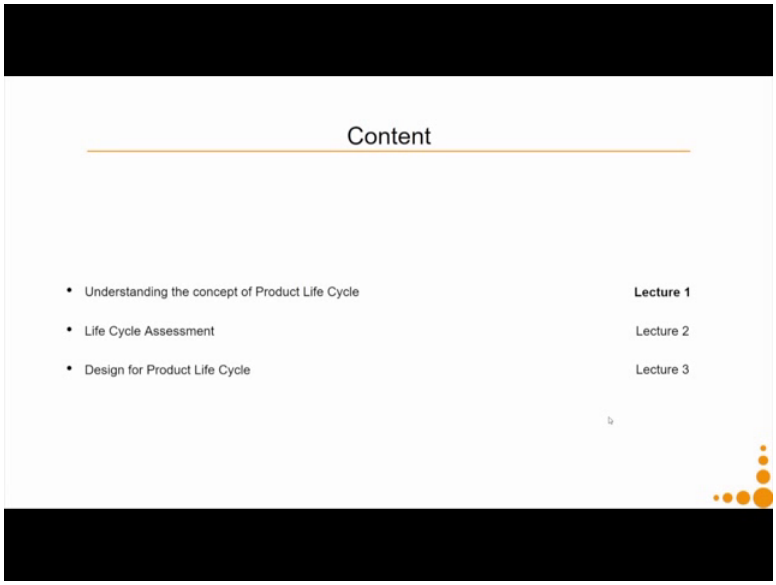
System Design for Sustainability
Prof. Sharmistha Banerjee
Department of Design
Indian Institute of Technology, Guwahati

Week - 03
Lecture – 02
Product Life Cycle Design – Methods & Strategies

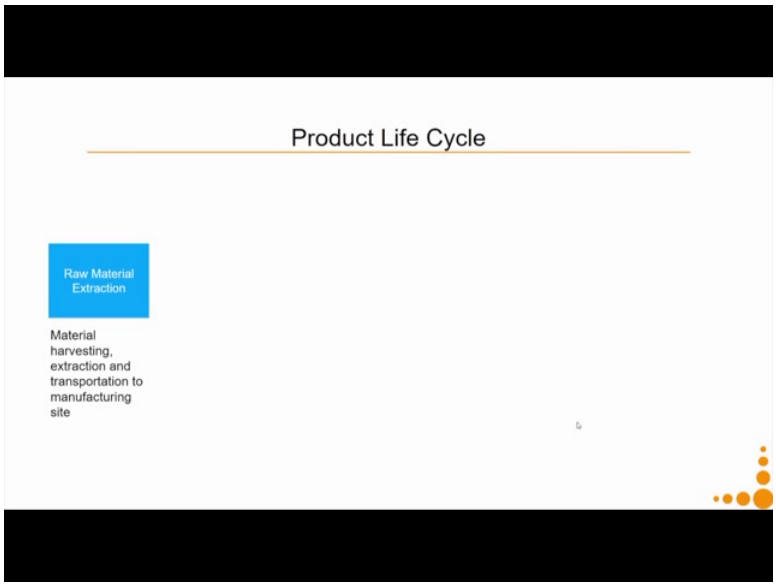
Welcome to our today's lecture. So, from today we will start on a new module and this module will be about Product Life Cycle Design. As we spoke about, while we are trying to understand what sustainability is product life cycle design approach is a product innovation level approach. It comes in the eco design category where we try to understand what are the different life cycle impacts of a product on the environment and try to design accordingly.

(Refer Slide Time: 01:06)



So, in this first series of lectures in this module, first we will try to understand today the concept of product life cycle, then we will talk about life cycle assessment, and how do you design for product life cycle. So, what is product life cycle or in short it is called as PLC.

(Refer Slide Time: 01:22)

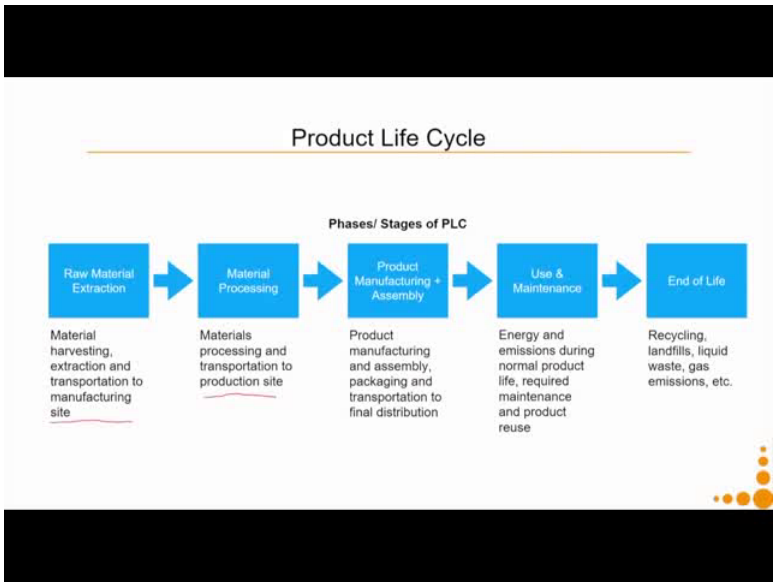


So, in different domains there are different definitions of product life cycle. If you lead rarely literature from marketing, product life cycle is defined in a very different terms. So, let us start with product life cycle definition, which is applicable in to the context that we are talking about. So, what this means is talking about the all the stages of phases of product life cycle. So, for any product say chair or table or mobile phone any product.

It starts with raw material extraction. So, if my chair is supposed to be made up of plastic my raw material extraction might mean extraction of petroleum, because plastics comes from petroleum. See, if I need my table out of some compounds which are made from wood, whereas other components are made up of glass and metal. So, then I will have material harvesting so the wood is harvested. For the metal parts it will be extraction of those particular metal, so if it is made up of stainless steel we will extract iron ore to make the stainless steel. For the plastic components into it again we will extract petroleum from the earth.

Then we need to transport all these raw materials to the manufacturing site. So, next time the product life cycle comes material processing.

(Refer Slide Time: 02:51)



So, what do we mean by material processing. There is a difference between material processing and manufacturing, which we will which will be the next phase. In material processing: so from petroleum you will convert it into that kind of plastic that you want to use in at chair or you will convert the wood into the kind of wood product that you want to use any a table. So, in material processing, we try to process the raw materials into certain forms which will be then used for production or manufacturing of a product.

Say it also involves all the transportation up to the products and sites. So, the transportation of the raw material to the material processing site is involved in the previous step. In the material processing what I am talking about the transportation to the production site which is my next side. So, in product manufacturing or assembly; so I will manufacture the product.

What is the difference between manufacturing and assembly is. So, say my table consists of five different components. So, I will first manufacture each of those components and then I will join them together, and that is called as the assembly process. Or say for example, car, first each and every component will be manufactured either in the factory itself or it will be bought out from another factory. And there will be particular assembly line where all those component should be assembled together to make car.

So, in this ah stage of the product life we include product manufacturing and assembly. Packaging we need to package the products that it does not get damaged when I am

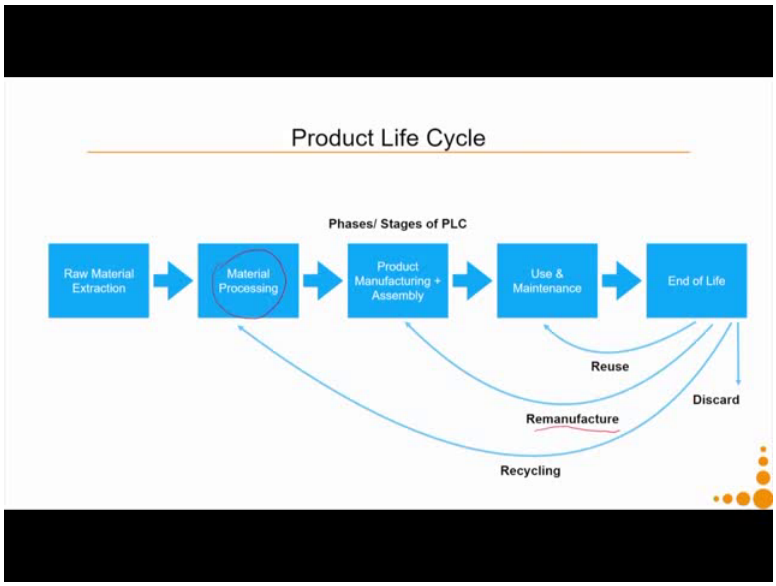
transporting you. Then transportation to the final distribution which might mean transportation from the factory to the wholesalers place, wholesalers place to the distributors place; distributor is someone who is the place from which me as a consumer will go and by. And from the a shop from which the consumer will buy up to the consumers house. So, this transportation to final distribution means all these transportations from the factory at which it has been assembled up to the house of the final consumer.

Next comes the use and maintenance phase. So, when we are trying to use that product so energy and emissions during normal product life required maintenance and product reuse. So say for example, I might buy a refrigerator after a couple of years I might decide to give that refrigerated to someone else. So, then it the same refrigerator is still in the consumer market and it is being reused. So, this reuse means that kind of a reuse and not life changing the product form into another form and reusing it.

The last face is the end of life. End of life contains many different processes. So, at end of life multiple things can happen to my product, either it can be recycled if it has been designed for recycling or if recycling is possible it can end up in the landfills, it can also become some kind of a waste which in terms of solid waste liquid waste or sometimes a some kind of gas emission in case of it is burnt. So, these are the various phases or stages of a product life cycle.

So, in order to have a product life cycle based design approach for sustainability what we have to consider is; what are the environmental impacts of each and every stage of this life cycle on the environment.

(Refer Slide Time: 06:53)



So, how do we do that? Before getting into it; so end of life can mean that it goes into a reuse wherein which was already accounted for in the use and maintenance phase. So, my refrigerator rather than going to a landfill or something it is used by somebody else. It can also go for remanufacturing. So, say my air conditioner has been built in a manner that the outer casing can still remain the same, certain internal components can be changed in that and then again it can be reuse. So, in that particular case I send it back to the manufacture for remanufacturing and then again it is ready for the use and maintenance phase.

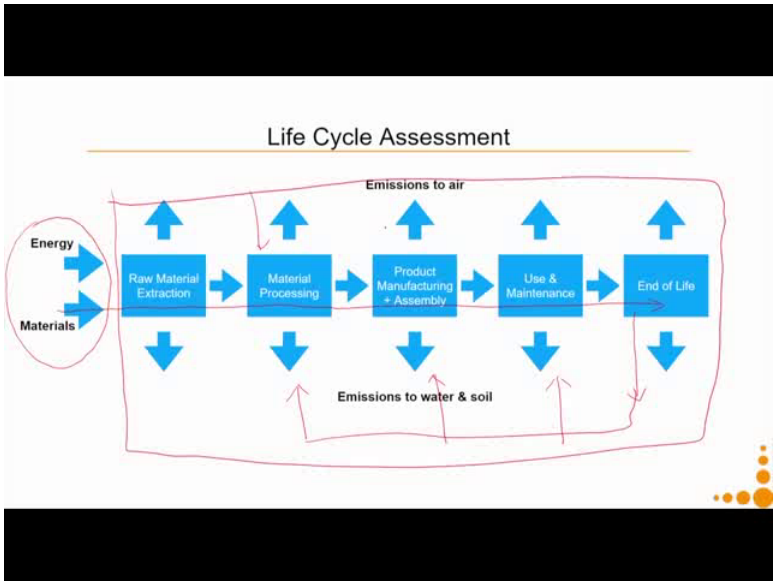
Another option at the end of life is recycling. What it implies that; it has to go back to the material processing unit where my product will be broken apart into the components and then it will be reprocess to give you the original material. These materials can be used in the same industry from which it came or it can be used in any other industry. Or the fourth option is discarded away. Even in discarding it away, we can either put it into a landfill which is real waste of precious resources.

But, there are also end of life processes like incineration and after you incinerate the product you reduce the volume of the in a waste, so the small amount of waste can be landfill. the During the incineration process you can extract the energy and that energy can be used for any of these material extraction, material processing, product

manufacturing or any other purpose for which you require energy. So, that is called as energy recovery process.

So, now coming to what is life cycle assessment.

(Refer Slide Time: 08:48)



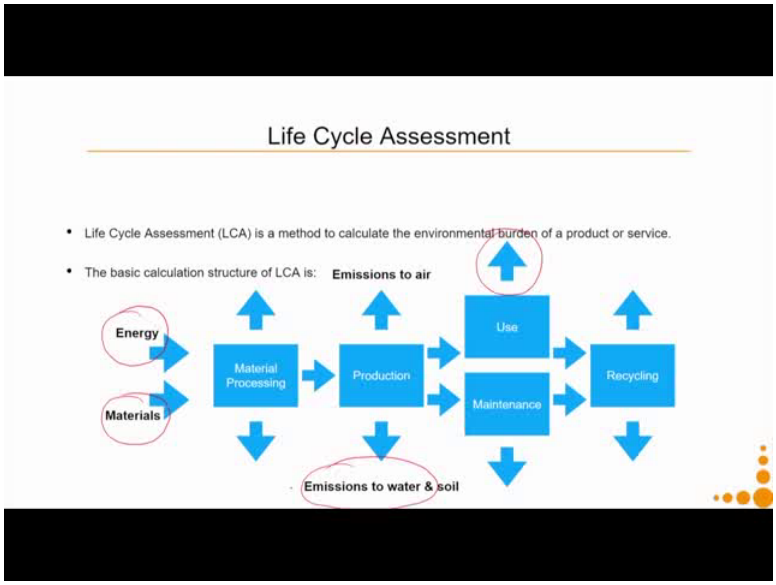
So, in this particular product life cycle which consists of raw material extraction, material processing, product manufacturing and assembly, use and maintenance, and end of life; then we try to find out what are the energy and material inputs at each and every stages, and what are the emissions into the air, and what are the emissions to water and soil as a result of each and every stage of the product life cycle, what we are doing is life cycle assessment.

So, you can see why do I have energy and raw material only at the beginning of it, because it is assumed that this energy and raw material. So, it will comprise of all the energy and raw materials that I am talking about at this particular phase. And then new material entrance does not happen. So, when we go into the example and how to do it we will see new material only flows in this particular direction.

But, there might be also some processes. Say for example, the end of life generates some byproducts these buy products which are also materials can go into any of these other cycles. I will not only require energy over here, but I also require energy over here. So, as a result these energy and material has been put at one particular end, but it does not

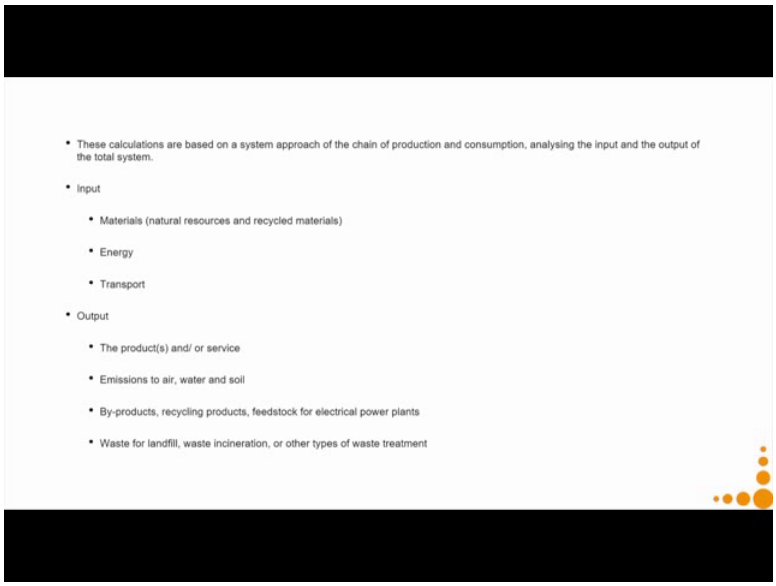
mean that the entries only to raw material. The energy and material is into the whole system, and all the emissions to air and emissions to water and soil as a result of that.

(Refer Slide Time: 10:34)



Now, life cycle assessment or as it is called as in a LCA: LCA is a method to calculate the environmental burden of a product or service. So, the purpose of LCA is to identify burden of a product or service. So, because the aim is so that is why we are trying to identify; how do you identify the burden of a product or service on the environment: by trying to identify how much energy it is consuming, how much material is a depleting, and how much emissions it is causing to the air and emissions discussing to water and soil.

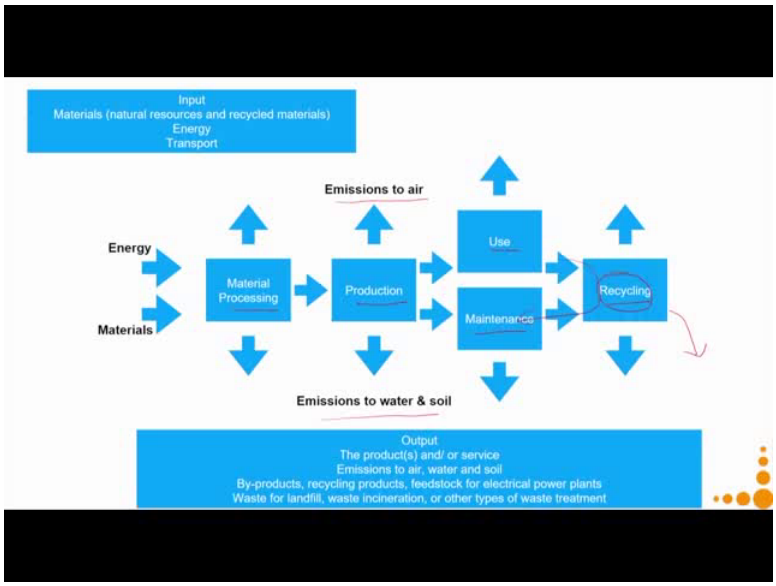
(Refer Slide Time: 11:14)



So, these calculations are based on a systems approach. Now this is an over system of the chain of production and consumption. It analyses the input and the output of the total system. So, the inputs are materials which are natural resources and can also be recycled materials: the energy and the transportation. The output in these cases are the products and or services, emission to air water and soil, any kind of byproduct recycling products feedstock for electrical power plants. So, when I burn it I am doing energy recovery which can be used as a feedstock for electrical power plants which then supplies power to other processes.

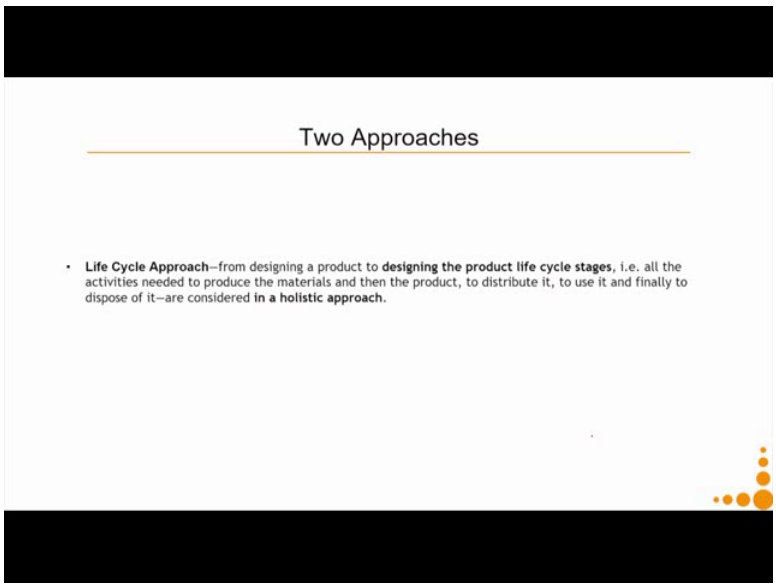
The output is also waste for landfill, waste for incineration or other types of waste treatment.

(Refer Slide Time: 12:11)



So, if you try to see this is the complete picture. So, on the input side is my energy, materials, and transport. The transport can be actually classified in terms the energy and emissions, again for the brought it down. Then I have my output which keeps on either cycling in this, so when I say recycling it can keep on cycling in this or it might also end into the end of life. So, what is life cycle design approach?

(Refer Slide Time: 12:46)

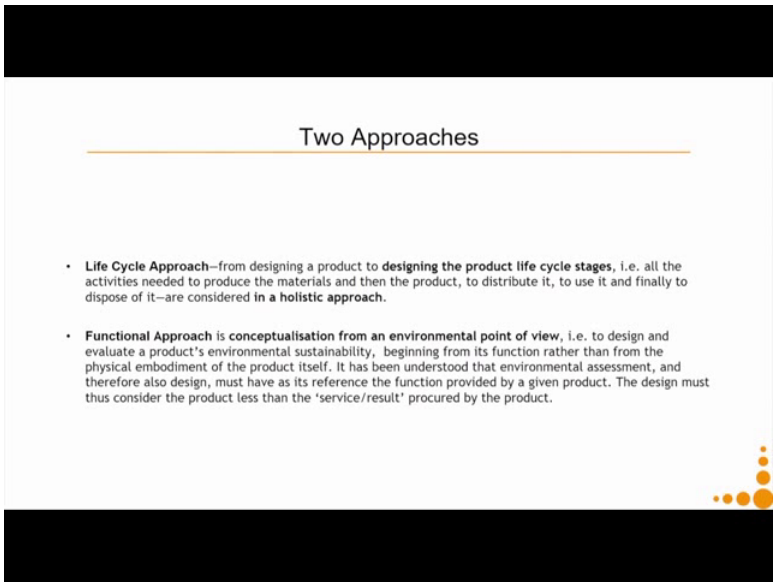


So, there are two approaches in this case. The first approach says that from designing a product to design the product life cycle stages. That is all the activities needed to produce the material, and then the product to distributed to use it, and finally to disposal.

So, consider a holistic approach. So, in that particular case when we consider a holistic approach what we can find out is in which of these stages my emissions to air or emissions to water and soil is the highest or in which of these stages, my energy consumption is very high or in which of these stages my material consumption is very high and it can be reduced.

So, this particular approach where we shift from designing a product to designing the product life cycle stages can be helpful in reducing the environmental impact. Another approach which is a better approach than this is called as the functional approach.

(Refer Slide Time: 13:46)



What we try is in the first approach the life cycle approach what we are trying to talk about designing a product to designing a product life cycle stages. So, I take a washing machine, so from design a washing machine with certain kind of impact on the environment I try to design a more environmentally friendly washing machine than the previous one.

But in the functional approach we rather than starting from the product embodiment; so the first example of the washing machine was where I am trying to develop a better

washing machine was an example of product embodiment level improvement. But why in functional approach we start from the function rather than the physical embodiment of the product itself. What is my it mean? You see in washing machine I need to turn my clothes along with detergent and water to get the dirt out of the cloth. My basic functionality over here is, how do I remove the dirt from the cloth.

Then I can start thinking from how that functionality can be achieved in a different manner rather than turning the close and the water in the washing machine. So, if I can come up with a solution which is functionally less environmently damaging then turning clothes in a ah washing machine I call this as a functional approach for life cycle design.

So, it has been understood that environmental assessment and therefore also design must have its reference the function provided by a given product, rather than the product embodiment then you can bring in much greater reduction in environmental impact. The design much does consider the product less than the service or result procured by the product.

(Refer Slide Time: 15:35)

So, LCA is a method. So if I ask you, I can transport fruits and vegetables using my first option which is paper crates these are recycled paper. This is my other option in which I can use plastic crates. Which one is a more environmentally friendly solution? You might assume that because this is recycle paper this is more environmentally friendly rather

than the second case which is using some kind of plastic. It is only when we do and life cycle assessment we can actually say which one is better by so.

So, it has been observed that this plastic crates they can be used for about 6 to 7 times after that those crates are no longer structurally strong enough to carry the fruits and vegetables over large distances, so they will have to be discarded. The paper crates on the other hand they can be used only once after that they have to be discarded. So now, imagine a truck which is bringing fruits and vegetables from first place a to a market in place b comes with a truckload full of fruits and vegetables in plastic crate. It has to go back to place a where my feels are located with empty crates. Whereas, my paper crates because now the paper crates are to be discarded, so my truck goes away the empty handled.

Another situation: a paper create is lighter weight as compare to plastic create. So now, plastic create because it is heavier it will consume more fuel in transportation as compared to the paper create, considering the weight of fruits and vegetables remains the same. So now, when we add on to all these different calculations depending on the distance between point a to point b the place from which I am sourcing my recycled paper the place from which I am sourcing my plastic crates, I can have different result it has been found out that in some context the paper comes out to be more environmentally friendly, whereas, in many other cases the plastic crate comes to be more environmentally friendly. I missed on to another thing which I had discussed in the previous class: paper is not infinitely recyclable.

So, this particular paper crate it is at the almost at the end of its life cycles it cannot be recycled anymore it has to go to a landfill for final resting. The ink used on this paper crates might be very environmentally damaging. So, how to I find out the environmental impact of each of these products? The only answer to it is life cycle assessment. And it has been; through many of these examples it has already been seen that it is very contextual sometimes the paper comes more sustainable and other times the plastic.

(Refer Slide Time: 18:38)

Again this is an example that we were talking about in our previous lectures which is more environmentally sustainable having water, which is to be a trunk from pet water bottles or glass bottles or having a dispenser with disposable cups or washable re washable reusable. So, if you consider the pet bottles the weight of the empty container is extremely low, whereas if you compare it versus the glass bottle the dead weight of the bottle is very very high. Just take to of these kind of bottles try to compare the weight, the difference in weight is very high.

As a result the fuel expenditure in water filled in plastic bottle versus bat field in glass bottle the glass water full expenditure is very very high. But, my class can be reused, my plastic bottle it cannot be reused but it can be recycled and put into other functionalities. I need to spend energy in cleaning my glass bottles so that they can be refilled again. See my glass bottle gets damaged the amount of glass is recyclable you can again put it through the heat treatment cycle and you can get back glass, but that consumes a lot of energy.

So, when we do all these calculations then our initial very quick intuition based answers that glass bottle is better or the glass made of glass or the paper cup or the cooler as we were discussing in our first lecture is better; those intuitive answers might come out to be completely wrong. So, life cycle assessment gives us all those stores in which I can calculate the environmental impact in terms of materials energy emissions to air and

emissions to water. But each of these products along its entire life cycle that is from raw material extraction to material processing to production to distribution to use and maintenance to end of life.

And come to a conclusion that in a given context the result that you get under the given context is never same in another context, it varies.

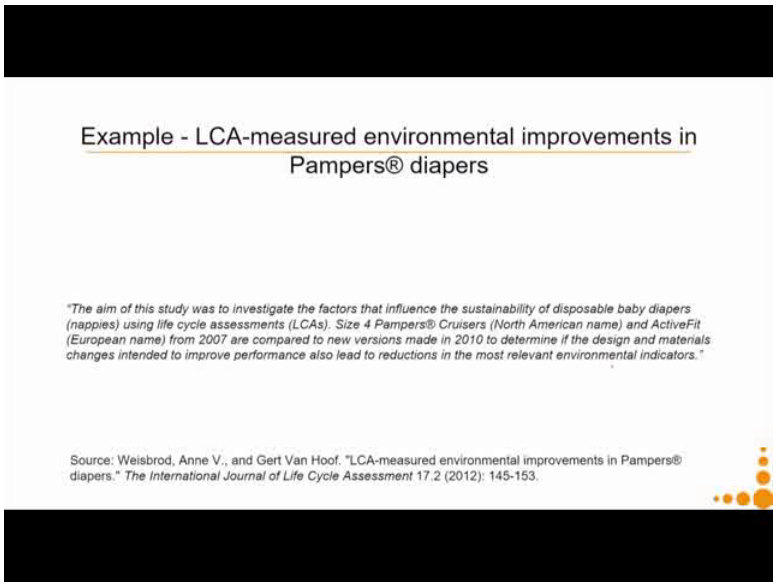
(Refer Slide Time: 21:01)

So, in a given context this particular product is more environmental friendly.

(Refer Slide Time: 21:05)

So, there are many many companies who use the life cycle assessment method very rigorously in the products that they try to develop. So, P and G, Huawei, Du Point, Good Year, HP; these are just very few big names to start with.

(Refer Slide Time: 21:25)



You can read this particular paper which I have mentioned on this slide. It is a paper which talks about life cycle assessment measured environmental improvements in pampers the diaper. So, it compares the diapers which used to be made in 2007 versus those which were made in 2010.

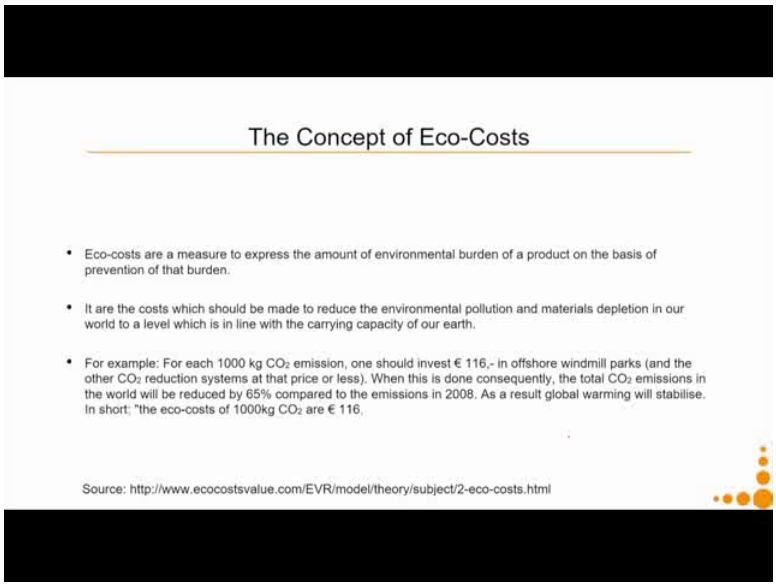
So, the company had done design and material changes in order to improve the performance. So, what the researchers try to study by using a life cycle assessment method is whether it also brought and environmental improvements and also or not. So, when you go through the paper you can see there are different parameters on which environmental improvements could be brought in.

(Refer Slide Time: 22:12)

So, this shows that businesses can use a LCA to decrease their footprint create opportunities and make value chains more sustainable. Remember that what we are trying to talk about is reducing the impacts without changing behavior of people. So, I am not doing anything in which people will be motivated towards more environmental friendly consumption.

So, life cycle assessment does not ensure that, life cycle assessment ensure that you know the impact and you as a designer can redesign the life cycle processes or ah stages so that you can reduce the environmental impact. So, before we get into how to do life cycle assessment, we will start with some key terminologies that are essential to understand this concept.. So, the first one is the concept of eco-costs.

(Refer Slide Time: 23:09)



So, why are we doing this life cycle assessment? Of course, we come to know about the environmental impact. Now how do I translate that in terms of money? That is covered in the concept of eco-costs, and I will come to the fact like why it is necessary to converted into in terms of money.

So, eco-costs are a measured to express the amount of environmental burden of a product on the basis of prevention of that burden. It is a cost which should be main to reduce the environmental pollution and material depletion in our world to a level which is in line with the carrying capacity of our earth.

For example: say if 1000 kg of carbon dioxide is emitted, because of the factory that I set up I would have to invest Euros 116, in certain activities which can offset that carbon dioxide. So, this money is this much amount of money is to be of invested in say some bin mills or setting up so panels and so on which will offset the carbon dioxide produce. How does it offset the carbon dioxide produced?

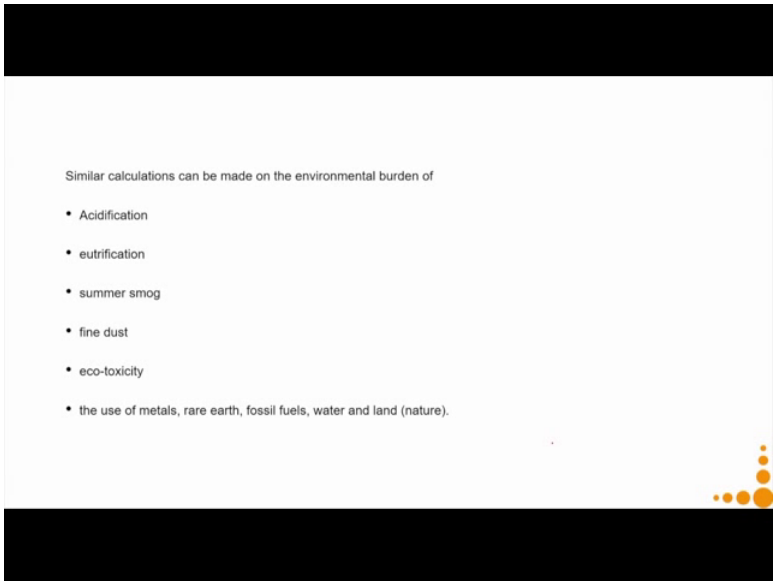
So, I am saying that: ok, I am not producing energy by using thermal power plants which could have generated so much of pollutants or I am doing something environmentally good by generating by energy from renewable energy sources. So, for each 1000 kg of carbon dioxide if for example we have to invest 116 Euros in certain activities which will offset that, not 100 percent offset; offset that to a level which is in line with the carrying capacity of our earth. People define those lines those definitions keep on changing.

So, when this is done consequently the total carbon dioxide emission in the world will be reduced by 65 percent compared to the emissions in 2008. So, you can see in this particular statement if statement is built. So, when I invest that much amount of money I will be able to reduce the carbon dioxide emissions by 65 percent come compare to the emissions in 2008. As a result global warming this is stabilized.

So what I mean is: eco-cost of 1000 kg of carbon dioxide in this case is 116 Euros. So now, coming back to the definition again eco-cost are I mentioned of mentioned to express amount of environmental burden of a product on the basis of prevention of that burden. So, I explained it with an example of carbon dioxide emission which is regarded as the greenhouse gas which causes global warming.

So, the eco-costs; so carbon dioxide emission is one of the parameters of eco-costs there are many other parameters for the environmental burden.

(Refer Slide Time: 26:12)



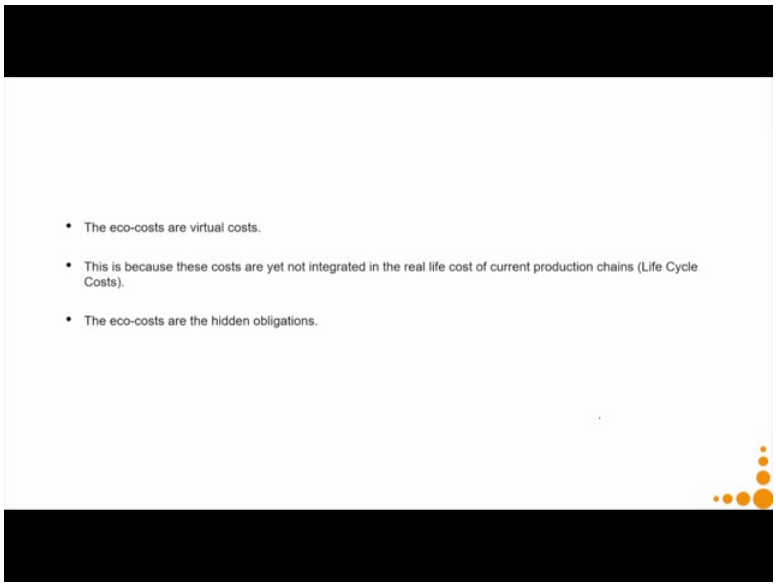
Like acidification, eutrophication, summer smog, fine dust, eco-toxicity, the amount of use of metals rare earth, fossil, fuels, water, and land. So, my LCA helps me to identify all these different, all the impacts caused on all these different parameters.

(Refer Slide Time: 26:36)

And try to identify what are the eco-costs. So, currently the problem of manufacturing or manufacturing processes or manufacturers is they coat a price for the product which is based on what is the cost of manufacturing it plus the profits that they would like to add to it. Eco-costs, because of the manufacturing process because of the consumption of the product and all the ecological burdens that it is causing I need to always do activity.

So say for example, acidification has happened now the government or some agency of the citizens have to spend some money to get rid of that acidification, but that is not getting captured in the product. So, eco-costs are virtual costs. So, in order to understand the real cost of a product, because we are causing ecological damage to it we need to understand the eco-costs. Only then we will be able to in terms of money which is more understandable to large audience of large variety of our audience we will be able to understand the ecological burden.

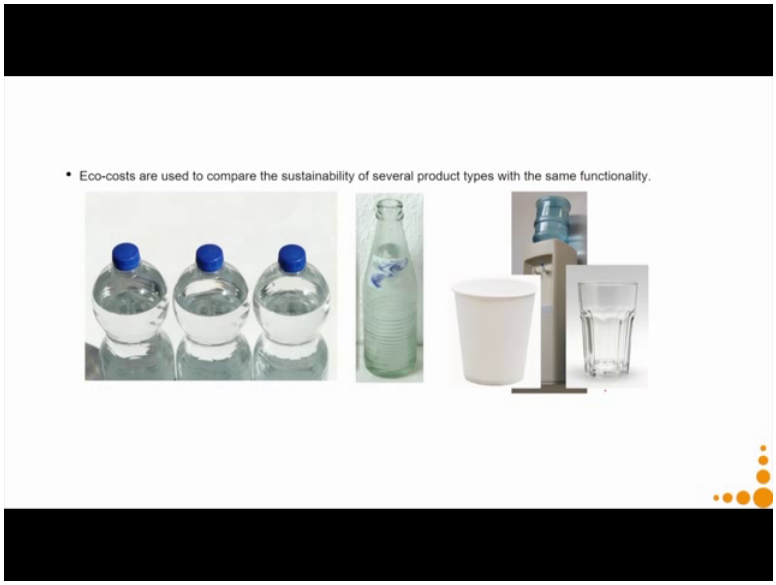
(Refer Slide Time: 27:52)



So, eco-costs right now virtual cost. This is because these costs are yet not integrated in the real life cost of current production change which are the life cycle costs.

So, the eco-costs are the hidden obligations which right now no manufacturer no consumer is taking a burden off. They also sometimes called as the external costs.

(Refer Slide Time: 28:13)



So, eco-costs are used to compared the sustainability of several product types with the same functionality. See for example: product a b and c all of them; so say in this case we have product example a b c and d. So, all this products will cause some amount of carbon

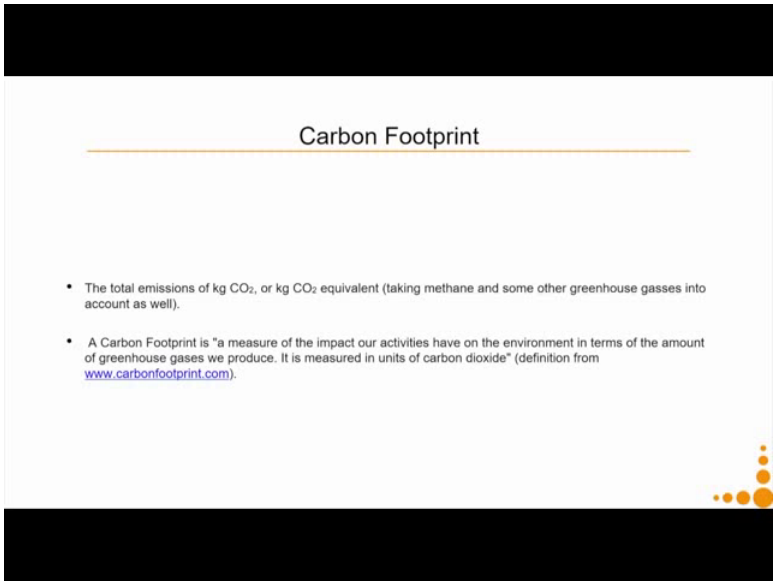
dioxide emission, some amount of acidification nutrification and so on, all the emissions that we listed out in the eco-costs. So, all of them will release certain amounts of it. Now say product a my ped bottle is very high on carbon dioxide emission, but very low on see nitrification, or may product be is very high on acidification but it is low on carbon dioxide emission and nitrification.

How do we compare each of them? Because my parameters for eco-costs the ecological burden; so carbon dioxide emission along with acidification, nitrifications, summer smog, fine dust, eco-toxicity, the use of metals raw ah say sorry; rare earth, fossil, fuels, water, and land. This is so many different parameters for the environmental burden how can I say, how can I compare these two. So, there is no other matrix to compare apart from the eco-cost, because eco-cost tells me matrix 1 versus matrix 2 if we have to nullify the impact on the environment how much money I have to spend.

So, that is the importance of the concept of eco-cost. It helps me to compare the some sustainability of several product types with the same functionality. Even though when we are doing an LCA we are getting our environmental burden result across many different matrices I can put the eco cost matrix on to each of them and I can get the monetary value, then it becomes easier to compare and make a decision.

Another terminology which you might have heard quite frequently is the carbon footprint.

(Refer Slide Time: 30:21)

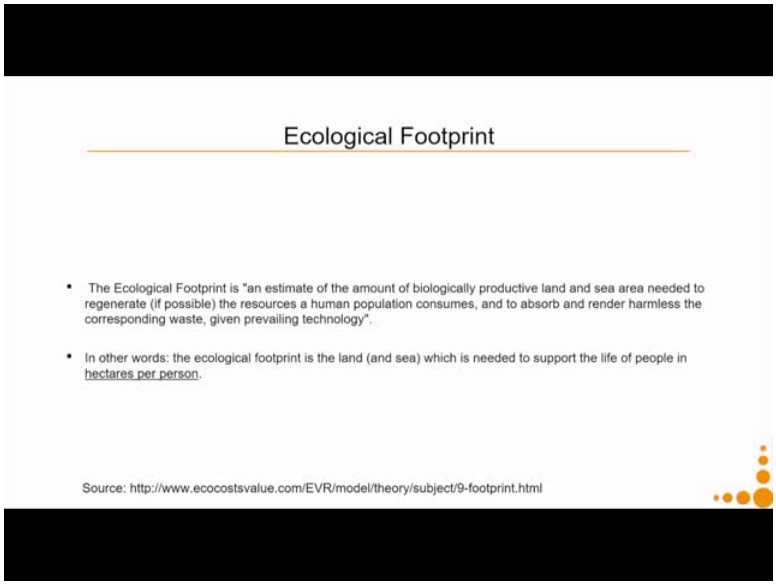


So, in life cycle assessment we will be talking about two types of footprints: first is the carbon footprint and the second is the ecological footprint. So, what is a carbon footprint? It is the total emission of carbon dioxide in kgs or kg carbon dioxide equivalent. What equivalent means is to carbon dioxide is regarded as the greenhouse a gas. So, when it is in the atmosphere it warms up the earth atmosphere more and more.

So, there are many other greenhouse gases. Say for example methane; because it becomes very difficult to use there are lots of molecules which cause greenhouse gas in house effect. So, there are lot of greenhouse gases. So, it is very difficult if you try to measure the foot print and of each and every such gas, so we have converted them into carbon dioxide equivalent, and came up with the terminology carbon foot print which is the total emission of carbon dioxide or carbon dioxide equivalents in terms of kg.

So, carbon foot print is the measure of the impact our activities have on the environment in terms of the amount of greenhouse gases reproduce it is measured in units of carbon dioxide.

(Refer Slide Time: 31:46)



Now, coming to the next one which is ecological footprint: so the ecological footprint it is an estimate of the amount of biologically productive land and sea area needed to regenerate if possible; always if possible the resources are human population consumes and to absorb and render harmless the corresponding based given prevailing technology.

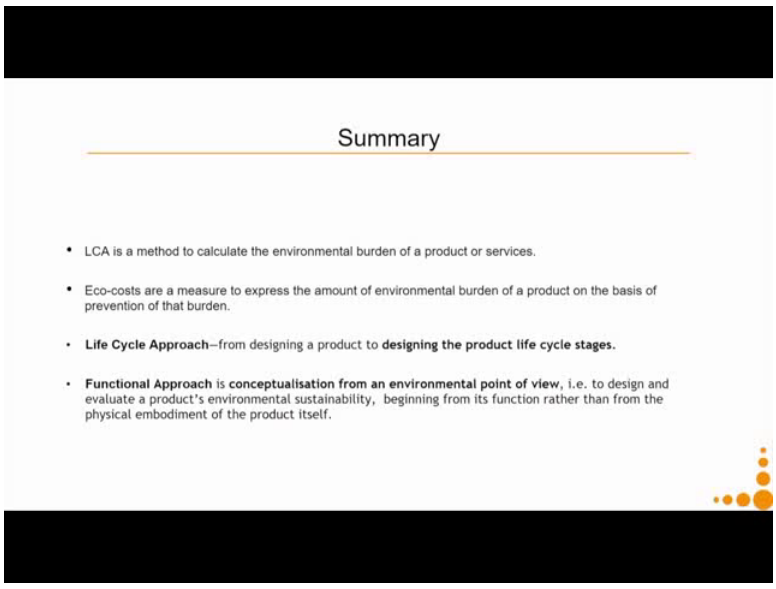
So, in other words ecological footprint is the land and sea which is needed to support the life of a person. So, it is its unit is hectors for person.

So, in one of our previous lectures I spoke about the number of earths that we need to sustain our activities at the rate to sustainable consumption at the rate at which we are doing right now it was 1.8 earth. So, in order to do those calculations what I need to know is the ecological footprint; this is the very.

So, because car carbon footprint is little difficult to visualize for ordinary people and ecological footprint has been a more effective advertisement tool. Or a more effective tool which is being used by NGOs and other such organizations in order to create awareness amongst people, because hectors per person is an easier to understand metrics for common people.

So, I can very easily understand if somebody comes and tells me that the rate of consumption that you are having at this moment we will require 1 hectare of land for you and what the globe can offer you is only say 0.5 hectares. So, I can understand in those terms that I need to reduce my consumption by half; so a good metric, so common people to understand.

(Refer Slide Time: 33:41)

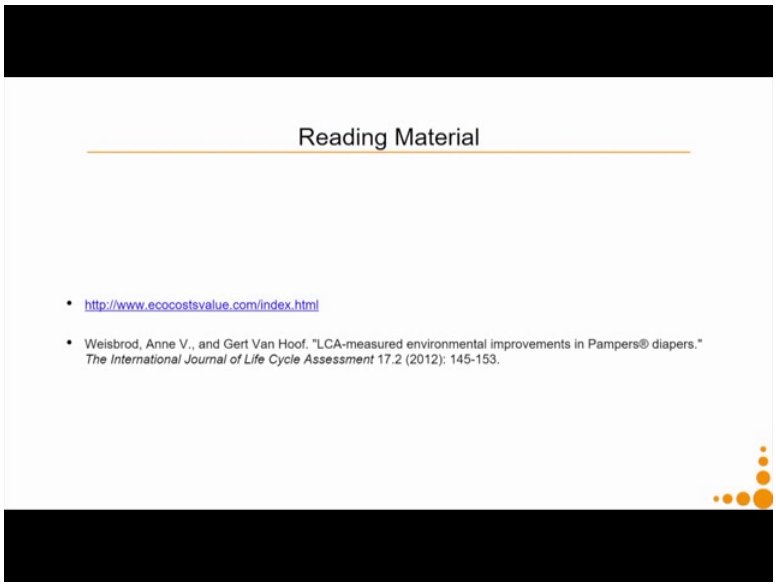


So, what we learn from all these discussions is: LCA will be a method that we will use to calculate the environmental burden of a product or service. After this module on product design with the life cycle approach we will go into the product service design module.

In that module also after we have designed products and services we need to use LCA as a method to quantify the improvements or the down grids that might have happened as a result of my design intervention. Hence, an LCA is a very important tool. Although, LCA does not have an impact on the consumption side, but it gives me in numbers in terms of the environmental impact that is being cost; as a result of the entire life cycle including all production phases, consumption phase, and end of life.

Eco-costs are measure to express the amount of environmental burned of a product on the basis of prevention of that burden. in life cycle of in a product life cycle design we can have a life cycle approach which is from designing a product designing the entire product life cycles that I can optimize it. Or I can have a functional approach which is conceptualization from an environmental point of view; that is design and evaluate a products environmental sustainability; beginning from its function rather than from the physical embodiment of the product itself.

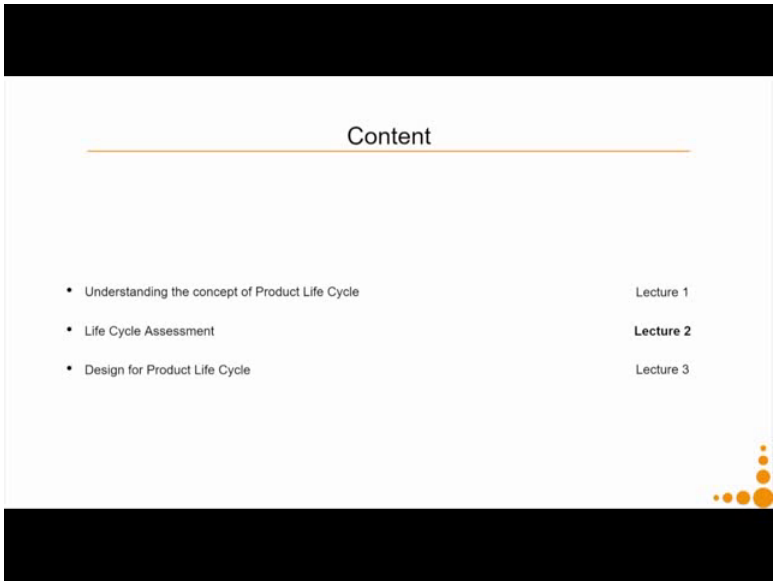
(Refer Slide Time: 35:10)



So, the reading material for this particular lecture and for the next lecture will be the first one is a website: it talks about eco-costs value, talks about life cycle assessment, and gives various examples for the same; you can go through all the content there. And the

second one is the paper that I mentioned which is a LCA measured environmental improvement in pampers diapers.

(Refer Slide Time: 35:39)



So, in the next lecture we will talk about how to do life cycle assessment. The various ways of doing life cycle assessment, so in this lecture what we are going to work on is something called as fast track life cycle assessment.

Thank you.