Life Cycle Assessment
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Lecture – 16
LCA – A Detailed Methodology

Let us a look at the detail; we will turn it in the next module, which is we will look at the detail example. As I as I said in the previous video we were looking at some small example of LCA comparisons.

Now let us look at a detailed example of a LCA comparison, and I will my goal in this particular video is to make sure by the end of this week by the end of this, example which may like a we will we will go slow we will go step by step, my goal is to make sure that you have a very good understanding of how this LCA turns. So, after this is detailed example, if somebody gives you an exercise to do LCA you should at least me able to at least list down on all the steps that is needed how to go about it to how to do the exercise and then of course you need a software to do the detail calculation.

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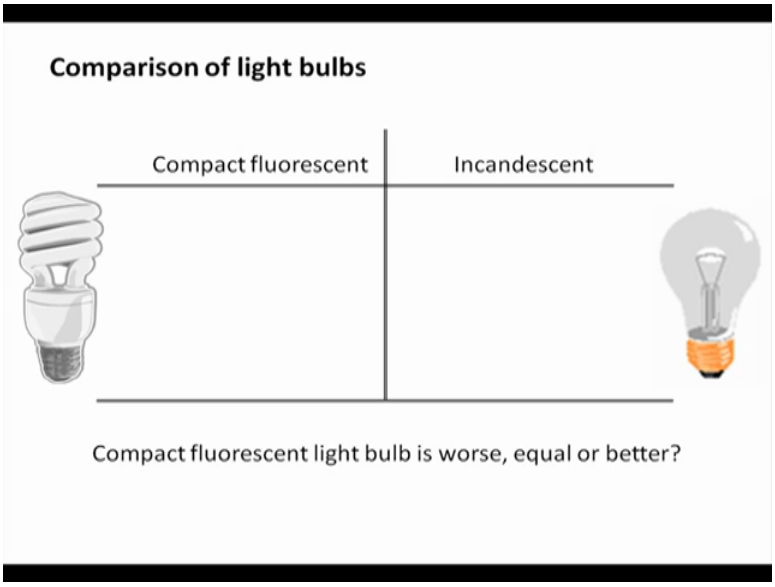

So, let us look at these detailed examples of LCA comparison. So, we will look at another example. What is the example compact florescent bulb versus incandescent bulb? Although this examples I prepared a few years back. So, if now I think rather than using this incandescent bulb, I should go for a maybe then, I need to make newer

example where replace this incandescent bulb with LED bulb, because now led bulb is more popular, but does not does not change our like the discussion that we want to have. So, say if we have a an if we still an many parts of the country we still use incandescent bulb with and some we for outdoors we still use incandescent bulb anyway and this is available in the market.

So, but say if you want to find out in terms of the compact fluorescent and incandescent, which one is worse are they equal worse or better or which one is better is a CFL better than incandescent. We can kind of know the answer already is not it because, but because we know that CFL is better that is why we have been using CFL extensively. Now how we do not, but in terms of the comparison, how we do the comparison and how the LCA exercise is done let us look at that a step by step.

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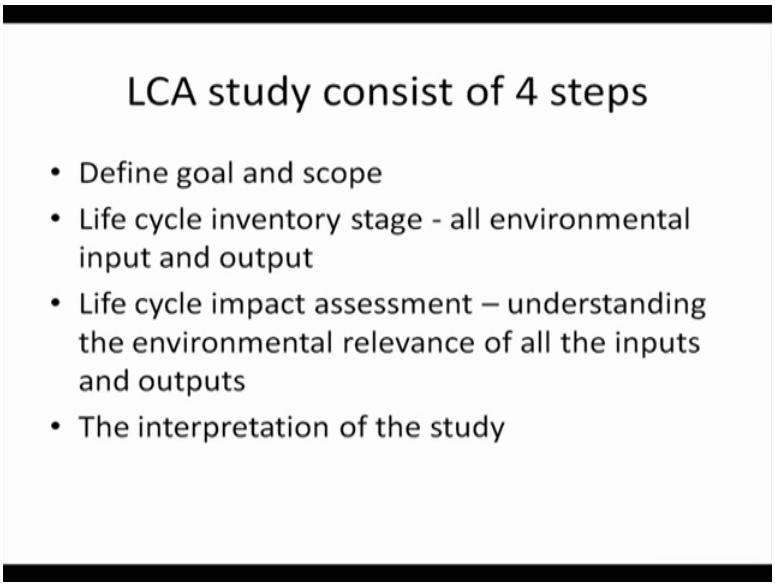

Now, again what was the LCA study consists of this consists of 4 steps. We have to first define the goal and a scope that was very like we have to get this goal and scope of this study. Now here what is the goal and scope the goal and scope of this is to compare this do different types of bulb, CFL versus incandescent. Then we need to look at the life cycle inventory stages. Before that we also have to do this functional unit and funds like function and functional unit and we will talk about that.

Then there is a life cycle inventory stages all environmental input and output we will look at that. And how to go from there to the impact assessment understanding the

environmental relevance of all the input output and then finally, we will have to interpret the study and we will see that as well.

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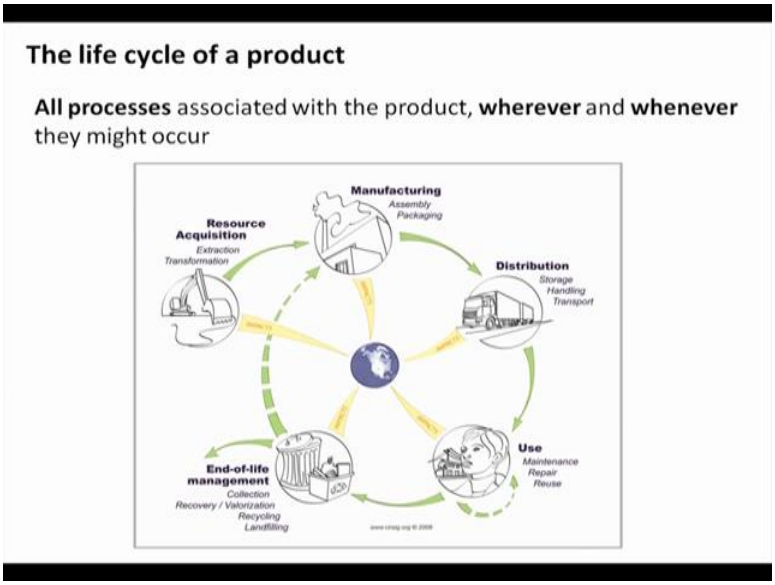

So, in terms of these 4 steps; so we will go one by one of these. So, if you look at this life cycle of a product, which is kind of again from time to time, I am kind of giving you a recap of what has been done earlier. All process associated with the product wherever and whenever they might occur. So, that is we have to get the life cycle, where we get all the processes associated with a product wherever and whenever they might occur.

So, if you look at this box over here, we have we can start with the resource acquisition. Remember that particular slide where I told you that you need to really understand the cradle to grave the same information has been put in a different pictorial form over here. So, you have a resource acquisition where extraction and transformation. So, when you do this extraction and transformation. We I have put this mother earth in the middle. So, this even in the extraction and transformation there is an impact.

So, there is an impact during the extraction and transformation your mining engineers will tell you during the mining activities there are lot of environmental impact, lot of water is used energy is used you are creating lot of noise pollution you are creating lot of dust and all that is. So, all these goes into in terms of the environmental impact then you manufacture which is you make things out of that with the assembly and packaging.

So, while during the manufacturing you have the impact as well. From manufacturing you go to the distribution system where you have the storage handling and transport during the distribution you have an environmental impact associated with that during the use phase where you have to do some maintenance repair reuse and you will be using lot of energy associated with that. So, there is also is an environmental impact and then there could be some reuse within the system then ultimately it may go to end of life where it could be collected recovered recycle land filling, and then there is an environmental impact associated with that and part of it could be disposed and part of it can even can come back. So, that is a circular economy the cradle to cradle.

So, from this arrow that you see the green arrow, all the way up to here is a cradle to grave where things gets out of the system, but one if you include this dotted green arrow it becomes cradle to cradle. So, while you are kind of re manufacturing and police, it is like a recovery of the material and putting it back into the supply chain. So, for all this is stuffs we have this environmental impact. That is why we have we have put this mother earth in the middle and showing you all the impacts coming in.

So, what we do in the cell c exercise is we kind of calculate we kind of calculate and tabulate and add up all these different impacts that is coming into the mother earth. And in what categories of impact is it a global climate, is it a global warming and is it a clamping like carbon change of global warming is it acidification, or is it a land using impact whatever is a different kind of impact we can put that all together.

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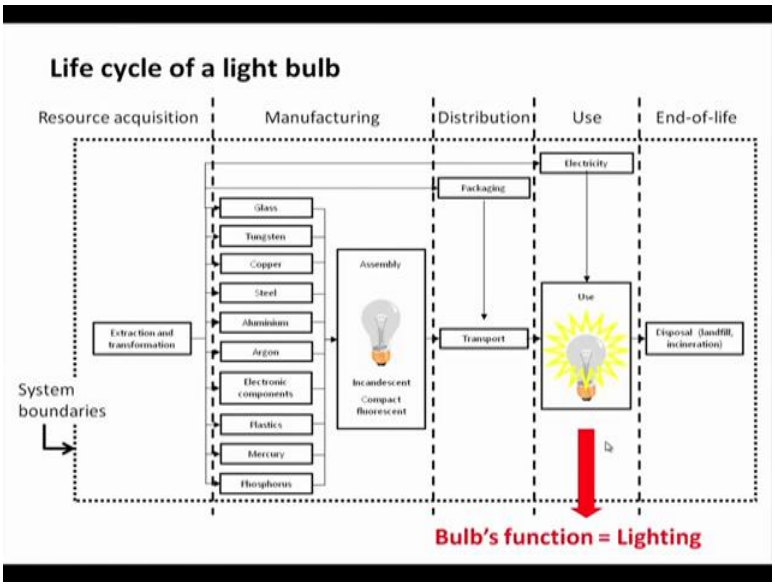

So, let us look at the life cycle of a light bulb. So, if we have this light bulb incandescent or compact fluorescent just. So, now, if this light bulb, I want to manufacture this light bulb. So, for manufacturer we need lot of materials; glass tungsten, copper, steel, aluminum, organ, electronic components, plastics, mercury, phosphorous. Think about just for a simple as simple as a light bulb these many items are needed to make a light bulb. And, but these may these things has to come from somewhere. So, we have to do this resource acquisition you have to do this resource acquisition, where it has to be extracted and transformed.

So, from the mining it is extracted and then transformed by our metallurgy friends then it goes to the manufacturing plant, where we put we will get all of this together and then assemble and make this light bulb. So, once this light bulb is made, it has to be packaged it has to be transported and it goes to the distribution system from the distribution system, you go and buy the product you go to the use phase where we use the electricity and you use it for lightning you produce light and at the end of life when though it is a kind of bulb gets defused or something happens it is energy called broken because of some reason it cannot be used anymore. So, it is an end of life disposal land filling generation where it may end up.

So, this is the whole and so, this is the whole how the life cycle of a light bulb is from cradle to grave. So, this dotted line the dotted rectangle that you see on from the outer

boundary. This is our scope that is the scope area and we also call it system boundary. So, this is the system boundary for this particular LCA exercise. So, our LCA exercise is of comprising of all the unit processes happening within this system. So, this is what we will be trying to come for. So, how will do that? First of all, we need to find out what is the function and the functional unit. Now what is the bulbs function bulb function is to provide light is and that is it is major function is to provide light.

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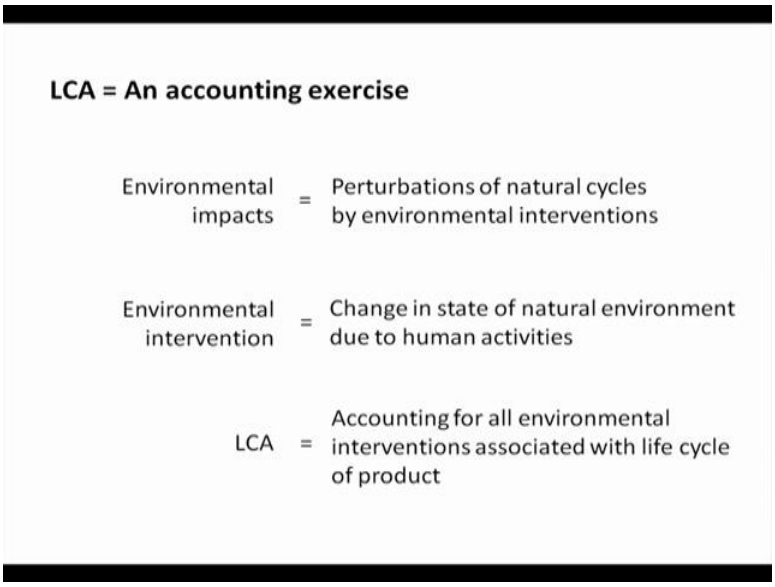

And then we will do this environmental like a LCA as an accounting exercise, where we look at the environmental impact environmental intervention, environmental impact is disturbance of natural cycles by environmental interventions, changes in the state of natural environment due to human activities. So, we will look at all that and that is for that functional unit and so, that is why we have to first come up with this functional unit number. So, this life cycle inventory resource acquisition manufacturing distribution use end of life.

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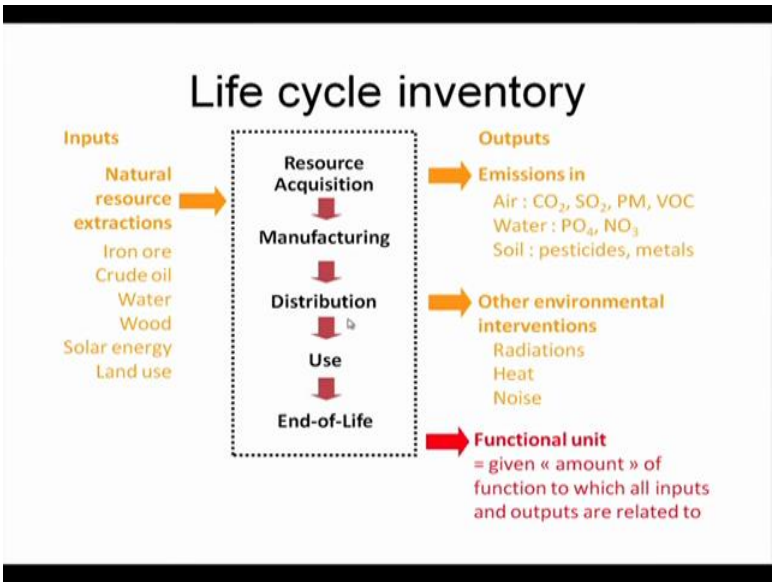

We have certain inputs coming into the system. Some natural resources extraction iron ore crude oil, water, wood, solar energy, land use all these inputs coming into the system in terms of the resource acquisition. And then you have your output which is emissions in air. Air emissions like carbon dioxide sax and nocks postulated madder VOCs phosphate and nitrate in the water pesticides metals in the soil. And then you may have other environmental impact in terms of the radiations heat and noise. So, we have to. So, as part of the LCI which is lifecycle inventory we have to come up with a like a total of inputs as well as the total of output and then we try to compare in terms of it is environmental food frame.

So, for all of these we have do it for a functional unit. So, the functional unit is the given amount of a function to which all inputs and outputs are related to. So, that is like a bio a base. Earlier if you remember from the previous example we were talking about we said 1 meter of writing. So, we based it 1 meter of that was the functional unit of using mechanical pencil versus the normal pencil that the wooden pencil. Similarly, here we have to come up with a functional unit where we are trying to compare these 2 types of bulb where which bulb is better. So, we need to do this calculation in terms of which bulb will perform a better.

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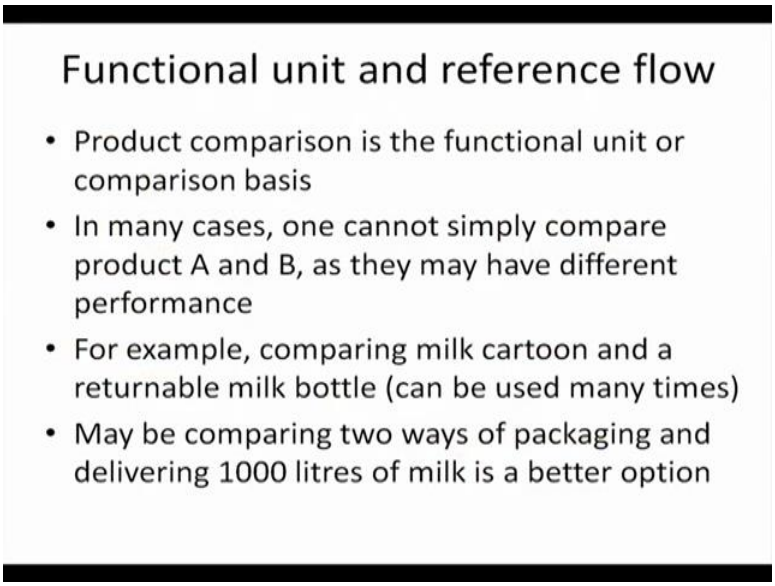

So, we have this life cycle inventory for that. So, we have to have a functional unit and based on the functional unit we have our reference flow. So, functional unit is used with for the product comparison based on the functional unit, remember we talked about functional unit of serving of 30 milks functional unit of 1 meter of writing. So, in many cases one cannot simply compare product A and B, because they have different performance; for example, again comparing milk cartoon returnable milk bottle. Returnable milk bottle can be used many times. I do not know these days it is very difficult to find a returnable milk bottle. We do not see them unless I would like most of the cities I have not seen it in an India or even in abroad.

But in olden days there used to be returnable milk bottle, if you have watched older Amitabh Bachchan movie, you see that many in some of the movie there is an if the bottle comes in they drop it and front the door they put it in a small like a there is one case like a holder bottle holder, they put it on front of the door and then they will put the call bell and the go way and then person will the house owner will take it inside. So, that is that is the bottle am talking about the bottle can be reused.

Similarly, we used to use thing we still use many of the bottles for say cold drinks Cococola Pepsi, Thumbs up and all those. There is a still use the glass bottles. So, the bottles are still being used, but for the milk supply, we do not use the bottle anymore, but we do use milk cartoons and some milk pouches and all that, but say now if you are to

compare like a comparing milk cartoon and returnable milk bottle, which can be used many times comparing them one to one like one milk bottle versus one returnable, one milk cartoon versus one returnable milk bottle it is not fair comparison because the returnable milk bottle can be used multiple times.

So, here the comparing could be you can compare the 2 ways of packaging and delivering 1000 liters of milk. So, for both of them for both the scenarios, if you want to package and delivery thousand liters of milk what will be the environmental food frame here. We are giving them both equal footing. So, that is the importance try to understand that that is again that is why I am trying to emphasize on this functional unit part, because the functional unit should give both the products or both the process whatever you are comparing if you are comparing 2 different process, 2 different products the functional unit is should give them the same fair chance. It should be not buys towards one process versus the other. So, that is you need to be very careful in doing that.

Many times in when you look at some of these product LCA reports, which is done by the companies, they tend to do that, they will tend to show try to show that product in a better life, than the others and then you need to you need to look at this system boundary in how they are very careful way to make sure they are not doing undue advantage to their product as opposed to the other product. So, coming back to this life cycle of the light bulb we have to have the bulb function is the lightening to provide the life. So, we know that the bulb function is to provide the light that is there primary kind of primary function now we have to define the functional unit.

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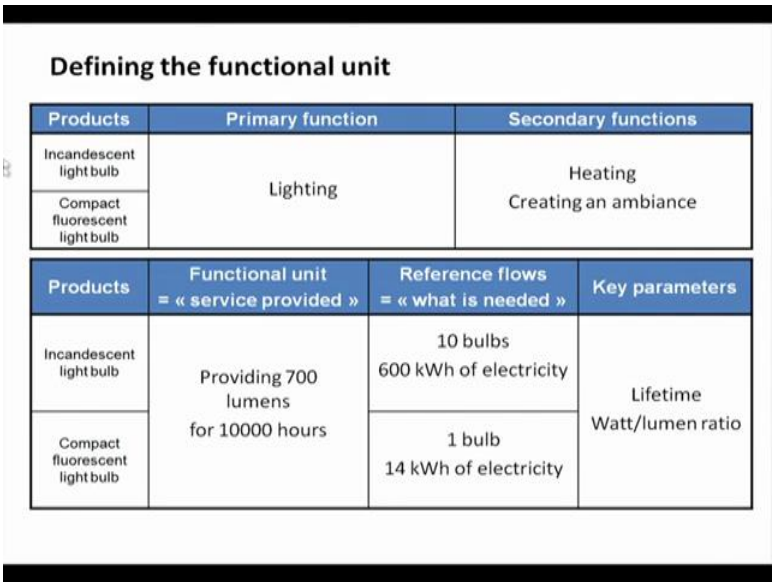

So, for any LCA exercise you do you can come up with a table like this you can make a like a table like this and try to fill in the information, which we will do it with you I will do it with you right now. So, this will help you understand how we arrive at the functional unit. As I said in the beginning of this particular video within the particular module that we will go in like in great detail about this example, just to by goal is by the end up this example you should be able to do a LCA exercise. At least you will have conceptually should be able to do it of course, you will need some computational have in terms of software.

So, coming back here say if you want to do this functional unit we have to find their functional unit now how will do that. We have 2 products that we are trying to compare and that we have listed on the top over here incandescent light bulb and compact fluorescent bulb. So, these are the 2 products we are trying to compare and same thing at the bottom we have listed here. So, now, what is there primary function? If you look at here I have listed here something known as secondary function, which we have not talked about until now in this course.

Now something is a primary function and there is a secondary function. So, for this light for this bulb the primary function of course, is to provide the light whether you are looking at incandescent light bulb or you are looking at the comparison compact

fluorescent light bulb. So, the primary function is to provide the lightening, but what about the secondary function.

So, we if you go to any of this like an even like a sari shop of a chudi shop or any of these like a market place in the evening, you say that you see over there that hardly any place you will find people is still using incandescent light bulb. Most of the places they use compact fluorescent CFL and of course, there may be switching to LED now, but the reason for switching from incandescent light bulb to CFL bulb of course, it is an energy saver, it helps in better energy efficiency, but it also gives a very good ambient as compare to incandescent light bulb.

The incandescent light bulb has that yellowish light. So, with the yellowish light it is kind of gives a dull atmosphere, and with the CFL or the LEDs it gives a very bright light. So, when you are in a market place you want to show your product in a bright light. So, those customers get attracted, so that is also it is a creating an ambiance, but how to define that creating and ambiance in terms of numen like a quantitatively that is more like a qualitative. So, it is very difficult to quantify that, but that is the secondary function could be is as is a creating an ambiance.

And on the other side, if you are in like in the winter month especially and some places where the heating is acquired where there possibly the chicken farm and other places, they are they tend to use incandescent light bulb more the reason for that, is incandescent light bulb gives more heat. So, as supposed to CFL. So, there is a like that is the secondary function, but how to quantify those secondary function it you can do that you have to make certain assumptions to go about doing it, but we will not spend too much time on that part that is becomes like a more advanced LCA exercise we will look at later.

But for now we will think about the primary function is lightening, but sometimes the secondary functions are also very important. Another example I will give you is that like a traditional bulb, that goes hard bound books that you see as opposed to like a e reader where you can read things on your, like an iPad or am kindle and all those different e readers available now. Say you look at any of the interview of the big like on the TV when whenever even our when our prime minister or the president is giving an address to the nation, many times you see them on the back of them will be a nice cupboard book

cupboard within very nice books all lined up, very nicely different volumes all hard bound looks really cool.

So, it creates an ambiance say if as a professor if in my office over here at IIT Kharagpur if I have a set of books very nicely lined up in my office when you walk into my office you get an impression that may be this guy is reading a lot, may be that is if it is reading a lot; that means, you must be must know something at least you will know something which I can learn from them. So, that is that is creates an ambiance. It could be there am not touch those books. I mostly do my reading online which happening these days especially with the younger generation not too much in our generation.

Yet even young generation older too as, but the younger generation they tend to read online, but I am not just saying am not promoting online reading I still feel that reading by book is the best way of reading, all though you may call it out day. You will you will call me an out dated old prof this one, but reading by like a regular book that is the that is gives you the even the research has been done where people have seen that the students who make notes in the older way in the class room not the typing on the keyboard or the laptop or iPad or even these days on smartphone or taking pictures of how their slide.

So, from professor's slides or professors hand written material from the black board what has been found and this was there was a paper actually just came out last year, when they found that is students who take notes by handwriting they actually do much better in their classes. Because when you write something by your hand it gets registered in your brain much quicker.

So, now coming back here so, but those are there are things there in terms of the secondary function, but coming back here, if you have this primary function is the lightening secondary function is heating and creating ambiance, as I said for this particular example right now will not worry too much about the secondary function. We will take all like 100 percent over here and lightening like a 100 percent allocation to the primary function. All though I use the word allocation and which will talk about that later. And the location where you can actually split the impact between primary and secondary say by 60 40 70 30, whatever, but again we will talk about that later because that will complicate the stuff let us try to do stuff here in a simple way first.

So, primary function is lightening. Now thing is that how much light, is that is the service provide that will be our functional unit. So, how much light we should take. I am suggesting that let us take providing 700 lumens. So, there is nothing hard and fast role over here you can choose whatever you want to choose, but it would be same for both incandescent as well as for the CFL. So, that is the key here it has to be the same. So, that you can compare why I choose 70 lumens 700 lumens for 10,000 hours the reason for that is for that I get a very good numbers like I get 10 bulbs and 1 bulb. So, I get 10 bulbs for incandescent light bulb and 1 bulb for CFL and this 10 bulb 60 watt 60 like a with 10 bulbs we have 600 kilo volt hour of electricity and for 1 bulb, I have 14 kilo volt hour of electricity that is what it is going to provide in 700 lumens for 10,000 hours and we can also do a life time volt lumen ratio calculation as part of this.

So, for any LCA exercise, you can a start especially when you are doing a comparative LCA. When you comparing that to even if you just doing one you can just put one stuff here, but if you are doing a comparative LCA which most of the times we kind of do this LCA comparing 2 different process 2 different products. So, here you have our encourage you to make a make a table like this make a table like this. And try to write it down what is the primary function what is what is the secondary function what is the functional unit you can chose what may make sense and then once you know the functional unit to achieve this particular to provide these 700 lumens for 10,000 hours we need 10 bulbs and 1 bulb and that is called reference flow.

So, this terminology is also very important because when you start using a software later on when you become a like a when you get more pro kind of things on LCA will be using this certain software to use it, and then then there will be use this terminology. So, reference flow is the amount like in terms of what is needed to provide then to provide the function as with as per the functional unit that we have chosen. So, the function here was lightening functional unit, we chose was provided 700 lumens for 10,000 hours and to provide that for reference flow is 10 bulbs of incandescent and 1 bulb of CFL. So, that is kind of hopes that is make you clear we spend quite bit of time on this to make you clear on that work.

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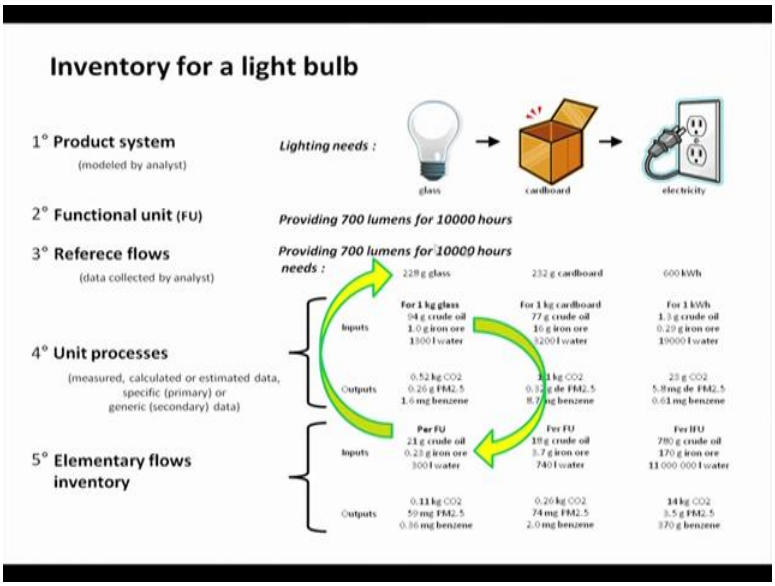

So, now let us look at this inventory of the light bulb, how will collect these data; so in terms of the light bulb. So, our product system is the lightening need we have the bulb, it needs to be packaged and then we have the electricity, so the electricity that we supplied. So, we have this bulb and this light packaging material and the electricity, so for the functional unit is our providing 700 lumens for 10,000 hours. So, we are that is that is what we have chosen. So, reference flow remembers with the reference flow that we like a providing 700 lumens for 10,000 hours, we need 10 bulbs and 1 bulb for this incandescent bulb we need 200 and to make 10 bulbs we need 228 gram of glass 232 grams of card board and 600 kilo volt hour of electricity.

Now we need to get the unit process and how we get this unit process it could be measured it could be calculated or the estimated data is specific primary or generic secondary data. So, that is the unit process that we kind of use for that and for each of this unit process we need the input and output. So, let us look at some. What we can get from the data bases that I have mentioned which comes with most of this software, we can get this data that for 1 kg of glass what is the input goes into the system and what is the input output coming out here we have listed only 3, 3 major that does not mean there is only 3 input and 3 output. These are the major ones there the list could be endless. There could be long list going up there. So, in in terms of 1 kg of glass I have input as 94 grams of crude oil one gram of iron ore 1300 litters of water. So, think about to make 1 kg of glass we need 1300 liters of water.

That is why if you remember from the first week videos I said that water without water we cannot have any industry. We need good potable water to really survive to make any industry to have any GDP going on we need good water in terms of emissions 0.52 kg of CO2 0.26 gram of a particular mated 2.5 1.6 milligram of benign. So, this is what is and again these list are not the complete list. These are just that the 3 top once for the input parameter as well as for the output parameter.

Similarly, you can get for the card board as well as for the electricity. For the card board to make 1 kg of card board you need 77 gram of crude oil 16 gram of iron ore 3200 litters of water. 1 kg of card board 3200 litters of water that is a lot of water. And then for 1 kilo volt hour of electricity again if you use the crude oil iron ore and then you use 19000 liters of water to make 1 kilo volt hour electricity.

And these are the assumptions emissions coming out and we have taken carbon dioxide particular matter and benzene and other 3 examples we have taken, but this is not the all the once. There is other once as well. So, this is for the unit process unit means for one unit is not it that is the inventory method you may have done in your math class as well long back in may be in your primary school. So, may be the secondary school in the inventory method where we put everything with of 1 unit. So, 1 kg; so here 1 kg glass 1 kg card board 1 kg of 1 kilo volt hour.

But what we need is 228 grams of glass we need to 32 gram of card board we need 600 kilo volt hour of electricity. So, what we can do is this is our functional unit. So, per functional unit we can take this data from here and then we can find out. So, for 1 kg glass this much how much will be for 228. So, same thing has been done over here; so for 1 kg of glass 94 kg gram of crude oil, so for 228 21 grams 0.23 300 litters. Similarly, the ambition we can as to do that. So, this is assuming that things are linear similarly you can do it for card board you can do it for the electricity here, the functional unit is 600 kilo volt hour.

So, we multiplied by 600 and then we get these values here as well. So that is kind of gives you this whole inventory of the light bulb, and this is again we are just talking about a small light bulb and there are. So, much items right there already and as I said earlier these are just we just to 3 parameters and for the 3 parameters we are seeing

almost and for this light the incandescent bulb very simple system, we are already saying 3 6 9 and then and then you have 36 day 36 data points.

So, lots and lots of data points that need that is why we need the software the software are needed to get to understand this like the 2 kind of compiler of the data we could we can do a simple LCA exercise using excel spread sheet as well, but that is how it is started initial excel LCA initial LCA studies were done using excel spread sheets, but now we are being using more and more software seeded with that. So, that is like a let us this is how the inventory is done and we will start kind of will kind of recap this in a few meant may be half a minute in the next video and will start from here.

So, again try to go through this example. If you want you can re-run this videos multiple times that is the beauty of having these online courses that you can like you can replay the video and unless you get everything you clear. Because these are really very basic and clear stuff if you understand this example, that is why I am taking. So, much time on this example to explain you in a very nitty gritty detail. So, that if you understand it will be much easier when you look at any other exercise for LCA whether you when use it for research for your teaching or whatever purposes.

Thank you. And I will see you again in the next video.