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Ecology and Environment

Risk Assessment and LCA: Lecture 6

Life Cycle Analysis

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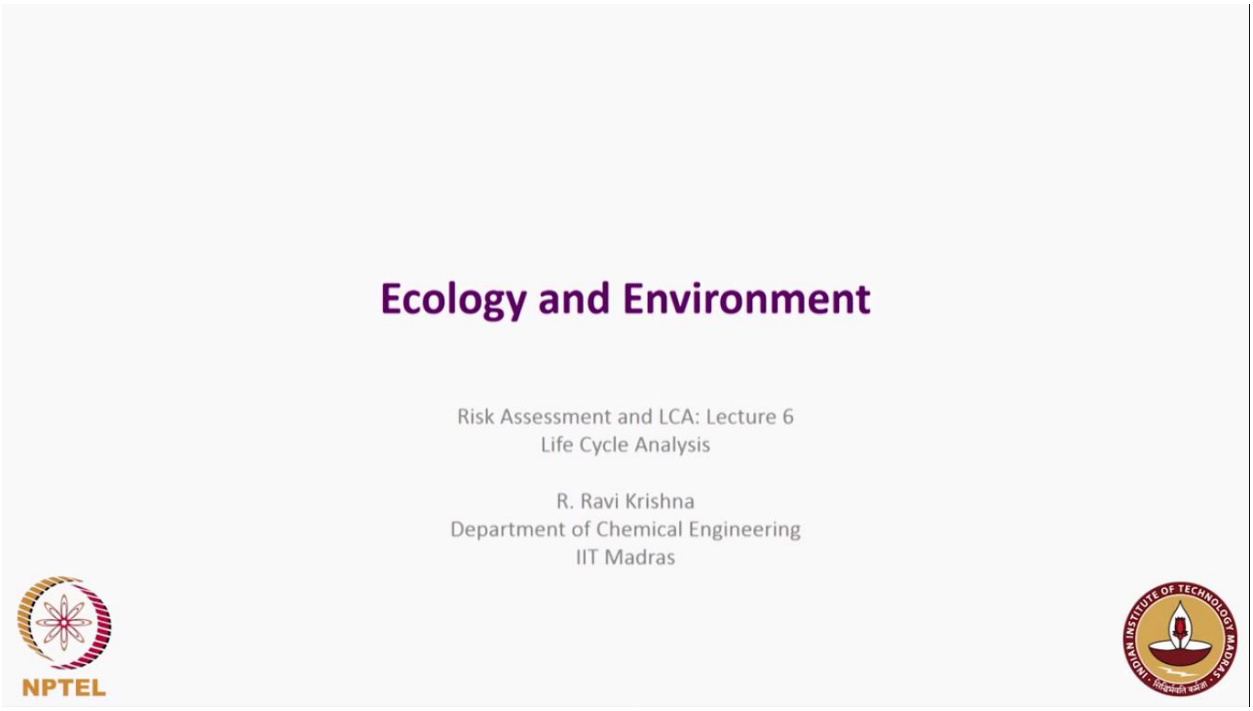
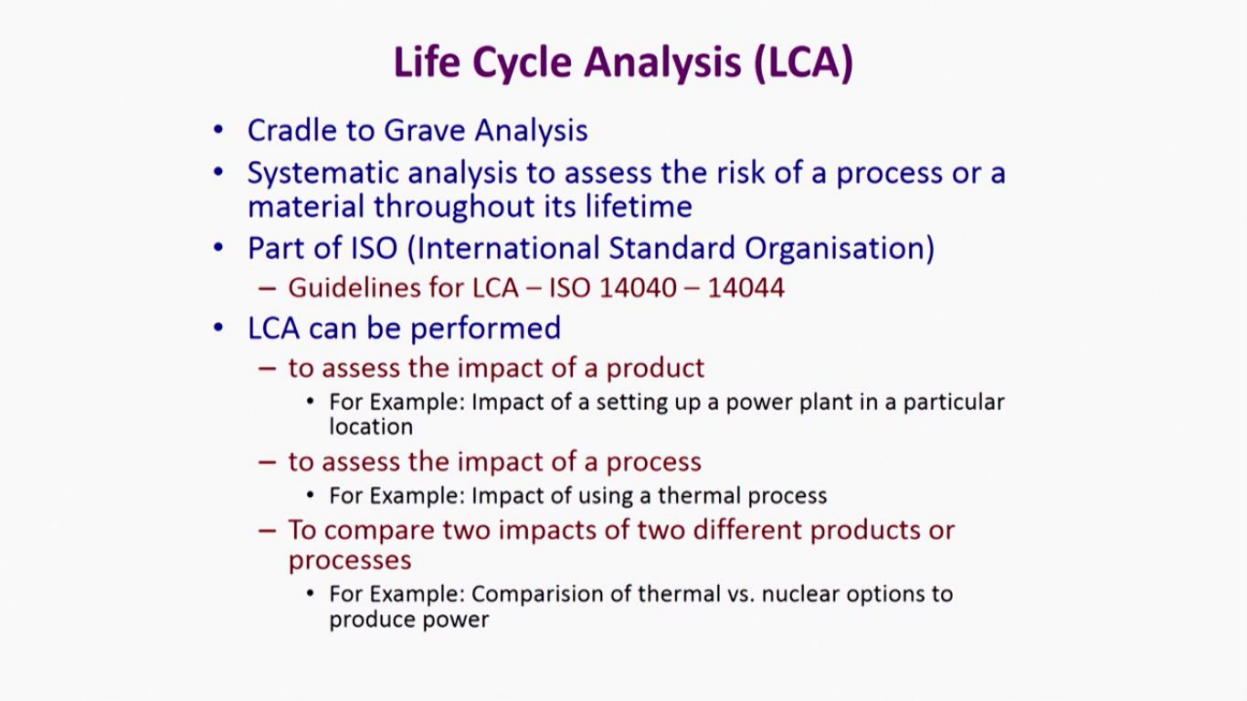
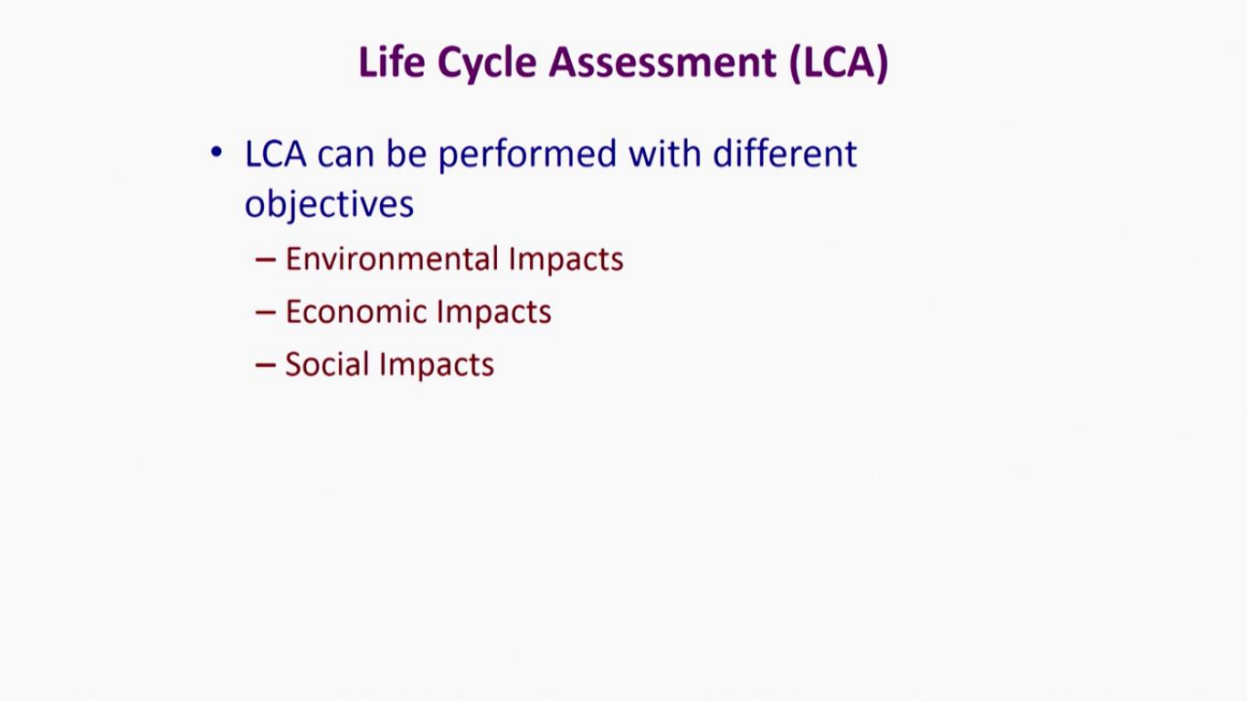


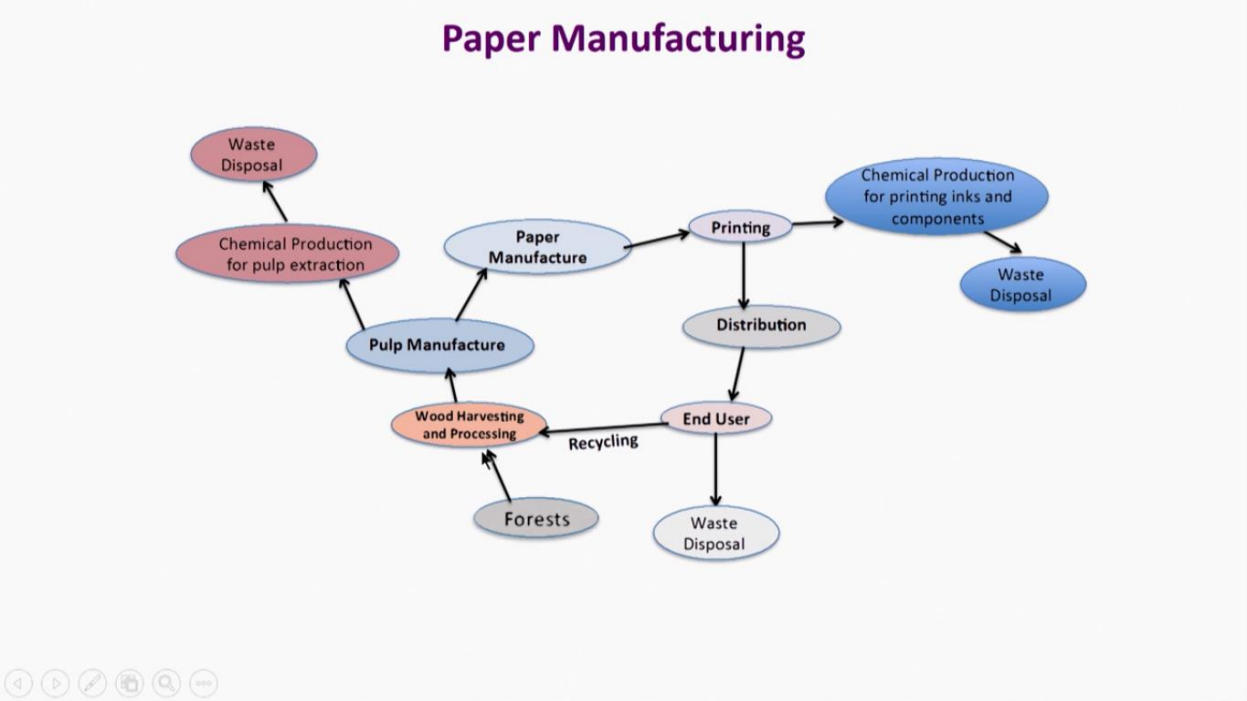
Hello and welcome to the last lecture and the sixth lecture of this series in the module risk assessment and life cycle analysis in the course on ecology and environment. So, the last lecture, the lecture five we ended with asking the question if there is a formal method for doing the analysis of a product or process in an organized manner and life cycle analysis is the method for doing that. LCA or Life Cycle Analysis is essentially a cradle-to-grave analysis of a product or a process. So, we would like to do a systematic analysis to assess the risk of a process or a material throughout its lifetime.



So, it is not just during its manufacturing process we see that in processes preceding the product and after its lifetime or during its usage we would like to see what is going on and track it. It is part of the International Standard Organization, and ISO guidelines for LCA or ISO 14040 and 14044; fourteen zero four four, and these are these keep changing over a period of time. So, one has to review this occasionally too. So LCA can be performed to assess the impact of a product. For example, impact of setting up a power plant in a particular location. The power plant is a product, is in some sense a product or any other component that you are looking for. To assess the impact of a process so impact of using a thermal process in a power plant, so the power plant itself is an entity in the first part the product is an entity that we do not really care how it is doing. It is a product that is it. The power plant. It is a thermal power plant that is one issue. Second is what kind of process is being used in the power plant. We can use different processes such as a thermal process or a nuclear process, and these are debatable things at which one causes more damage and in long run or short run in the case of an accident and so and so. You can also compare two the impacts of two different products for the processes, for example, comparison of thermal versus nuclear to produce power. So, this kind of analysis can be done in a systematic manner in order to produce, in order to give results and data that people can use in order to formulate policy.



So, LCA can also be performed with can be performed with different objectives. So, this is a very wide scope for LCA, and as you can see here we can do an LCA for environmental impact which is the objective what I will be talking about, and we have been discussing for the last six lectures, but LCA can also be performed for economic impacts or social impact. For example, starting a particular industry can reduce employment opportunities for a particular group of people that is both social and economic and it can it can change for example changing the import-export policy can change the economic environment in a country and so on. So, these are these are the other life cycle assessments that can be done. So economic and social impacts are very closely linked, and the environmental impacts is what we are going to be discussing primarily, but it can be done with other objectives as well.



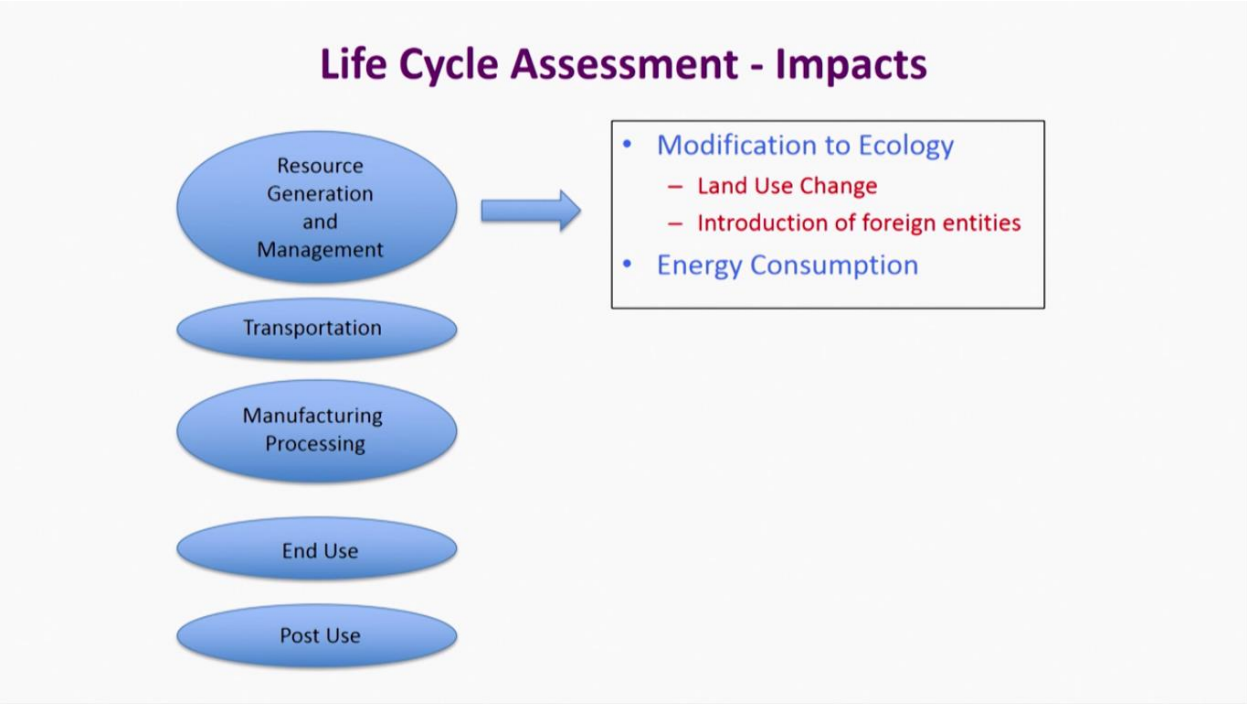
And, so let us look at a simple example of LCA to set everything in perspective so that it is easy for us to understand. This is a very general example. One does not need to know the details of this process except from very crude. So, paper manufacturing, the source of the raw material it comes from forest so forest; trees, paper made from wood, trees, wood pulp. So, we need forest for that. Those are the raw materials. From the forest we take wood. We harvest wood, and we process the wood, and we manufacture the pulp. The pulp is extracted from the wood. And this is a chemically intensive process because the wood is made with different components, and the pulp that is used for paper manufacture is one component of the wood, and it has to be removed chemically. And that is a very chemically intensive process and one of the original chemical very intensive chemical processes that started. And then we manufacture paper.

From the pulp, paper is manufactured in different grades by adding other additives and purifying it further, and paper manufactured, and printing is done on paper. Paper can also be used as it is but people write. So, printing can be seen so printing can be seen as both either you write with a pen that is printing as well or printing with in a printing press and then it goes to distribution and then end-user and then once end-user is done with a paper product. So, we all see that in our lifetime we have used a lot of paper and we have thrown it and so where do we throw it? When we throw it some of it goes recycles goes back to the pulp in the wood processing plant and they extract again and get the useful components again, and the rest of it goes to waste disposal. So, the waste disposal either ends up in a dumpster or a landfill or gets burnt or something like that incinerated some other thing.

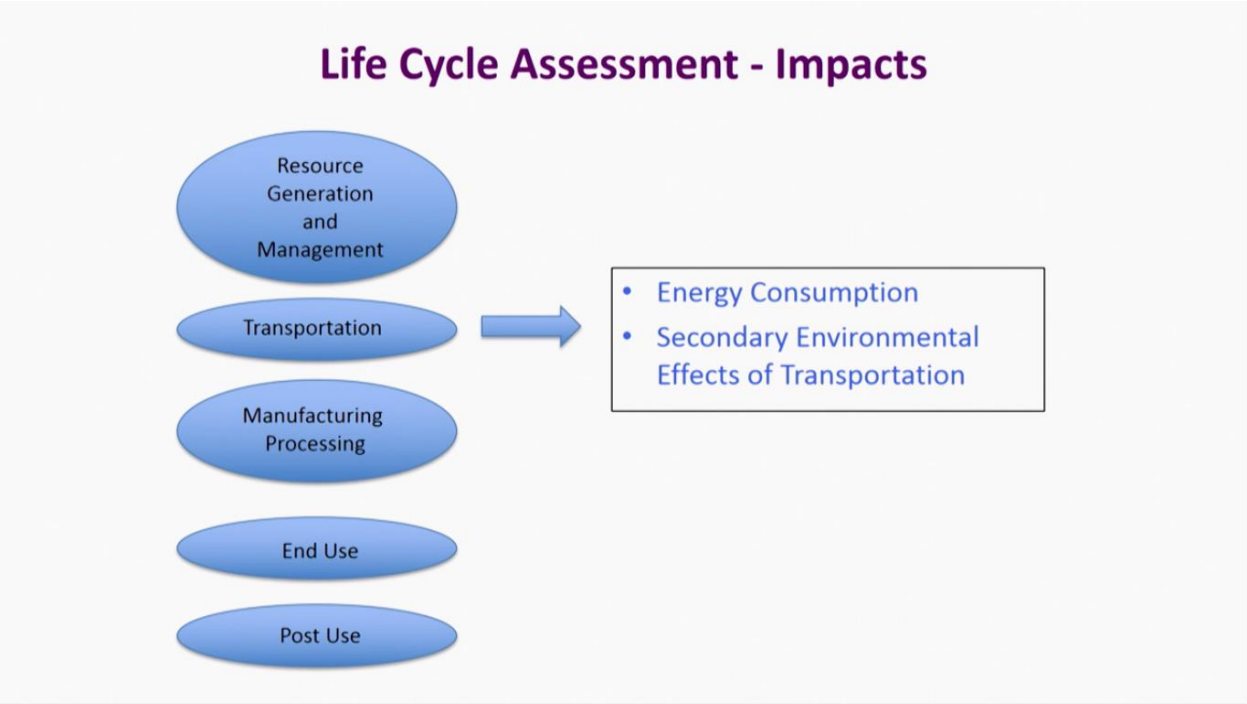
So, this is your main cycle of this paper manufacture. However, if you notice there are a few other secondary cycles here. The first one is the forest itself, a very specific type of wood may be required for specific types of paper and so and this is a big - and this has this has occurred in other processes as well. So, in order to have a particular product you need to have a particular

kind of raw material, and that raw material is not available, one grows this raw material. So, for example, if you want to have paper of a certain kind if that – if the wood that is naturally occurring in the area is not present then one would plant trees of that kind and then change the ecology of the system. So there is an ecological impact here, in a forest we have all mango trees and you cut on all the mango trees and put some other trees that are useful for paper manufacture, then you are your original ecology of the system is destroyed along with the mango trees the other things, there are several other things that will disappear and there is a new ecosystem that is formed and we don't know what is the impact of all that. So, so that is a change in the ecological pattern.

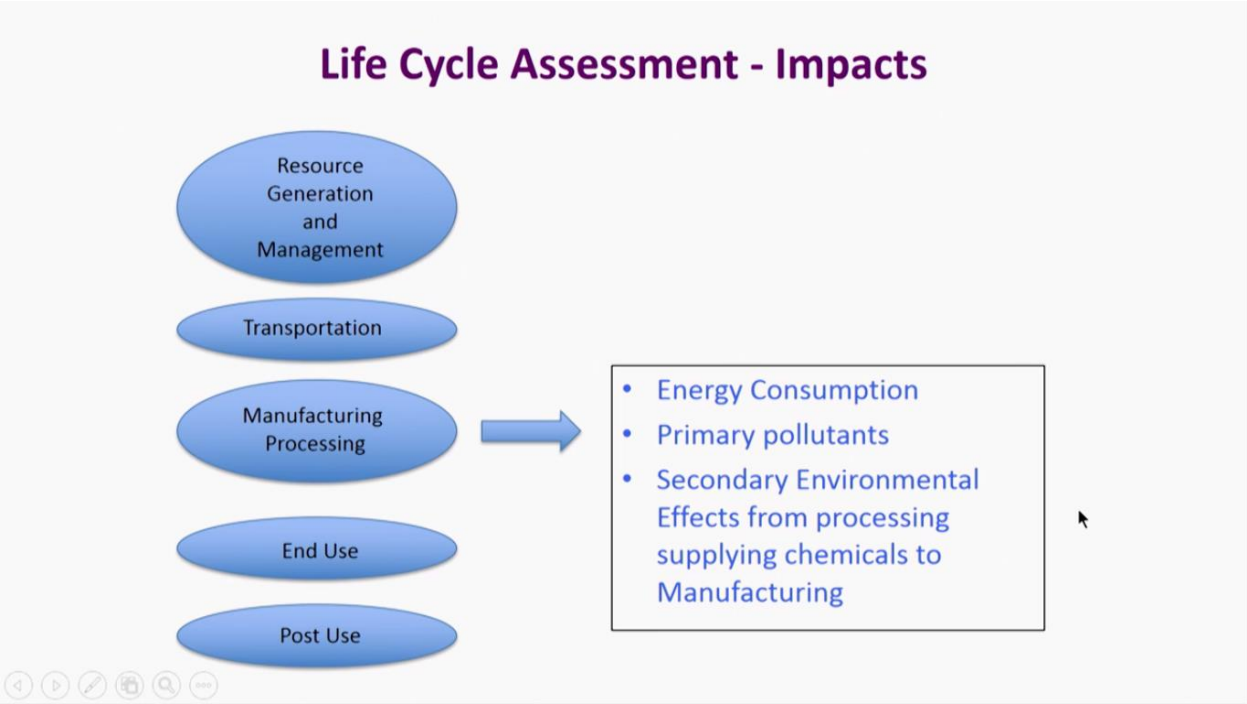
Second thing is as we see here, this in the pulp manufacture you have a as I mentioned it is chemically intensive process so which means there is a lot of chemical that are used in this. Which are produced just for paper manufacture, pulp manufacturing and as a result of this there is some waste chemicals that are released and we have to talk about their disposal. The waste disposal of those particular kind of chemicals and then you have another set, where you are printing, so if you are just writing, even if you are writing on paper you have ink, and an ink is a chemical and that is manufactured from somewhere. And there is a set of industries that do whatever it is necessary to manufacture the ink and other inks. When we talk about ink we are talking about printing toners, we talk about those kind of any ink printing inks and there is an entire there is an entire cycle. So, if I can take the production of this chemical ink as a separate life cycle by its own, but this is all part of the paper manufacture and sometimes these kind of industries come in close proximity to paper manufacturing industry because they supply their main end-user is the paper manufacturer and then we have the waste disposal of that also. So, then we have of course we have distribution, we have transportation cost. So typically, the forests – there is transportation cost involved in the forests to this thing, but if you notice paper manufacturing facilities along in the world they are located near forest, raw material is nearby and therefore the pulp is manufactured, and papers manufactures are all nearby but then the end user need not be nearby. End user is usually far away, paper that is printed somewhere and it is used somewhere else. So, there is distribution and transport and the end user may be very far away okay.



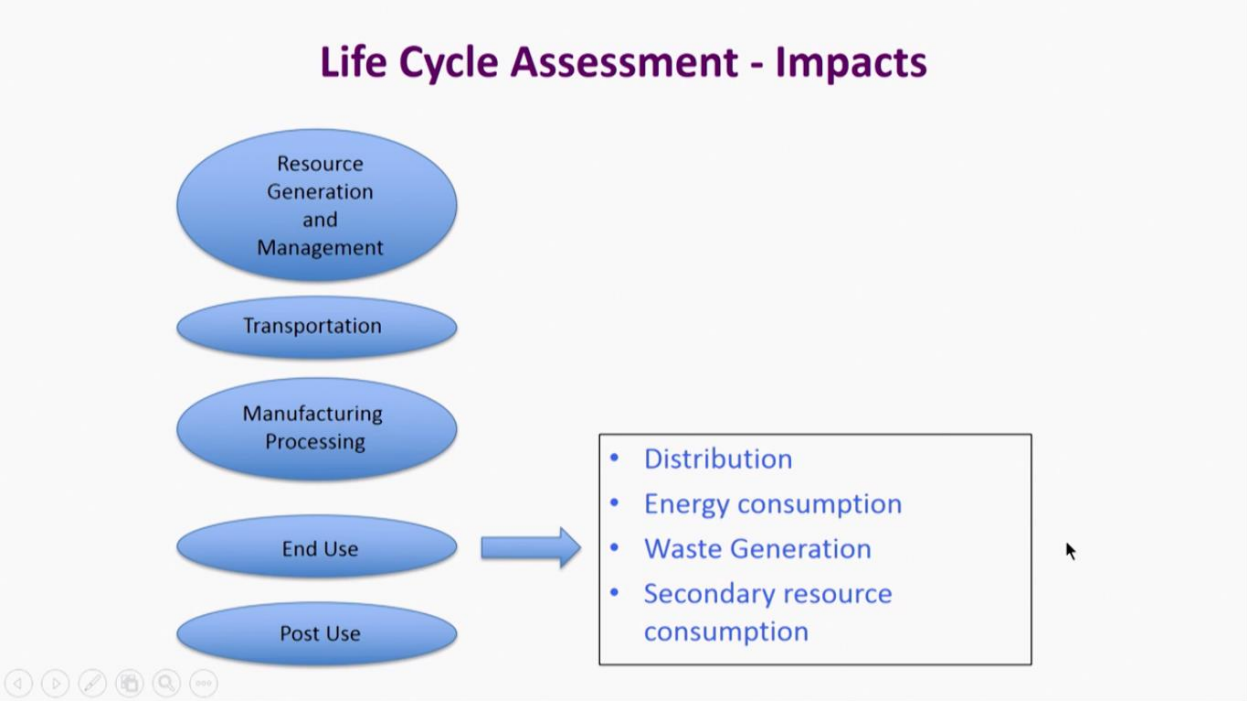
So, we have a set of impacts that can occur, and we have – I have again broken this up into different categories here. So, we at look at look at resource generation and management. So, the first thing is it is the case of a forest we have a modification to ecology, we have land-use change what we call a land-use is land is used for certain things. Land can be just waste land. It can be a forest, natural forest. When we clear natural forest to make a plantation, we are altering the ecology of that system and for example, we clear the forest and make a building there, we are also altering the ecology. So, these are all examples of the same thing. So, if you want to make a large factory you you clear a large section of forests and therefore or an apartment complex, you can clear large amounts of forest and make. What is the impact of that? To a lot of things, there can be impacts to groundwater flow. There can be impacts to climate, temperature and all that. So, these are all the impact that can happen and then, of course, there is energy consumption in all of this and introduction of foreign entities. This is a big problem. So, when we talk about ecology, we do talk about introduction of foreign plants and that along with it whether in the long run, this is good or bad needs to be evaluated and sometimes it is difficult to predict sometimes it is a question that one cannot answer but it can have serious repercussions to the way. So, it is not an easy question to answer and there is no straightforward solution to this, and it has to be seen in the context of the other aspects of sustainability in terms of economics and society and in a in a holistic manner.



We have transportation of different things. We have transportation of raw materials, chemicals, and the end product. There is obviously energy consumption. So, energy consumption is a big chain by itself. Now, we talked about global warming. We talked about the use of fossil fuels and how much of energy is consumed to transport. So, one way or the other transportation has to occur either transportation of the raw materials or the end products, transportation is inevitable and there when you have transportation you have secondary effects of transportation you have vehicle exhaust and things like that. So that is the case.

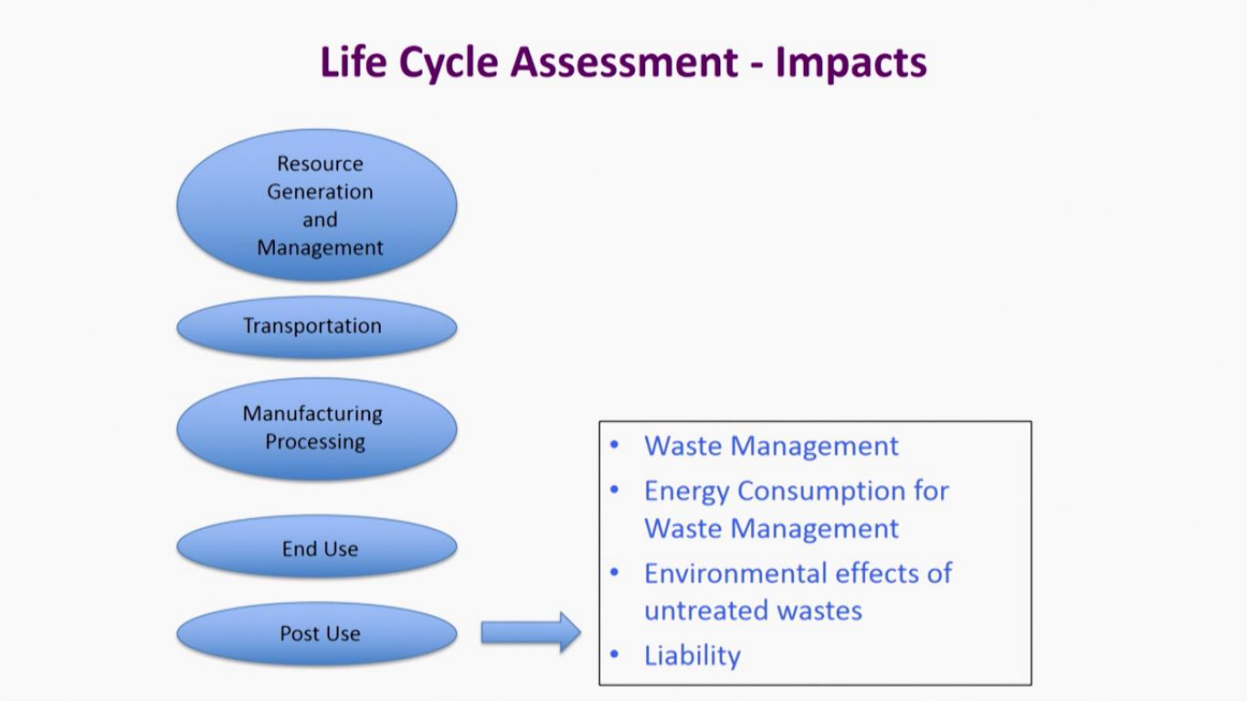


Then we have manufacturing process. Which is usually the most visible part of a life cycle chart, is that; people focus all their attention on the manufacturing process and that is the only thing that they look at because there are pollutants coming out of a process usually. There is energy consumption, a lot of energy consumption and then there – but here we also have to look at secondary environmental effects of processes chemicals that are being supplied. They are not manufactured here or used here. They are used here but not manufactured here, but there are secondary industries that do that. So, you can look up examples in any region. For example, a cement plant uses limestone and limestone is usually located near a limestone quarry or some such place. So, the facilities for these things are nearby, and there is a large section of other subsidiary industries that crop up which is economical, the economic environment of a particular process involves secondary processes which are important for the sustainability of the economics of that region as well. Okay.

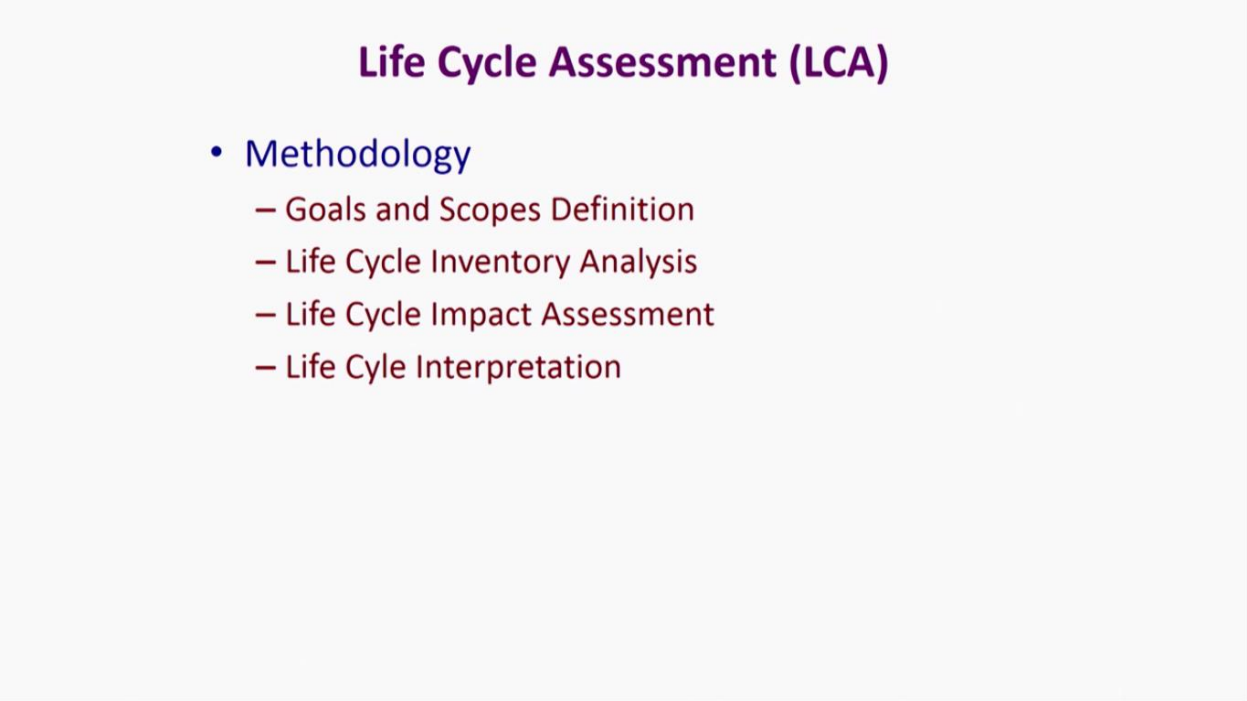


And we hear different stories about different communities and different industries getting wiped out because there is a change in paradigm. For example, if you have electrical cars a lot of car manufacturing and their subsidiary, if cars have thousands of components and these components are made by smaller corporation all of that would vanish. So, and what that would do to an economic and social sustainability social and economic conditions of certain large sections of people is something that needs to be evaluated as well.

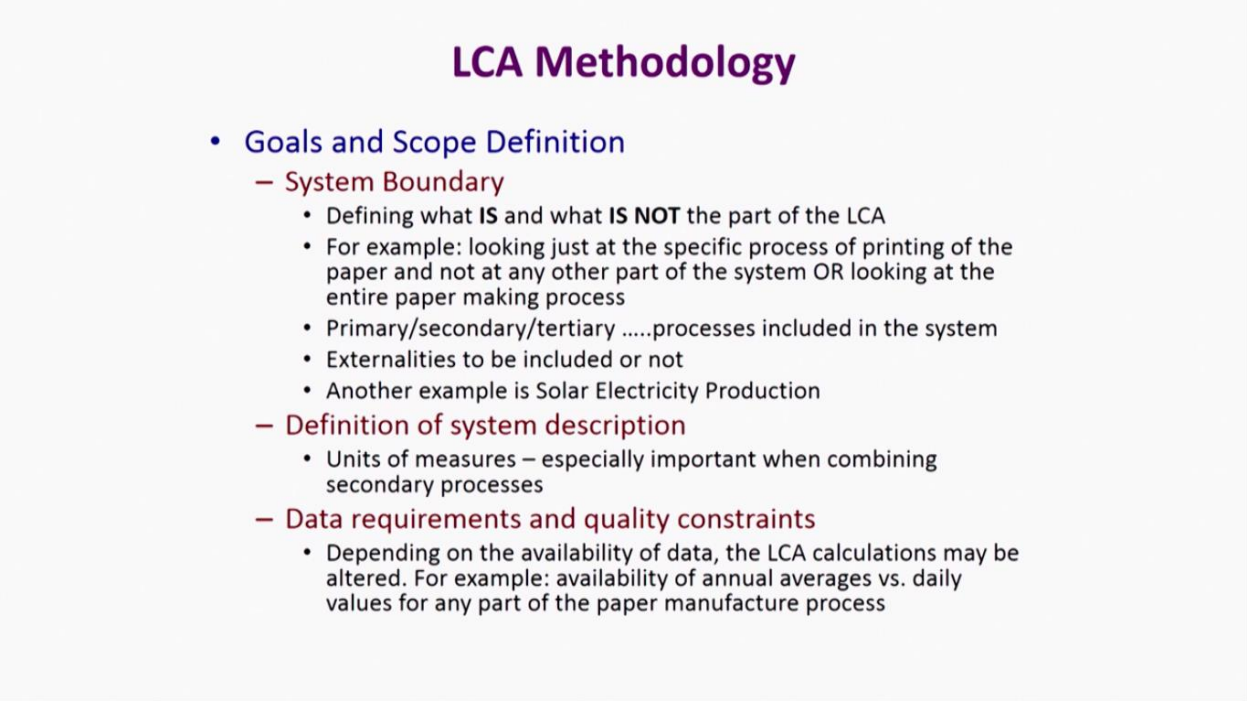
So, end use, we have again, distribution and energy consumption, waste generation, and the secondary resource consumption.



Post use is the disposal, is, once the paper is being used, what do you do with it and – so the paper is an example, is a soft example of various things and we saw this in the previous lecture the case of contaminated sediments. This waste management, there is the environmental effect of untreated waste, and there is a issue of liability and this can all come and hurt the corporation later.



So, there is a methodology for life cycle assessment. This has been developed over a period of time, and the first part is you define the goal and scope of the definition, and the second part is a life cycle inventory analysis, and the third is life cycle impact assessment. So, and the interpretation of the life cycle So we will go over each one of this, what it means in the context of mainly a paper manufacturing industry and some other examples.



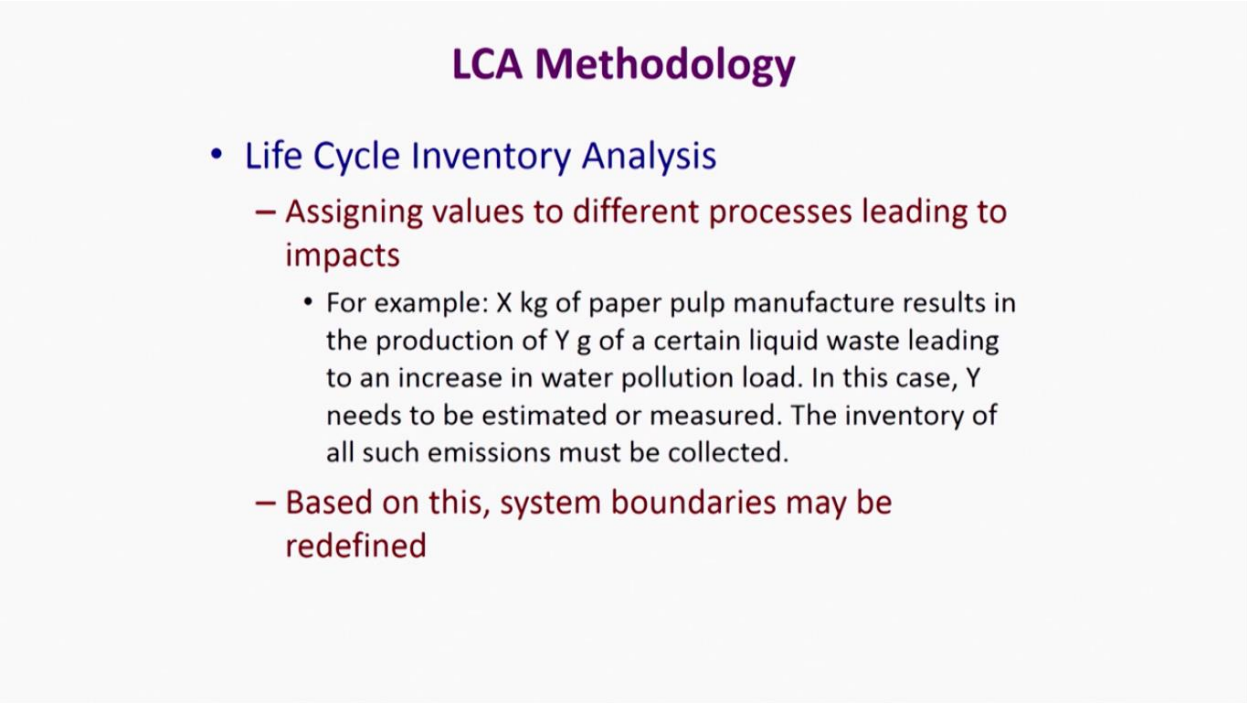
So, we look at goals and scope of definition. The first off, we have to define what is the system boundary.

So, in the flowchart that we gave for paper manufacture, you can only look at paper manufacture, not even pulp manufacturing, only the paper manufacturing part and say that you know, what is the – what is happening inside this and what is coming in, what is going out and that is all. Your concern is only that, but you can increase the scope, and you can say the scope of my analysis includes the forest and other subsidiary companies that are there. So, this entire scope is big, and you are saying what is going in, what is the raw material going in, what is the end product coming out, what is happening to these and so on and so the entire impact of the entire process. Obviously, the scope and the complexity of the process increases as you increase the scope and there are sometimes there are good reasons to do scope redefinition. We have a very specific problem. We have identified that one aspect of the process is causing more problems than other, we look at only that and see if that is – which of this process is really making a big impact. And so, what we – whether we include the secondary and tertiary process and externalities. So, what we call externalities in this context is something that you yourself are not directly getting.

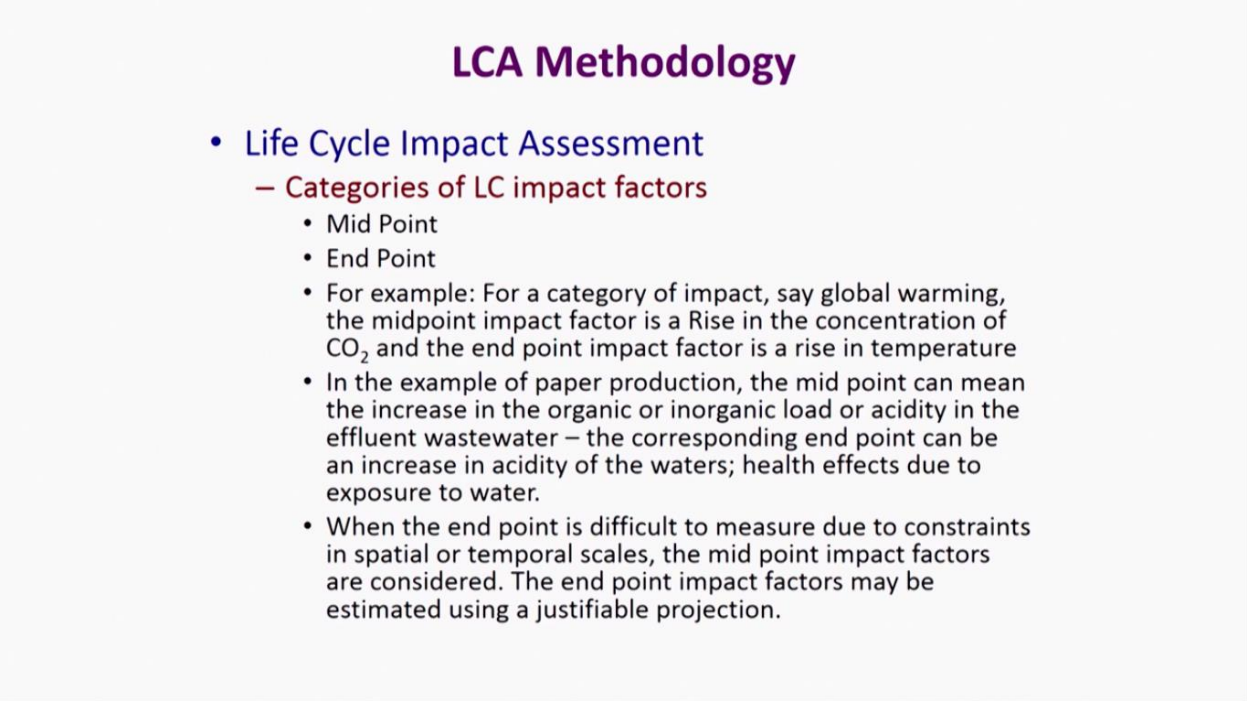
So, you are getting electricity from somewhere else, you are getting raw material from somewhere else, and you do not really know how it is -- that is being done. Okay. For example, I am buying a product, so I do not know where it is coming from. I am using it. So, if I take that into account then my my decisions about buying a certain type of product may change. So, this is the example of externalities and whether how energy is to be produced and so on. So, for example, solar activity production, if I am interested in installing a solar panel. So, my concern is only bringing a solar panel, but I am not really looking at where the solar panel is made, how is it made, whether that is a sustainable process and so on. So, if I want to include that my decisions about installing a solar panel may change and then definition of system description, we have

units of measures, important when combining secondary process and then data requirements and quality constraints.

So, one of the biggest problems in LCA is that if you have such a large process sometimes data is difficult to come by and you have to collect data and sometimes they may not be the exact kind of data that you need. For example, availability of annual averages versus daily values for any part, it may be - you may have to interpret or interpolate and guess these values are calculated based on some rationale, and this is usually a problem.

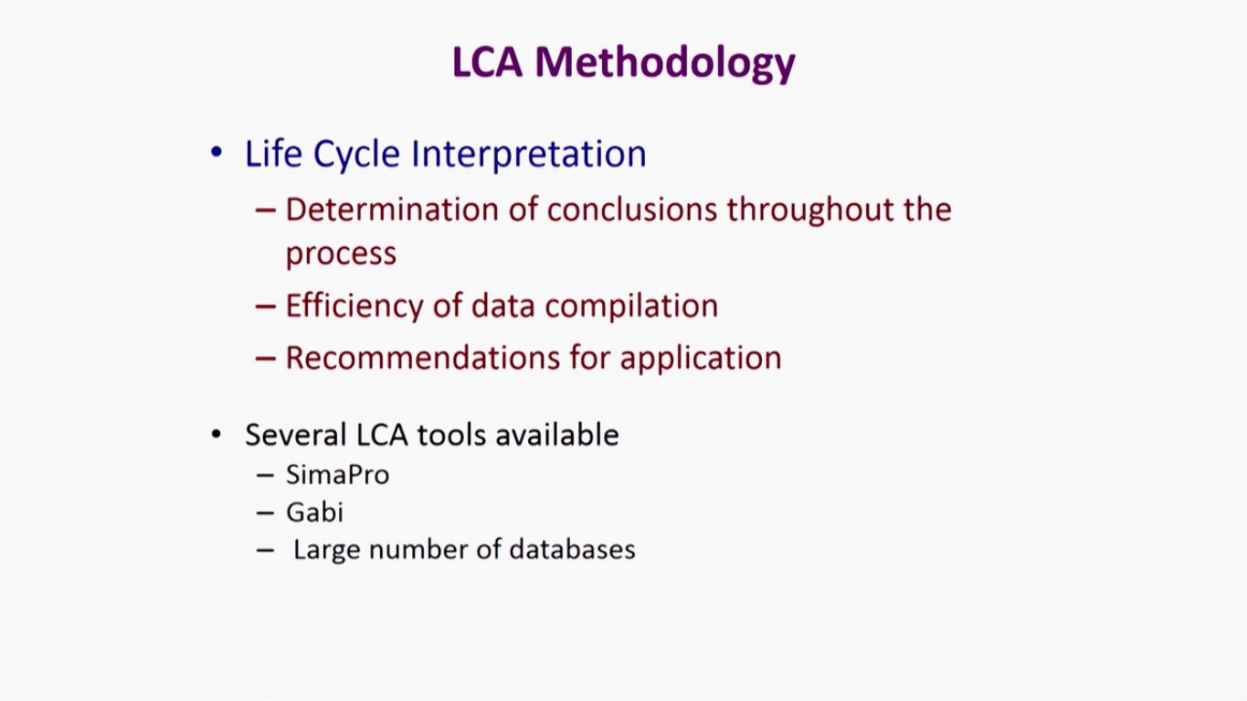


The second part is the life cycle inventory analysis. This is we are assigning. This is a very important part and a very data-intensive part. This is in fact the backbone of the life cycle analysis is assigning values to different processes leading to impacts. For example, very simply we look at X kilograms of paper pulp manufactured results in the production of Y grams of a certain liquid waste which leads to an increase in water pollution. In this case, Y needs to be estimated or measured. The inventory of all such things should be calculated and measured, and this is sometimes a big problem, and this data does not exist, and one has to then study and get this data and sometimes this is done by industry themselves. Sometimes it is done by other people like universities or private consultants. So, based on the availability of this kind of data the system boundary may be again redefined.



And the third part of its life cycle impact assessment, so the impact factors, for example, we can do it as a midpoint or endpoint. For example, for a category of impacts say global warming, the midpoint is a rise in the concentration of CO_2. But this rise in concentration of CO_2 is a midpoint because what really would happen because of a rise in CO_2 is an increase in temperature. But temperature increase may take 50 years for you to measure, if two degrees of rise in temperature will take, for one degree of rise will take 20 years then you cannot wait for 20 years. So, you are looking at concentration of CO_2 somewhere halfway, CO_2 has increased from, if it takes X amounts of percentage increase of CO_2 and that will lead to a certain increase in temperature, you can measure CO_2 and say infer that this is going to cause a certain increase in temperatures. That is a midpoint or an intermediate point. So, it is not necessarily exactly a midpoint. It is an intermediate point. So, in example in paper production the midpoint can mean increasing in the organic load in effluent wastewater, the corresponding endpoint can be increasing in acidity of the water or the water's reaching – releasing the pollutant wastewater into soil necessarily does not directly at that point in time result in an impact in health. The impact in health will take maybe five years, four years so but this is an this is a intermediate point where we can measure, and that is seen as an indicator.

When the end point is difficult to measure due to constraints in spatial or temporal scales, the midpoint can be considered, and it is justifiable.



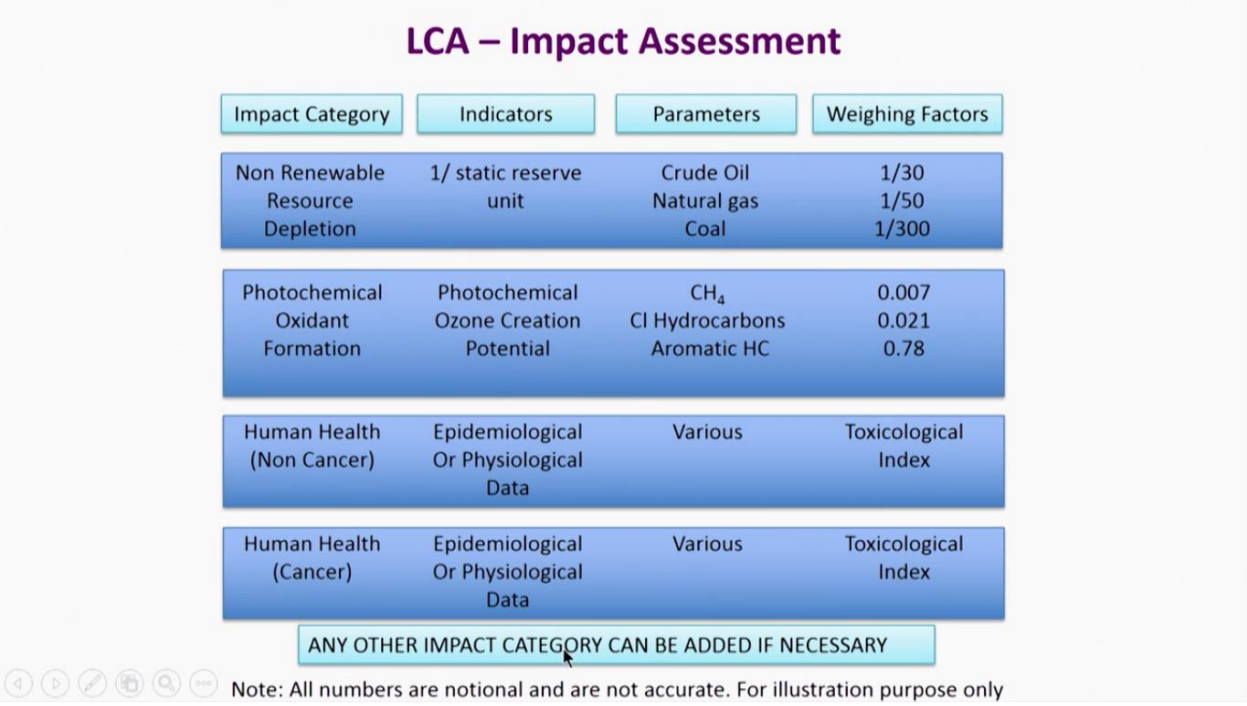
So, interpolation here again, one has to make interpret the data correctly, and this is again it is a holistic process. This is something that determination of conclusions that throughout the process. And it relies on the efficiency by which the data is comprehend and the correctness of this data that is collected also. And the recommendations and one has to make recommendations of the applicability of the LCA; what are the policy changes or the management changes or the process change that needs to be done using this LCA methodology. Several tools are available. These are, some of them are free to use called SimaPro and Gabi and a large number of databases. This database is the biggest challenge, constraint in terms of LCA methodology because this is process driven and then enough studies must have been done either by the corporation or sometimes the data is not available easily. One has to go and get it, and one has to worry about. This is the role of regulatory agencies, and other academic institutions becomes very important in this kind of processes.

LCA – Impact Assessment

Impact Category	Indicators	Parameters	Weighing Factors
Global Warming	Global Warming Potential	CO_2	1
		CH_4	23
Acidification	Acidification Potential	SO_2	1
		NO_2	0.7
		HCl	0.88
		NH_3	1.88
Eutrophication	Eutrophication Potential	NO_x-air	1
		NH_3 - air	0.7
		N - water	0.88
		NH_4^+ water	1.88
		P- water	
		PO_4^{2-} water	
		Organic load	

Note: All numbers are notional and are not accurate. For illustration purpose only

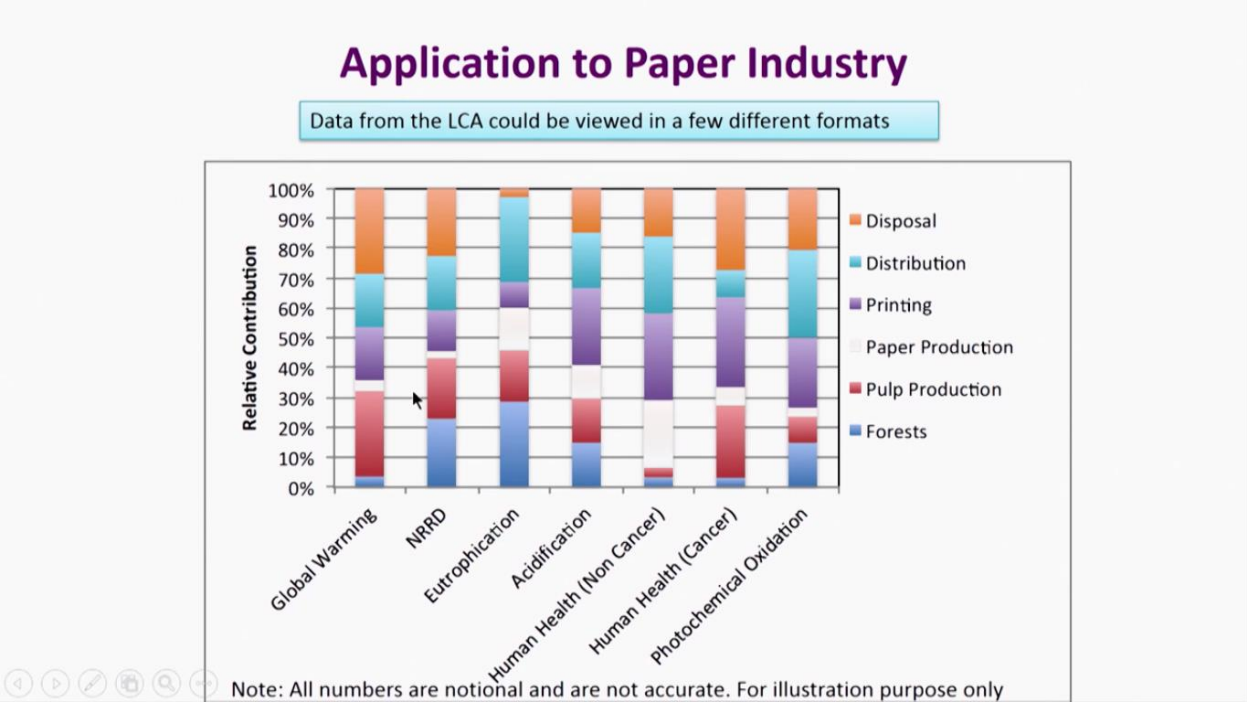
So, let me just go and illustrate the categories by which impact assessment is done. One of the impact categories that we can look at is say global warming and indicators for the global warming or global warming potential, the parameters that we are looking at is things like CO_2 and CH_4 or methane concentration and weighing factors. So, what we mean by weighing factors is the effect of methane is 24 times the effect of carbon dioxide. So, this is what is meant by a weighing factor. So, these numbers are all notional, and there are not accurate numbers. I am just giving you an example of what an impact assessment could mean. Another impact category could be acidification of water or air or soil. Any of these things. So different components of this enter different parts of the environment. So, we have acidification potential. The parameters are sulphur dioxide, nitrogen oxide, HCL, ammonia and so on, and different weighing factors. We have eutrophication. Eutrophication as many of you would already know is the potential to form algae in water and we have a large set of compound of nitrogen and phosphorus in the water and air and if they have different kinds of weighing factors and all these numbers are notional and not accurate and only for illustration purposes as I had mentioned.



The other set of another set of impact categories are non-renewable resource depletions. So, for example, this is things like crude oil, you know they are not renewable. There are fossil fuels. We have crude oil, natural gas, and coal and we have indicators, this is the fraction, per the static reserve unit. Of what fraction of it is being used up and this indicates that how much of it is available remaining. So, we are only using up one three hundreds of this available coal this thing, and that will mean that this reserve will last how much time after this process is done. Photochemical oxidants formation. So, this is an important fact. Photochemical oxidation is an important process in urban air quality. This is a big focus on photochemical oxidation, in few decades ago starting with the in Los Angeles and other cities similar to its topography, and there was a lot of research done there because of smog formations. Smog formation is in important in many cities we see that and smog is a mixture of all the things that you can see in the atmosphere, and there is reactions going on, and this reaction happens because of photochemical oxidation because of sunlight and all that. So, and certain chemicals are responsible or can aggravate photochemical oxidation and form certain species of chemicals that will result in photochemical oxidation.

We have human health as an impact category, and this human health is again divided into two categories; human health non-cancer and human health cancer. So, as we have discussed in the first two lectures of this series we have – the way we find out, the indicators for this are health effects eventually these health effects are epidemiological. What it means by that is we can correlate as I mentioned in the first few lectures. If you do not have physiological evidence, for example, you have a health impact because of air pollution of a specific nature okay. So, one needs to find out whether that specific air pollutant is causing that health effect or something else is causing. So, people look at statistics of how many people are exposed to it and the concentration the outside, and they try to correlate the concentration of the pollutant in the atmosphere to the health effects. So that is a indirect correlation, statistical correlation and this is

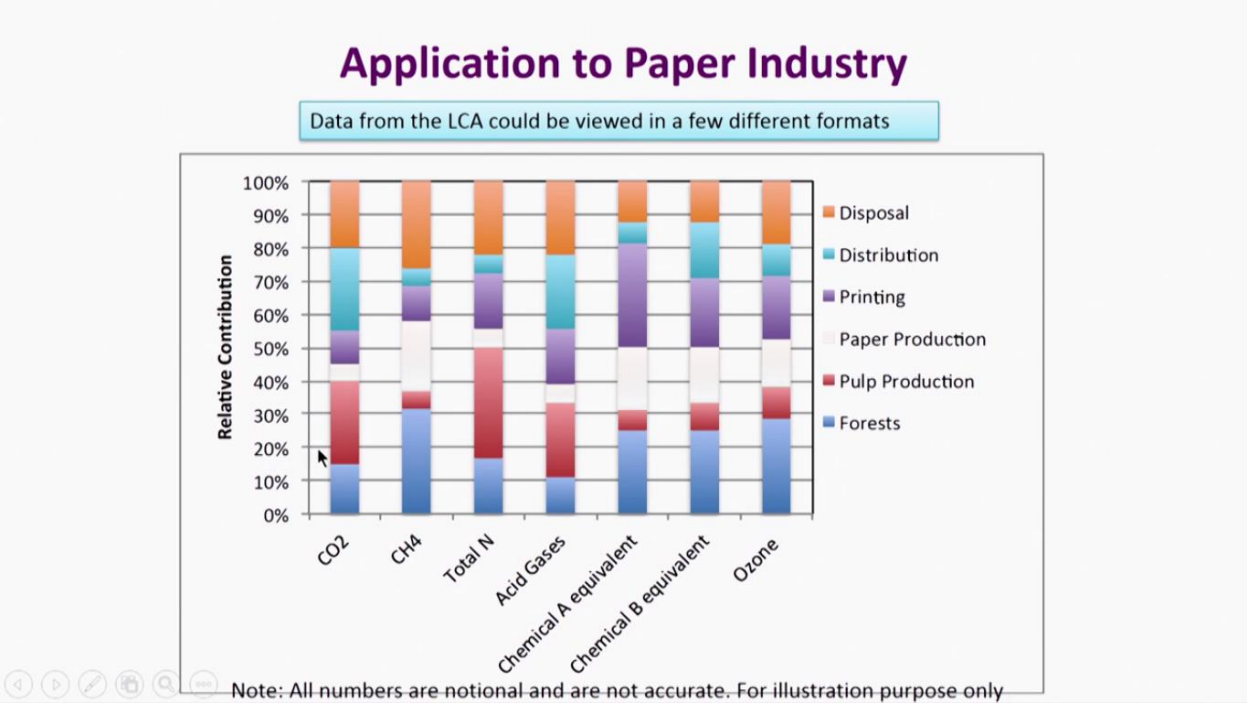
called as epidemiological, and this looks, this takes surveys from, and the hospital records of a very large number of people and then makes this connection. In contrast to this physiological evidence is direct evidence from the human body that you find reserves of a particular pollutant there and says this is direct evidence that this is causing this kind of effects and people do have toxicology data for many of these things but not for humans. We have it for other species, and they are then interpolated to -- extrapolated to apply to humans, and there are various parameters. These parameters are the concentrations of different species of chemicals that can cause chemical impacts.



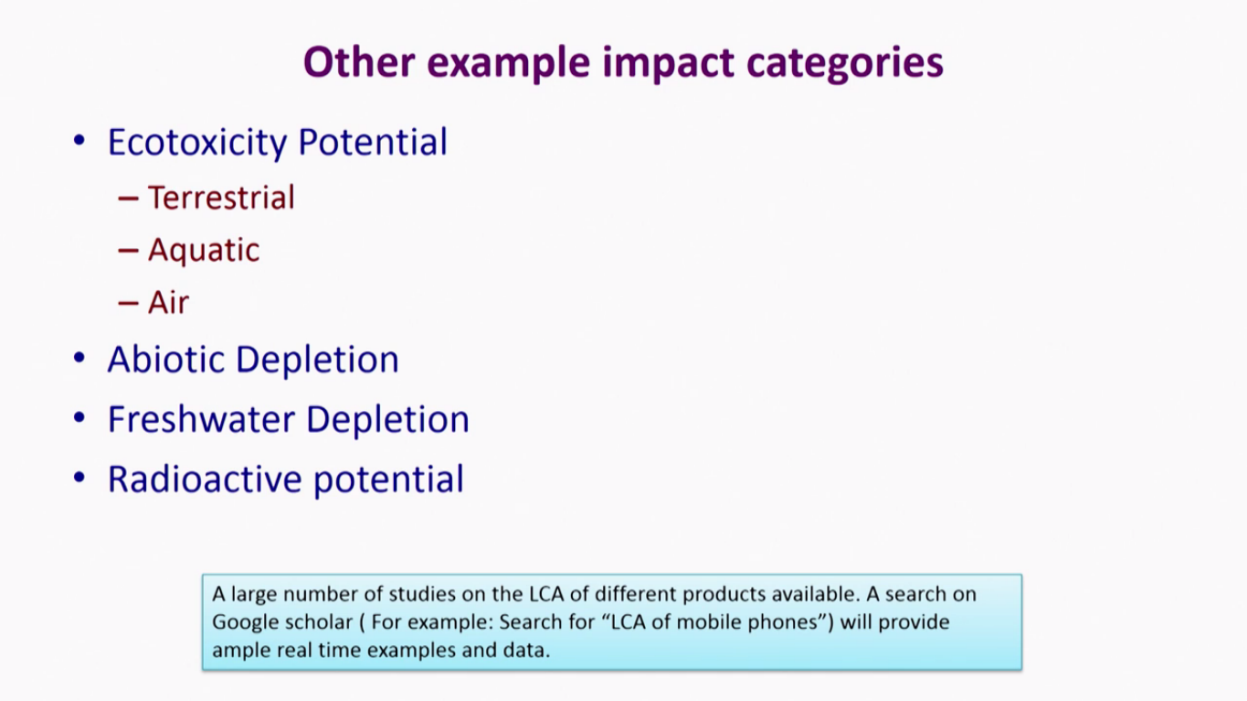
Any other impact category can be added to this if necessary, and this example of this will show you shortly. So, application to the paper industries data from LCA could be viewed in a few different formats. One format is the following. We have a relative contribution from different processes. For example, we have we have forests the aspect of raising a forest, the way the trees are grown from the pulp production, from paper production these are different processes in the paper – this is again notional. This is not the actual – these numbers are not actual and please have to take it in, as an illustrative, but this can be done. What I am trying to show is this can be done, calculations can be done using LCA to get this kind of data interpretation.

So, we have what is the global warming contribution by each of this process. So, in this process say the disposal causes the paper pulp production and disposal are - give highest contributors to the global warming and so you can see that in different categories are different kinds of this human health cancer. So, it it does not mean that these all these risks are the same. Each one may have a different amount, the actual human health cancer for potential may be very small, but these are the different distribution of these things different process for that particular cause. So, these are not within that category. There is a 100% distribution, so actual numbers of this are not

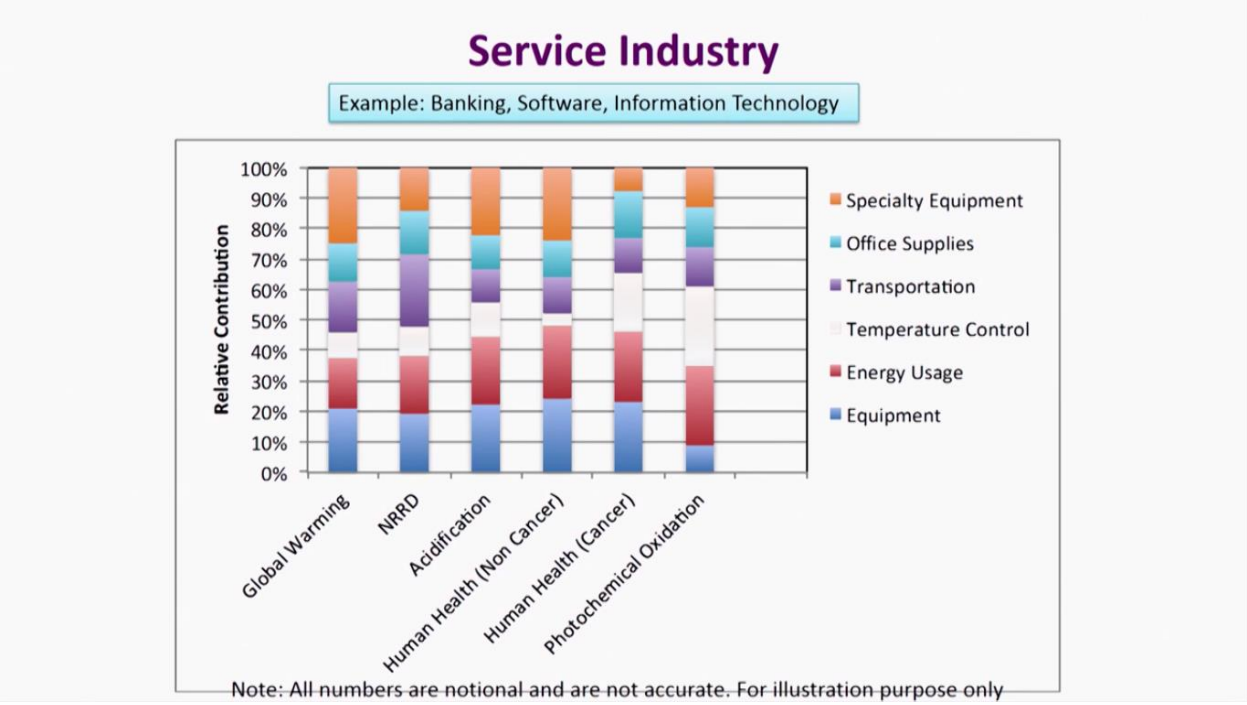
comparable human health cancer cannot be compared with global warming. Each one has its place. They are two different aspects and cannot be pitted one against the other.



The other type of interpretation or the data view is like this is looking at the parameters themselves and which one of these processes releases more of these parameters. So, this is sometimes a useful analysis to do because if you identify that CO_2 is coming from a particular process and you do not want it, and you can focus on modifying that process alone and to reduce the CO_2. So, in some analysis, we also have a negative contribution that people have made all of advances and therefore they can – there is something called as a carbon credit system or something especially applicable in some kinds of some category such as global greenhouse gas potential and all that. So, we will not talk about it here. It will be discussed in another module if possible.

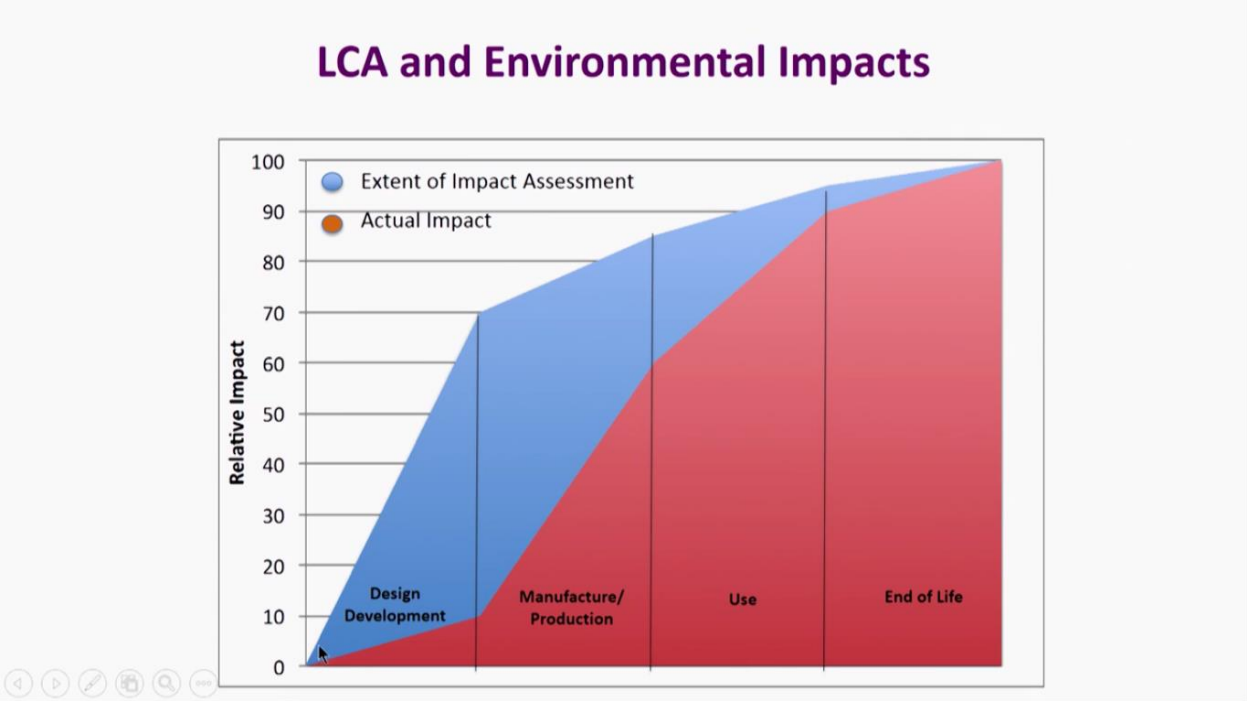


Other examples of impact categories are ecotoxicity potential both terrestrial, aquatic and air. Terrestrial is to land, to soil, to forests and anything that is there on land. Aquatic is water and air. Ecotoxicity is again degeneration of the quality, environmental quality of these phases. Abiotic depletion and then we have fresh water depletion. This is a big case in a country like India. This is an impact that is very significant. We have several cases where industry several industries have been alleged to have take deplete water supplies and if you go and look at paper reports and this is an important this thing. So environmental impacts, this is not a health impact, but this is an environmental impact. So, this is – there is also radioactive potential based on certain kinds of process; not all processes use radioactivity material, but definitely, something like a nuclear reactor or something which we have debates in several parts of this country that about the safety of having nuclear reactors. This is definitely a case. So, a large number of study on LCA and different products are available. You can go, and search say on Google Scholar or some such search engine search for LCA for mobile phones for examples, and you will get publications real-time examples and data, and I encourage you to do that for any industry of your of your choice.



One other thing that I would like to point out is the LCA for service industries and most of us believe that one of the important points that we would like to make is for service industry and most of us believe that LCA applies only to industries that manufacture something. Service industries do not manufacture a product. They manufacture software or service something like banking or IT industry or software, and you can notice that there are studies that have been done where these same kinds of categories of impact exist here also. The magnitude may be different. The actual magnitude of global warming potential may be different from a service industry as compared to a power plant, but it does still exist, and people are required to do it, and this categories are of course different. You see that here we have things like equipment that a company might have, energy usage, temperature control because air-conditioning is a big part of some of these industries software industry and all that and then transportation is a big part. Office supplies, specialty equipment. So, there is no – so hospitals, for example, they are service industry, and hospitals have a very large potential for a lot of things, and therefore it has to be evaluated.

Again, these numbers are notional and not, is only for illustration.



This is an illustration of where the LCA is useful and how it should be implemented. So, if you look at this the extent of impact assessment, the assessment of the impact which means that at what stage if you do the impact assessment in the design and development stage if you put – if you do the actual impacts may be less if you do it here. If you do the impact assessment here – if 80% of your impact assessment is done at this stage you get actual impacts at here, and if you do not do it, you do you do impact only at the end of the process you get all of it. So, this is a kind of a suggestion that impact assessment, the design should be done at the design stage, so you must have all the aspects of the life cycle assessment of a process to be done at the beginning. So, to the extent possible. So, it is always – it is not possible to predict everything that will happen, but to the extent possible one must have the these categories calculated.

So, we will summarize this particular lecture and the entire module by the whatever we discussed here, is that the design of processes must be evaluated from cradle to grave to the extent possible. So, and this I think is important for maintaining the all aspects of our sustainable development goals. All impact must be evaluated at every stage. Technology development must have LCA framework implicit in its design and must be included in the business plan. So, a lot of time environmental impact or any of these things are seen as an externality, as an overhead and what we mean by externality is they are dumped to somebody else.

So, I think that should not be the case ideally and then one should incorporate everything within the process and think about what kind of component one is including and making in their process. So that it it makes it easier even at the expense that the society has to pay for it. So, we are all part of this system. So, sometimes it becomes that if I make a sustainable product it is more expensive but then if all of us buy into this philosophy then I think we all have to pay for it and this is an economic concept that it also has some traction and some theories. So, technology has to evolve in order to meet and the data that is associated with evolving technology must also be generated, and all processes must adapt to create a more sustainable environment and society.

Thank you very much.