grave system it looks something like this cradle is where all the material source from then the production into the product then into the use then into end of life so, in a cradle- to- grave system.

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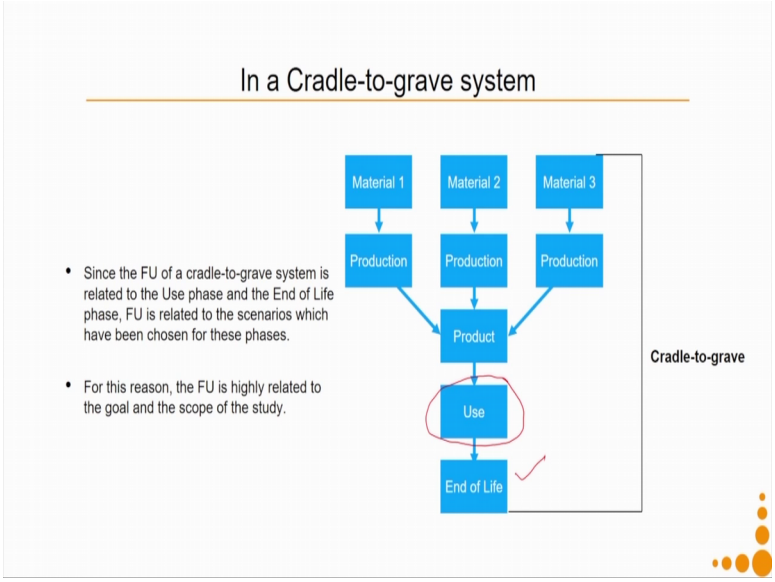

The functional unit is a combination of the functionality of the system. What all the system is supposed to function as an output of the in a system and the unit in which the

functionality is expressed. So, say for example, if the functionality of the system is to collect garbage, then collected garbage and the unit over here is in kg per year. So, there can be many different ways of expressing it in terms of per kg, per year, these are the different kinds of units then we can use per kilo watt or say it is per kilometre, per ton this one per ton per kilometre which is per ton dot kilometre or per piece and so on.

So, since the functional unit of a cradle to grave system is related to the use phase in grave cradle - to - grave we have a use phase. So, my functional unit is connected to the use phase. So, that is what the functionality is suppose to be of that particular system and it is also conduct connected to the end of life phase. So, functional unit is related to the scenarios which have been chosen for these phases. So, we can choose different scenarios in each of those scenarios we will have a different functional unit. So, for this reason functional unit is highly related to the goal and scope of the study.

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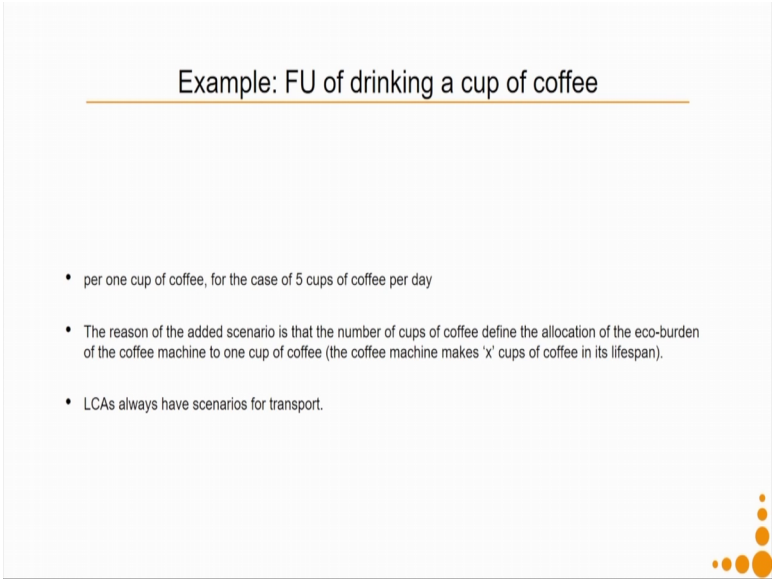

Let us see an example. So, for the same for drinking coffee for the personal use coffee machine, per one cup of coffee for the case of 5 cups of coffee per day, why so, because whenever I design a machine I design it for a particular life time. So, say for example, I design my coffee machine for 'x' cups of coffee in it is entire life span.

Hence it is not only important to know that this is the whole life span and which was x. So, say this coffee machine has been design to make 400 cups of coffee. So, now, the life of the coffee machine depends on how many cups of coffee I will make per day hence

the functional unit is per one cup of coffee. So, I am going to calculate the echo burden of each cup of coffee, for the case of coffee case of 5 cups of coffee per day that gives me in terms of also the number of years for which my coffee machine will be working.

So, the reason for the added scenario is that the number of cups of coffee define the allocation the eco burden of the coffee machine to one cup of coffee, where the coffee machine is supposed to make x cups of coffee for it is life span. LCAs always have scenarios for transport.

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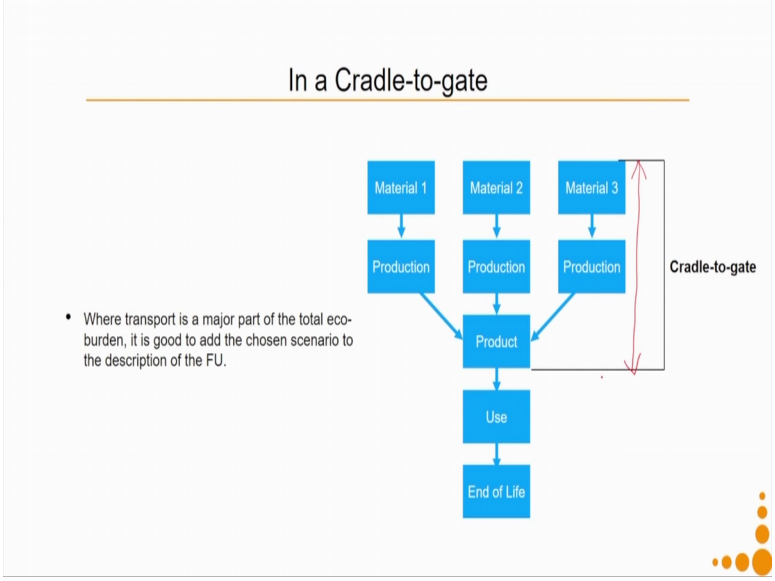

Why so? Say for example, so, the scenario for transport is important in a cradle – to-grave it is way much more important in cradle- to- gate, where I am only talking up from the material extraction up to the gate of the factory. Why this is more important in this case because when you take the component of transport percentage of the eco-burden in this whole system of transport is quite significant, but transport is important in cradle-to-grave cradle- to- gate in all kinds of system.

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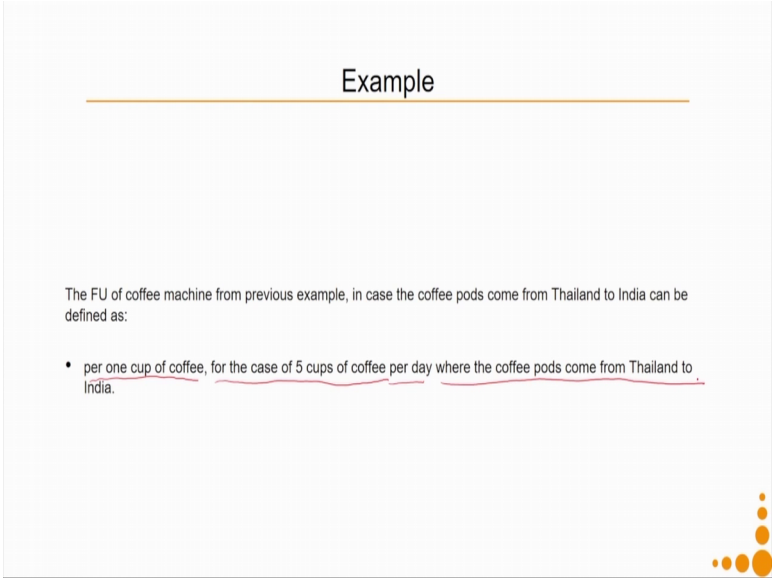

So, say for example, the functional unit of coffee machine from previous example in case the coffee pods were suppose to come from Thailand to India, now you can see that for. So, one cup of coffee can be made with one coffee pod and each of this coffee pods is coming from it is being shipped from Thailand to India that is the scenario of the usage. So, I have to cal so, transport here becomes a big eco burden for my products for my product in the use phase. So, in this case my functional unit will change it will become per one cup of coffee, for the case of 5 cups of coffee per day where the coffee pods come from Thailand to India.

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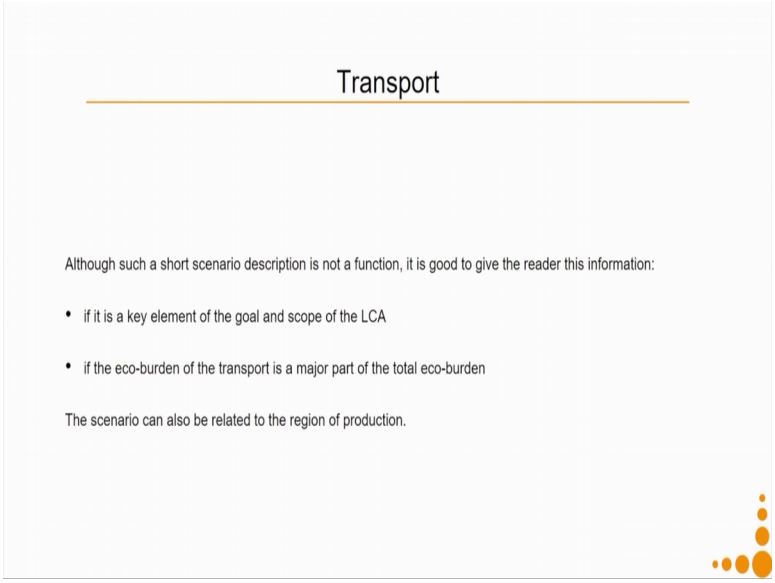

So, although such a short scenario so, this place which it talks about where the coffee pods come from Thailand to India is called as the scenario From Thailand to India.

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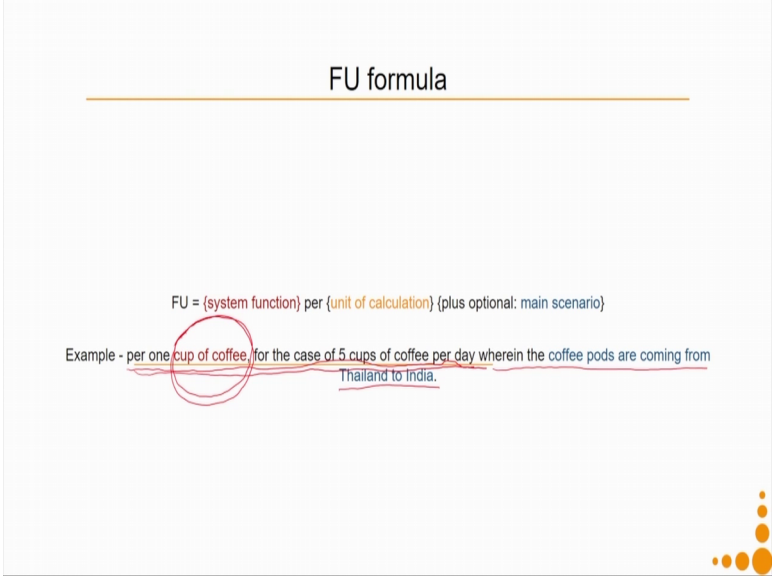

So, system function making a cup of coffee per unit of calculation which is per one cup of coffee, for the case of 5 cups of coffee per day plus the scenario wherein the coffee pods are coming from Thailand to India you might have multiple key scenarios also.

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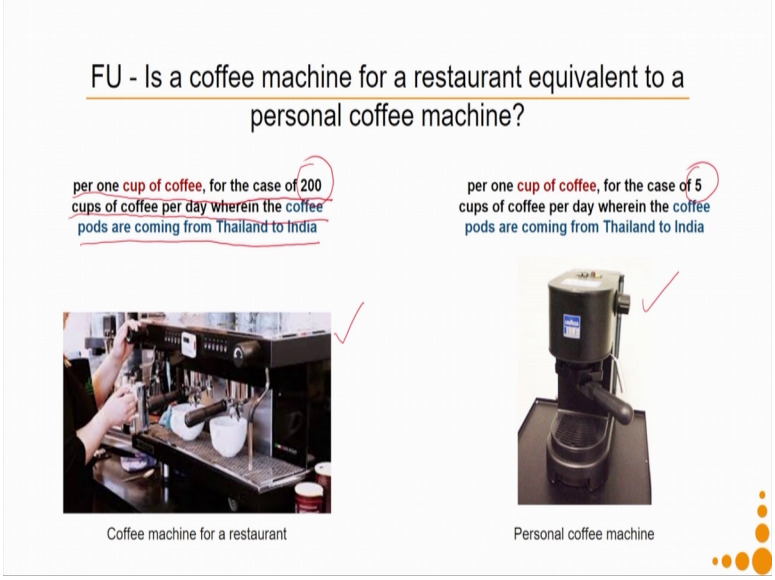

So, is a coffee machine for a restaurant equivalent to a personal coffee machine? Let us come back to that question again. So, for the coffee machine for a restaurant, the

definition might be per one cup of coffee, for the case of 200 cups of coffee per day wherein the coffee pods are coming from Thailand to India, let us assume that the scenario of the coffee pods is the same for both the cases, but what is changing very importantly over here is, for the case of 200 cups of coffee per day and here it is for the case of 500 cups of coffee per day. Because it is a personal use machine the machine has been designed by the life time of certain number of cups of coffee, at a certain speed to be delivered where as the other machine which is a commercial use machine it has been designed for way much larger number of cups of coffee, the speed at which the coffee will be brewed is very different from the personal use machine.

The amount of material which has been consumed in the commercial machine you can see it is very large as compared to the that of the personal coffee machine. It the amount of material amount of energy goes into it is supposed to be distributed over a larger number of cups of coffee for the restaurant machine. And hence will give you all together a different kind of a eco-burden and that for the personal will be very different, hence the functionality of both these machines is very different. So, we cannot compare these 2 machines against each other in terms of life cycle assessment.

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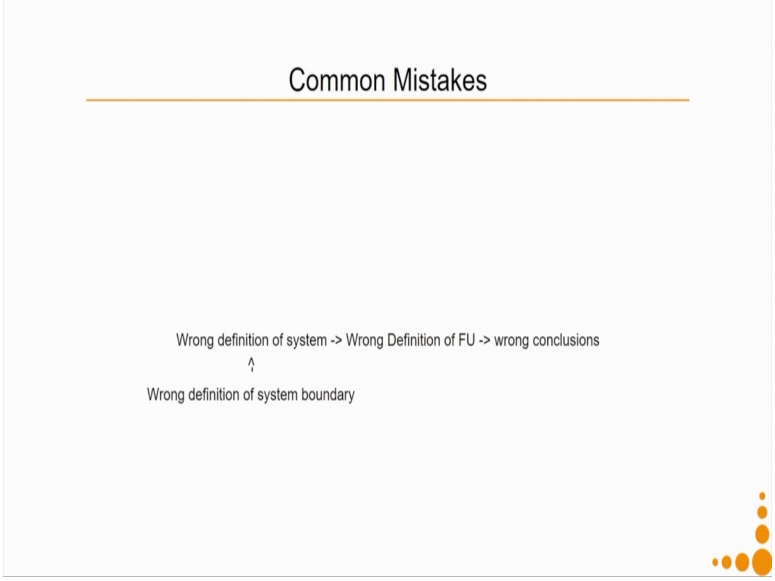

So, the common mistake that happens while taking into consideration a functional unit is we usually do a wrong definition of the system. So, in our previous case if we did not define the system properly which is like machine a is for commercial use and has hence

certain system conditions for using it the machine 2 it is for personal use and has hence a certain system in place to for it is use. So, if you go wrong in the system definition we will go wrong in the definition of the functional unit and hence we will make wrong calculations. There are times also you can go wrong with the system boundary.

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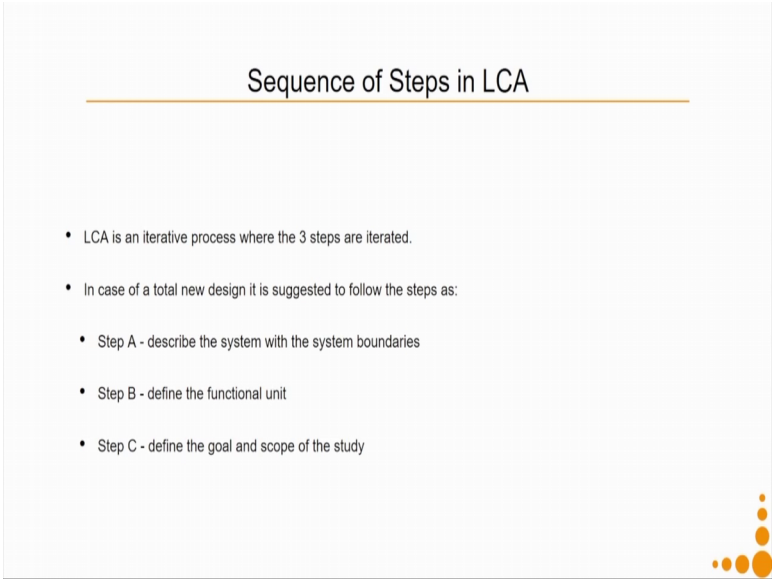

So, the sequence of steps in life cycle assessment are so, I will tell you a sequence, but that is not basically a sequence which is suppose to be followed once and gone. It is more like an iterative process how so, in case of a total new design which is what our aim would be in case of total new design we would suggest to follow the steps in a iterative manner.

First what we try to do is, describe the system with the system boundaries. So, I am going to design a coffee machine, which is going to work with certain kind of coffee beans or say for example, specific coffee pods. The coffee machine is going to be used for personal purposes, the coffee machine will be manufactured in xyz location, the coffee machine will come with one reusable ceramic cup and so on.

So, what I am doing is I am describing the system I could have described it in another manner say for example, my coffee machine is going to work with electricity that is one particular system boundary in a system definition. The other can be my coffee machine is going to be gas stove top coffee machine, it can be also a induction top coffee machine and so on. So, that changes my system definition. So, because it is a totally new design I

need to define what my system is with the system boundaries, before I can define the functional unit and then the goal and scope of my study.

So, say for example, my goal of study can be let us figure out whether making a coffee machine with coffee beans is a better option or making coffee a coffee machine with coffee pods is a better machine. So, which means I am trying to compare in this case the beans versus the pods as a measure to see which has a low eco burden, here goal and scope can be very different.

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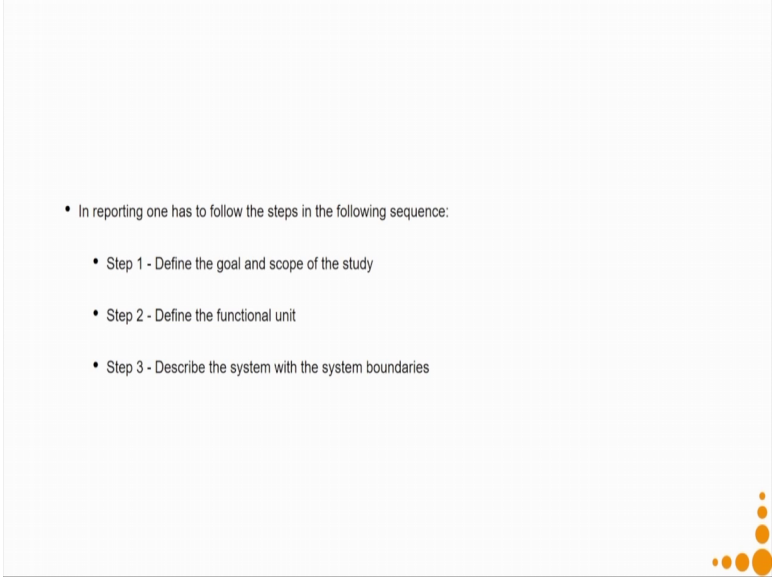

Now, when we are trying to report this so, since when we have completed our design process and we have decided this is my final design and we come to reporting our life cycle assessment result we follow the reverse order. So, we first tell this was my goal and scope of the study. So, I define my functional unit like this and my system and the system boundaries were defined as in this particular manner.

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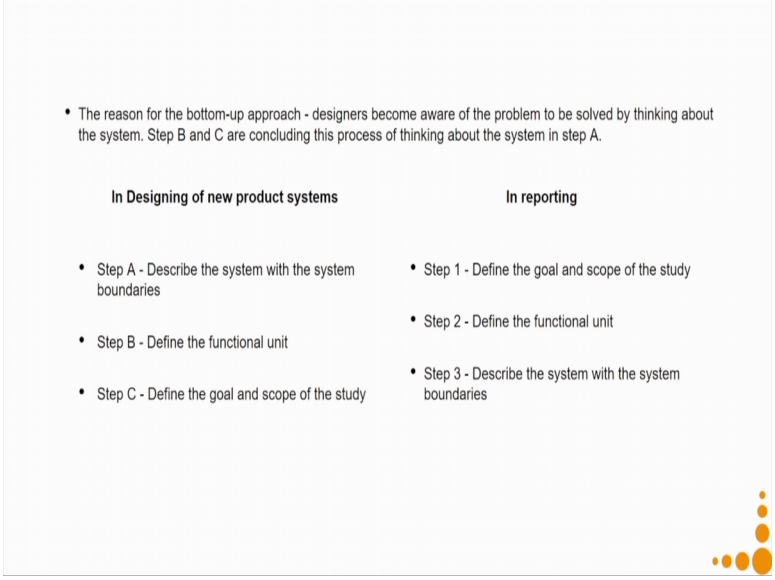

Why do we follow this reverse approach is because, when we are trying to design until and unless we do not know what the system and the system boundaries are for which we are designing that is your design job. We cannot define the functional unit and the goal and scope of the study, but when you are reporting it is meant for someone else to read it they would like to see ok, what they are interested more in the or final products life cycle assessment. So, they want to read about what was your goal and scope of the study and functional unit then describe the system with the system boundaries.

In design process when we are trying to design the product because first we will be doing concept design where we will have many different concepts and we will try to define each and every concept, while we are trying to do that when we refine a concept A to concept B we might have to change the description of the system again.

Say for example, we did the calculation with the function particular functional unit and while doing it we realise that there is another aspect of the design which we could have improved or which we could have brought into the functional unit, we again redo and change the description of the system change the description of the functional unit. So, as a result when we are in the design phase LCA is more like an iterative process, where we keep on iterating step A B and C and try to optimise our design.

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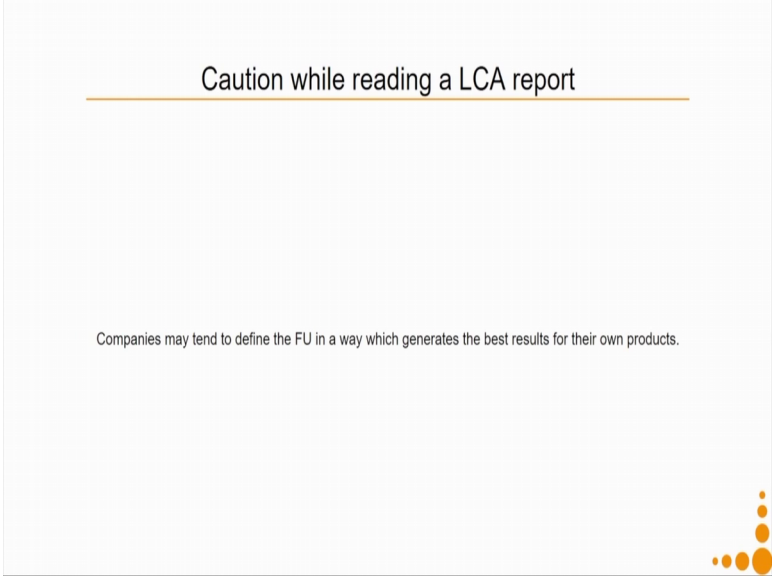

So, one caution while you are reading a LCA report. So, this LCA report has been prepared by someone else and you are reading it. One caution that you have to have while reading a report is, companies may tend to define the functional unit in a way which generates the best results for their own products. So, you have to be very careful while reading a particular report that what is the functional unit selected.

So, the result might be very favourable for them, for their product because it might be that the functional unit has been selected in a particular manner that it is very favourable for their product. So, you can criticise the product by criticising the functional unit as well as the system boundaries.

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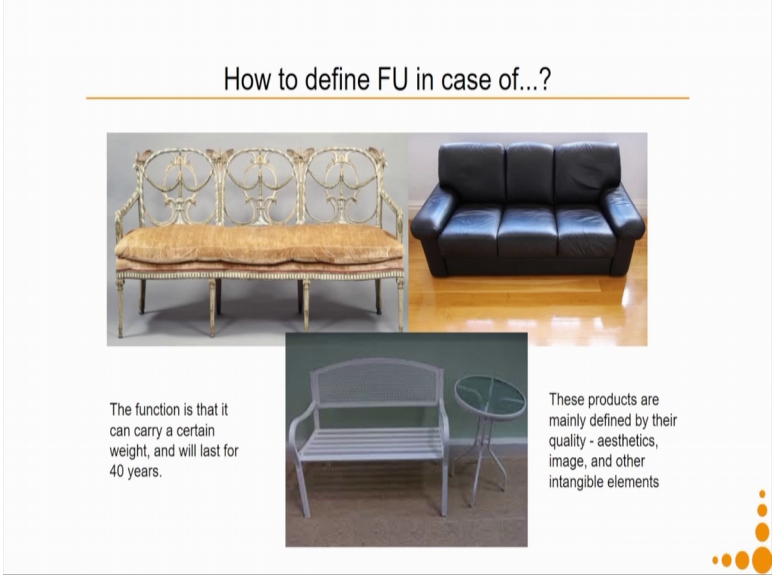

Now, let us come to this particular context how to define the functional unit in case of these sofas, all of them are sofas they are meant for seating. So, say the function that it can carry a certain weight and will last for 40 years. So, the functional unit is same, but do we buy these products on the basis of functional unit, no we buy them on the basis of their quality, which might be the visual quality, the comfort quality, that they offer or the style quality suits my living rooms style and so on. So, these products are mainly defined by their quality that is aesthetics image and other intangible elements like I spoke about like fashion choice for colour and so on.

Also these products although these has been designed to last for 40 years they might not be used for 40 years because say I want to break my living room or say the fashion has changed and I want discard these and bring in new products or I want to show a change in my status level so, I want to bring in a different kind of product. So, what do we do in such context? So, there comes the importance of something called as it as declared unit.

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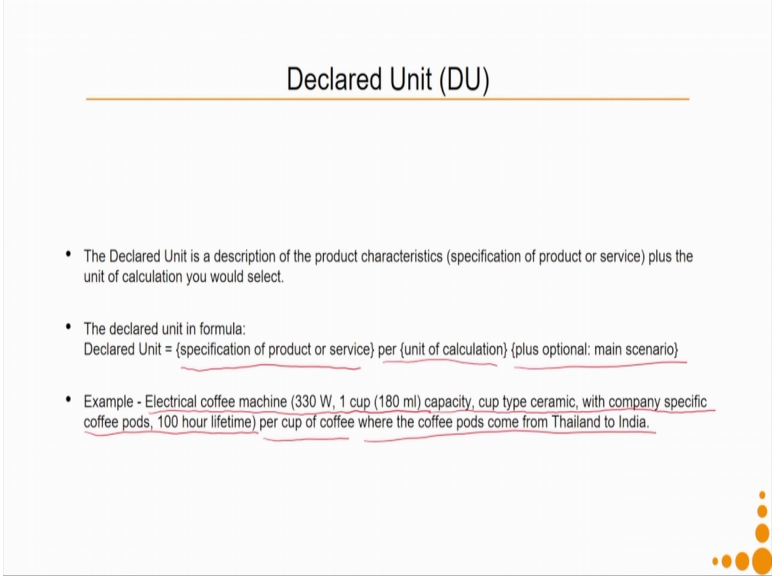

So, the declared unit is a description of the product characteristics that is specification of a product or service plus the unit of calculation you would select. So, if I look at the formula it says specification of a product or service. So, this one is very important specification of a product or service. So, let us take same coffee machine, again if we consider a coffee machine also we will not go and buy any coffee machine because we are we want to have a coffee machine for personal usage. So, it will make coffee which is function is going to be same.

But we will be again consider about the considering the quality say for example, aesthetics, the test of the coffee which is being produced or the style or the brand preference. So, comes the declare unit what it consists of is specification of product or service. So, my specification electrical coffee machine 330 watt one cup of coffee which is 180 ml capacity, cup type is ceramic with company specific coffee pods 100 hours life time. So, I took the specification of the product or service, per unit of calculation so, here it is per cup of coffee my unit of calculation plus my optional main scenario where the coffee pods come from Thailand. Let us compare it with the function unit again that will make things more clear.

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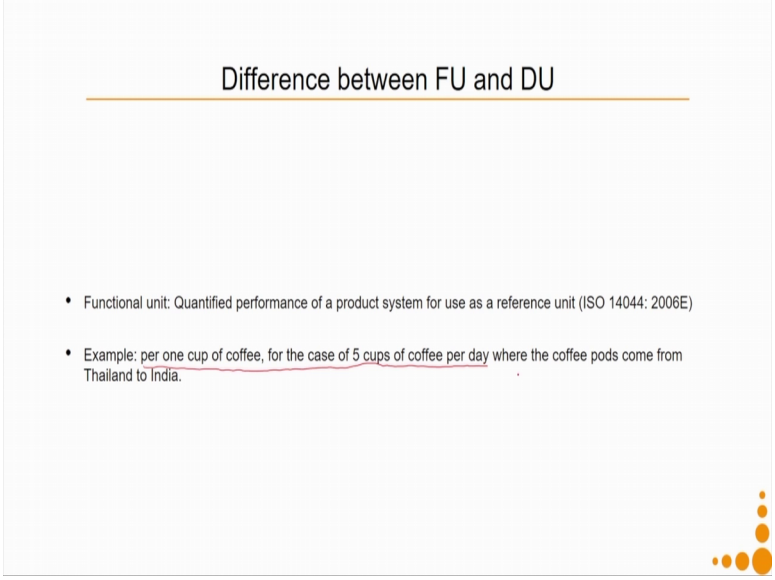

So, in functional unit what we have is a quantified performance of a product system so, quantified performance which is per one cup of coffee for the case of 5 cups of coffee per day along with the main scenario.

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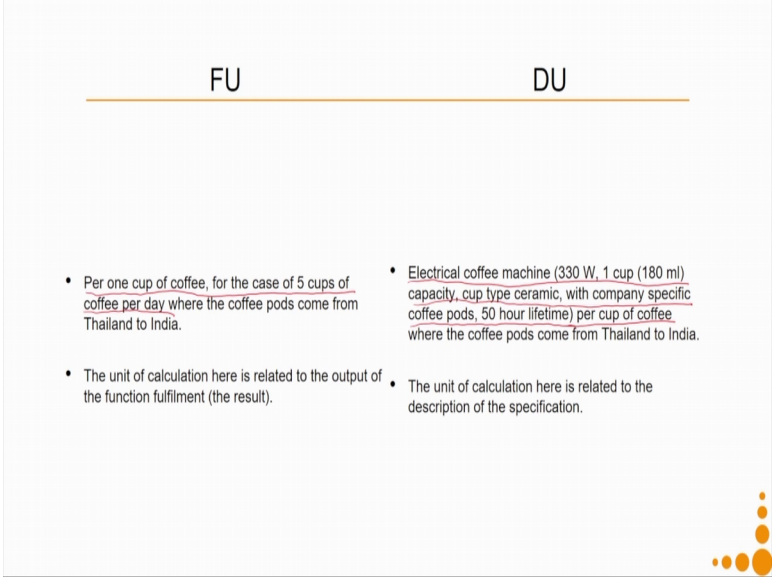

So, if you compare it is per cup of coffee for the case of 5 cups of coffees per day and here I am giving the specification electrical coffee machine with 330 watt one cup which is 180 ml capacity cup type ceramic, with company specific coffee pods, 50 hour life

time per cup of coffee. So, specification followed by the unit and then the main scenario which is optional.

So, in functional unit the unit of calculation here is related to the output of the full function fulfilment. So, a coffee machines function output function was one cup of coffee. So, the unit of calculation is related to the output of function fulfilment that is the result of the product whereas, in declared unit the unit of calculation is related to the description of the specification of the product.

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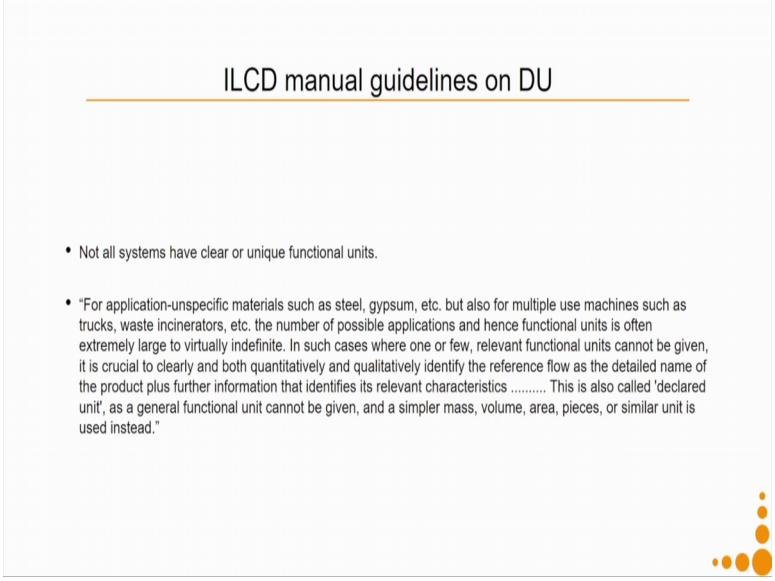

So, what ILCD manual guidelines on DU is, not all system have clear or unique functional units like the case of sofa or say shoes, jewellery, specially services they do not have a clear unique functional unit.

So, for application - unspecific materials, even say for example, steel, gypsum etcetera, but because they can be used in many different machines for many different applications say for example, I can use trucks incinerators etcetera in many number of possible applications and hence functional unit is often extremely large to virtually indefinite.

So, the truck can view in too many contexts so many functional units do we define, it might be too large. So, in such cases where one or few relevant functional units cannot be given it is crucial to clearly and both quantitatively and qualitatively identify the reference flow as the detailed name of the product plus further information that identifies

it is relevant characteristics which means the specification. So, I can talk of a truck in terms of specification which might be the volume of product, that it can carry the weight of product, that it can carry and so on. So, this is also called the declared unit as a general functional unit cannot be given and a simpler mass volume area or pieces or similar unit is used instead of the functional units.

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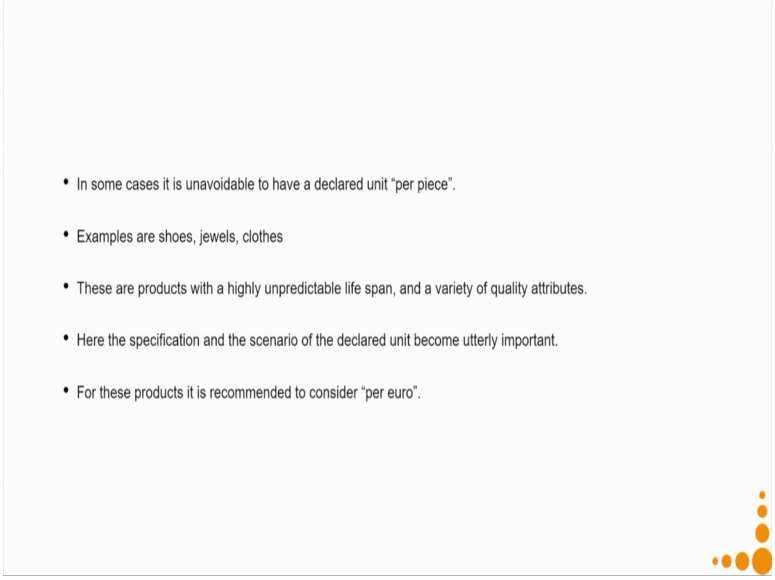

In some cases it is unavoidable to have a declared unit per piece, because we are not able to do anything like per kg, per kilometre and so on. So, in that case we use something like per piece examples can be shoes, jewels, clothes, these are products with a highly unpredictable life span and a variety of quality attributes. So, jewellery or a shoe or a cloth they all have very unpredictable life spans and a variety of quality attributes.

Hence the specification scenario of the declared unit becomes utterly important. So, for these products it is recommended to consider "per euro". So, that we can do it per piece, but better way of doing it is per euro, what do we mean by that? This is called as the model of Eco-costs by Value Ratio or the EVR model.

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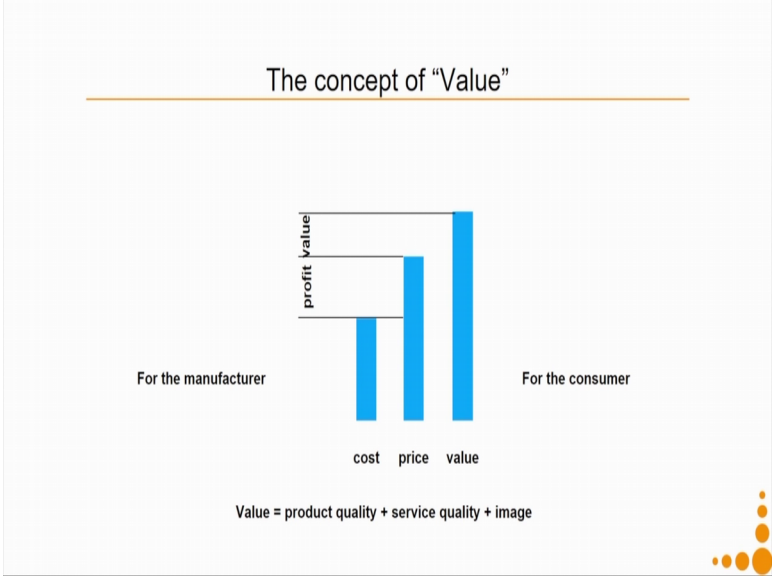

So, the how do we let us define the concept of value. So, for the manufacturer there is cost. So, in order to make a particular shoe the manufacturer will have to spend some money on making the different components of the shoe or buying the different components of the shoe, then putting them together and then bringing it up to the user for buying it. So, there are certain cause to this system manufacturer adds certain amount of profit and we get price of a product this is how the manufacturer sees at.

Now, how a buyer or a consumer sees a product, they see it plus addition of some value these values are intangible values say for example, if I want to buy shoe from brand X I want to buy that shoe from brand X because it is endorse by my favourite sports man and I (Refer Time: 21:50) of that particular product. So, when I see particular product in the market say I go and see on a shoe rack shoes from 5 different brands at the same price level. I will be associating different values mental values these are my own assumptions like how much do I value a product something like that.

So, all the 5 products from 5 different companies might have the same price, but I will associate different values in my mind to each of this product. So, I buy from brand X, I might have a feeling that it gives me better image or I feel more connected to my sportsman who is the brand ambassador for that product. So, for a consumer a product is whether a price of a product is right or wrong whether it is justifiable or not depends on

whether the consumer is able to see the value in that product, the value that product is going to bring in his or her life so, this is meant by the concept of value.

So, value is equal to product quality it might be related to many different product qualities like ascetics brand value and so on, the comfort, the service, quality for by the manufacturer plus the image that is being created.

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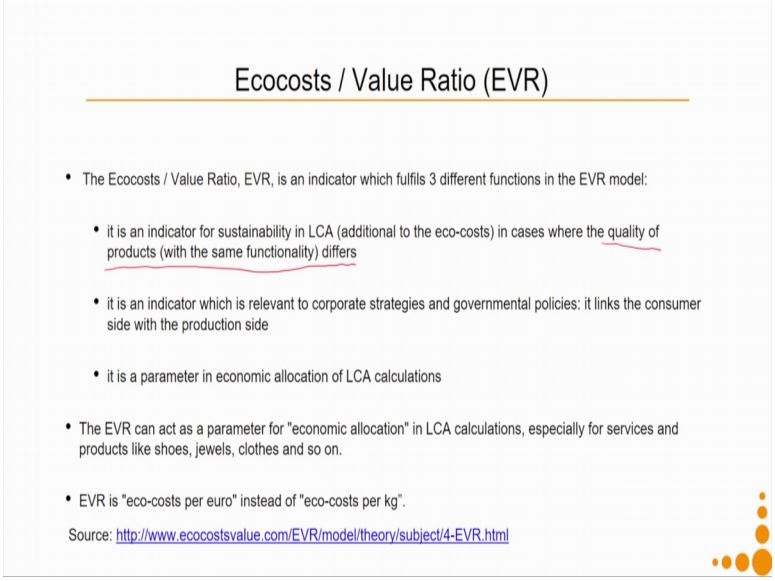

So, what the eco costs value means is. So, the Eco costs value ratio EVR is an indicator which fulfils 3 different functions in the EVR model, first it is an indicator for sustainability in LCA additional to the eco costs in cases where the quality of the product with the same functionality differs. So, I might have 5 different running shoes in terms of function they are same they are running shoes, but the quality that differ only in terms of the quality or in terms of the value that we associate with that product particular product. So, in such cases I can use this eco costs versus value ratio.

It is an indicator which is relevant to corporate strategies and governmental policies, it links the consumer side with the production side because I am talking about value which is associated by the consumer to a particular product, which might be created because of corporate strategies, which might be like advertising or say certain products are complain to certain kind of government policies.

Say certain products have an ISI mark and we know that ISI mark is a mark of authentication of product quality so I might value that product higher. So, this value can be created either through corporate strategies or through governmental policies, at it links might product to the consumer side that is the production side or the consumer side is related because value is completely a mental association that a consumer creates with a product.

It is a parameter in economic allocation of LCA calculations. So, we can do for shoes and all shoes and jewellery per piece, but a better way is because they are products in which it is the value on which they a consumer attaches to them that it says so, a better option is we take the EVR.

So, the EVR can act as a parameter for "economic allocation" in LCA calculations, especially for services for products like shoes, jewels, cloths and so on where like you saw the quality of the product with the same functionality differs. EVR is called the "eco - costs per euro" instead of "eco-costs per kg".

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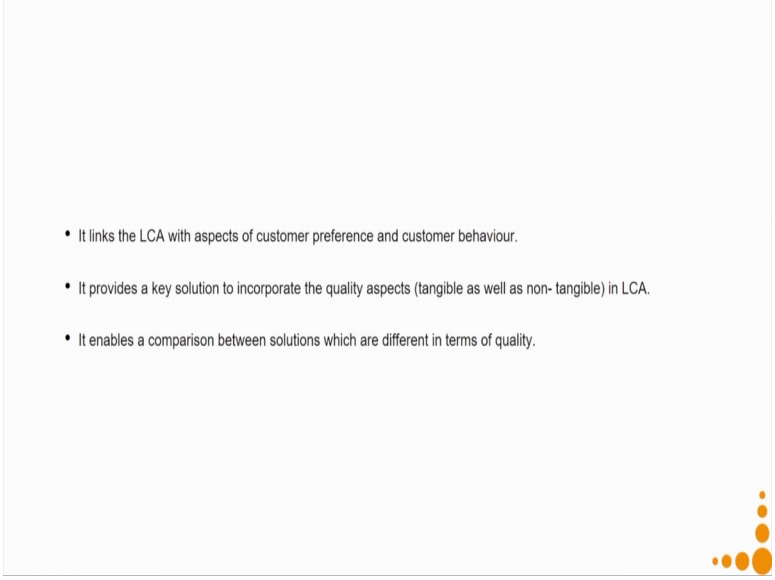

So, it links the LCA with aspects of customer preference and customer behaviour. It provides a key solution to incorporate the quality aspects like tangible and non-tangible in LCA, this is the only way in which we can bring these aspects into it. It enables a comparison between solutions which are different in terms of quality.

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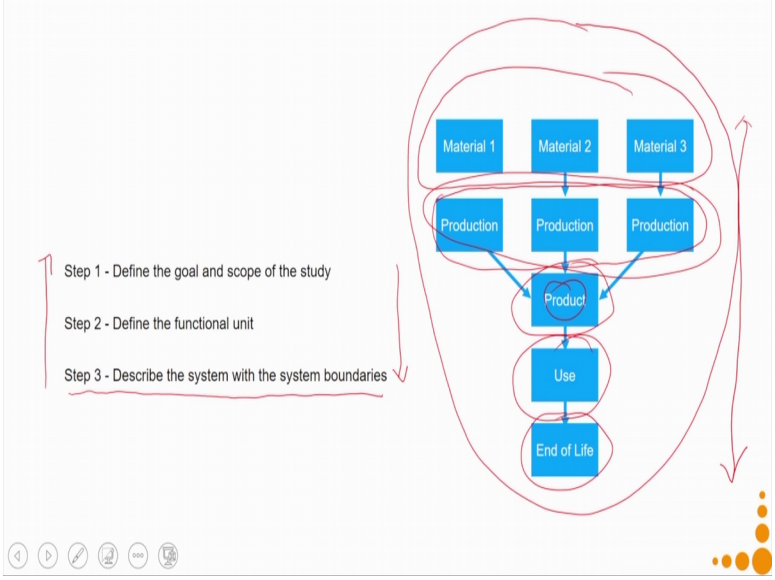

So, how do we conclude now? So, say for example, we have this particular system composing materials, the production, the product, the use and the end of life. First is we when we are going to report our study, this is the 4 steps if we start with design of a new product we go the reverse way. So, we say the context of designing a product first we go to step 3 as my first choice describe the system with the system boundaries. So, here you can see I have selected this particular system with a system boundary; I am interested in the cradle to grave system.

Then I will discuss what is the functional unit of this or what is the declared unit of it, then my last step will be define the goal and scope of the study I will keep on iterating it in the next lecture we will take a product example and we will see how do we follow this steps.

Now, coming to by-products and ways so, here you can see this one was our first initial very simple system definition here you can see all these 3 materials after this production process go into one particular product, but usually that is not a case what we will get is by products as well as some ways.

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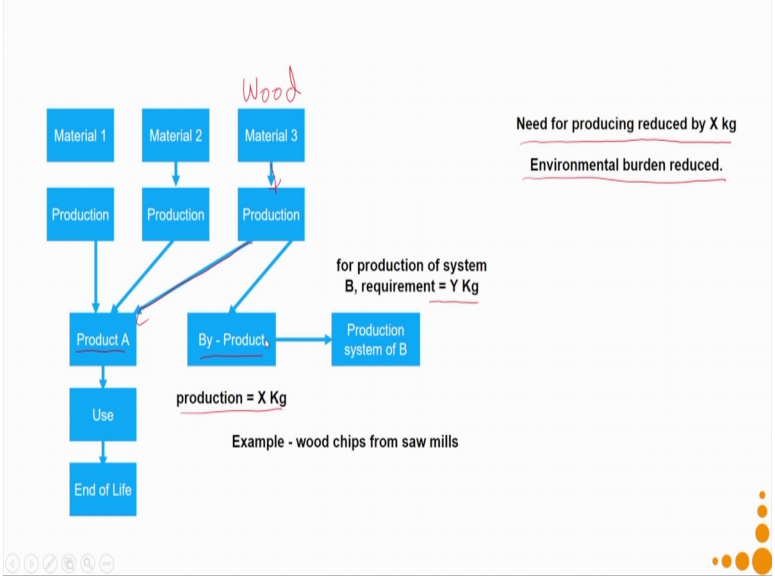

So, we need to also see what is the impact caused by them. So, now let us discuss how do we take into consideration there the impact of by-products and ways. So, let us say our diagram in which what I am getting is product A as a result of my production processes and say my material 3 production leads to a particular by product.

Let us take the example of a furniture industry. So, I am making chairs which might consists of some wooden components, some metal components, and some plastic components. So, let us material 1 B plastic, material 2 is metal and the material 3 is wood. So, when I take my material 3 wood as a result of the making of this product a through the production process wood I will get is wood chips from the saw mills. So, my wood chips from the saw mills is the by product.

This by-product can be used in the production of system B say for example, these wood chips can be used for making ply-wood or they can be used for the used in production of MDF or can be incinerated and used for production of electricity. So, if my by-product goes for into the production system of B say production system of plywood, then because of my this initial product a production I got a X kg of by product.

Now, my production system of B which is my production system of plywood I require Y kgs of saw dusts, but of course, my by-product is on X kg and assuming that X kg is lower than this Y kg. So, now, my need for producing this saw dust is reduced by X kg, which means my environmental burden is reduced because I am using this by product I

am not throwing away this by product, as a result my environmental burden of this whole system reduces by X kg of this by-product.

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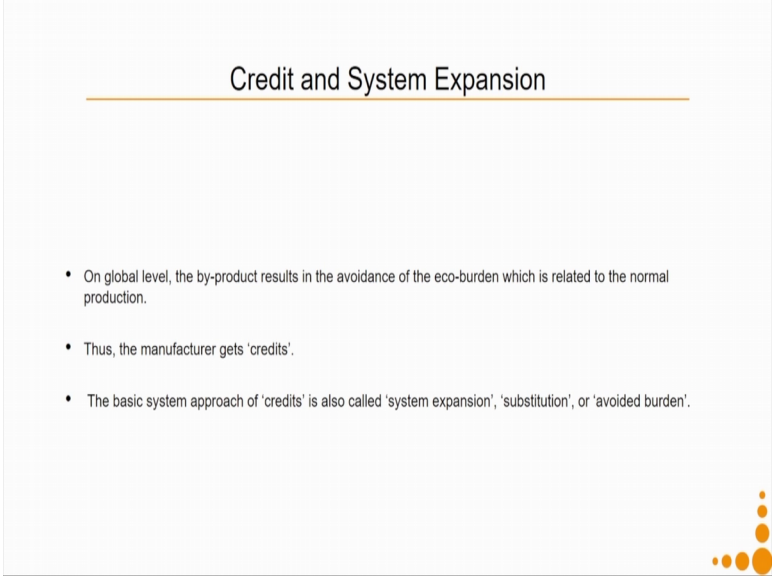

What it means is, I can use this as a credit. So, all my eco burdens they are all my debits and now I am using this by-product to into another production system so, that becomes a credit. So, I this way I go ahead with my expansion of my system.

So, on global level, the by-products results in the avoidance of the eco burden which is related to the normal production. So, if I can find an alternate use from my by- product I can always reduce the eco burden, thus the manufacturer gets credits for doing that. So, the basic system approach for credit is called the 'system expansion', 'substitution' or 'avoided burden'.

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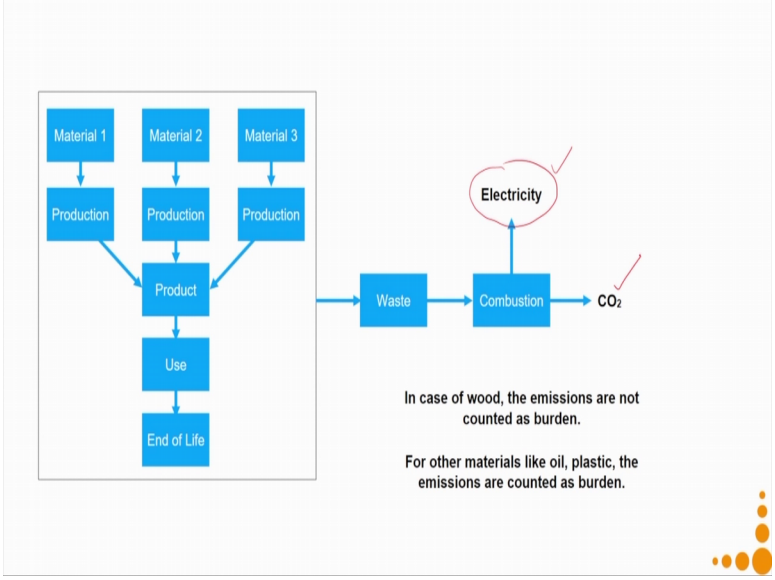

So, say in case of wood the emissions are say for example, if I take the whole system, this whole system is going to generate some kind of waste, waste can be generated at the production levels, the waste can be generated at the use level, at the end level, right now I am talking about the whole system as a block and the waste which is coming out of it.

So, I might have certain ways now in case of wood or say plastic or we will not incinerate metal. So, I am only considering wood and plastic and other inceneratable materials. So, the is the waste is incinerated that is I go ahead with combustion as a process, it will release carbon dioxide, sulphur dioxide and other such emissions and it will also create energy. So, why do I combust them? I do not combust them just to reduce the waste, but I also while combusting it I recover the heat and produce electricity out of it and there will be emissions of carbon dioxide.

As per the LCA calculation norms in case of wood the emissions are not counted as a burden for other materials like oil, plastic, the emissions are counted as burden and electricity goes into your credit. So, in case of wood you will have electricity as going as your credit you have no eco burden, in case of oil and plastic you will have electricity as your credit and carbon dioxide and other emissions as your debit which are the eco burdens.

Now, coming to 2 ways of so, we discussed about ways to recycling now another way another way of end of life is recycling. So, there are 2 types of recycling, we had also in

our previous lecture try to touch upon 2 different concepts of open loop and closed loop recycling when we were trying to discuss about what is the issue with cradle to cradle life cycle assessment. So, the open loop and closed loop recycling these concepts are applicable for plastics and metals, because these are the 2 recyclable materials that we have.

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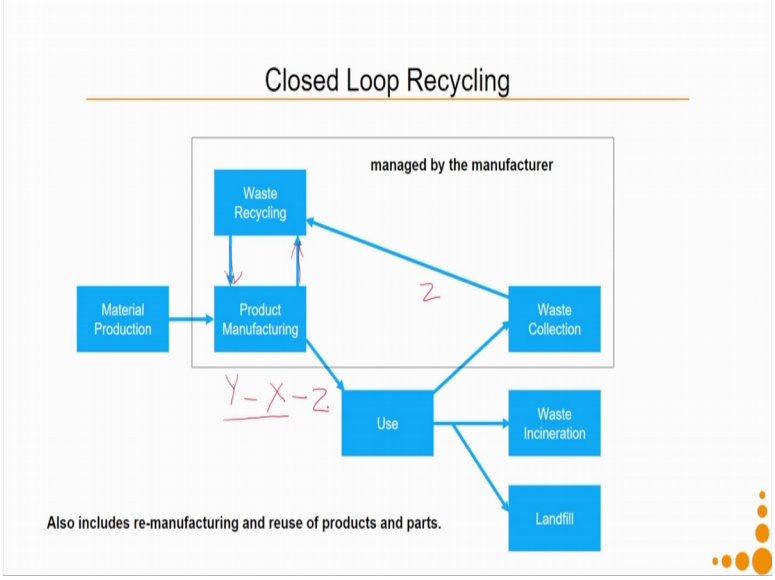

So, what is the closed loop recycling? So, I have material production from material production I will go to product manufacturing. So, say polyprolene as a plastic that is the material production stage that goes into product manufacturers. So, I make a chair out of it, as a result of this there will be some waste which will be generated. So, say some of the plastic chairs they were not found properly, it keeps on circulating inside the system so this is called a closed loop recycling.

Then we are doing so, it also. So, in this case we were talking about waste collection, but it also includes things like remanufacturing, reuse of products and parts. What remanufacturing, reuse means is, say my air-conditioner is no longer very efficient. So, I want to change it, I give it back to the manufacturer, the manufacturer wants to still retain the air-conditioner outer recovery, but by changing certain internal components can refurbish the air-conditioner again into a more efficient air-conditioner. So, those are contexts in which I am remanufacturing certain parts or I am reusing the products or

parts of it. So, when it done by the same manufacturer then we call it as a closed loop recycling.

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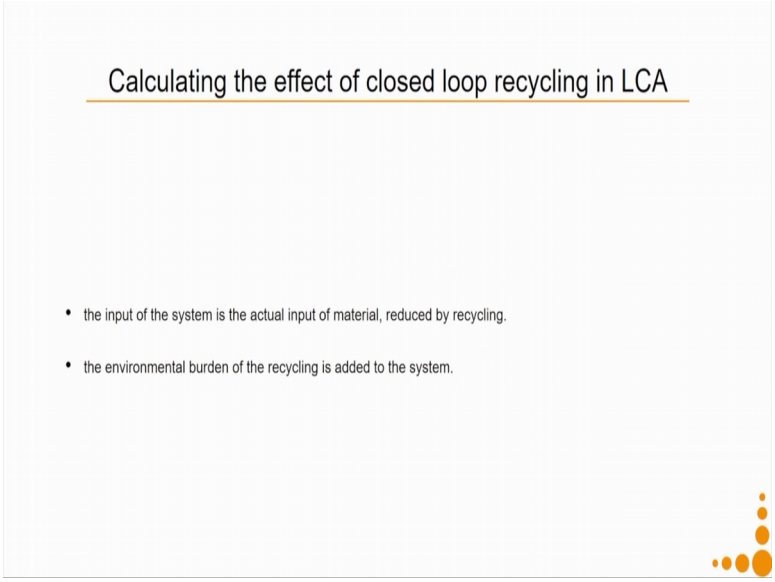

So, how do we calculate the effect of closed loop recycling life cycle assessment? So, the input of the system is the actual input of the material reduced by recycling. So, like we discussed in this example the input becomes Y minus X and now when this waste collection starts this is again some Z quantity this becomes Y minus X minus Z. So, the input of the system is the actual input of material reduced by recycling.

The environmental burden of recycling is added to the system itself. So, the manufacturer takes responsibility of the recycling. So, environmental burden of recycling is taken care by the manufacturer. So, it is added to the system itself.

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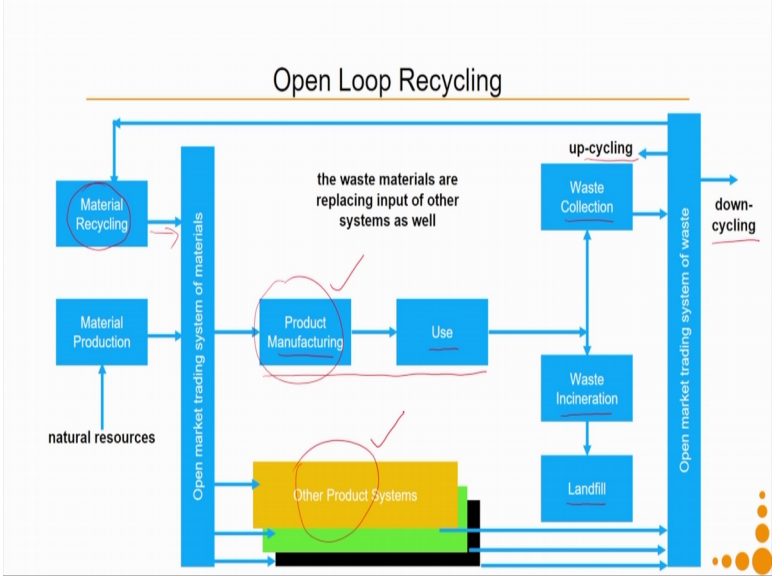

Now, let us look at open loop recycling. So, open loop recycling is a better more efficient option when it comes to plastics. Open loop recycling can work more efficiently with plastics because plastics only when they are recycled at high volumes the recycling is more efficient. So, in it is more advisable that even if you have a metal part a metal part can; obviously, go into open loop recycling also, for closed loop recycling metals parts are good options. Remanufacturing, reuse of certain components or parts are good options when it is into closed loop recycling, but for plastics it is advisable to go ahead with open loop recycling.

So, what happens in open loop recycling? So, I have material production, from natural resources then this material production. So, say for example, a particular kind of plastic then it enters the open market trading system of materials. So, many product manufacturers will buy this material from the market. Now say for example, this product manufacturer manufactures the product, then it is used, then after use it can go for waste collection, it can go for waste incineration or land fill same will happen for the other product systems also.

All the waste collection from this product manufacturing and other product systems the waste collection will go into open market trading system of waste. This waste can be either down cycled, can be up cycled or can go into material recycling, which is the same quality of material and this can again enter the open market trading system of materials.

So, what you see over here the difference here is the eco burden of the recycling is not taken up by the manufacturer it is done by a separate set of state holders. So, the waste materials are replacing input of other systems as well. So, the waste that is being collected that not only influences my manufacturing units input, but also influences other product systems inputs.

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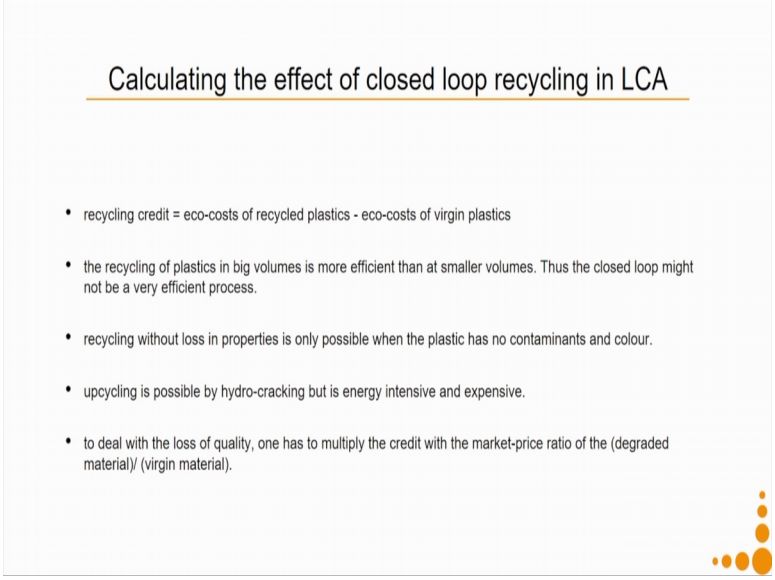

So, how do we calculate the effect of close loop recycling in LCA? So, we have recycling credits which is eco cost of recycled plastic minus eco-cost of virgin plastics. The recycling of plastics in big volumes is more efficient than at smaller volumes, thus the closed loop might not be a very efficient process for plastics hence for plastics open loop is better option.

Recycling without loss in properties is only possible when the plastic has no contaminants and colour. In case it has then it has to it goes for down cycling up cycling is possible by something called as hydro cracking which is very energy intensive and expensive. To deal with the loss of quality one has to multiply the credit with the market price ratio of the degraded material or virgin material.

Thankfully you do not have to consider so, many different calculations all you have to do is build the systems. So, you build the systems map and we have softwares, which can help you to do the calculation. So, you have to map the system and the softwares help you in selecting in calculating the eco-burden. So, this will be our topic of for the lecture

for the next 2 days of DV where we will take an example and try to do a simple life cycle assessment.

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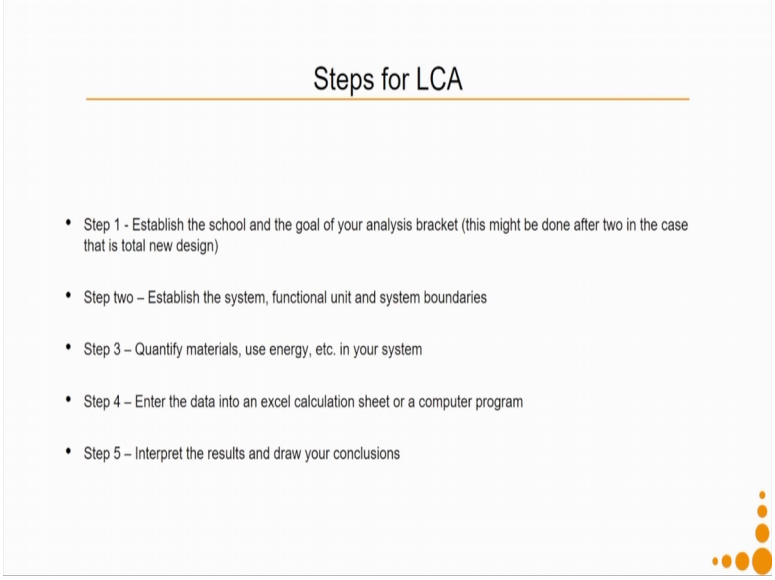

So, the steps for LCA which we will be discussing in the next lecture are, the first step is, establish the scope and the goal of your analysis. The second step is, establish the system functional unit and the system boundaries. The third step is, quantify the amount of material and the energy which is to be used. So, my chair requires 5 grams of polypropylene or 12 grams of polypropylene that is what we mean by quantify the material energy in the system. Then we enter the data into in our case what we are going to do is we will enter the data in to a computer program. Then we will interpret the results and draw our conclusions.

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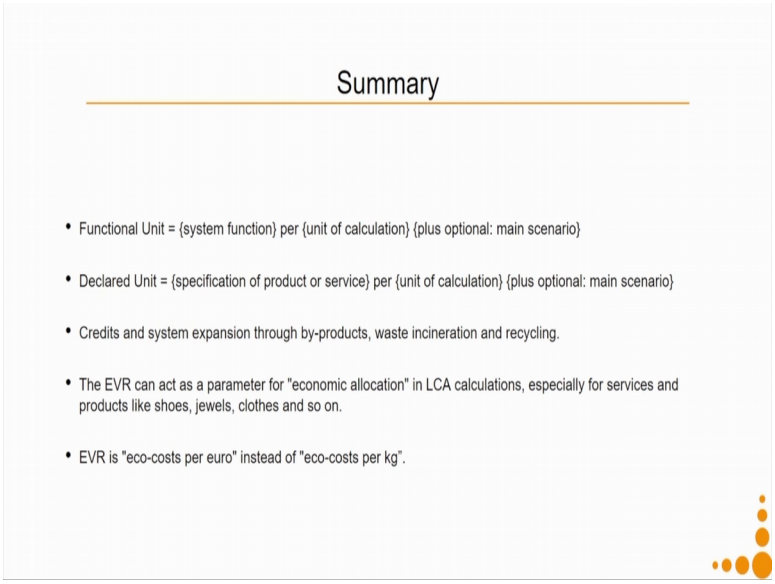

So, the summary from our lecture today is, functional unit is system function per unit of calculation plus main scenario whereas, declared unit is specification of a product or service per unit of calculation plus an optional main scenario. And credit and system expansion through by-products waste incineration and recycling it has to be also built into the system that you define. The eco-cost value ratio can act as a parameter for "economic allocation" in LCA calculations, especially for services and products like shoes, jewels, cloths and so on. EVR is eco cost per euro instead of eco-cost per kg.

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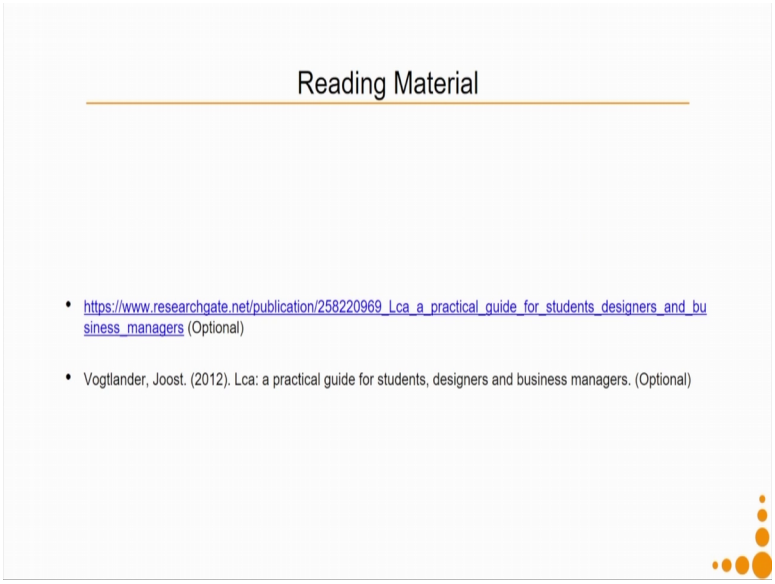

So, the reading material continues to be the same as the previous lecture it is an optional reading material you may choose to go through them if you want to know more about life cycle assessment.

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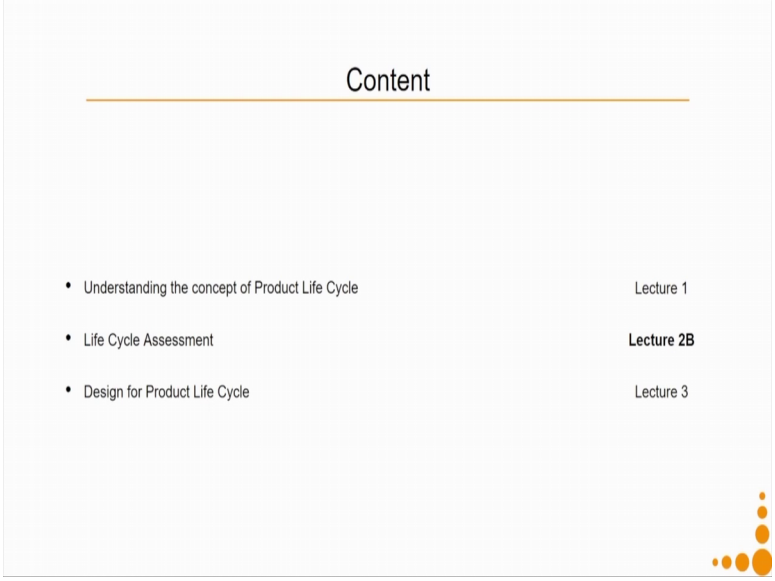

So, in the next 2 lectures of the this week we will go through design of how to do design a product life cycle and we will do LCA in the context of design by using a software.

Thank you.