Urban Services Planning
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Lecture 40
Life Cycle Assessment

Welcome back. In Lecture 40 we will talk about Life Cycle Assessment.

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The concept that we will cover is the ISO 14040 2006 LCA framework. Within that we will talk about goal and scope definition, goal and scope definition in the context of solid waste management, lifecycle inventory analysis, landfills as carbon sink, life cycle impact assessment, life cycle interpretation and finally, we will show you some examples.

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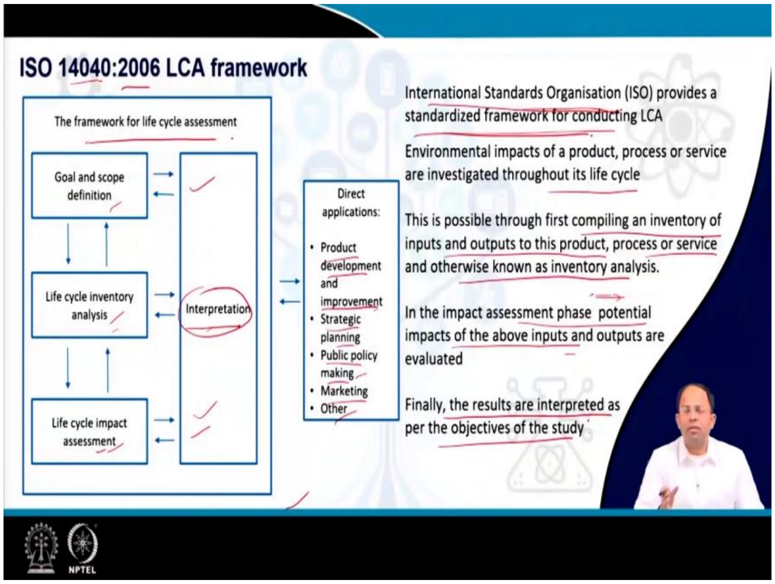

So, we have earlier we have talked about evaluation between different waste disposal alternatives, or different technologies for that matters. Now, we can do it in a very broad way using the cost of those particular options and all. But if you really want to do a detailed analysis of two technologies that are involved, or two processes that are involved, it is better to use the LCA framework.

And as we have discussed earlier, there is environmental impact assessment and then there is the LCA framework. And in case of LCA, as you remember LCA looks into the entire gamut, the entire extent of the product's lifecycle starting from cradle to grave, and that is how it gives us opportunity to compare the product not only at the final as a final option that is at the disposal or like during the final choice.

But during every stages of that particular product starting from when it was mined to how it was processed then how that particular product what sort of processes went into that all these things if I compare then at every stage there are emissions there are environmental impacts, and if we compare all of this and together we can assign that total environmental impact of that product is this we may find that some obvious choices of technology.

Which we feel that this is a better technology actually turns out to be not so good in the long run. So that if I consider the entire lifecycle of that particular product, so that is why LCA framework, LCA analysis is more detailed, and it gives us opportunity to really investigate a product or a process.

So, this ISO 14040 2006 LCA framework. So this is developed by the International Standards Organization. So, it provides a standardized framework for conducting LCA. So, we can always because if there are no standard frameworks, then anybody can compare any two products in whatever way they feel is more suitable or more or based on availability of data, they can add up their own methodology.

But if that is done, then there is no, standardized method or in some in some cases, certain things will show some results. In another study the same two items will show different results, which one is better or which one is more, friendly to the environment, and so on. So it is better to create a standardized framework following which everybody can do this LCA analysis.

So, that is where ISO has provided this framework 14040 2006, 2006 is the year and in which this framework was updated. So that is why the year is given, but the framework is ISO 14040 framework. So, environmental impacts of a product process or service are investigated throughout its lifecycle in LCA.

And, so, how we do that, so to do that, we follow certain steps. In this particular image, you can see the steps which are listed in the framework for lifecycle assessment as given in the ISO guidelines. What are the steps the first step is goal and scope definition. The second step is lifecycle inventory analysis.

The third step is lifecycle impact assessment and finally, interpretation. As you can see, that there is all these stages the arrows goes both ways. That means when I define the goal and scope of my work, based on that we have to create lifecycle inventory. But based on the inventory based on data availability based on many other things, we may modify or cooler scope.

Similarly, for lifecycle inventory, we can determine its impact that means for different products, different components of the products, different inputs for the products, and processes of course, for each of these, there are different impacts that are generated. Now impacts also, may help because certain impacts are when we compare across different products some impacts are same.

Exactly same impact is happening for both proceeds in that case I may say that, these are the components which are same between the two products, so, I can ignore those parts.

So, accordingly I have to modify the inventory as well. So, all these things that means, this is not a fixed procedure step by step in sequence, we can always modify it in each direction and then we can finally come back come to a position where we can say that, this is the final LCA framework for or final comparison between two products and all these stages, there is a stage called interpretation.

Interpretation is done at the beginning and also at the end that means, once all these results are coming in, in terms of the production processes, for each product or each process, the we have to see their impacts and so, on. So, then we have to interpret this impacts or interpret what it means, as per the goal and scope of our work and accordingly we have to take a decision.

So, this interpretation stage is actually happens at each of these intermediate stages as well as in the, at the final stage. So, this LCA is used for usually, once you do the interpretation then based on the interpretation we can determine. So, how our product which processes should be adapted for a product development, which products are more environmentally friendly, and how we can improve the existing processes of our product.

So, that is what our existing processes that are adopted, maybe if I consider land-filling and incineration so, each has got different processes, different products involved in it. So, in which stages we can make improvement, then it can help us in strategy planning to, to take decisions beforehand, public policymaking.

So, because we are evaluating two products, we can say that these are the environmental impacts of this particular process or product. And that actually helps us in making public policy and finally, it helps us to do marketing and also in other aspects. So, to do all this, first, we have to compile an inventory of inputs and outputs to this product process or service or otherwise known as inventory analysis.

So, inventory of inputs and outputs, for each product process and service has to be first listed, that means input means what things goes into making of that product or that process and what are the outputs from that product or process. So, all this needs to be first computed, the impact assessment phase determines the potential impacts of the each of these input and output and then determines which the overall impact and output for this particular sorry impact for this particular product.

So, each input that goes into making a product or a process, each input results in some pollution, some emission some effect. Now, sometimes, two inputs together goes, into a process and then there is an emission. So, I have to assign certain amount of the emission to each of these, input.

So, these are the challenges that are there, but overall, we have to understand that there are certain inputs goes into the process, there are certain outputs comes out and some of these outputs are harmful from the environment. So finally, the results are interpreted as per the objectives of the study.

So interpretation is not like there is a straightforward yes or no answer, we have to compare the product at different stages of its life cycle, see what kind of effects is happening, which are the common effects, which are the uncommon effects, then we have to determine as per our objectives of study what should be this product which should be chosen or which part of our process of that particular product has to be changed or modified to make it more environmentally sustainable.

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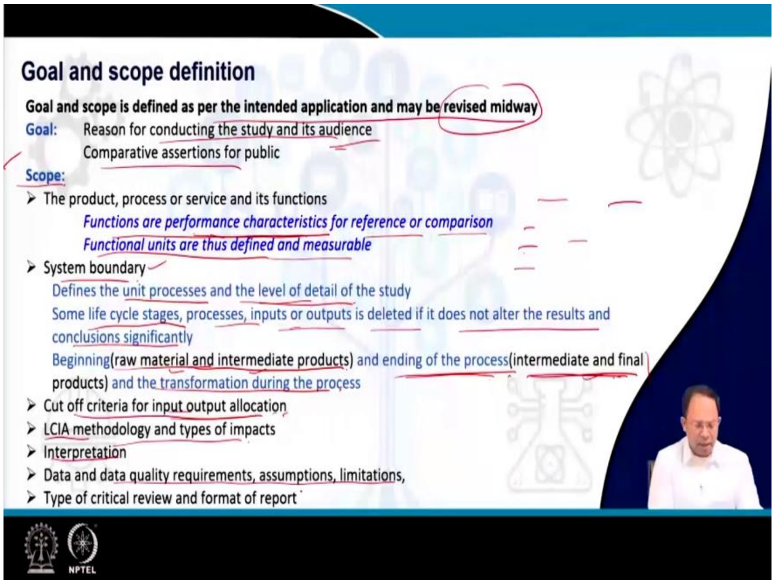

So the first step is goal and scope definition. And goal and scope is defined as per the intended application. And it can be revised midway. So I have already told you that we can revise the goal as per the inputs or as per subsequent stages we can modify the goal a goal and scope.

So goal and scope gives us the reason for conducting the study and its audience for whom we are creating this particular study. So LCA study, if I am creating it for a decision maker, it may have a different goal compared to if I am creating it for a particular industry, it will have a different goal based on what are the targets of this particular intended audiences, one may look at reduction of the overall cost provided some constraints on emissions are there whereas the other may look into the reduction of overall environmental and other kinds of cost for a particular process or a product.

Then this also helps us to give comparative assertions for public between the products the scope within a particular product or a process the functions are defined these are performance characteristics for reference or comparison. So, each product can have different functions or different characteristics.

So, we are comparing those for different for reference or comparison between the two products and functional units are does defined and measurable. So, functional functions are performance characteristics, that means, whenever we are comparing different products, we break it into different functions and those are the ones which can be compared I will give you some examples later.

So, system boundary once this basic functions are defined are performance characteristics are defined based on which we will compare the two products then we have to define the system boundary. Now, the system boundary could mean the different processes and the level of detail of the study.

That means, when I am comparing two products, if I go into details of the study we can reach to such minor details, which may be too difficult for the audience to understand or it could be at such a level where that both of the studies are more or less same. So, that means, suppose one is incineration one is landfill.

In that case I made ignore certain processes or, like for example, transport of the waste to each of the sites, maybe the certain aspects of transportation like what sort of vehicle was used and all this we can ignore that because, that is more or less same in both the vehicle, but the distance of transportation that I will consider. So, when I am considering overall waste management or bid or comparison between incineration and landfill, it involves transportation cost, it involves the vehicle of transportation all these thingss.

But I can assume that the vehicle is same in both cases and I can ignore the entire, aspects related with vehicles for this study. So, that is how we define the system boundary. Some lifecycle stages, processes, inputs or output is deleted, if it does not alter the results and conclusion significantly.

So, that is what I was saying that some of the stages of processes or some of the processes some of the inputs outputs, if they are the same among all the different options that we are comparing, then we can even ignore them. The other thing is beginning and ending of a process that is, for example, in case of waste the beginning of the comparison of landfill and incineration should start from the waste itself.

But the waste was waste did not start as a waste, it was some other material, that material was created using some other processes, it came from certain raw it used certain raw materials. So, how far ahead we will go. So, where is the beginning, so, raw materials and intermediate products, which are there for each of this process or product that we are evaluating?

So, this raw materials and intermediate products, which comes in between some of them could be considered some of them can be ignored. And similarly, for ending of the process for example, once the waste is discarded, in that case, that some of this waste could be transferred to a recycling facility where it is converted into another product.

So, should I end the life or end my analysis, when I am, processing this product, there is some amount of energy spent some cost spent at that level or should I again considered the next product which is prepared out of this product and again follow it up. So, this boundaries needs to be considered and the transformation during the processes.

So, beginning and ending of the process and the transformation of the process, what we should consider what should be the boundaries that is determined. Then cutoff criteria for input output elevation not all input output, has to be considered things which are common can be ignored things which we are not comparing that can be ignored.

Like for example, CO2 emission happens at different stages of making a particular product or a process, but maybe we can say that CO2 coming from biotic resources we will not consider why, because we assume that whatever is a biotic source that could be that means a plants.

We can again plan that we can again grow another plant and when it grows, when a new plant grows, it will take the carbon from atmosphere a CO2 from atmosphere and the carbon will be held within the plant, then when you decompose or when you, when this plant gets decomposed eventually then again the carbon is released into the atmosphere.

So, I can decide that I will not consider this process because I will assume that for whatever plants I am destroying, I will also put in similar amount of plants, but we are not if we are not doing that, then that has to be considered. So, that is what this input output allocation this cutoff criteria has to be considered.

Then else this then impact assessment methodology and types of impacts that we are considering is also needs to be determined that means, what sort of impacts we will consider there are different impacts that is caused by a certain product, but not all may be considered because it is beyond our goal and scope that is beyond the need for the current scope of study.

Then overall interpretation is also aligned with goal and scope data and data quality requirements assumption limitations, these are determined and type of critical review and format of report which is required finally, that is also required.

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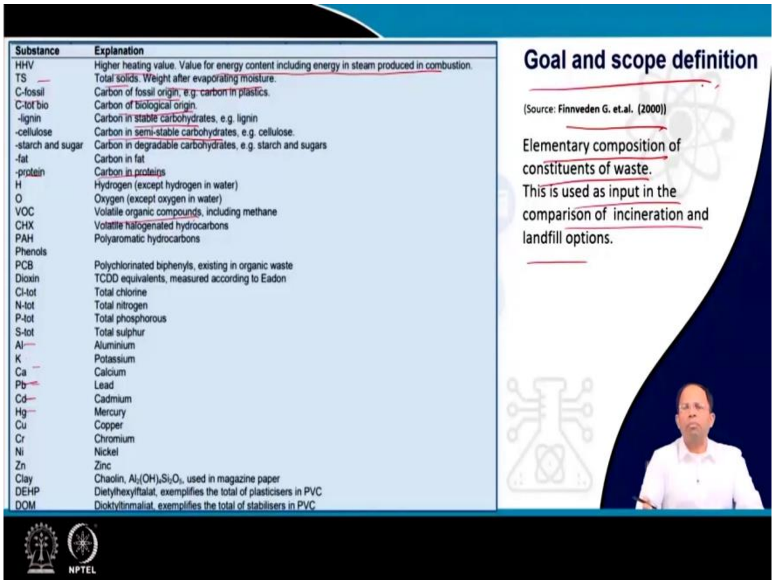

So, just to give you an idea over here, I have taken this from this study, where you can see the elementary composition of constituents of waste and this is used as input in the comparison of incineration and landfill. Now, for example, you can see that if I break a particular product or if I break a if I take solid waste management, if I take paper or if I take organic waste or if I take plastic waste, each of them could be broken into its primary elementary constituents. So, these are some of the elementary constituents that we can consider.

Now, it is our job to determine which we will consider and which we will not write for example, this TS is that total solid that is weight after evaporating moisture, HHV is the higher heating value this is value of energy content including energy in stream produced in combustion, C fossil is carbon of fossil origin, C tot bio is carbon a biological origin, C lignin is carbon in stable carbohydrates, C cellulose is carbon in semi stable carbohydrates then coming to protein carbon in protein form H is hydrogen except hydrogen in water, O is oxygen, VOC volatile organic compounds.

Then, PCB polychlorinated biphenyls, then you take all the different aluminum, potassium, calcium paper, sorry lead, cadmium, mercury, so, these are the primary constituents of any product right. So, some of these constituents should be there in a product in other products it would be not. So, now, it is our job to determine which of these inputs we will consider that should be defined in the goal and scope definition that because we are only looking at this sort of environmental impacts, then maybe some of this we can ignore.

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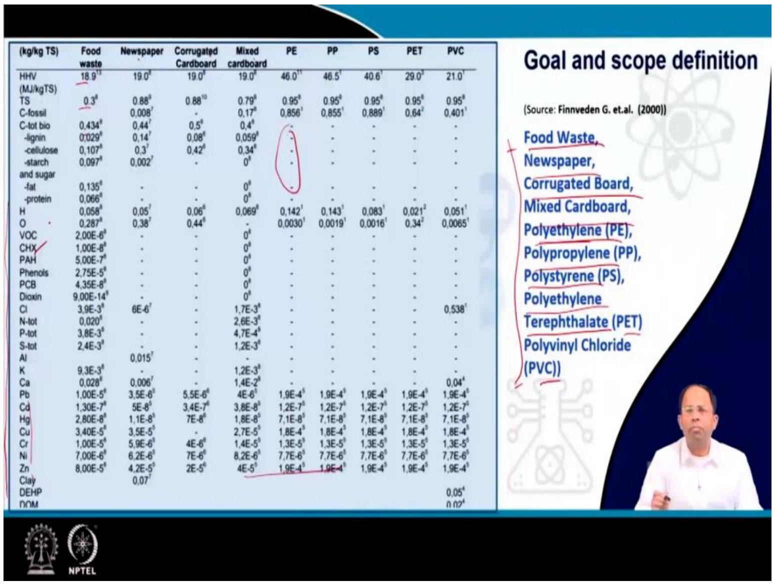

For example, if I take food waste, newspaper, corrugated board, mixed cardboard, polyethylene, polypropylene, polystyrene, polyethylene, terephthalate, this is paid bottles polyvinyl chloride, this is PVC. So, this kind of material is there in any kind of municipal waste stream. Now, if I break it up for each of those primary elemental constituents you can see the quantity of each one of them in food waste newspaper, corrugated cardboard, mixed cardboard and so on.

So, like these are the items which are not there in PE. So, that is polyethylene whereas, this kind of there are other things like for example, over here like this kind of metal are available in all the materials. So, you can see that these are some common items. So, these are specific to these particular items that we consider.

So, we have to determine what sort of input we should consider and what sort of we should not. So, this is a very, very detailed analysis of, taking what inputs goes into making of a product and a process, because until unless I know the inputs, I will not be able to determine what would it be the environmental impact of this particular input that goes into the process.

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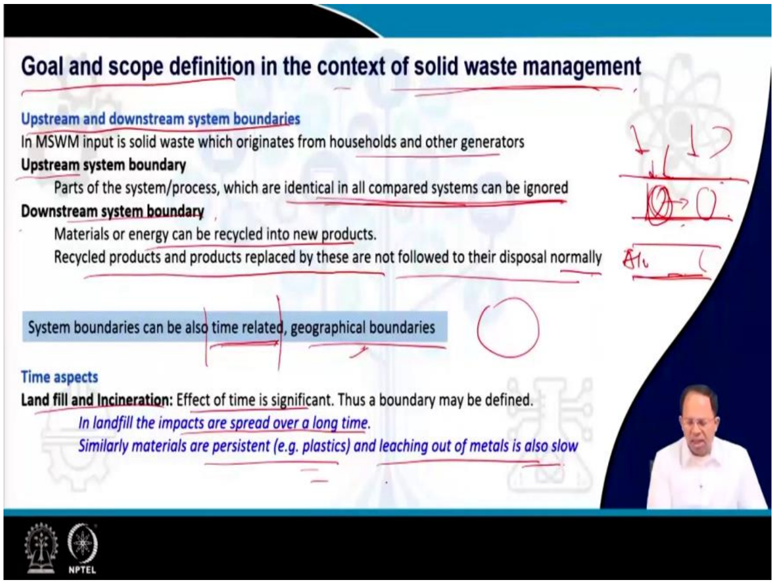

Now, coming in the context of solid waste management, when we are defined goal and scope there, I mean, we have defined it in generate terms, but if I think the context of solid waste management I will make things more simpler. For example, I have to consider the upstream and downstream system boundaries that is part of goal and scope. Now, in municipal solid waste management input is solid waste which originates from households and other generators.

So, in that case, the upstream system boundary could be parts of the system or process which are identical in all compared in all compared systems can be ignored. So, part of the system process which are identical in all compared systems can be ignored. So, if I am considering incineration and landfill both are dealing with waste.

So, everything beyond before this item becomes a waste that can be ignored, because these are all common between incineration and landfill. So, I am only concerned about once it becomes waste then what happens in incineration are then what are the inputs and then each of these inputs will lead to some amount of emission or some amount of environmental impact that we have to decide for each of these particular, all these different aspects.

So, as we are discussing that, all parts which are identical in all compared systems can be ignored. So, we are only concerned with the part where the solid waste has been disposed the waste has been disposed by the households and all that then we start comparing them. Similarly, downstream system boundary materials or energy can be recycled into new products, recycled products and products replaced by this are not followed to that disposal normally.

So, normally we do not do that, but sometimes we do that, that means, if I have a aluminum can after recycling it becomes again aluminum can. So, should I consider that aluminum can as well or till it becomes is finally disposed. So, what should be the end of my comparison? So, when I am comparing between different processes that means, different processes to recycle aluminum can I should not look into what happens in their subsequent stages.

So, I end what at the end of this first recycling procedure. So, that is how we create this upstream and downstream boundary. So, these are very, very subjective it depends on the goal and scope of the study, it depends on what is my reason why I am doing the study and so, on why I need to compare these two processes and so on. So, based on that, we have to determine this.

So, system boundaries can be also time related and also geographical boundaries. Why because some of the impacts are also based on geographical boundaries. That means, if I am if there are some pollution happening that means sprayed into many bigger larger geographical area should I consider everything or it could be spread over a long time, for example, in landfill and incineration the particularly in this two things the effect of time is significant, why? Because it landfill impacts are spread over a long time.

That means in landfill the waste products remain inside and then gradually those breaks down. For example, materials such as plastic will keep on being there for the next 10,000 years maybe whereas certain metals and all keeps on gradually leaching out that means leachate starts, keeps on coming out of this particular material, from metals and all, so this will also be a slow process, but it is not as long as for plastic, but it will still go out for a long time.

Whereas in case of insulation that is immediate whatever energy of putting into incinerate and then it some amount of emissions coming out so we can know what emissions are happening within a very short period of time. So we need to create this time boundaries, that means when I am comparing incineration and landfill I may consider a longer time boundary for landfill, but we have to determine how much is long. So, this time boundaries are also important. So, these are the different kinds of boundaries we need to create before we start any sort of evaluation.

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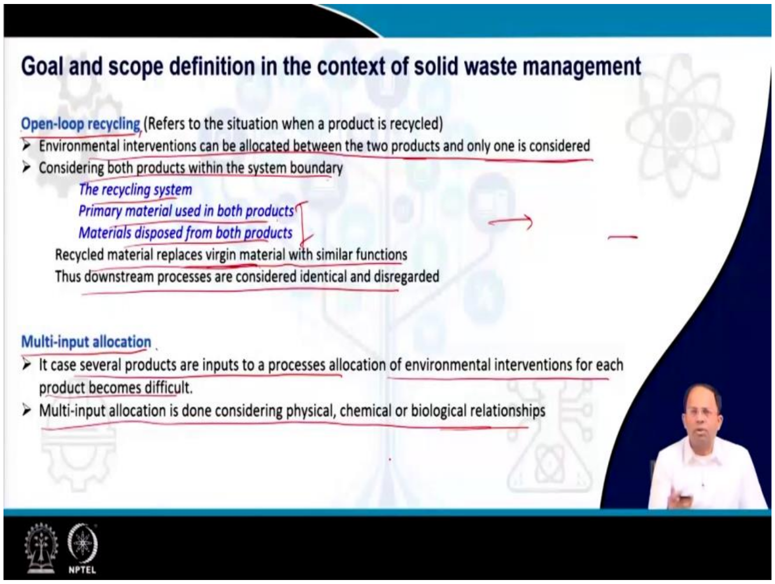

Then open loop recycling. Now, we earlier talked about that once a product is recycled, we may ignore it. So we do not need to look into downstream, but there are some cases where it has to be considered. So, why is that means environmental interventions can be allocated between two products and only between two products and only one is considered. So that means wherever some impact happens, the final impact which product should I consider should I consider it as the first product or the recycled product and so on.

So if that second product would be recycled further downstream. So, eventually the environmental impact has to be divided amongst these three products or it should be assigned to only one product or considering both products within the system boundary. So we consider both the products within the system boundary, we considered the recycling system.

What process has gone into what energy what material has got into the recycling process, the primary material used in both products and materials disposed from both products are considered. So the disposal can happen at the end of life of the second product, or it could happen all throughout the life of that product.

Depending on what sort of product it is, suppose it is a tire, so it keeps on losing material all sorts of life. And then once it is retreaded and it is used for the second time again, it will keep losing material. So it is it will be looked into for the entire life of that particular product over multiple uses, over its life.

Recycled material, but along with that, suppose the product is recycled or recycled material replaces virgin material with similar functions. That means when I am using a product, when I am recycling it, what is happening is I am not taking new material from the environment or new raw material. So that is reduction of virgin material.

So, that also needs to be considered. So, there is more cost, transportation costs transportation energy or certain process costs that goes into recycling, but at the same time, we are avoiding transportation of virgin material avoiding taking up this new material. So that is obviously a benefit.

So, the entire thing needs to be considered, that is downstream processes are considered identical and disregarded in some cases, sometimes it can be considered, sometimes it can be disregarded. So, that is what we have to decide. So, open loop recycling is another aspect that we should be careful above, then multi input allocation in case several products or inputs to a process allocation of environmental interventions for each product becomes difficult.

So, for making one process or making one product, there is a certain process, but it requires many production go into that. So, as I have shown you that there are way we can break a product into many components.

Now, once that is there, which product component is leading to which pollution that is very, very difficult. So, this is something which is very, very problematic. So, multi input allocation is done considering chemical, physical, chemical or biological relationships. So, that means, you have to study the chemical, biological and other processes in detail to understand what is being changed into what and what are the emissions resulting from each aspect and accordingly do this allocation of emission to a certain input.

Now, why this is important, because there may be another product where I can change that input. And I can improve the process significantly because this input is creating that pollution. So, if I change only that one single input or sub one single constitutional element, then the product would be significantly better. So, that is why we have to say, which input leads to which output or which pollution that they are generating or which emission they are generating.

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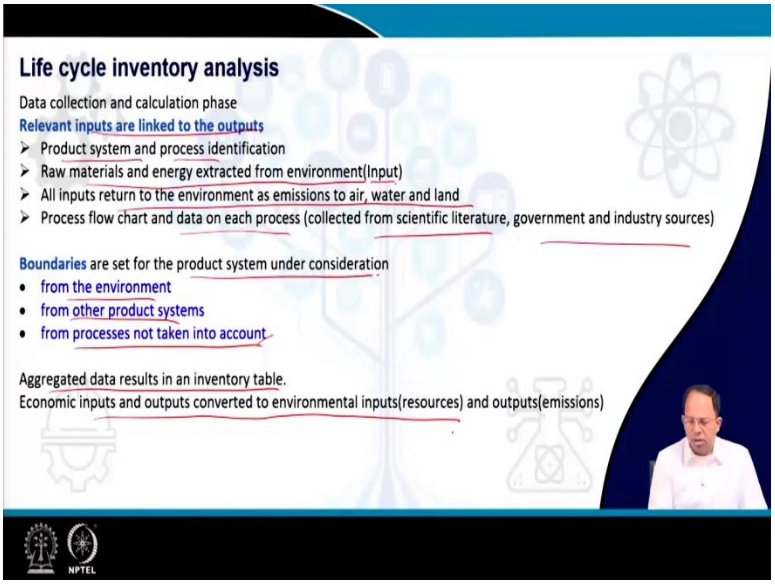

So, lifecycle inventory analysis is the data collection and the calculation phase and where relevant inputs are linked to the different outputs. And so, to do that, we have to identify the products systems and the processes that are involved, raw materials and energy extracted from the environment.

So what this is known as the input, and all inputs returned to the environment as emissions to air, water and land and processes, flow charts and data on it process needs to be collected. So, we really need to look into scientific literature government and industry sources to see that what are the processes, what sort of inputs they take, what is the output, we need to understand the overall process in detail to do this kind of input output allocation or to create these kind of inventories, boundaries are set for the product system under consideration boundaries in terms of the environment, from other products systems and from processes not taken into account.

So, what process we should not consider, those are immediately late out. So, took the aggregated data results in an inventory table and economic inputs and outputs converted to environmental inputs, resources and outputs emissions. So, I will show you some examples.

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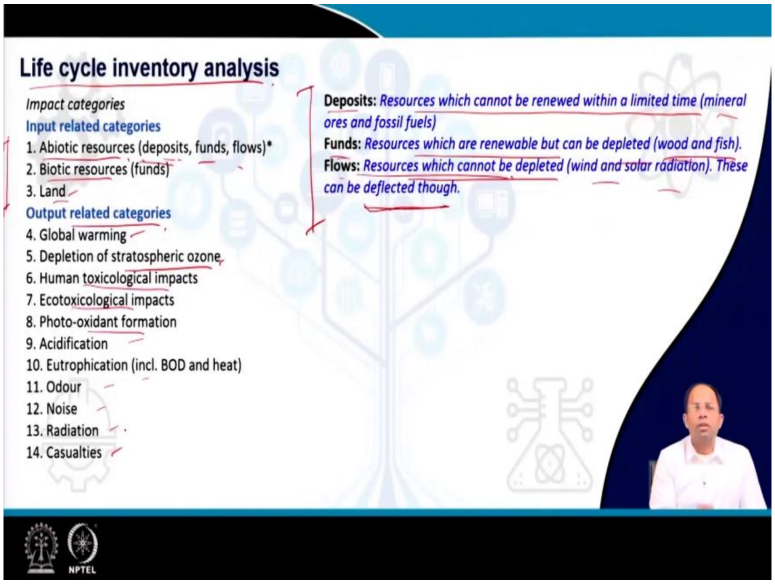

So, these are some of the different input related categories and output related categories. So, in lifecycle inventory analysis, we actually determine what are the inputs and outputs and we also in goal and scope, we determine which inputs we should consider and which output we should consider.

So, inputs are abiotic resources, biotic resources and land, abiotic resources could be again of three kinds deposits, funds and flows, water deposits, deposits are resources, which cannot be renewed within a limited time such as fossil fuel and maybe some mineral ores, that is once we use it, they cannot be reused again or we cannot recover those materials again.

Funds are resources which are renewable, but can be depleted that means wood fish, if you keep on taking it from the environment, you will run out of it, but if I plant a tree instead of once I cut a tree I also planted within it will be we are renewing that particular resource, flows that resources which cannot be depleted like wind, solar radiation and all these things, this cannot be depleted at all. So this cannot be depleted, but they can be deflected, that means they can by changing wind patterns and all we can deflect or we can make sure some people are getting it other people are not getting it.

But usually they cannot be depleted. So anyway deposits funds and flows are there. And these some of these could be abiotic resources, but for biotic resources, then most of these are funds that means wood fish these are mostly biotic resources. Whereas abiotic resources could be both deposits funds and flows. So and land is of course another input.

So these three are the inputs. And then we have to break these inputs, each of these input into constitutional elements to determine the detail composition of this particular inputs, then again, how much detail you will go into that is up to you. So it depends on what processes are involved. It depends on which interventions you are looking at.

So if you are looking at incineration, but you want to improve the process, so in that case, you have to go into those detail compositions, and then each process and which inputs goes into each process, you have to look into that in detail. But if I am looking doing a study in broad comparing incineration and landfill, considering the overall environmental impacts, then probably I do not look into that much detail.

So, what are the output related categories or what are the impacts, it could be global warming, depletion of stratospheric ozone, human toxicological impacts, ecotoxicological impacts, photo oxidant formations, acidification, eutrophication, odor, noise, radiation, casualties and so on. So, these are the different impacts that we can consider for each of this particular product.

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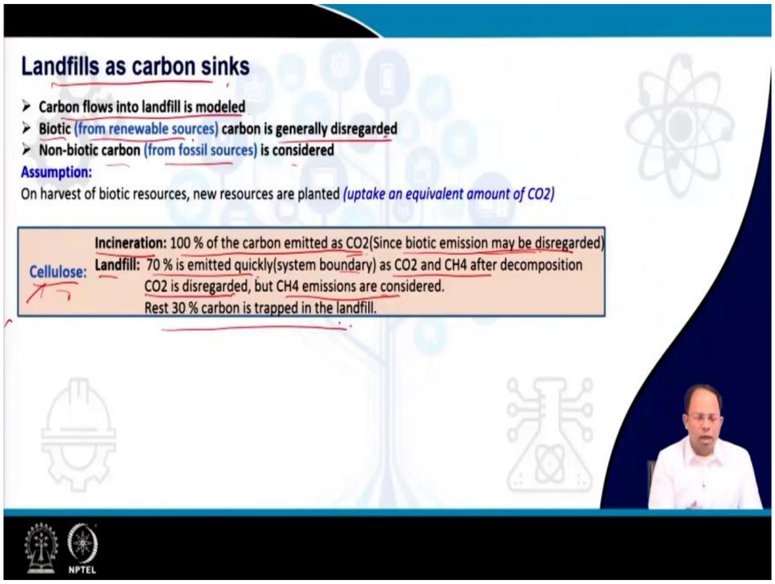

So, I was talking about this landfills could be modeled as carbon sinks, carbon flows into landfill when land in case of landfill what happens we are putting mixed waste into the landfill we can put mixed waste into landfill? Even though it is not suggested we should only put in art and other kinds of waste, but we can put mixed waste into the landfill.

In that case, what happens a lot of carbon gets trapped inside the landfill. So, in that case, should I consider that biotic carbon from that is from renewable sources such as plants and all is usually not considered why because as I told you that it is as soon as I plant another tree, it will take carbon from the environment and it will again grow?

So even though I am putting it in the landfill site, it is not considered. Because we are again taking that back that carbon from the atmosphere. Then because once you put in the landfill site, decomposition will happen and this CO_2 will be released into the, this carbon will convert into CO_2, CH_4 it will get released into the atmosphere and the plant is taking back this carbon from the atmosphere.

So it is a cyclic process so we can disregarded. Whereas for non battery carbon such as from fossil fuels is that considered. So, cellulose in case of cellulose in where I compact incineration and landfill 100 percent of carbon emitted as CO_2, since it is biotic emission desert disregarded. So in insulation when I burn cellulose in that, again, it is organic matter, so when I bought it, CO_2 will be released but we do not consider this as an impact.

Whereas in case of landfill 70 percent is emitted quickly. As and the other, the rest takes a long time beyond my system boundary. So within maybe 510 years 70 percent is emitted. So it is my system boundary, but after that I am not even capturing the gas and all so it is beyond my scope of work. So I am not considering it within system boundary.

So 70 percent is released a CO_2 and CH_4 after decomposition. So, in that case, CO_2 is disregarded, because it is coming from biotic sources and all but CH_4 is not disregarded, because CH_4 is a harmful global warming gas, it is almost 19 to 20 times more harmful than CO_2. So, we will consider that. So, it is how we evaluate or what we consider what we not consider that up to how we frame our problem, rest 30 percent of carbon is trapped in the landfill.

So, what we should consider what we should know what we should not that depends on many assumptions depending on system boundaries depending on goal and scope, we have to finalize this. So when I compare incineration landfill, what I should consider what I should not, these are the things that we have to be careful about.

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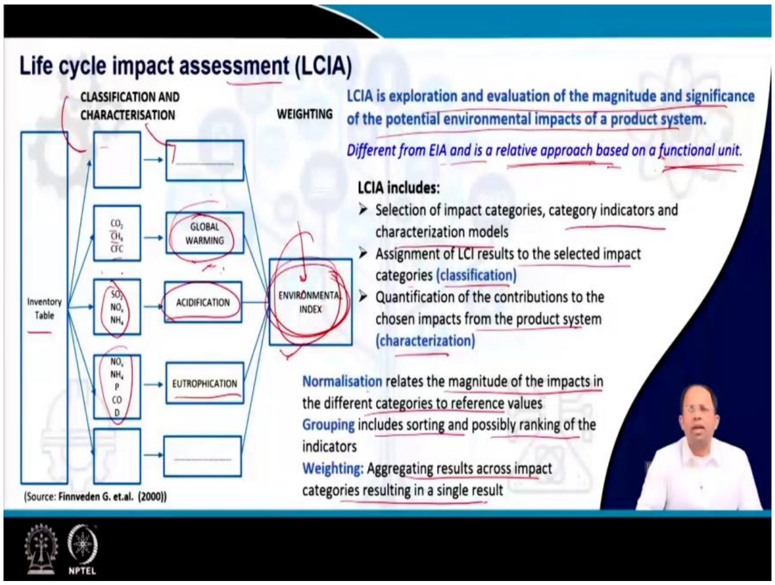

Then comes the lifecycle impact assessment phase. So, this is the phase where we actually look into its effect on the environment. So, we have the inventory table from there we have create these different kinds of impacts, these are the gases CO2, CH4, CFC, these are coming out, this leads to global warming, so, this is the impact similarly, SO2, NO2, NH4 that comes out as output from based on the processes that input goes through, then this leads to acidification, NOx NH4, P this leads to eutrophication overall.

So, these are the different effects that is created, each of these effects may be of different causes different nature of harm, this could be again added up to create a environmental index to create a overall effect on the environment. So, each of these effect categories could be again combined using some procedure.

So that we get a overall index, so that we can tell that which product or which process leads to what sort of impact in the and accordingly we can take a decision. So LCI lifecycle impact assessment is a exploration and evaluation of the magnitude and significance of the potential environmental impacts of our product system.

This is different from EIA and this is a relative approach based on a functional unit. So EIA is absolute values, but at done at the as a impact of a particular project or a particular product. Whereas this is a relative approach similar to the ranking procedures that we have discussed earlier.

And it is based on the different functional units that we are considering as per goal and scope. It could include everything starting from cradle to grave, or it may include only a certain part of it. LCI includes selection of impact categories. These are the different impact categories, category indicators and characterization models.

Assignment of LCI, LCI results to the assignment of LCI results to selected impact categories, which is known as classification so, this is classification. Quantification of contributions to the chosen impacts from the product system this is characterization, so, this is classification, this is classification. And this is characterization, normalization then we have to normalize the results relates to the magnitude of the impacts in different categories to reference values.

So, we can take a reference category and then accordingly we can normalize the entire result. We group grouping includes sorting and possibly ranking of the indicators, which is creating the most highest problem, weighting is aggregating results across impact categories resulting in a single result. So, we can give weights to each of these values, each of these effects, characterization effects and then that will lead to this environmental index.

So, similar to what we have done there is an impact, what sort of impact it is creating and the weight of that particular aspect to create overall environmental index. So, this is what lifecycle impact assessment is all about.

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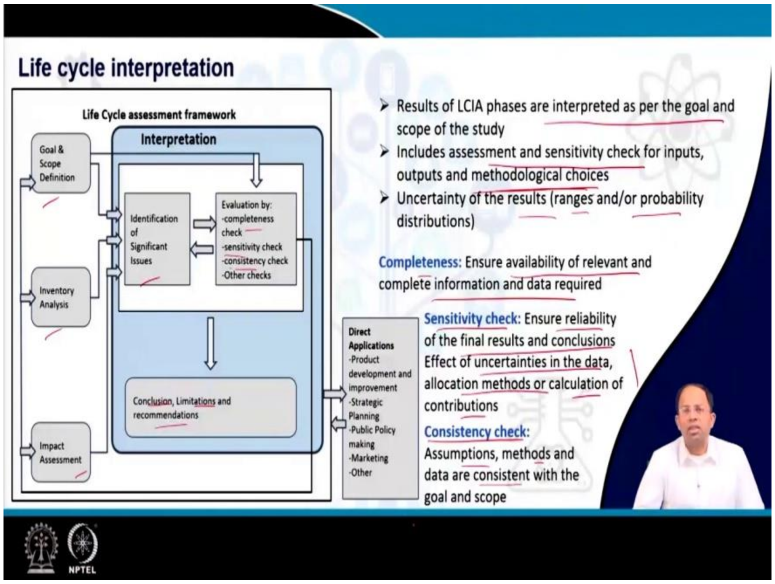

Finally, comes the lifecycle interpretation phase. As you can see that we have goal and scope inventory analysis, impact assessment, all of these stages is interpreted all of these has to be interpreted and we have to identify the significant issues and with evaluation is done and it is checked for completeness, we check the sensitivity and consistency and also some other checks are there.

And finally, conclusion limitations and recommendations are done based on the interpretation that we do. So, results are interpreted as per the goals and scope of the study. So, as per our goals, we will do the interpretation this includes assessment and sensitivity check for inputs and outputs and methodological choices.

So, for each input if I change the input by this how much would be the effect that is the sensitivity analysis and methodological choices, what methodology leads to what sort of effect that we can evaluate. Uncertainty of the results sometimes the results that we are predicting these are uncertain.

So, instead of giving single values, we can give ranges or probability distributions for some effects, what should the probability of that happening so, we can give that as well then, the different checks are completeness, which ensures availability of relevant and complete information and data required to do this kind of checks. So, completeness check of the data sensitivity check is ensure reliability of the final results and conclusions.

Because we are checking what effects what and we are checking that multiple times effect of uncertainties in the data allocation methods or calculation of contributions, this is actually taken care in this particular step. Consistency check is assumptions methods and data are consistent with the goal and scope that consistency check also has to be done.

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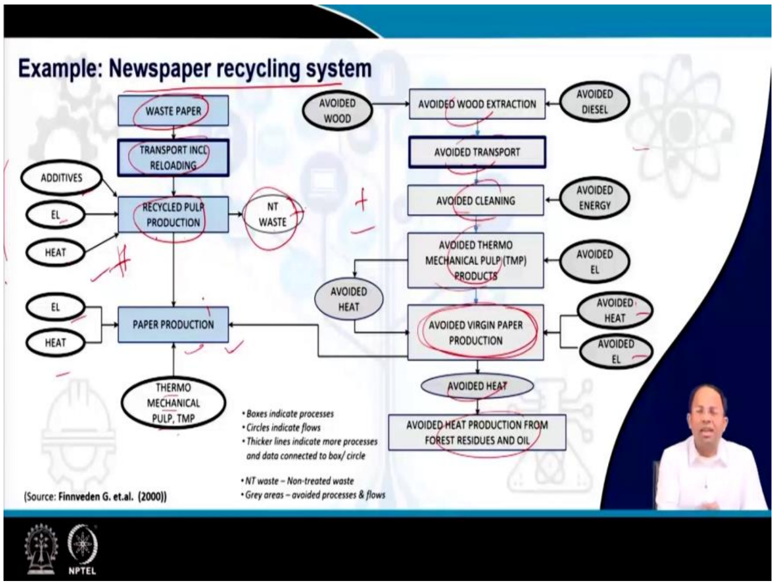

So, coming to some examples, I can compare between different processes or we can compare a single process single product or a single option and we can look into the different processes and we can see that how are the impacts happening and which stages and then we can suggest certain changes for certain changes as well using LCI analysis.

For example, over here we are discussing newspaper recycling system using paper of course, so, paper production requires thermo mechanical power production some amount of electricity and heat is given to do this process and this could be augmented or we can reduce virgin material use by using recycled pulp production, but recycled pulp production requires first collection of waste paper.

Then transport and reloading of this paper to the maybe the processing center of that pulp production center. The pulp production process requires additives electricity heat, and it also generates some amount of non treatable waste which has to be taken to the landfill site. So, there is energy use some impact for all of these stages eventually the paper is produced, but in the meantime, what is avoided, avoided watching paper production if I would have used this produce this paper, then we could have viewed used heat, electricity.

So, these are all avoided because we are not using this then avoided thermo mechanical products avoided cleaning avoided transport avoided wood avoided wood extraction transport of it cleaning of the wood conversion into pulp and so on.

And similarly, avoided heat avoided heat production from forest residues and alls and so on. So, you can see that we because we are using recycled material we are avoiding lot of processes in the because we are using recycled material, but recycling also takes up certain energy certain electricity to certain heat and so on.

So, I have to compare both of them to see if the additions in terms of environmental impacts because of these processes is more than the avoided environmental impacts because we are using recycled material. So, if this is less compared to the environmental impacts definitely this is a better process.

So, we will adopt that. So, sometimes we can say that we should recycle but sometimes it may happen that if I recycle, the overall impact is actually higher compared to if we are not recycling. So, in that case it is better not to recycle. So, these kind of decisions would be taken when you do detailed LCI analysis.

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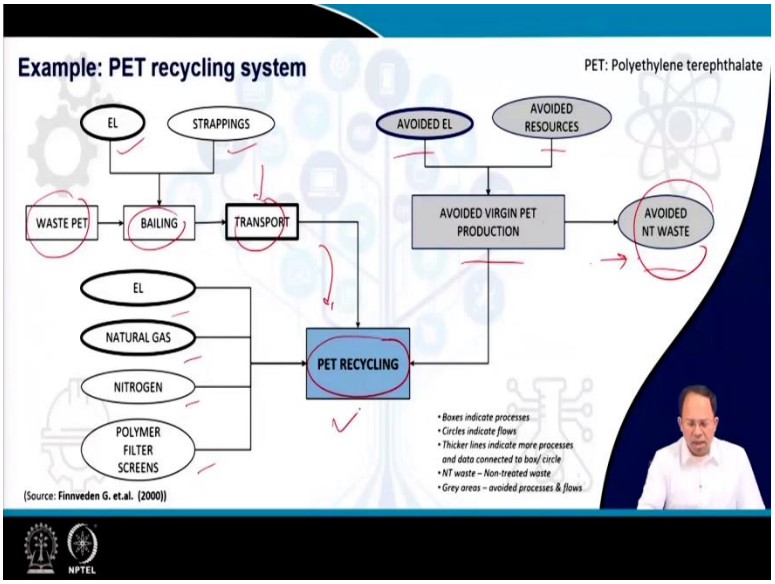

Coming to another example, this is PET bottles recycling this is one form a plastic recycling. So here also transport first of all we collect this waste PET bottles we bail them, (())(43:14) we know that that is we press them make it them into blocks that requires electricity, they that require certain strapping and all to, make them into bales.

Finally, these are transported that also we will spend energy on fuel, we will spend fuel and also that will lead to certain environmental impacts and all. So, eventually pet recycling happens, we required that electricity, natural gas, nitrogen polymers and all these things for pet recycling, but in the meantime, we have avoided virgin paid production avoided electricity avoided certain resources avoided this waste that is also generated from pet production.

So, we are looking into in detail all the different processes which are connected with this pet production including transportation, transportation of waste come generated in the processes and also the emissions and all that is happening and eventually we are taking a decision if this is suitable or not.

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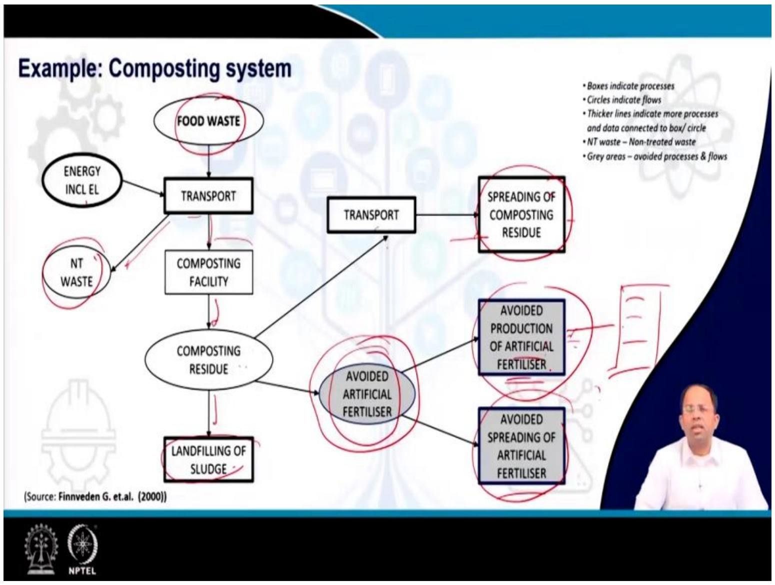

Finally, coming to the composting system, composting leads to fertilizer production. So, once we are this is the food waste that is generated it is transported and that requires energy and some amount of non treated waste is also there in food waste that goes into the landfill site, the race goes into the composting facility, then it generates some amount of residue which also needs to be transported to the which also needs to be some of it generates some amount of sludge in some amount of other waste material which goes into the landfill.

So, it has to be transported similarly, the rest is transported and used as fertilizer in the fields, spreading of the composting facility. Now, because we are doing composting, we avoid creation of artificial fertilizer, and because we are avoiding artificial fertilizer creation, then avoided production of artificial fertilizer avoided spreading of artificial fractal fertilizer.

So, these are the two savings that we are done. Now, we can again go into detail of this particular process and we can find out what sort of energy what sort of environmental impact is there for artificial fertilizer production. So we have to look into that entire process in detail. So if I just look at composting, the cost of composting cost of transporting it, then it is it will feel that composting will lead to lot of cost compared to just the cost of fertilizer.

Whereas, if I consider that because of composting, we are not producing fertilizer and all production of fertilizer have got many processes inbuilt in that and we are avoiding each of these processes emissions from this process then probably composting is a very desirable way to treat this organic waste that is originating in urban areas.

So, this is how we should analyze each of these aspects in much more details compared to what we have learnt earlier. Then we can take a really proper column which should be done or not, which process should we adopt it or not?

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So these are some of the references that you can study.

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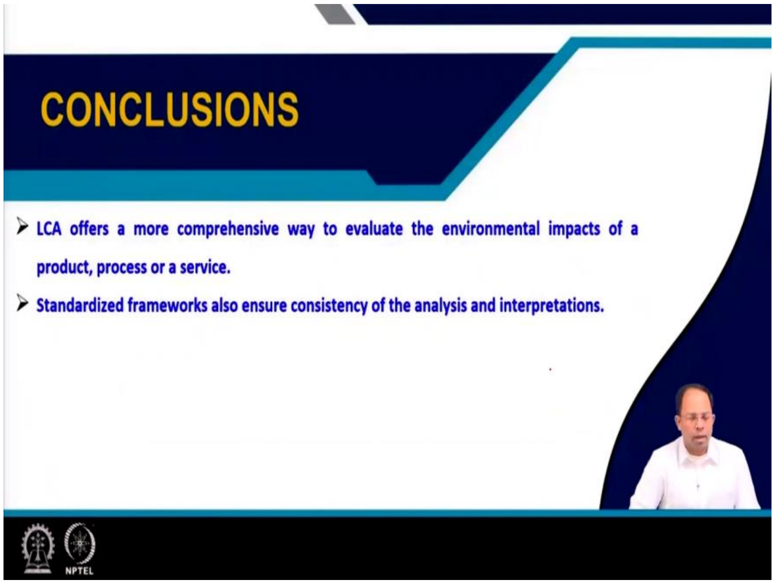

And to conclude LCA offers a more comprehensive way to evaluate the environmental impacts of a product process or service. And standardized frameworks also ensure consistency of the analysis and interpretations.