System Design for Sustainability
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Week – 03
Lecture – 03
Product Life Cycle Assessment

Welcome to our today's lecture on Product Life Cycle Assessment. So, what we are going to discuss about today is how to do life cycle assessment.

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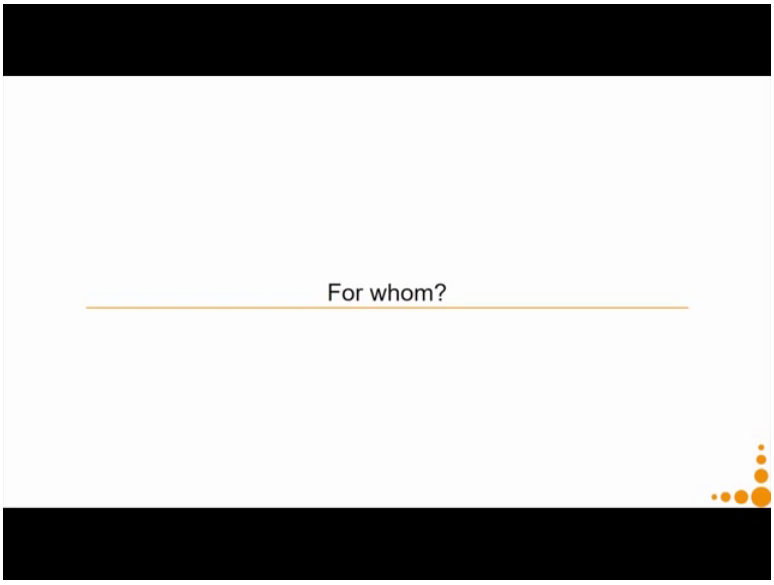

So, first for whom this particular life cycle assessment method that I am going to talk about. So, the method that I am going to talk about is called as fast track life cycle assessment. So, for whom it is meant to?

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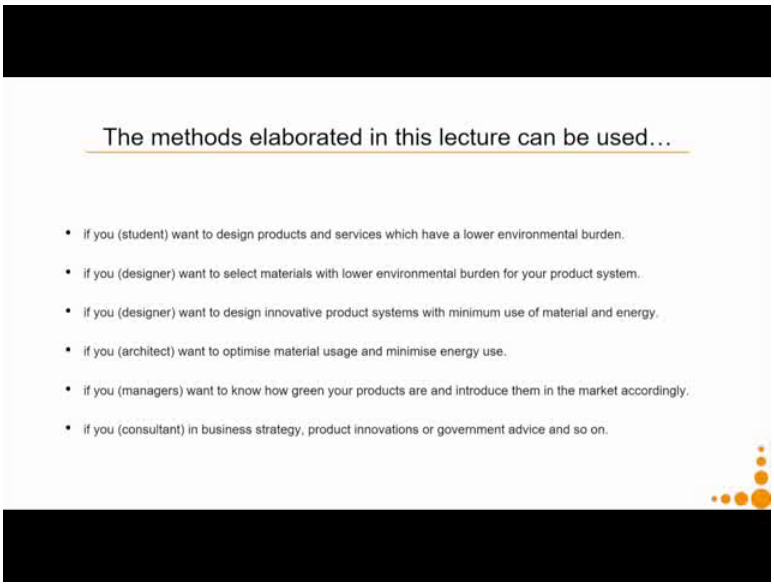

So, the methods elaborated in this lecture can be used if you are a student and want to design products and services, which have a lower environmental impact. If you are a designer who wants to select materials with lower environmental burden for your product system, if you are a design and who wants to design innovative product systems with minimum use of materials and energy, if you are an architect who wants to optimize material usage and minimize energy use.

If you are managers and want to know how green your products are and introduced in the market accordingly, also if you are a consultant in business strategy product innovations or government advice and so on. I will come to shortly into what the current method is for whom this current method is not meant for. So, this is all those people for whom this current method is very useful.

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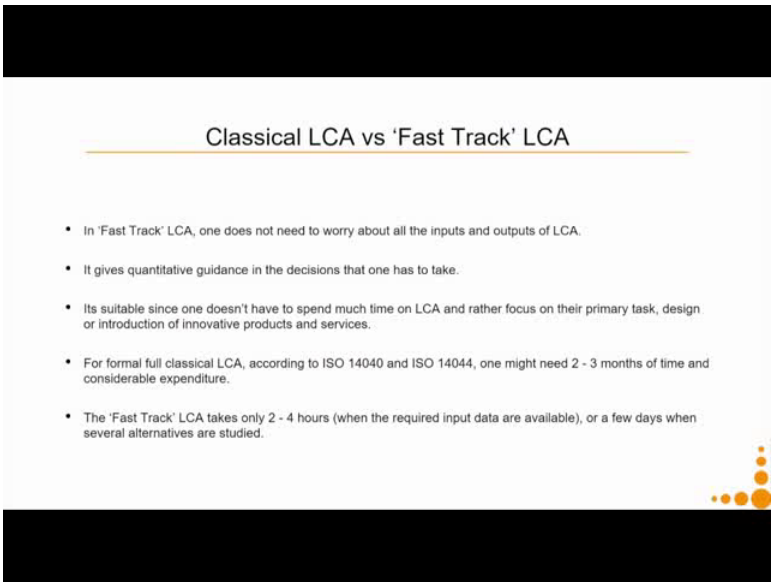

So, we are going to talk about fast track LCA the other version of LCA is called as the classical LCA or full LCA. So, in fast track LCA one does not need to where worry about all the inputs and outputs of a life cycle assessment. We need to worry about very few of them what they are I will come to them. It gives us quantitative guidance in the decisions that one has to take.

So, can say product A to product B this much of environmental burdens less. So, you get quantities how much is less. It is suitable since one does not have to spend much time and LCA and rather focus on their primary task which is design of or introduction of innovative products and services the formula of full classical LCA which is conducted. So, the fast track LCA is also supposed to be conducted as per the rules of ISO 14040 and 14044, but this full LCA which when conducted according to these standards it might take something between 2 to 3 months, and considerable expenditure as well. Whereas, the fast track LCA takes about 2 to 4 hours, when the required input data are available of course, or a few days when several alternatives are to be studied.

So, you want to make certain modifications in the process and keep on studying what is the impact in terms of environmental burden. So, you might take couple of days depending on how many alternatives you try. So, but do not assume that the accuracies are low the accuracies are comparable to the classical LCA.

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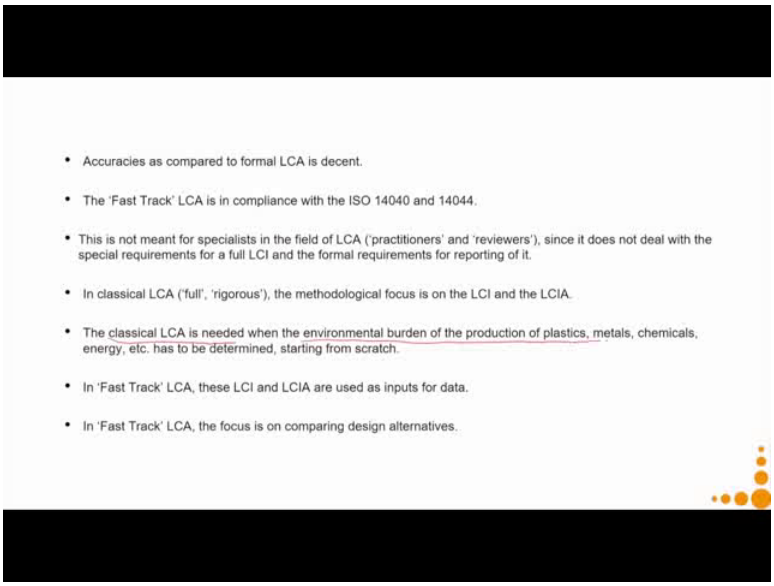

So, the fast track LCA is in compliance with the ISO 14040 and ISO 14044. These are 2 standards which are have been developed for life cycle assessment. This is not meant for specialist in the field of LCA.

So, the people who want to become like LCA experts practitioners reviews this particular fast track LCA is not meant for them. They are advised to go ahead with classical LCA. Why? Because it does not deal with the special requirements for a full LCI, LCI is life cycle inventory and the formal requirements for reporting it. So, in classical LCA the methodological focuses on how do I create an elaborate life cycle inventory. And then do the life cycle inventory analysis which is LCIA.

So, the classical LCA is needed when the environmental burden of the production of say plastics, metals, chemicals, energy etcetera has to be determine starting from scratch. Which as design as or as students or as consultancy that is not our purpose. Our purpose is when we have a product we can directly take the inputs from the classical LCA from other peoples data and use them in our methods.

So, in fast track LCA the LCI and the LCIA from the classical LCA I used as input data. So, in fast track LCA the focuses on comparing design alternatives. Rather than what the classical LCA is which talks about calculating the environmental burden of production of plastics and metals chemicals energy etcetera.

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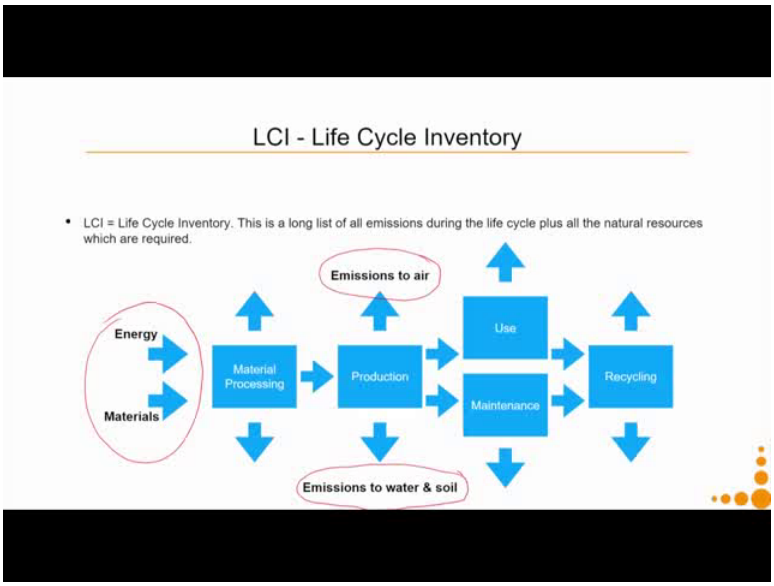

So, what is the life cycle inventory? Like we discussed in our previous lecture life cycle inventory it is a long list of all emissions during the life cycle plus all the natural resources which are required. So, at the material processing at the production at the use maintains recycle recycling all the energy and materials that we will be using. And all the emissions to air or water or soil which are going to happen, they form the part of the life cycle inventory.

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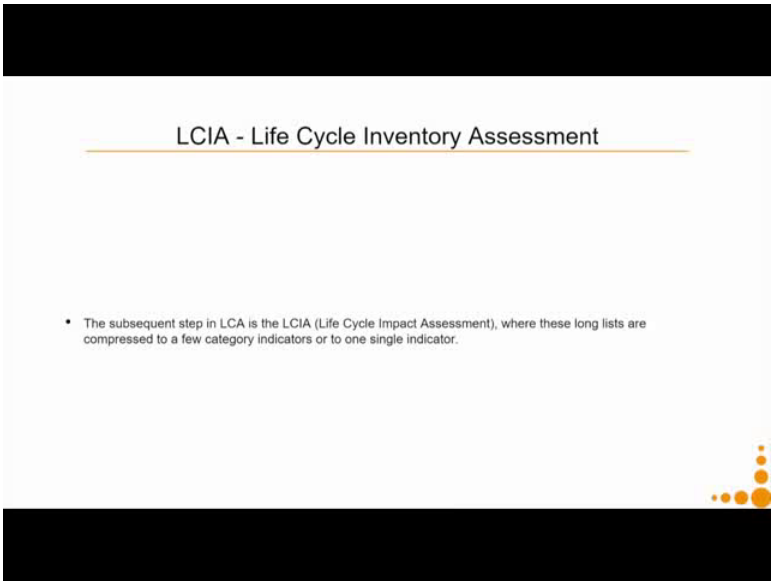

Then, what we do is life cycle inventory assessment. So, the subsequent step of LCA where these long lesser compress to few category indicators or to one single indicator.

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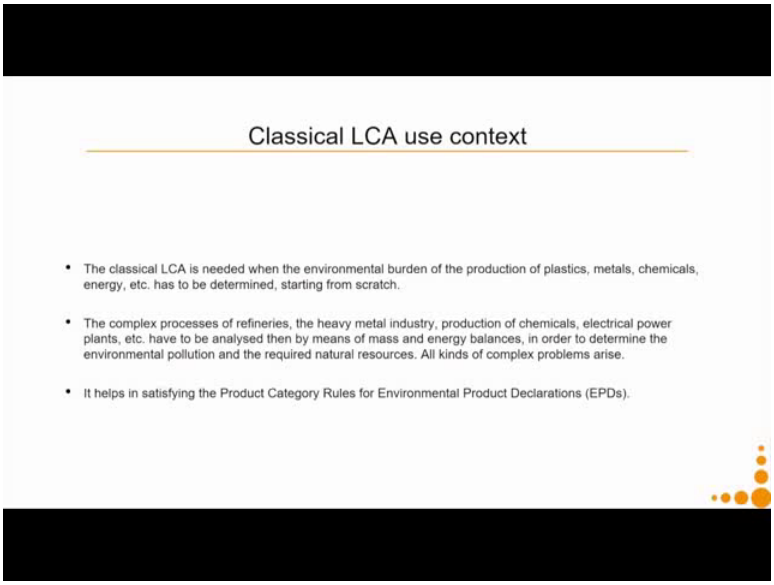

So, classical LCA use context. The classical LCA is needed when the environmental burden of the production of plastics metals chemicals energy etcetera has to be determined starting from scratch. The complex processes of say for example, refineries the heavy metal industry production of chemicals electrical power plants etcetera have to be analyzed. Then by means of mass and energy balances in order to determine the environmental pollution and the required natural resources.

All these are very complex and require also deal with complex problems. So, in those cases classical LCA is used, which is beyond the scope of our course. And it is also not required for the target audience that we are talking about whose main purpose is to design. The classical LCA helps in satisfying the product category rules for environmental product declarations which is not achieve by fast track LCA.

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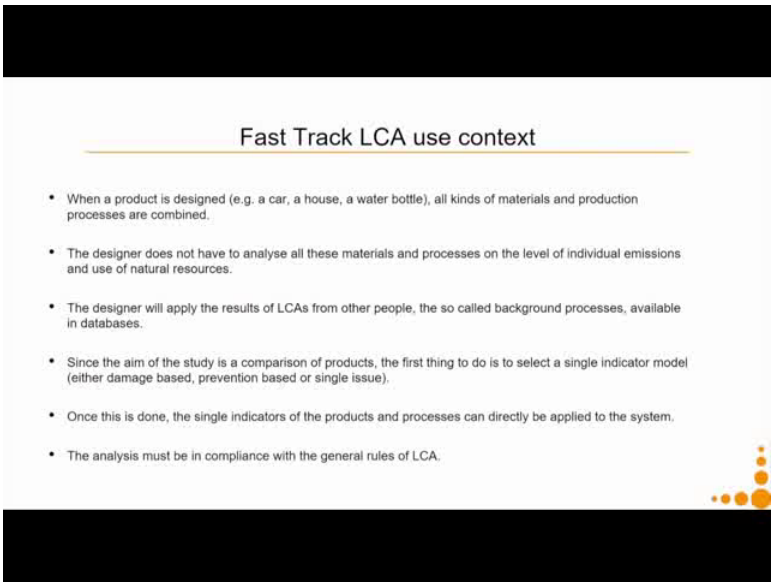

Now, fast track LCA use context. So, when a product is design example a car, house, water bottle and so on. All kinds of materials and production processes are combined. So, the designer does not have to analyze all these material. So, say for example, a car might be made up of 5 different types of materials. So, we do not need to analyze each and every material and the processes from this scratch. What we can do is use the assessments already done by someone else in LCA in class though as LCA calculation, and use them in our contact. And these classical LCA data is already available through many data basis.

These data basis our country specific region specific because say for example, transportation is a cost which is supposed to be added to it. So, it becomes very region specific. Since the aim of this study is the comparison of products. So, our aim is like comparison between 2 designs of between 2 products. So, the first thing to do is to select a single indicator model, which might be damage base as we were discussing last time eco costs is a damage based or a prevention based model and then we go ahead with it. So, once this based on the single indicators of products and processes can directly be applied to the system.

As we go through this whole process of doing a fast track LCA with examples each and every step of these will be more and more clear. And we will again come back to these pointers at the end of the lecture to summarize it; at the end of the module to summarize

it. So, the analysis must be in compliance with the general rules of LCA even for fast track LCA.

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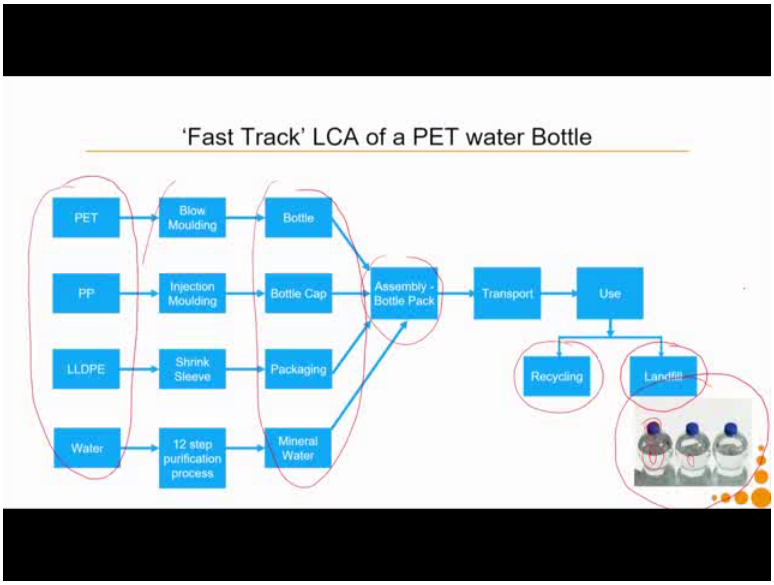

So, how do I do a fast track LCA of a pet water bottle. So, you can see below the image of a PET water bottle. So, the transparent part it is made up of plastic called PET, the cap is made up of a plastic called polypropylene. When I want to send this bottles out of the factory, it is kind of an assembly. And assembly which consists of this pet bottled the polypropylene cap the water and couple of bottle say 12 bottles or 24 bottles together will be packaged in a shrink feel. So, that during transportation they stay together for additional support.

So, if I want to do a fast track LCA of this water bottle what I will include is. So, my I start from my assembly which is my bottle pack. So, in this bottle pack what are the individual product. So, usually you will see that if it is not a very simple product say for example, cup most products are made up of several component.

So, most products are an assembly of several components. So, this assembly which is the bottle pack it consists of the bottle, the bottle cap the packaging and the mineral water inside it. Now, how each of these is manufactured. So, the bottle is manufactured by a manufacturing process called blow moulding. The bottle cap by a process called injection moulding packaging is done by a shrink sleeve the mineral water is made by a 12 step purification process. To this be at the basic materials.

So, how we start is like the assembly, what are the components in that assembly. So, this is my assembly the components in the assembly, how are they manufactured what are the materials used for manufacturing them. So, this is up to the production part. Then I need to transport it to my uses then it needs to be used in the use phase of a water bottle, there is not much there is neither any energy consumption nor any emissions.

But they are might be other product say for example, of coffee machine. In the use phase there is lot of energy consumption there are also raw material like coffee pods which might be consumed by the coffee machine. Then, comes my last phase which is the end of life, which might be either through recycling or land filling in this particular context. There might be other context where it might go to an insulator and so on. So, I have to decide at this phase whether I will be going for recycling or land filling or incineration or a part of each of them can be possible.

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So, how do we so, you saw this example what we are trying to define somewhere is what is this system that we are trying to look at for my life cycle assessment. So, the first step of doing life cycle assessment is described the system to be studied. It can be done in 3 ways or called as 3 paradigms.

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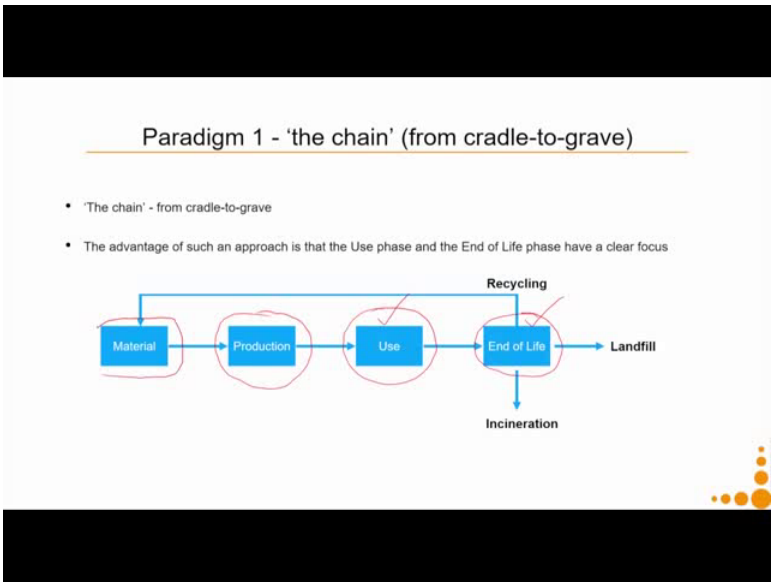

So, the paradigm one is called as the chain which is from cradle to grave, see you can see material so, in my previous example.

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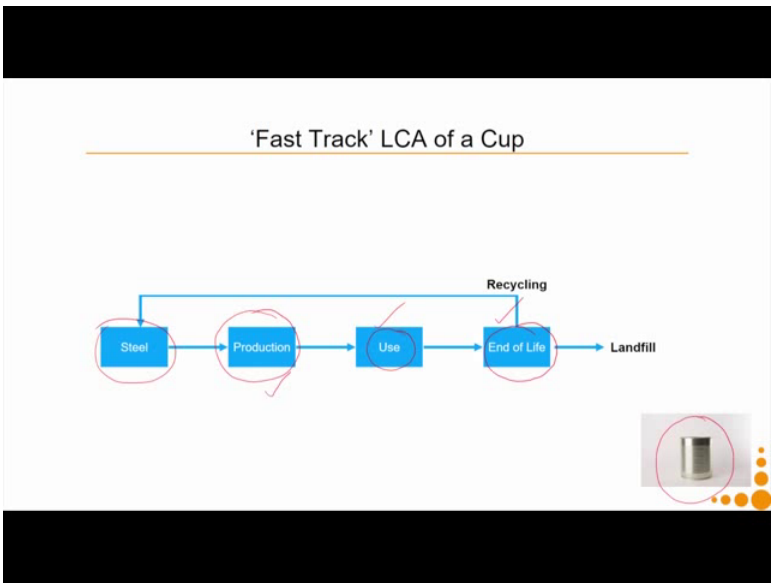

Or let us say let us take another example in order to make this steel cup my material is steel. So, my material that is the cradle from where it comes I have to consider all the extraction related consumption because it is a fast track LCA. So, I will not do a detailed study of the material extraction phase component by component. What I will do is I will

directly take other peoples data of LCA and which is with respect to the steel. Then comes the next step which is the production.

So, production of the steel using appropriate methods, we can do a break down over here depending on what kind of steel container I am trying to make what kind of design I have. I might get different production techniques. There might be a separate production technique for making the handle and then attaching it to the body. Then comes the use phase then finally, comes the end of life, which can be land filling incineration and recycling. Recycling means it goes back again to the material stage.

Now, you can see I am bringing it back to the material stage. I am not to bring it back to the production are the use ways, which means I do not know exactly this material we will go back into the same industrial it might go back into another industry. There is a big difference which comes between these 2 concepts, which we will discuss eventually during the course of this module. So, the first paradigm which is the chain paradigm it talks about from cradle to grave.

So, the chain the advantage of such an approach is that, I can very nicely considered the use and end of life phases, which means I can optimize how the use phase we will work and how the end of life can be improved so as to have least environmental burden. Now the problem with this particular approach the benefit of this approach is as I told you that you can elaborate on the use phase and on the end of life phase, but use phase is not we only can make the best assumptions.

We really do not know how the user is going to really use that product. So, we can come up with certain scenarios, which are basically our assumptions. So, if you use only one use case then, it is not a very good life cycle assessment. Because you can never predict that the user is going to use it in that particular manner.

So, we will have to use couple of use a scenario. Similarly, we will have to use couple of end of life scenarios. Because, again the end of life is not in the hand of the manufacture or the designer. Yes, it also gives you the scope on designing for a certain end of life process. In that case you have to redesign the entire product system how the product will be collected back and recycle.

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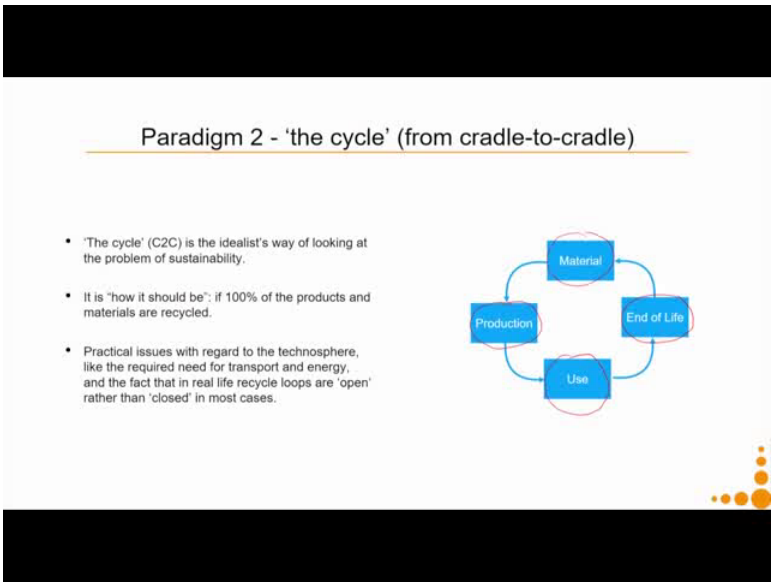

The second paradigm is called the cycle the cradle to cradle approach. So, the cradle to cradle is the idles way of looking at the problem of sustainability.

So, you can see I start from material, I go to production, I go to usage of it at the end of the life it is again collected back and uses in the same cycle again back. So, it is how it should be if 100 percent of the products and materials are recycle, but practical issues with require to the techno sphere like the required need for transport and energy is not accounted for in this case.

Again another problem which is related to open rather than closed life cycle loops. What it implies is like I was discussing in the previous example, when I say my re material is recycled it really does not imply that the same steel will be used in the same product. It can be used in a different product altogether or it can be used for different purpose, let us say. So, we will come to the discussion on open and closed loop.

So, that is what it is meant over here as well. So, it has the same problem because I do not cannot ensure until and unless I define proper systems for collection of each and every piece of my steel cup that the material will go in the closed loop as depicted in this particular diagrams.

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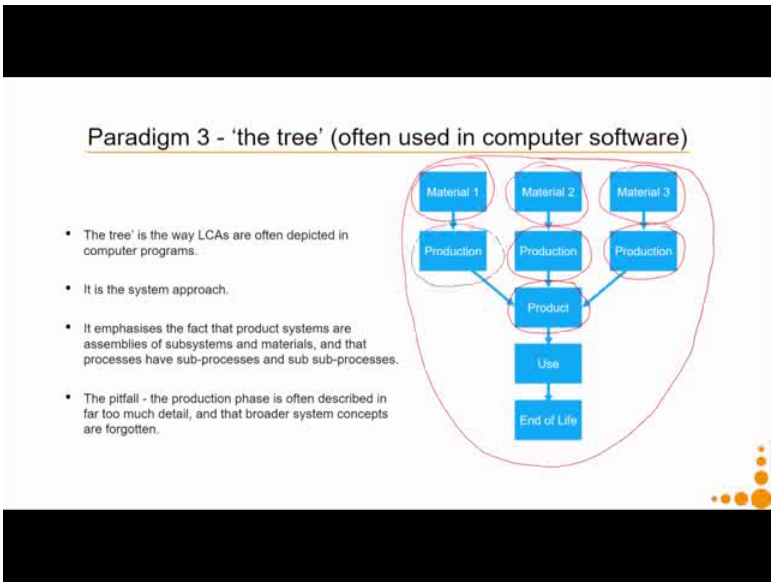

Now, comes the third paradigm the tree which is often used in most of a computer softwares. There are lots of softwares available for doing life cycle assessment for both fast track life cycle assessment as well as classical life cycle assessment what we have. So, the software helps you to do the calculation. What the software needs as an input from your side is these kind of structures that I am showing you.

Which are a depiction of the different stages of the whole product life cycle. On how you define these different stages of the product life cycle the success of your life cycle assessment we will depend on that. So, the tree life cycle I will show you one example.

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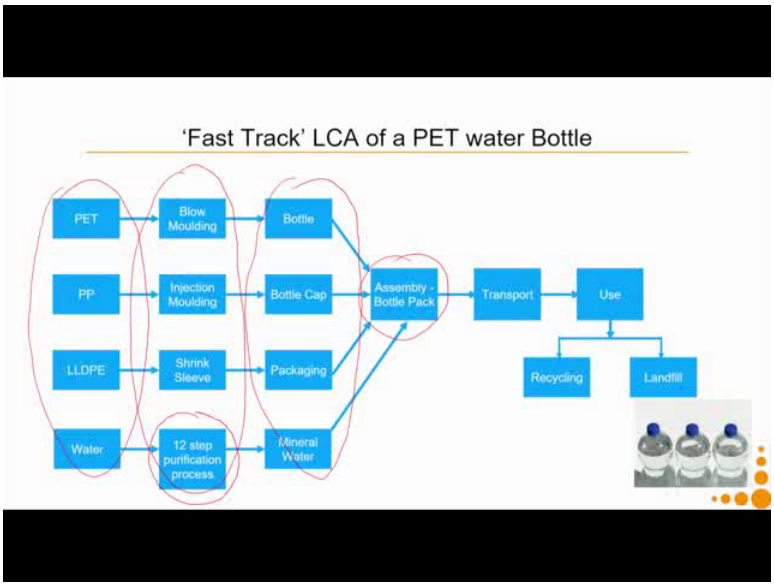

We come back to our previous example of life cycle assessment of the pet bottle. So, in real life scenario most products are in assembly of products or an assembly of components.

So, the tree structure helps you to achieve that. So, here you can see the product which in our next example is the assembly of bottle pack. I have material 1, material 2, material 3 which are led into certain production processes. And finally, they give me the assembly. So, you can see these are my materials they go through a particular production process give me the components and then finally, my assembly package made out of it.

Then I will have use phase then I will have end of life. So, the tree is the way LCA is are often depicted and computer programs, because most products consists of a couple of components. It is a systems approach. It emphasizes the fact that product systems are assemblies of subsystems and materials. And that processes have sub processes and sub sub processes. So, here you can see in production I have only spoken about one technique, but this might be a combination of couple of processes. Say for example, here what I mentioned is 12 step purification process, which means from water to mineral water I have several sub processes, which might also have sub sub processes.

So, depending on the database that you are using, if your database has value for the whole process. So, if the data base has one value for say converting water into mineral water, in which all the 12 step processes have been combined together you can use that

data. In that case you do not need to sub divided into sub processes, but say data is not available in for this whole 12 step process. Then we will need to break it down into sub processes and try to find data per sub process if again data is not available we have to further sub divided into sub sub processes. And that is how fast track LCA works. The pit fall is the production phase is often described in far too much detail. So, you can see in on the production phase on this diagram the production phase is so heavy and I keep on detailing it further and further. And that the broader system concepts of forgotten.

So, that is how a trap you might fall into because they put in too much of effort on the production side. So, we have to be careful that we do not put too much of attention on the production side and forget the use and the end of life side.

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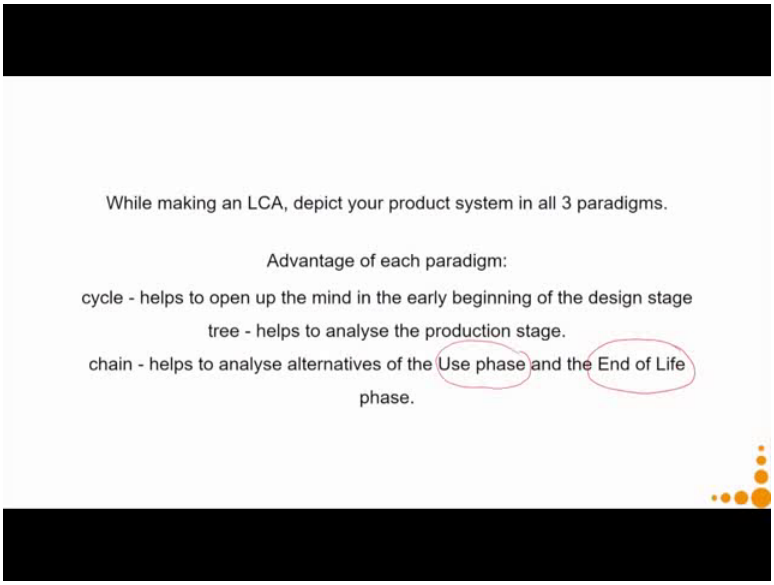

So, while making an LCA which system should you use out of the tree paradigms. So, it is always suggested that you use all the 3 paradigms. Why because it which of them have it is own advantage and because your purpose is to design new products and product systems or compared to products and product systems. When you are in the comparison phase better idea is to select one of them. When your work is to design the better idea is depict your product system in all 3 paradigms.

Advantage of each paradigm is this. If you put it into the cycle that is a cradle to cradle cycle it helps to open up the mind in the early beginnings of the design stage about what are the complications related to getting back your product again to the manufacturer. So,

that it can be taken back in a life cycle. And then maybe you can design product systems accordingly.

If you put it into the tree system, it helps you to analyze the products stage in very in depth manner. And as a result you can reduce the environmental burden during the production state in a very efficient, in a more efficient manner. The chain it helps to analyze alternatives of the use phase and the end of life phase. Because for most products which have a long life which are supposed also specially products which are supposed to use energy while there in the use phase or large part of the impact is because of the use phase and end of life phase.

These might actually be way much greater than the impacts that lies in the production phase. So, the chain helps you to analyze various types of alternatives where use and the end of life phase. And see which one gives least amount of environmental burden and then design accordingly. Now, the next step is setting the system boundaries.

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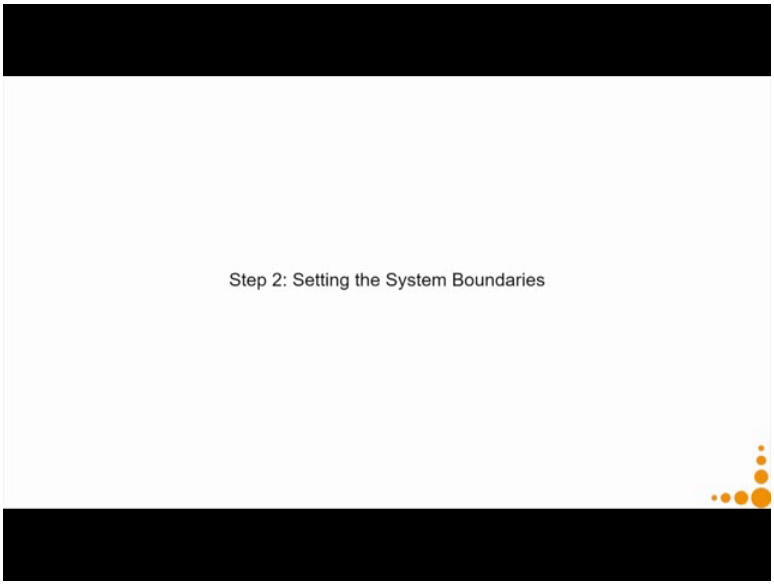

What do we mean by this is.

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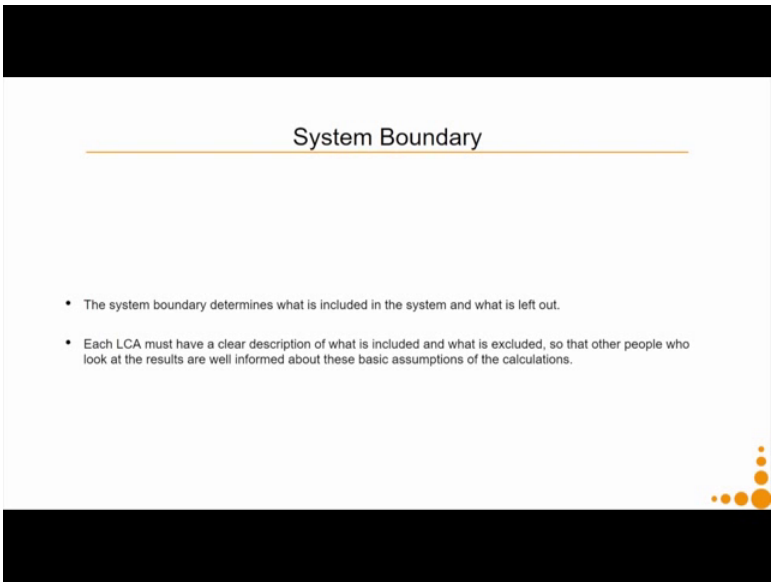

So, the system boundary determine what is included in the system and what is left out.

So, each LCA must have a clear description of what is included and what is excluded. And you have to also mention that in your report. So, that the other people who look at the results are well informed about these basic assumptions of the calculations. Because, say for example, you only considered the production phase, and you classified your product having only x amount of environment burden.

But your product is a energy guzzling machine. Say for example, it is a coffee machine which requires energy which requires coffee pots. While it is being operated and those coffee pot end up in a dustbin. So, the consumption the environmental burden at the use phase is actually very much higher than what it is at the production phase. So, we are reporting that my coffee machine is very environmentally friendly, might not be having the same it will not be able to give people a clear understanding like in what stage it is very environment friendly. So, let us coming to the different system definitions we can go ahead with.

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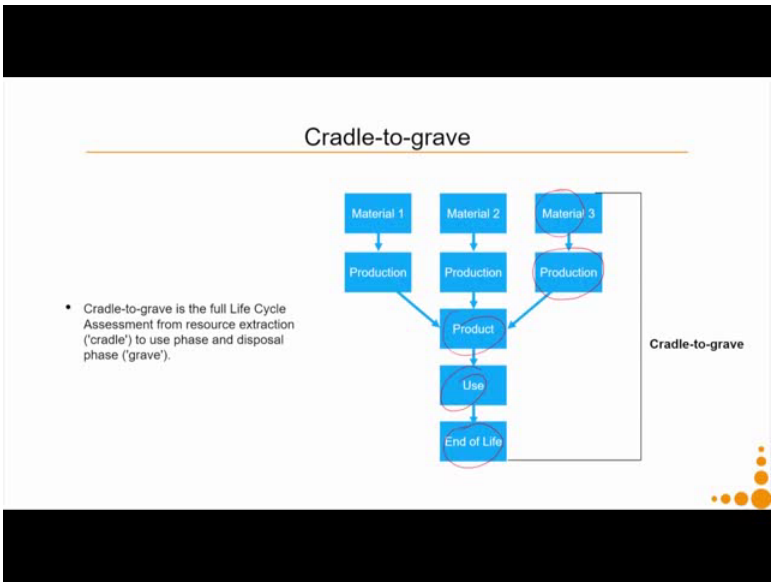

So, the first system definition is cradle to grave. Where it is the full life cycle assessment from resource extraction the material then production the product they use to the end of life. So, cradle to grave is a complete life cycle assessment of any particular product. The advantage of this is it considers both the production side as the u side as well as the end of life phase.

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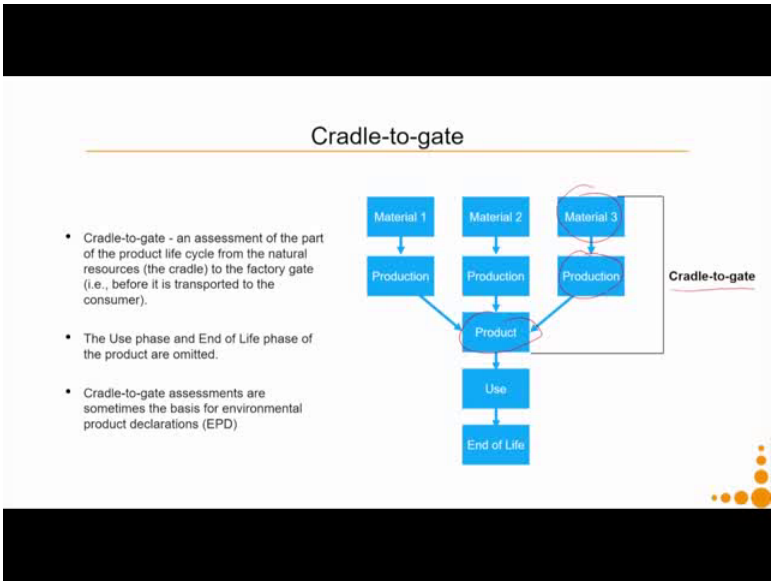

Another assessment which can be done, because we are not very sure about the use phase about the end of life phase there with these are scenarios different people can take up

different scenarios. And you might not be able to have much control over those scenarios. Hence another approach to do it is where a manufacturer has good control is a production side. That one is called as the cradle to gate. What it means is from the materials to the production up to the product up to the factory gate. So, and assessment of the part of the product life cycle from natural resources that is the cradle to the factory gate that is before it is transported to the consumer.

The use phase and the end of life phase of the product are omitted in this particular case. Cradle to gate assessments are sometimes the basis for environmental product declarations. Because the manufacture does not have much control over the use and the end of life they usually declare the cradle to gate environmental impact in there environmental product declaration reports.

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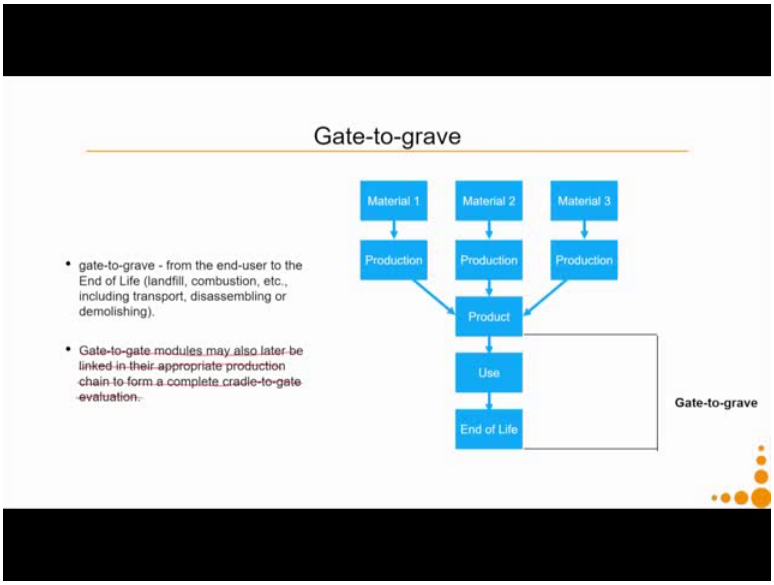

The other one is gate to grave. So, gate to grave is from the end user to the end of life, which might be landfill combustion including and it includes transport disassembly or the Malaysian all those activities which might be required. Where do we consider this particular context? The gate to gate modules they are link to the sorry for the error in this particular slide please ignore the second point. In gate to grave what we can do is we can put better emphasis on the use phase and the end of life phase.

As a result, what we are trying to target is some way in which I can influence the consumption behaviour. So, I come up with various scenarios and do a detailed analysis.

At a later stage I can join this analysis to my previous level which was the cradle to gate. So, I have a one value for cradle to gate and I have multiple scenarios for gate to grave. And I add them together to see what is the final environmental burden. I can also compare whether the burden at cradle to gate was higher or the gate to grave was higher and the different scenarios.

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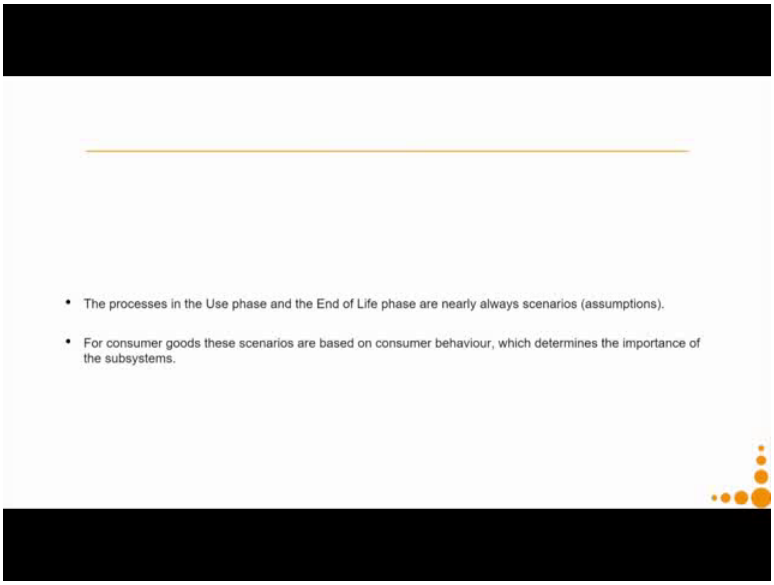

So, the processes in the use phase and the end of life phase and nearly always scenarios or assumptions. Because you do not know how the consumer is going to use them for consumer goods these scenarios are based on consumer behaviour which determines the importance of the subsistence.

Say for example, if a consumer does not switch off the air conditioner, that is one particular scenario. So, it is supposed to run for whole day. Say there is another consumer who might just keep the windows open and run the air conditioner. So, we have very few less control over that particular domain, but we can assume the best possible scenarios of usages as well as the worst possible usage scenarios and all in between. And maybe this will trigger as to develop new product say for example, sensor based switching mechanisms. Or say for example, a sensor which says your air conditioner is overloaded so, please close the windows.

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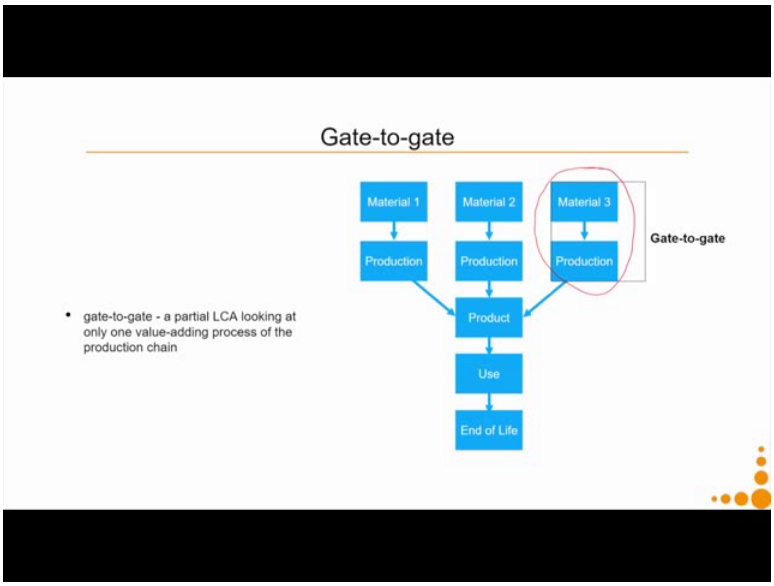

The next subsystem definition can be gate to gate in this case partial LCA is being done of one particular a chain only. So, here you can say I just did it for the material 3 and it is production. So, one particular product's gate to gate.

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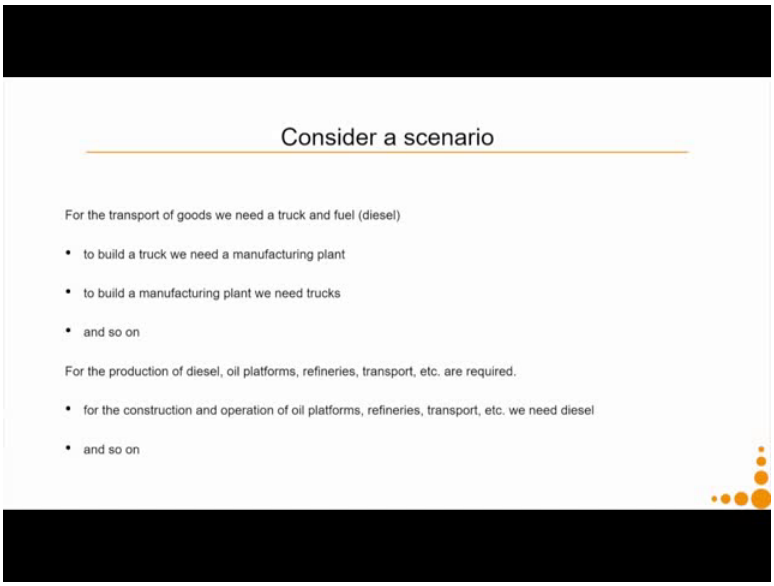

So now considered a scenario for the transport of goods we need a truck and fuel say diesel. Now to build the truck we need a manufacturing plant, not build a manufacturing plant we need trucks and so on. So, you can see a cyclic scenario in this life cycle assessment. Say for the production of diesel oil platforms refineries transportation and

transport etcetera required for the construction and operation of platforms refineries transport etcetera we need diesel. So, for the production of diesel also we need diesel and so on. So, what do we do in these cyclic conditions.

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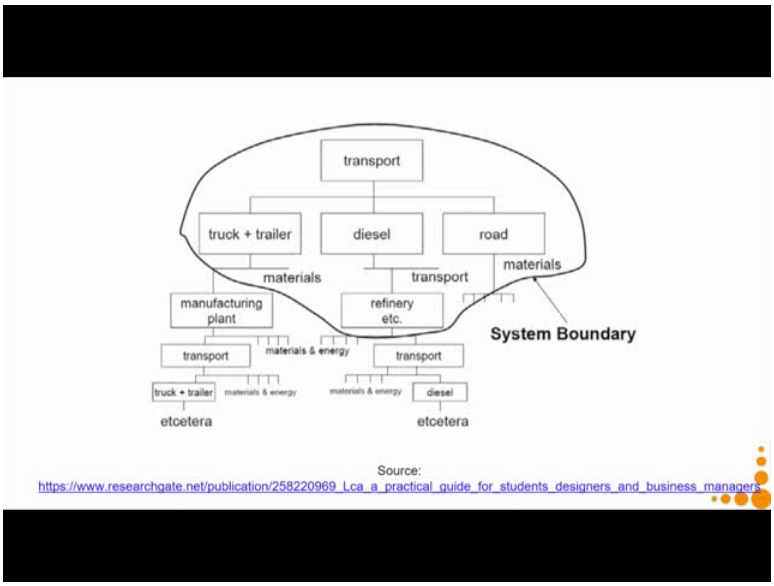

So, system boundary is very, very essential in such context. So, here you can see I created system boundary. So, I defined now I will not get into that loop of cyclic problem.

So, I have my for my transport I have my truck and trailer I have my diesel and I have my road. And I will take the inputs for these from my classical LCA and I will not go ahead with going into component wise for that bifurcation of each and everything. So, my system boundary is defined.

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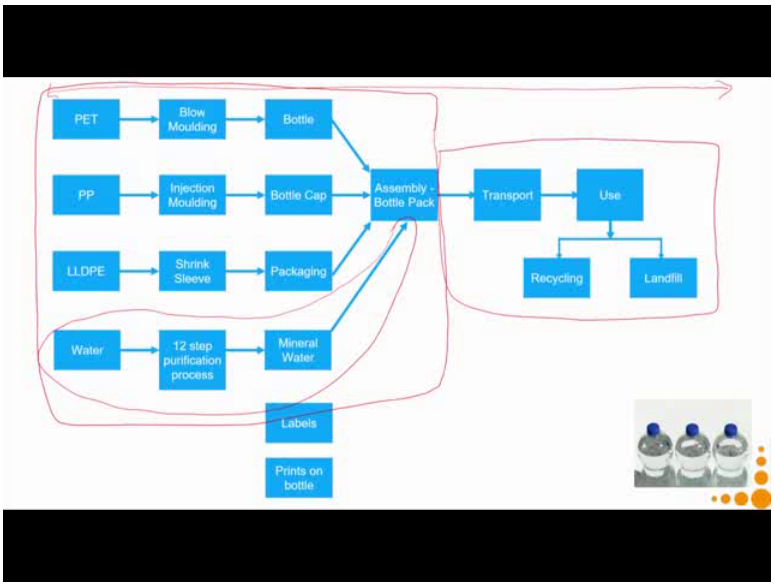

So now again coming back to this particular slide our example of packaging packaged drinking water. So, I can do analysis of say such water that is gate to gate. I can do an analysis of only this phase that is gate to grave. I can do and analysis of the whole system which is cradle to grave. I can do an analysis of only up till the product is produced up till the factory gate which is cradle to gate. Now, let us say can we add more components do it yes of course.

So, all these bottles will have some kind of a label on top of it. They will also the label gives you certain information, other information say like information which are liable to change like manufacturing date expiry date and so on.

They are printed on the bottle using ink. So, prints on those bottles. So, they again have materials and production processes. So, here in this case it is also important to see what all products what all components we need to consider and what all components we can ignore because say for example, the bottle and our example cases the simpler example. I might have a more complex product which large number of components then it might not be. Then on the production side if we try to list down each and every components of it might get 2 complex.

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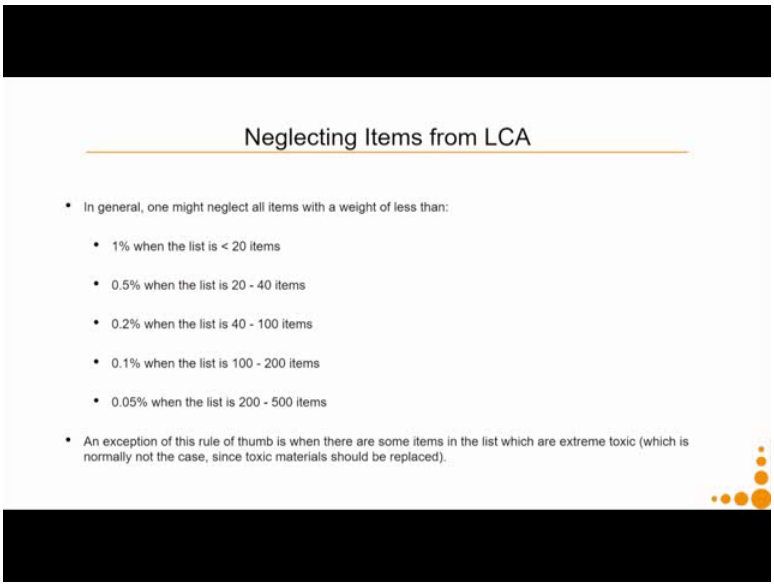

So, neglecting items from LCA is possible for which we have certain rules. So, in general one might neglect all items with a weight of less than 1 percent, when the list is less than 20 items. So, if you are assembly is made up of less than 20 items you can ignore the weight of a products which are less than 1 percent. And the aggregate of these should be also less than 1 percent. So, say I ignored 4 products. Each one of them should have less than 1 percent and when I add up on the impact of all the 4, it should be less than 1 percent of the total weight. It goes down to 0.5 percent when the list is 20 to 40 items, 0.2 percent when the list is 40 to 100 items and 0.1 percent when the list is 100 to 200 items, 0.05 percent when the list is 200 to 500 items.

And exception of this rule of thumb is when there are some items in the list which are extremely toxic, but actually we should eliminate those extremely toxic products way. Because they have very bad environmental impacts we should not include them, but in case it was unavoidable to have them in your product, then even if their weight is in the neglectable limits we still need to consider them in the LCA. Because even they are in very small quantity they are environmental burden is very, very high.

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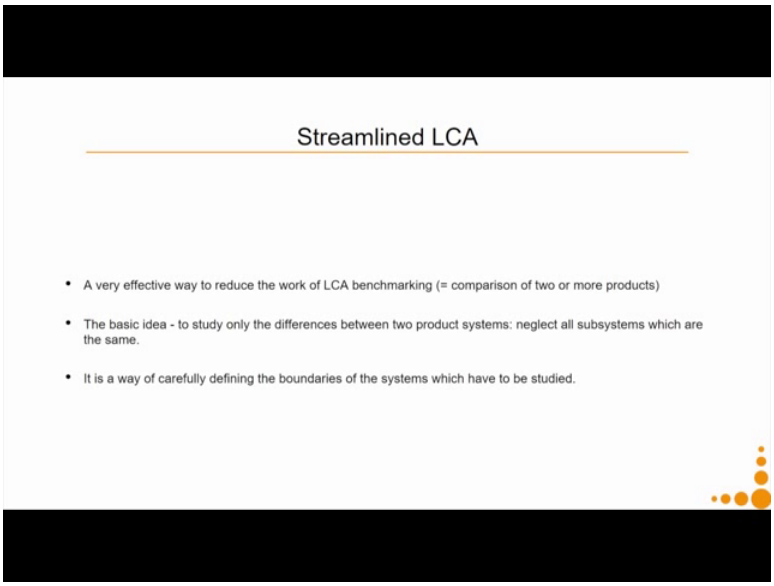

Now, coming to something called a streamlined LCA. What is streamlined LCA? It is an very effective way to reduce the work of LCA benchmarking when you are comparing 2 or more products. So, the basic idea is to study only the differences between the 2 product system neglecting also subsystems which are the same.

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Say for example, I have 2 different charging boxes. Say one of the charging box is made up of plastic, the other charging boxes made up of a another non conducting material say like wood or cork.

All the sub-assemblies all the components, where in the metallic components all the electrical circuitry and everything remains constant. So, I do not need to do an LCA for all the components. What I do is something called as a streamline LCA where I only compare the products with the housing in this case, one housing is made up of plastic the other housing is made up of wood or cork or any other material.

So, I just do a streamline LCA comparing these 2 hosing, say it is a way of carefully defining the boundaries of the system which have to be study. So, I took a very simple example of a charging box where only one component is different. Where is they might be other more complex situations.

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Let us go to a more complex situation which cannot be resolved by the concept of streamline streamlining or system definition.

So, hence we have to brought in bring in another dimension, which is functionality. So, consider the first coffee machine. These are 2 coffee machines the first coffee machine is supposed to be used in restaurants, the second coffee machine is a personal coffee machine that you can use at home or in small offices for it can make in one go one cup of coffee. It is also a slow machine whereas; the other machine will be much faster because it is a restaurant construction. So, if a coffee machine for a restaurant, equivalent to a personal coffee machine? Can I do an LCA of these 2 products and compare them

against to each other? No, because in terms of functionality they are very different. So, here comes the third step.

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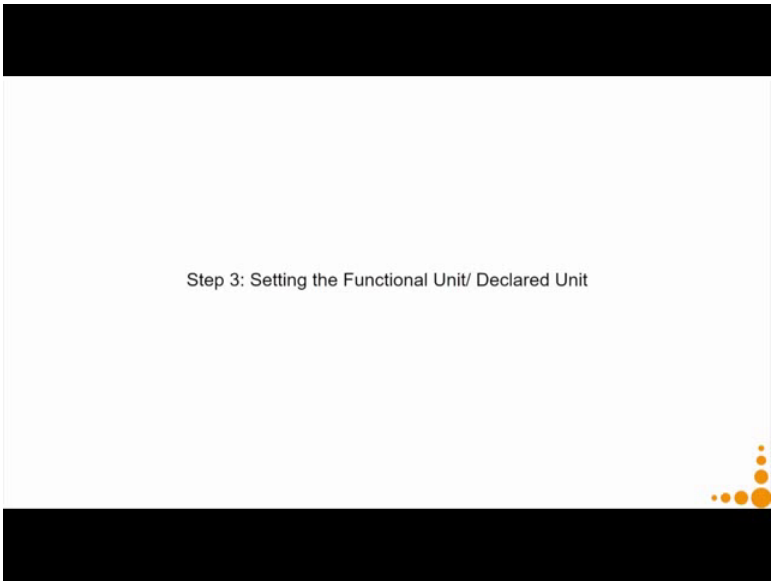

That is setting the functional unit or say the declared unit. Why do we have these 2 terminologies? Functional unit declaration is more easier for technical products. Say for example, I can say the functional unit for an air conditioner to be a cooling a room of 100 square feet in per hour. Whereas, because air conditioning is a functional product. Whereas, say a chair beautiful chair, how do I define the functional unit. Because they might be 5 chairs each one of them are satisfying the same function of chair, but the chair is bought also because of it is aesthetic value.

So, in order to solve that issue we use something called as the declared unit. So, we will go into further clarification of what the function unit and declared unit is in the next part of this lecture. To summarize what we have learnt till now is.

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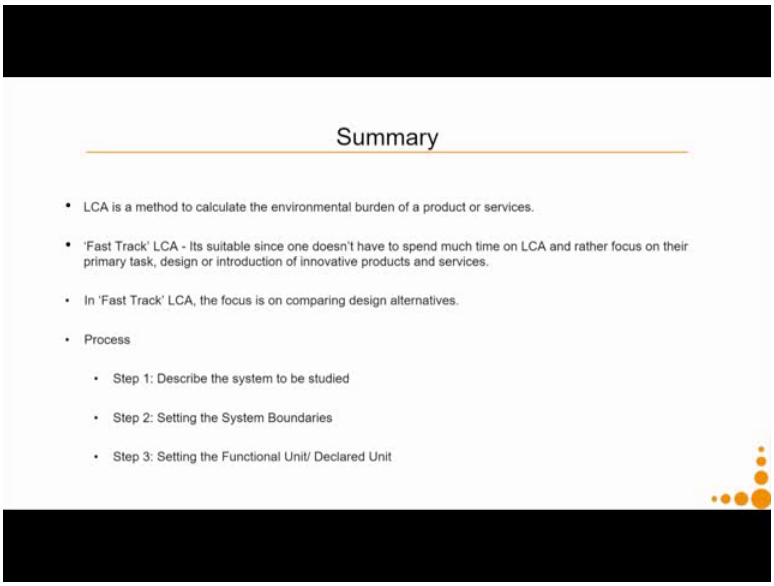

So, life cycle assessment is a method to calculate the environmental burden of a product or a service. Fast track LCA it is suitable since one does not have to spend much time on LCA and rather focus on the primary task which is design or introduction of innovative products and services. In fast track LCA the focus is on comparing design alternatives. The process that we follow is first step is described the system to be studied, the second step is setting the system boundaries, the third step is setting the functional unit and the declare unit. And then we are ready to go for a life cycle assessment.

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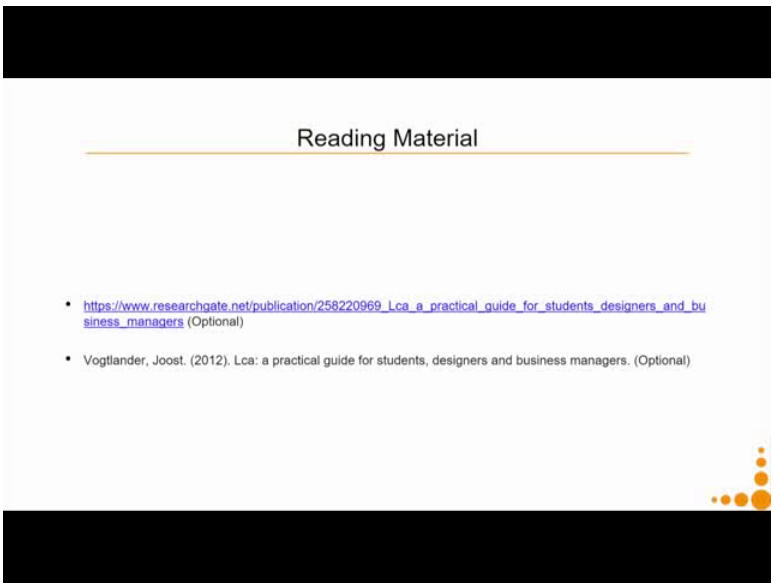

Not compulsory reading material, but if you are more interested in exploring what life cycle assessment is, then you can go through this to reading material. The second one is the book. The first one is the author has uploaded part of the same book couple of chapters from the same book as given in here second bullet and uploaded it them on research gate.

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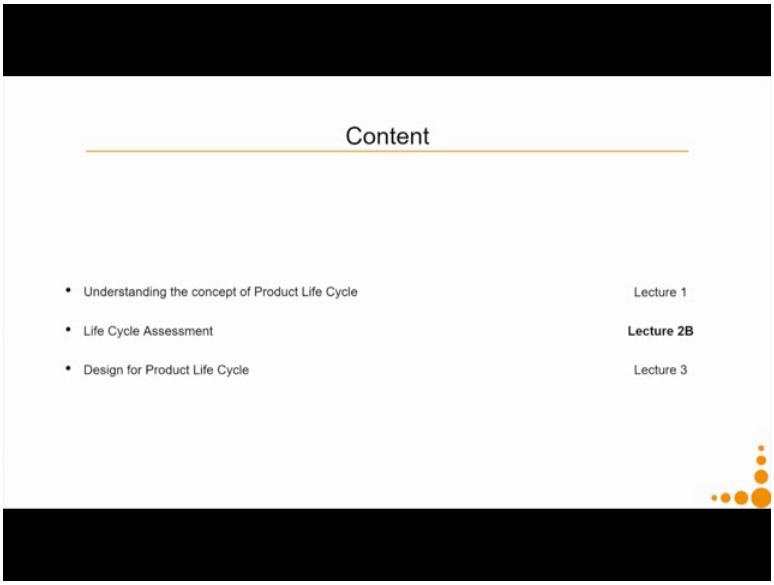

So, in the next lecture we will continue with life cycle assessment and we will take up product example to see how it can have different implications on design for the same product, depending on what we learn from our life cycle assessment.

Thank you.