Life Cycle Assessment
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Lecture - 15
LCA Methodology

Welcome back. This is the forth module for the third week. So, we will start where we left in the previous module.

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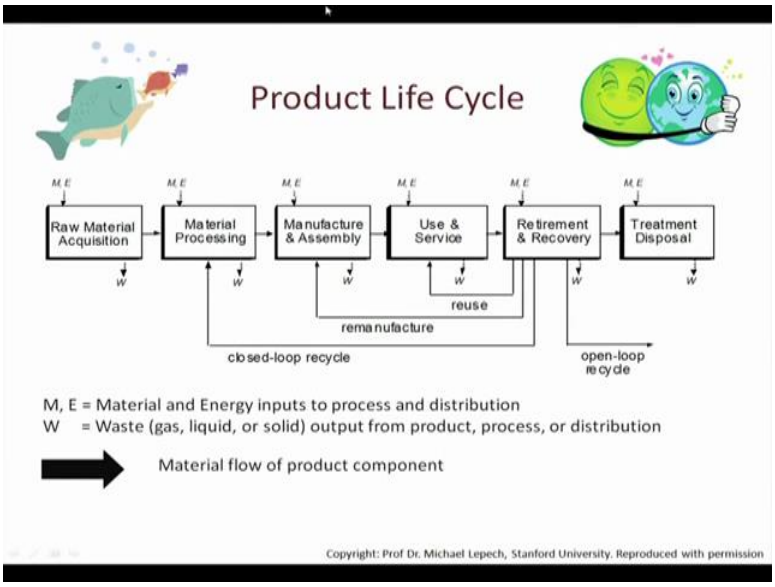

I was giving you some examples of like basics of how the life cycle is done. If you remember we looked at the slide like just a couple of last two slides I have reproduced here just to kind of recap, how, what we have done in the previous video, the last module. So, again just a quick recap: you start from the raw material acquisition, you go to the material processing, then manufacturing and assembly, using service, retirement and recovery and treatment and disposal. So, you are looking at from cradle to grave. So, that is we talked about that earlier just as well.

And then in between you may have some reuse, remanufactured, closed loop recycle, open loop recycle. And for each of these units we have material and energy input into the process and we have waste being produced, and this waste does not have to be a solid waste, could be a liquid waste, and could be a gaseous waste. So, this is what a product life cycle is from cradle to grave. Again I mentioned several times in the last video that

you need to really understand this just I wanted to recap before we make further progress into this particular module.

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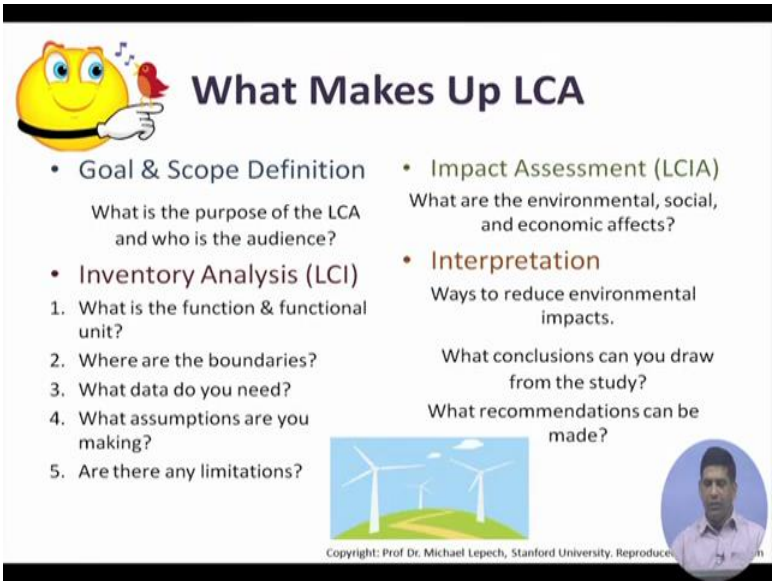

So, we also look at the slide, this was the last time we looked in the previous segment where I said that based on the ISO definition we need to have a goal and scope definition, inventory analysis which is the biggest part of doing an LCA exercise, then you need to have impact assessment and interpretation. So, in this module and module after this we will be going into each of these in great details and with several examples, I will give you some small examples then we will cover a big example where we will go step by step of all these aspects which will make you clearer in terms of the methodology of how to conduct and LCA.

And towards the end of the course if you look at the syllabus, we do have several case studies. So, again we will go back, here I am using this is these examples to explain you the concepts. And then we will apply this concepts again in several of the case studies which are many of those case studies are essentially the case studies which came out of my research projects over the last few years. So, we will talk about several; some of those research projects is already have been converted into the like technical reports of publications. And I will give you a link of that if you want to meet further.

That will be towards the end of the course, I would probably from maybe the last week we will do that. But, in terms of LCA let us look at a very simple example.

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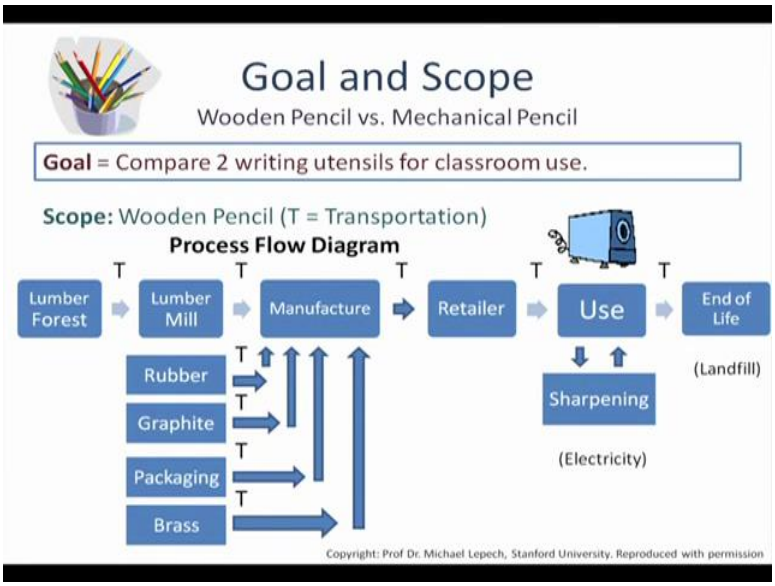

So, this say we write where like we all are learner whether as a student or a professor or a instructor or a teacher we do have to write things write notes. So, there are different ways you can write it. So, here there are say if you take a two example of a wooden pencil versus mechanical pencil. So, these are the two examples we are looking at. So, wooden pencil very common; you go and buy Natraj used to be very common in India. Now also there are other wooden pencils out there. So, wooden pencils and versus the mechanical pencil will look at.

So, the first step if you remember for the previous slide goal and scope. So, what is the goal of these two kinds of, type two different products? Goal is to write, is not it; the goal is to write. And for here we are trying too, the goal for this LCA exercise could be compared two writing utensils for classroom views. So, we are trying to compare these writing utensils for the classroom. Say we can take a classroom if environment where some people are writing with wooden pencil, some people writing at mechanical pencil and then we have to compare in terms of their environmental footprint which one is better.

Now, if you look at the wooden pencil to this scope in terms of the wooden pencil we have to have a process flow diagram, how these wooden pencils are made and its uses. So, since its wood it has to come from lumber, lumber the wood that is the lumber forest so we need to have cut the trees to get the lumber from the forest, and then it will come

to the lumber mill. The T in between is a transportation, you see several T's in this process flow diagram and all the T is repairing the transportation from one place to another place.

So, lumber forest transported to this lumber mill, at lumber mill you have got like stuff ready to make the pencil. Then from there you added you need rubber, rubber is that eraser which goes at the end of the pencil. If you remember most of these pencils wooden pencils also comes with an eraser at the end, so that is what we have the rubber. Then we have graphite, which is the pencil things that we write that is the middle part of a any wooden pencil or is the graphite led in the mechanical pencil. Then it has to be packaged, and then there is also a brass. Brass if you look at a wooden pencil very carefully towards the end of the pencil when there is an eraser out there, the eraser and the wooden part of the pencil is connected with a brass ring. So, that is what we are talking about here.

So, if you look at this particular picture very careful over here you can see the brass ring as well. So, that is all this stuff that you will use to make to manufacture. And once the manufacturing has been done then it has to go to the retailer. Again if look at each one of these rubber, graphite, packaging, and brass each one of them has to be transported, so you see this transfer T, T, T, T. So, this is the transportation of rubber to the manufacturing plant, graphite, packaging, for the packaging you need the cardboard, you need some like a cello tape for the duck tapes of those that and then brass need to be prepared and send it to the manufacturing plant as well.

So, that is where this manufacturing plant versus pencil would be made. It will get sent to a retailer to any shop, and then from the shop we will buy it, and when we buy it we will use it. In between when you are using it we may have to use sharpener. Sharpener most very common sharpener is the mechanical sharpener, but in some schools now and at some places this electrical sharpener is also being used. This electrical sharpener that you see over here although the video is a bit wrong the pencil does not go inside pencil actually comes out. So, you put it in, it gets sharpened and you get the pencil coming out; it does not just go and get disappeared.

But this is a example of a electrical sharpener. But even if you use a mechanical sharpener; think about a mechanical sharpener how, what it has. Most of the mechanical

sharpeners these days are made of plastic which have blade in the middle and then you also have a screw, like a very tiny screw which gives a blade on the plastic. So, that is your sharpener. And either you use mechanical sharpener or you use this electrical sharpener, but it sharpener needs to happen from time to time. And then at the end whatever is the; here because the most of the time when you are sharpening it the wooden pieces are coming off, the wooden savings are coming off and we are resuming that that is going to the land fill. We can also have a scenario where that goes to a compose plant.

So, this whole process from the lumber forest all the way to the end of life is the cradle to grave for these wooden pencils. So, think about that. For as simple product as wooden pencil you need to go through all these processes. So, that is a to take care of all the processes and think about all the transportation, like just for this is small product we had T's 1, 2, 3, 4, 5, 6, 7, 8, 9 times, so we have to take this transportation data. And these transportation data mostly you have to find out whether it is a transport by sea, like a whether it is a river based transport, water based transport or whether you have a like transportation by trucks transportation by rail. So, all those things information has to be collected as well.

So, this all the data collection that goes with that this is what that was what the LCA is; that the life cycle inventory data, and that is very critical. This is was for the wooden pencil.

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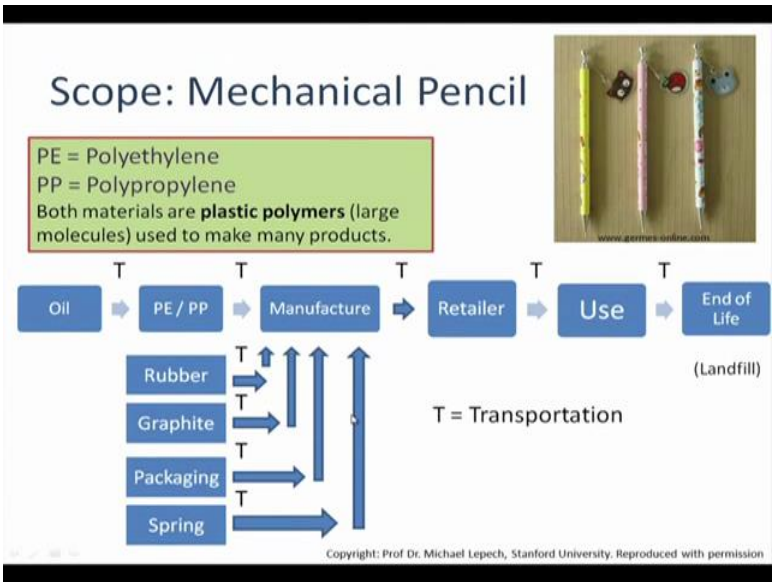

Now next, if you have the mechanical pencil: so same thing the goal is to write, but you rather than having wooden pencil we have this set of mechanical pencil, I will take one of these mechanical pencil. Now mechanical pencil mostly they are made of; these days if you look at the mechanical pencils there are mostly made of plastics. So, plastics are the polyethylene or polypropylene. So, that is what you have both materials are plastic polymers, basically large molecules used to make a many products. So, they are made of plastics.

Where we get the plastic from? Plastic comes from oil. So, you have the petroleum based, so it is oil. So, from the oil polyethylene and polypropylene will be made. Again the transportation involved here, then you take it to the manufacturing plant where these mechanical pencils will be made, and then in the mechanical pencil you need to again eraser, eraser is there. Graphite: those graphite needles a like we call it led. Graphite led you can buy it in a separate small containers for refilling of them, then packaging as usual for any product. And if you remember, if you have looked at any mechanical pencil this mechanical pencils also come with any spring, you need a spring to put into the mechanical pencil.

So, all these things, these stuff will go into the manufacture, then again it will go to retailer it will be used and at the end of the day are most of the led will be used up, but you will have this mechanical if the plastic things gets broken down. You have this

plastics going to the land fill, like we have assumed a scenario going to the land fill. So, now if we have to compare these were the two scopes from cradle to grave for both of the scenario we have a cradle to grave scenario that is a complete life cycle. These days we also talked about cradle to cradle. Many times I joke that all this cradle to cradle concept has come from the western world, but if you think about our in India we many of us who believe in Hinduism we think about a [FL] like when you are rebirth

So, cradle to cradle is very much a concept like rebirth. So, we are talking about rebirth of the material. So, the materials which have been used at the end of it is use rather than going into the end of life we are recycling it and we are bringing it back into the economy. So, that is the concept of circular economy; the cradle to cradle concept which is very popular these days. If you look at any environmental a magazines or environmental, if you follow environmental news you see this few people talking about circular economy a lot.

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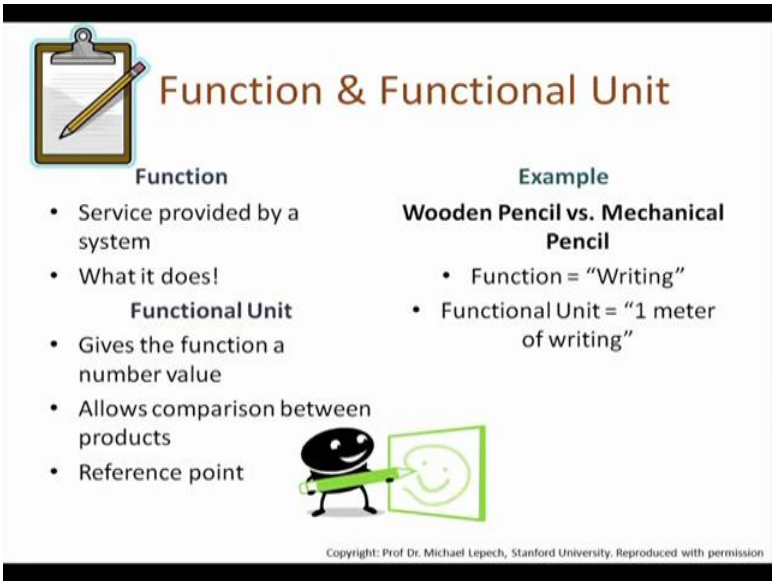

So, coming to now we have figured out the goal; the goal is to compare the mechanical pencil versus the wooden pencil for its writing. Of course, that is what the pencil is used for. Now, how we will compare? Is it a fair to compare one wooden pencil versus one mechanical pencil? Because one wooden pencil will last if you are writing every day, day in and day out in your classroom, from a regular class hours from say morning 8 o clock until 2 p m you are using a wooden pencil every day. It may last for a month

depending on how much you write, how much you make may be 2 months. Supposed if you look a mechanical pencil they may last for a year or if you do not break things too often. So, it will last for a much longer period then a wooden pencil.

So, will it be a fair comparison between a wooden pencil versus a mechanical pencil? The answer is no, because a wooden pencil will you get used up quickly, wooden pencil requires less much much less energy for to make everything as supposed to mechanical pencil. So, it is not fair comparison. But if you think about in terms of their writing wooden pencils versus mechanical pencil what is the function; function is to write. So, when the function is to write we have to look at what is their functional. Remember I talked to you earlier that this function and the functional unit these concepts again try to understand that.

So, function for both of these is to write. So, what we can take is we can take a functional unit; we can take a functional unit of say 1 meter of writing. Say if you have to do 1 meter of writing which one is better; whether we should go for a mechanical pencil or a wooden pencil, which one comes out to be better for 1 meter of writing? This 1 meter writing is noted not a like a hard and fast rule, you can take one page of writing, you can say one A4 page of writing with a standard it is spacing and these many number of lines or 10 lines or you can even say 10 A4 pages, 20 A4 pages whatever. You can come up with a functional unit where the function is to write.

So, in this case it is much simpler, like you have wooden pencil versus mechanical pencil the function is to write. But sometimes when it is things may not be that easier and I will talk to you in a minute about that. So, the functional function here is writing, we can take the functional unit as 1 meter of writing, so what is the function? Function is the service provided by the system. So, what it does, so that is the function. For this mechanical pencil versus wooden pencil their function is to help us write, so that is why we said to writing.

Functional unit is we give the function in number value. The reason for that is we have to give a number value so that we can allow comparison between the products. So, that becomes a reference point. So, all these LCA data that life cycle inventory data that you will collect that has to be collected based on certain like a basis. So, here we can say 1 meter of writing using either mechanical pencil versus wooden pencil. Say for example

wooden pencil, their last for say 10000 meters of writing; so whatever is the environmental impact for 10000 meters of writing for that one particular wooden pencil we can scale it down to 1 meter of writing. And similarly we can say for the mechanical pencil say one mechanical pencil may go for 10000 or 20000, 50000 meters of writing and then we can bring it down to what it would be for 1 meter, and then we can compare.

So, that is like a comparing what we call apple to apple, both of them are giving us a function of 1 meter of writing.

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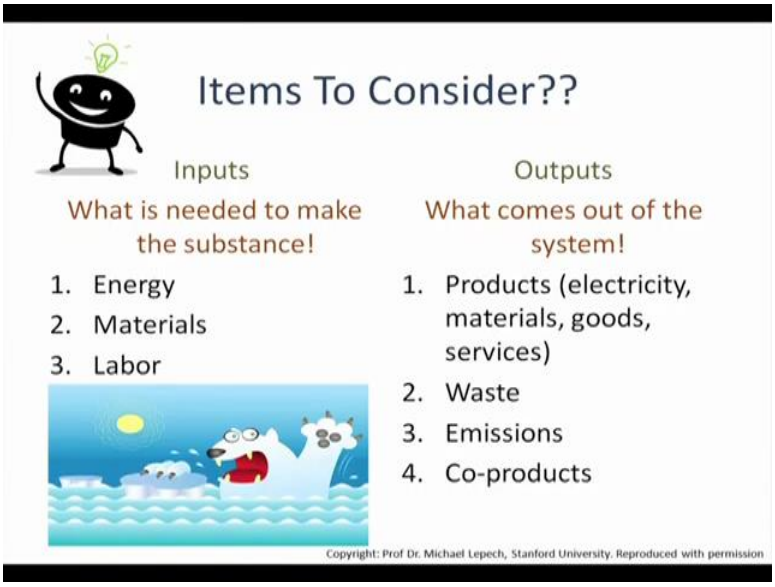

So, in this case things are much easier to do those kinds of stuff. In some other cases things may not be that easy. We will talk about that in a minute. So, in terms of that the data say for 1 meter of writing that we talked about in terms of data what kind of data we need, we need that what is the input going into the system, how much energy is being supplied, how much material going in, we also look at the labor, and energy, material; material does include water as well. So, we have energy, materials which includes water, labor that goes into the system to make it; and what is the output? Output is our product it could be output is what comes out of the system. It could also be like if you are producing electricity, it could be electricity, it could be material, it could be goods, it could be services. And then we have certain bi-products or co-products.

Bi- products that could be some of these are waste that could be liquid, solid, gaseous waste. Gaseous waste we also call emissions and we can have some co-products coming out of that tube. So, we have to do kind of an inventory between those two.

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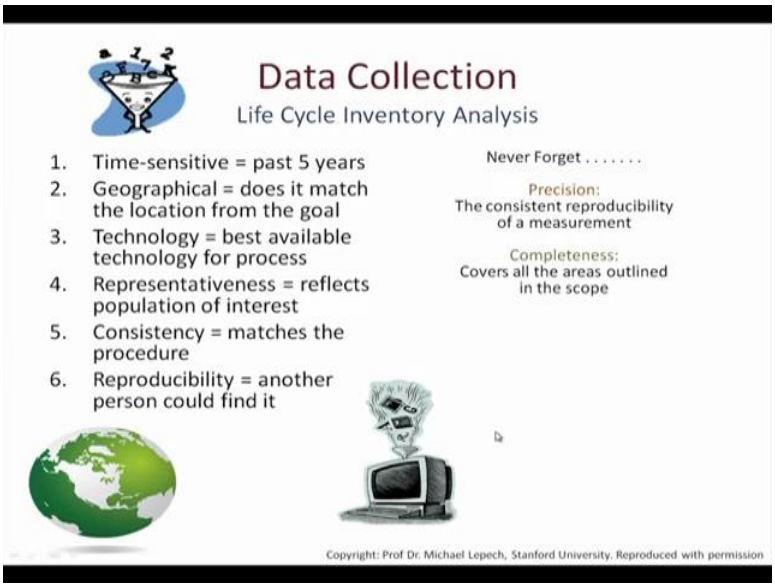

So, we do have it inventory which is call as life cycle inventory analysis. So, we have to collect data. So, that is very very important; we have to collect the data coming out from this to compare. So, that is why if you remember we looked at some of the previous module I was emphasizing you a lot on the data, data quality, how the environmental data is collected, just because of this particular reason, because we have to collect a lot of data. And if your data is bad say, if you have what is the life cycle analysis this is a software surround there and we will I will introduce you to some of the softwares as well.

So, you have a software package and the package you are into you and you are in putting a certain date, but if the data quality is bad the software cannot do any magic to it, whatever the output that will come out will be bad anyway. So, having the good quality realistic data for doing good life cycle analysis is very very important. That is the reason we looked at some of those videos last week, and early this week, that in terms of the data; quality why in terms of how the data is collected and all that.

So, again kind of emphasizing on this particular slide, for the life cycle inventory analysis; inventory analysis essentially the data collection part. So, what are the things

will look for here? We want the time sensitive, so past 5 years. Now why we want this time sensitive? Again you should ask this why question. For everything you should try to ask this why question to get yourself comfortable with what you are getting the information.

So, why time sensitive fast 5 is because, the technology keeps on changing. So, the first bullet, first point that we have listed here is time sensitive past 5 years, because the technology keeps on improving. Just look at the electronics technology; I give examples of electrons from time and time because we all relate to it much quicker, we all have some electronic products with us so we can think about that in a better way. So, I like (Refer Time: 18:35) 5 years ago whatever the laptop used to be today laptop is much different.

Even the cell phone 5 years ago the way the cell phone used to be, today the cell phone it is again much much different; more powerful and much lighter. So that is why the technology keeps on improving. Technology keeps on improving and that is why we have we are looking at the time sensitive of past 5 years data, because if you have older data that does not really gives you the current picture. So, you are doing LCA exercise, but you are actually you are being biased towards the whole data that may not be the realistic or what is happening today.

Other point second point is the geographical: does it match the location from the goal. So now, if your goal is to compare certain things in an Indian contest and the data that you generate, the data that you collect is always Western European countries or American countries of Canadian or American countries including US, Canada and other places. So, that is not fair, because the data has to be as close to the place where you are trying to get the study term, where you are trying to look at the impact. Although, LCA exercises a global exercise, its gives you impact on global scale but then the local data, the local information needs to be fed in because we are trying to get the impact from the processes that is being used in that geographical region.

So, for that you need to kind of rely, as I said earlier most of the data that we have today in those data bases and you will see those data bases examples. So, the most of the data that is there in the database coming from the Western European countries, some from US, we have some Indian data being generated right now as well. I think I mention to

you earlier that eco invent the company which looks at the data collection which is time to collect the data for all the standard unit processes for different things happening in industry. So, they are trying to collect the data from throughout the world. Right now we are working with eco invent on a project, we are trying to collect data for the textile industry in India that project also has FICCI- Federation of Indian Chamber of Commerce as one of the partner too.

So, you have to be have the data as to be geographical. One of the most important part becomes is your energy mix. So, if you are using the energy data; say for example, in Indian context we use still our coal based thermal power plant is one of the major source of energy, but that is not the case in many other countries. If you go to the Western European countries we have more nuclear, some places we have more hydro. So, now if you take that energy data and try to use it an Indian context of course, our results will not be correct, is not it; because they have different environmental footprint.

At the very beginning of the class I showed you that how the energy, like even just if just think about from the water demand; water demand was so much different for different types of energy sources. So, that is why you are impact will be different. So, this geographical region is important, does it to match with the location from the goal. Then you try to find out the technology the best available technology for process. So, what does that mean; for save there you are trying to compare two different products, and for that particular product try to use the best available technology in the market, so that you are not being unbiased.

Usually, old technology will be less environmental friendly or may not be true in all the cases, but these days as we are trying to go for more pollution prevention green engineering most of the companies are trying to have better technologies out there; so in terms in better technology from the environmental perspective. So, in terms of the technology try to look at the best available, then it should be of a representative; we should not try to pick it technology which is just being used for say 5 percent of the product rather than 95 percent of the product is not made using the technology, although the technology maybe very green, but it is not going to give us the true picture. So, we should get the technology which is representative; that means majority of the product made is made by using that particular technology.

Then the data should be consistent, and likewise as part of this data quality data if you remember we are talked about the qa qc. So, the fifth and sixth bullet kind of reemphasizes the qa qc over here data should be consistent, so it should match with the procedure and if you try to collect the data and again and again you should get similar values. And then it could be reproducible, like another person could also find it. So, that is what the reproducibility means. That it is not that you found the data, but others cannot find similar dat.

And again part of that qa qc procedure you make sure the data is precise. So, that is what it is talking about. The consistent reproducibility of a measurement, it is not that is why we talked about doing the replicates and all that. And then data should be complete covers all the areas outline in this scope.

So, again this data collection part of this LCA inventory is life cycle inventory analysis is the biggest task in terms of life cycle analysis that we do. So, that is a very very important.

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Now another example: let us look at the LCA in action. Let us let us think about this paper plate versus China plate. China plate is a plate you wash and reuse, that is the plate that we use. Like a similar to your law paler set or the other set that you buy from big bazaar or other places. It is called China plate because the reason behind it is initially it was used in China and it kind of came from there.

So, if you have to compare paper plate versus China plate, now how will you go about that? So, in terms of comparing it again, if you remember what is the function; there are several in this particular slide as you can see we have listed several questions and I will try to go and answer each and one of them. Like and I would encourage you to think about the answers to these questions as well.

So, what is the function of these two plates, for paper plate versus China plate? The function is to serve the meal. It is the meal like either you can serve the breakfast, of the lunch, of the dinner. So, it is a serving of the meal is what is the function of this. Now in terms of the functional unit: functional unit we can be again compare one paper plate versus one China place will it be a fair comparison. One paper plate in ideal scenario should be used only once, sometimes in like a university hostels you may end up using it more than once, but usually it should be used only one. So, we will assume that normal scenario where you are using it only once. So, you are using it once and then it gets thrown away.

So, paper plates are used only once, China plate can be used multiple times and tell you break it. But when you are using multiple times; again I am not talking about the scenario in a hostel where you may be using the China plate without washing it for breakfast to dinner, but that is not that is usually not the case. So, we will assume that after every usage you are washing it. So, that is you plate you wash and then you reuse it. So, the function is to serve the meal.

Now in terms of the functional unit we have to pick a functional unit, why we need to pick a functional unit? Again the why question. Why we need to pick up the functional unit, because you want to make sure that all the data that we collect that LCI inventory that we collect is based on the is the functional unit that we choose. So, here what would be an ideal functional unit? One paper plate versus one China plate is not a good one, because paper plate can be used only one China plate can be used multiple of times. So, it is not a fair comparison.

In that case what an ideal functional unit, if you think about that; what is the function? Function is to serve the meal. So, we can pick a functional unit which is related to the serving of the meal. So, in that case let us think if that ok let us take a scenario where we serve 100 meals or 30 meals or 50 meals something like that. So, that could be the

scenario where we can pick it up where in terms of this much meals would be serve. So, say we take 30 meals; 30 meals for paper serving of 30 meals. So, for that we need 30 paper plates in ideal scenario normal scenario we can use one China plate and we will use it, so it has to be washed 29 times to use for 30 times assuming that first time it is already washed. So, the functional unit is say 30 serving of meal.

Now what materials and resource are used for it? The materials for the paper plate, of course the paper is there and they will be some place to be process this might be some glue because there is a different layers of paper glue together, so there be a process associate with that. For the China plate: the China plate all the ingredients that go there that needs to be made in all that. So, what does it take to produce both? We have to make the list of all the materials, so that is what the kind of your LCI inventory.

Now we have to eat in terms of all the materials that goes into their what is the impact on environment. So, what are the impacts to the environment that we need to list is there any waste. Does washing of China plate produces waste? So, when you are washing the China plate you use you need detergent, the detergent is also coming from somewhere. The dishwasher if you using a dishwasher you are using energy, you might be using hot water. So, it is again you are using energy, so all these things has to be there. So, all what like what types of data you need the all sorts of data you can think about in terms of the life cycle of these two product you need to list them out and then you do LCA exercise to know which one is better.

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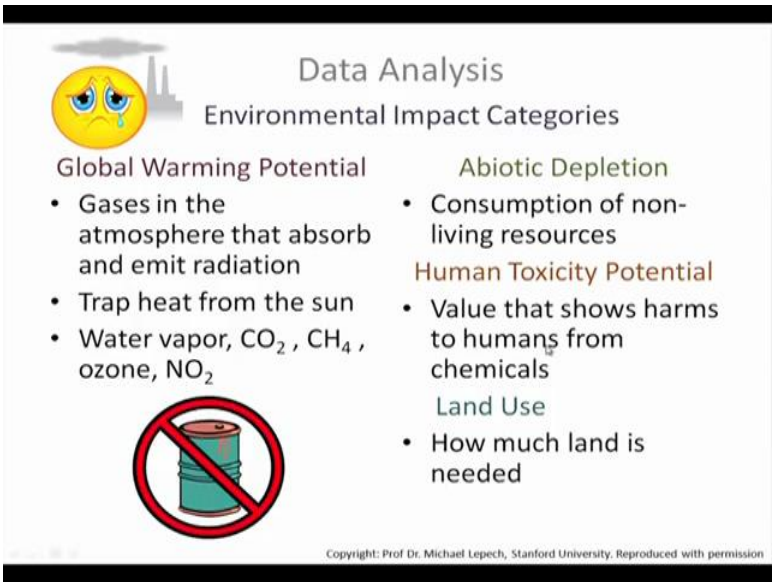

And once you have the data; once you have collected all these data in terms of different emissions coming out of these, different materials being used, we can find out in terms of what is the global warming potential. So, that is the impact categories will look at the environmental impact categories, what is a global warming potential. So, gases in the atmosphere, global warming is gases in the atmosphere that absorb and emit radiation. So, what is does it straps the heat from the sun it does not let the heat go away and that is some of the global warming gases includes water vapor. CO 2 methane ozone and those are that is one in terms of the impact category.

These are some of impact category we looked at. A biotic depletion which is a consumption of non leaving these sources which you consumed. Than human toxicity potentials; whether it will have harm to the humans from chemicals, in the land, use how much land is needed. So, those are the impact we look at.

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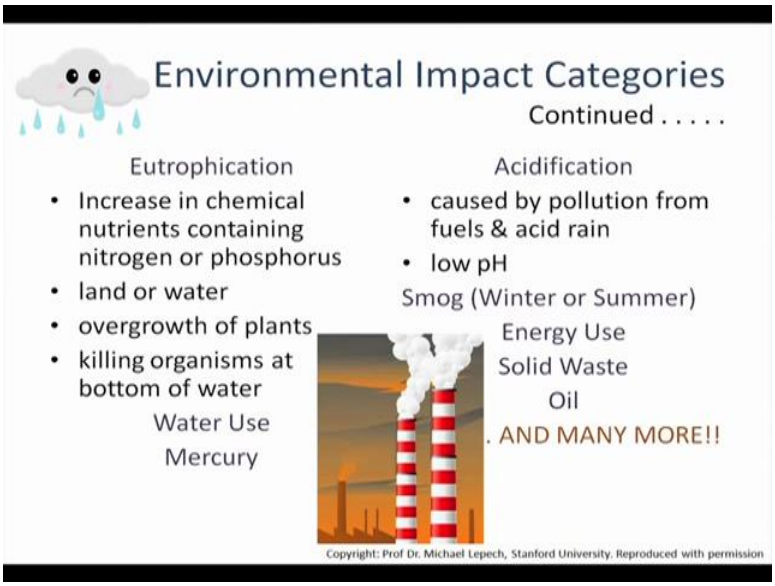

Eutrophication some of who have worked who have taken a course on water quality or even in waste water you may be familiar using the nutrients. Increase in chemical nutrients containing nitrate and phosphate and that leads to eutrophication problem. Impact on land and water, overgrowth of plants, killing of organism at the bottom of the water because top level we have so much of an LGA that what and the lower level the oxygen supply gets a cut off and then there is a the water usage problem, Mercury problem, acidification called by acid rain, fuels, low pH. We have the smoke issues; we are in the winter month write now. So, we will have this smoke in Delhi which w we here the time winter or summer. We have then energy usage solid waste produced oil and many many more.

So, all these in fact, kind informental impact categories based on all the emissions that is coming out due to the all activities associated with production of these materials we need to find out the different impact categories.

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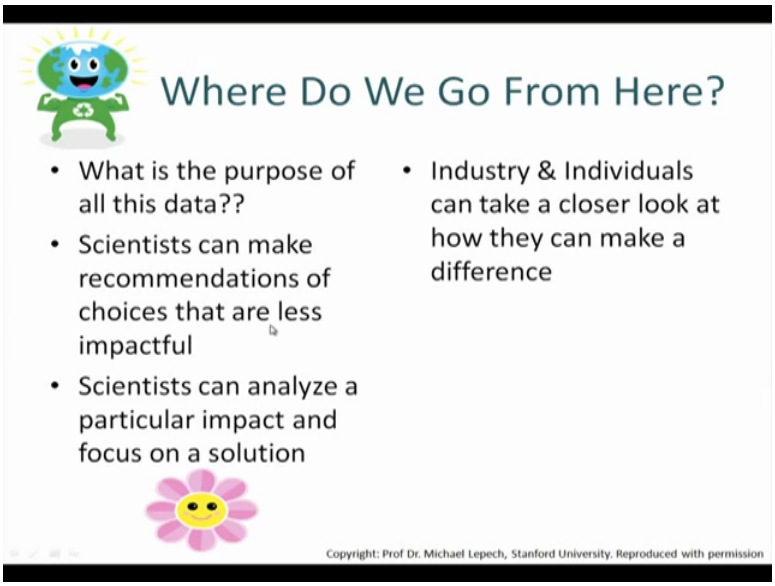

So, where do we go from here? And what is the purpose of all these data? We collect all this data and we look at their environmental impact categories so that as a scientist we can make recommendations to of the choices that are less impactful, which is the less impact. And then we can analyze a particular impact and focus on a solution. If we analyze a particular impact is too much, like we see that this is very high environmental footprint, we can as a designer as a environmental scientist working with designers with the engineers like a traditional engineers we can come up with how to really, what we can do.

And as a industrial individual we can take a closer look at how the difference can we make. So, this is was a kind of just to get you started in terms of like how this LCA is done. And we have given it, like I have given you are to very is quick examples one of the mechanical pencil; and traditional pencil versus one other one was on China plate versus paper plate just get it thinking off. What are the things goes in, in terms of developing this LCA inventory and all that.

So, next we will end this module now and then in the next module I will look at a detailed example. And that example it is a long example which we will see. And in that example will go into this more detail, like will go into very very small small steps that we do and it is so been a really good attention. Of course, you need to look at this video and after you understand things over here the next video will be much easier. So, if you

need to take like a rerun on this video I listen it again and again go ahead and do that. And again I will see you in the next video.

Thank you.