Sustainable Transportation Systems
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology Roorkee
Lecture 33
Life Cycle Assessment (LCA): An Introduction

Hello friends. You may recall that we have studied the role of EIA in achieving sustainable transportation and then we also discussed about land dues, land planning and then the planning of the transportation itself, traditional, the new one, traffic calming, different measures, and all those things. So today we will start to discuss about life cycle assessment.

This is also one tool which is very useful, very important, because it gives us the complete scenario from one end to the last end like cradle to grave. From initial point of the origin to the last when anything is discarded and what is their impacts. So in that sense life cycle assessment approach is also very important perspective to look at things, and it can be used to achieve sustainable transportation systems.

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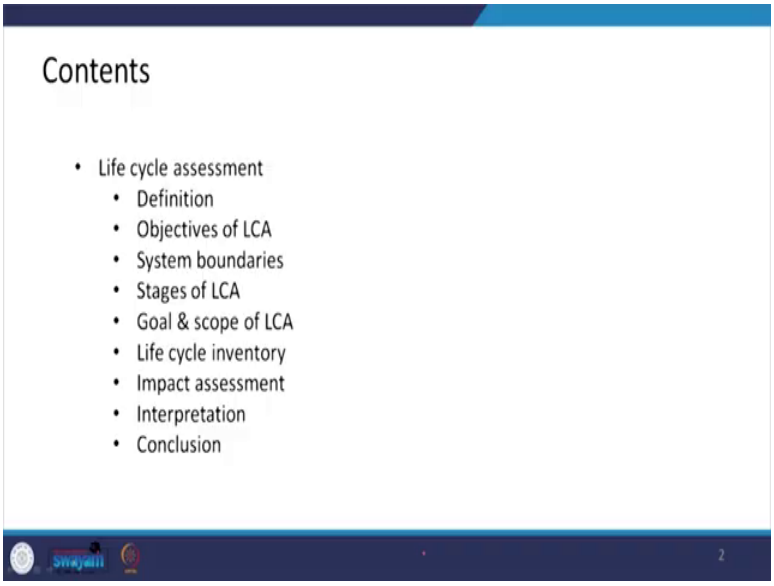

So today we will discuss about the introduction, what is the life cycle assessment, how to define it and what are the purposes of life cycle assessment basically, then the system boundaries' role, because life cycle assessment can also be categorized or classified in different small segments and then the stages or straps of LCA life cycle assessment, and the scope and the goals of LCA.

How to achieve those and then what is the role or inventory of data collection and preparing of the inventory for achieving this life cycle assessment exercise and then we do the impact assessment and how to interpret those assessment which we have carried out and how to conclude or what is there in conclusion in a nutshell, the introduction of the life cycle assessment. So today this is the introduction of LCA or life cycle assessment.

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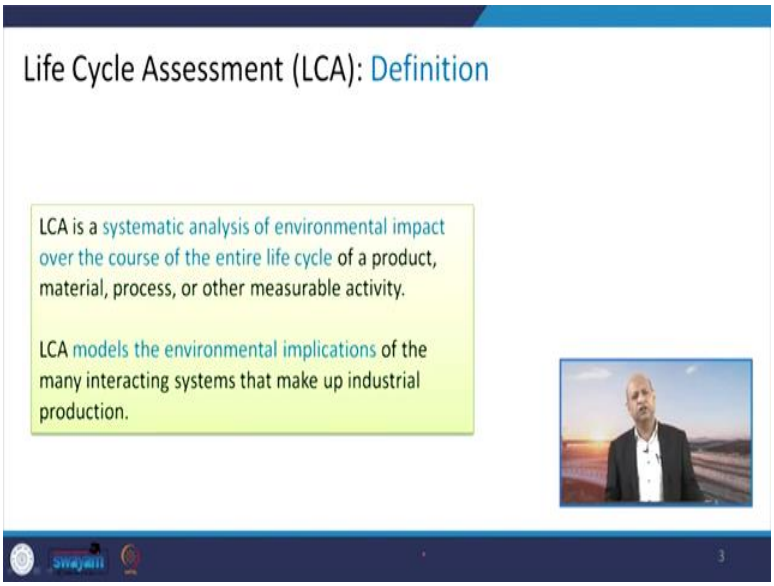

So it can be broadly defined like it says systematic analysis of environmental impact, because we have already seen the environmental impact assessment, EIA, so after going through this particular lecture, I am sure you will be able to differentiate between EIA and LCA. What is EIA?, in what way we look for the impact assessment, in perspective of the environment of a particular activity, or the project and what is the LCA of a particular product or service or project, whatever it is.

So LCA is basically again, it is related to environmental impact, but over the course of entire life cycle of a particular product or material or process or service or any kind of activity which is measurable, which we can quantify. So completely life cycle, that is the biggest difference. In EIA we do, like for example some project is coming up, so we conduct the EIA, what is the impact on air quality.

So we compare with the baseline data and see its impact and during operation also whether during operation of a project like of a factory or a particular highway, will it influence the air quality or water quality and those kind of things. So we see a particular duration, but in this we see the entire stretch of the life cycle of that particular activity.

So this is the big difference and then the modeling or the viewpoint of the environmental implications is also very important from several aspects, means different system viewpoint and the activities viewpoint. So we put together in an integrated way and we see that the complete life cycle of that product or process, how does it influence the environment in all the aspects, complete aspects. So it is a comprehensive exercise basically.

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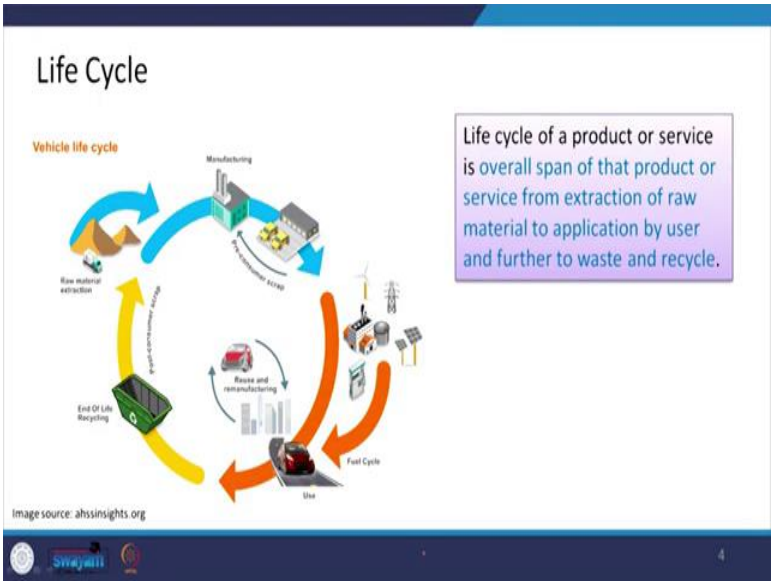

So in this pictorial representation you can see the life cycle, let us have an example because we are discussing the transportation systems. So let us see if a vehicle is there. So what is the life cycle of that particular vehicle? What happens basically, like for a vehicle if we need like steel or metals, etc., so first of all the raw material is extracted from the mines or whatever source is there.

So it starts from there and then it goes to the manufacturing plant, so there this is processed, even before, between this also, like iron ores, then it is processed properly and converted into an iron sheet or steel sheet or pipes or different kind of products. Then it comes to this car manufacturing

factory, so then there are some scraps also during this production of the car so that scrap goes again to the manufacturing plant where it is melted and again converted into sheets, etc.

Then it comes to the usage, so it takes some energy, if it is driven by like fossil fuel, etc., what is the energy source, if it is driven by battery then electricity can be there otherwise petrol pump is there which will be used for gasoline or diesel. So then it will be used by using this energy source. So this is another aspect.

Then we are using it so in complete life cycle whether 15 years or so, when we are using this particular vehicle, so in that duration also we are using petroleum products, we are emitting some suspended dust, so there are various activities related to even transportation. So during that also there will be impact on the environment, like oil leakage and fugitive emissions, passive emissions, all those non-exhaust emissions, exhaust emissions.

And then when the use is over then it is gone to the scrap. It is discarded. So it will be broken into different pieces and maybe some useful items will be recycled in the market otherwise it will go to the landfill or different parts can be used for other activities. Something can be recycled, something can be reused and that way it will be finished.

So it starts from this particular raw material extraction, to the complete disposing of that particular car. So from that cradle to grave, this is known as, so that complete life cycle. How does it influence the environmental segments, environmental component, whether air, water, soil all those things.

So, entire life span is studied and every step, every kind of activities, incorporated, included and quantified so we see the cumulative impact. This is much more than an environmental impact of a particular activity for few years, it is the complete life cycle assessment. So this is overall span of the product which is studied basically.

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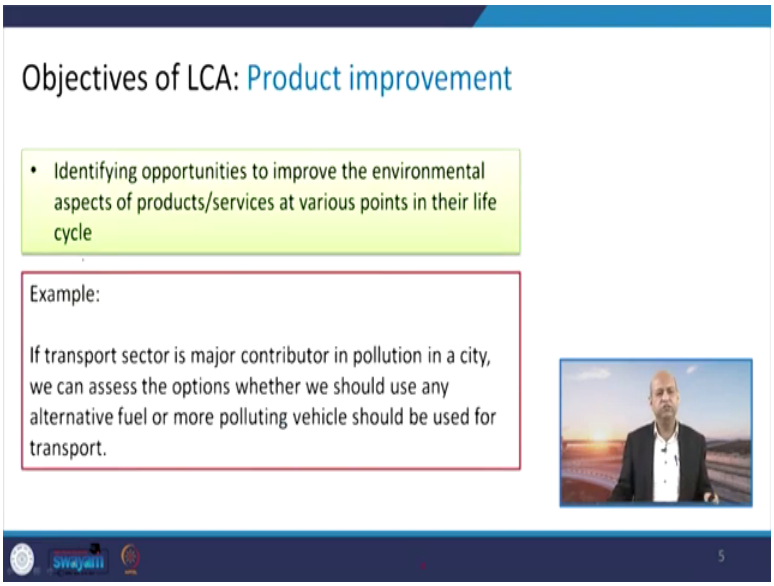

When we see like what is the purpose of LCA, why do we conduct LCA, what is the objective, what do we achieve when we conduct life cycle assessment? So it can be used or the purpose can be manifold basically. For example like if you want to improve the product so through life cycle assessment, if you know that if you change this particular raw material how life cycle assessment will be there. Some material usage may be different, then fuel may be different.

So those kind of products, like example is there, in a city transport sector is a major contributor of the pollution. So whether we can go for different options of alternative fuels, example is there of Delhi when diesel was used. So the emission was different, when CNG is being used the emission is different. So, that way air pollution has been reduced.

Of course not all pollutants have been reduced, but significantly deduction is there, improvement in air quality is there. So how can we achieve those kind of different life cycle assessment depending upon different fuels. So that will, we able, means it enables us, this life cycle assessment exercise enables us that if we change the fuel what will be the total impact.

So product improvement may be there in terms of fuel or even car like battery operated car, how LCA will be of this battery operated car, vis-a-vis petroleum driven car or gasoline driven car. So comparison can be there and we can improve after comparing LCA related strategies.

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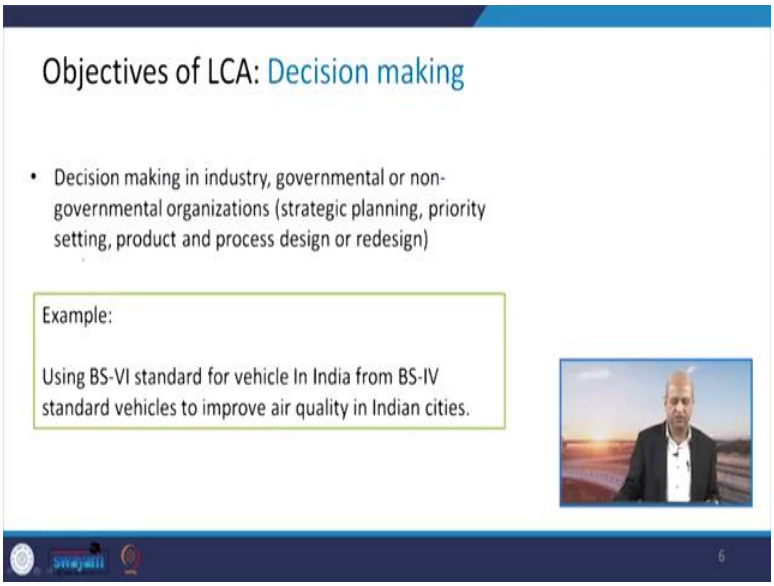

It also helps in decision making. What is the better strategy, what is the better plan, what priorities we should give to some processes or some policies? So policy impact evaluation can be or some decision making process can be held by LCA, example is very simple like this BS-VI standard for vehicles in India from BS, Bharat Stage IV, like Euro I, Euro II, we also have BS-I, BS-II.

So, from BS-IV or Euro IV if we are jumping, doing like a leapfrogging kind of a thing to BS-VI and avoiding this BS-V altogether; so how this will impact the air quality and then indirect impact on the health of the public. So those kind of things, decision making can be there through LCA also, because when you are conducting LCA, it will give a better picture whether the contribution of BS-VI, how much advantage or profit will be there in terms of air quality improvement and health risk reduction.

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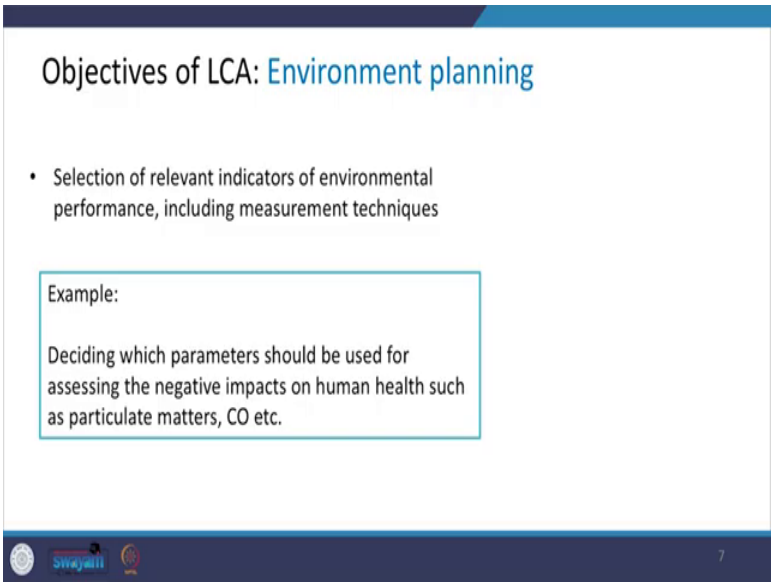

Also like environmental planning we can do some relevant indicators which are related to performance, including some techniques, those kind of things, so if you want to decide some parameters based on LCA for environmental planning, it is also a good tool. So, some negative impacts on the human health or a particular pollutant let us say particulate matters, CO, etc.

So if we are planning, we are doing a planning for the environmental impact through different kind of pollution sources so we can see through LCA that which pollutant stream will be less in a particular planning strategy. So that for planning purpose also LCA helps us.

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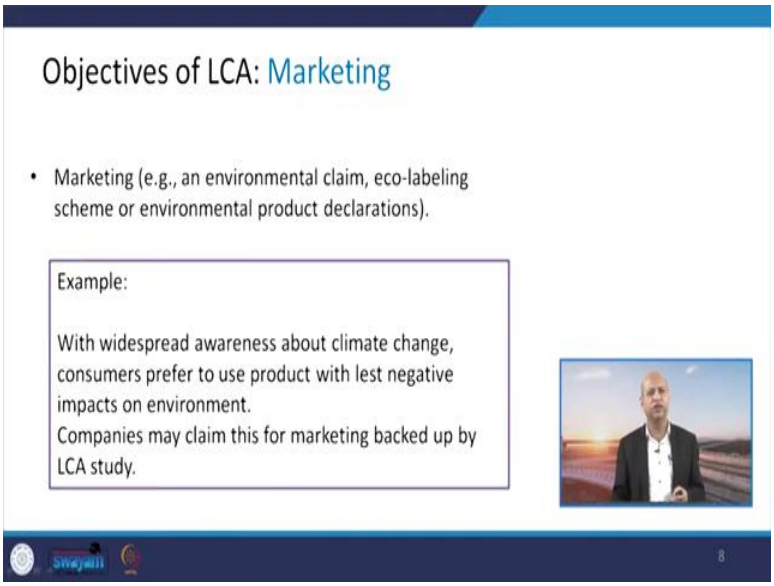

In marketing strategy also, because when you are able to have good decision based on LCA, you know categorically that this particular process or product is better when you are doing exercise from beginning to the end, so you can always claim or publicize the product that this is the better product from LCA perspective.

So you can influence the clients or the consumers because nowadays consumers are very aware about the green technology or those products or services which influence the environment in less amount. So some awareness related campaign or some other product related strategies for marketing and publicity LCA can also be a very good tool.

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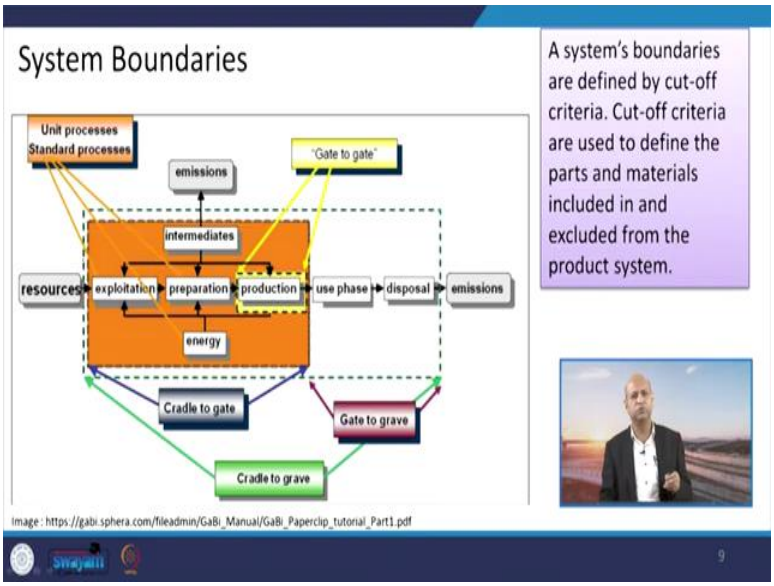

Then we go for like system boundaries, because whenever we are going for some stages or the LCA, then the role of system boundaries is important, because we do, based on certain criteria, cut off criteria for example some parts or materials, whether we should include it or exclude it. So it will depend upon how much boundary condition we are applying.

So it may be from the initial to end, plus also we can divide it into different segments or parts and we can carry out this LCA related exercise. Here you can see for example if you are doing LCA of this product from this end to this end, gate to gate kind of a thing, so this is only, this is the boundary condition, limited boundary condition. It is known as the gate to gate LCA.

And from gate to discarding of the product if you do the complete exercise, these steps like production then the utilization phase and the disposal then we call it gate to grave phase, so this kind of boundary is there, when we are encompassing complete process, so the cradle to grave, means the complete boundary condition if you are applying this system boundary if you are using then it is cradle to grave.

So, that way we can define different kind of boundary conditions and we can carry out the LCA and we can give the specific recommendations based on the LCA, within that boundary condition. This has to be remembered because the same kind of exercise but in different segments will give different results.

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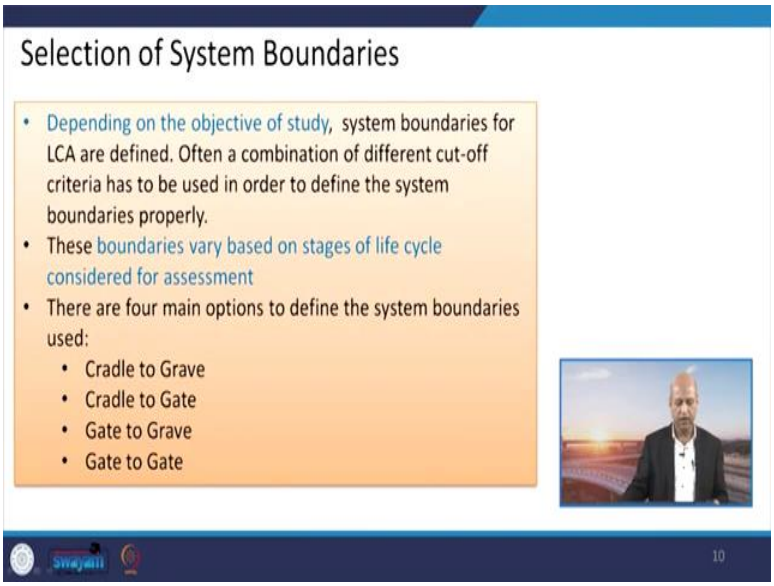

How do we select the system boundaries, so there are ways like what kind of exercise we want to do, whether the complete, then cradle to grave and if from extraction of the raw material to the factory production then cradle to gate you can say, means production plus extraction. Then gate to grave as we have seen, that from production to the utilization and disposal. So that kind of.

Gate to gate, very simple, as we have just seen, that within that input, when material is coming, so we are forgetting what was the extraction impact, but only when we are starting to using this raw material for producing some product in the factory. So within the factory, the production process related LCA is gate to gate basically.

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And there may be like a production chain in different ways so like linear production which is a manufacturing technique, so the material extraction, then production and then packaging and distribution, then utilization and use and disposal so waste treatment or recovery, so this is a kind of linear production stream you can say for this particular LCA exercise.

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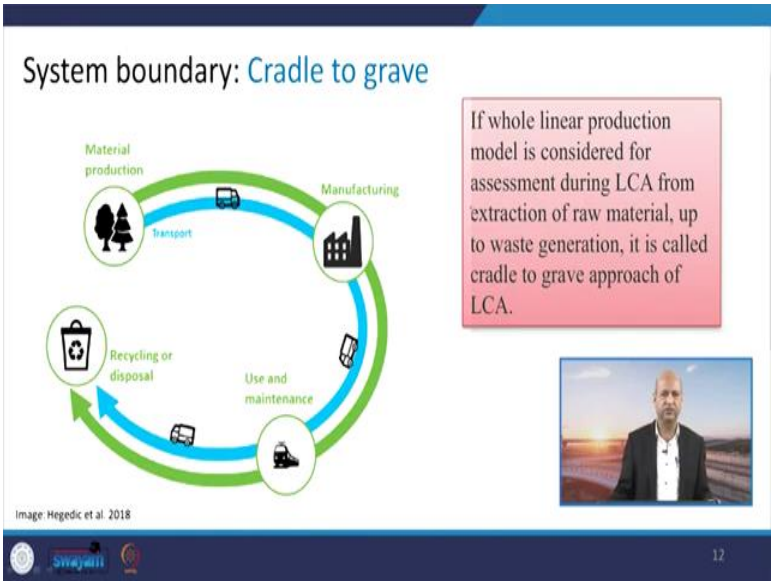

And the system boundary which we have seen is explained in detail, in these slides like cradle to grave so that means the material production will be there, then it would be transported to the

manufacturing units. So there will be some impact, we will carry out this one. Then from manufacturing it will go for utilization and this is the example of this transportation sector, then recycling after the utilization. So that way the complete cradle to grave kind of LCA exercise can be carried out.

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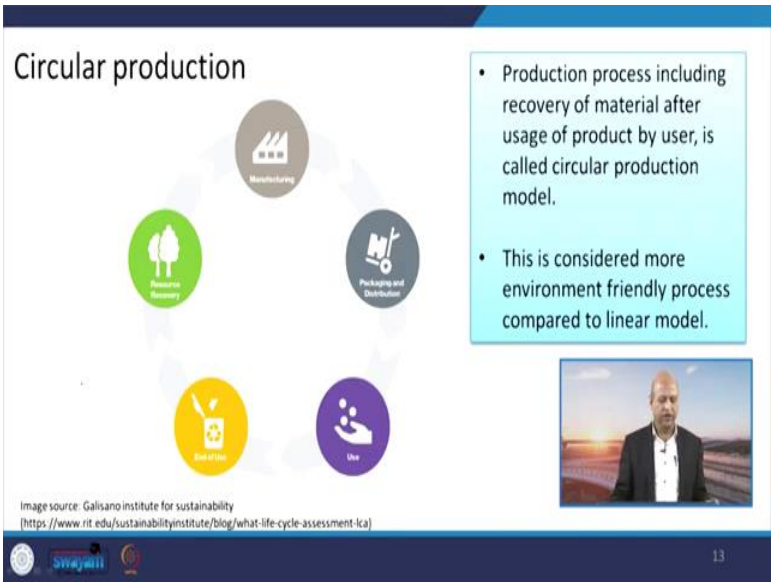

If we see the circular production basically, so this is again the model representation of the LCA, manufacturing, packaging, utilization and end use and again your recovery. So then it is a circular, means just you are discarding something then it is linear, when you are using something, discarded material then it becomes a circular way, because you are using some waste material also as a raw material. So that way the impact will be less, basically.

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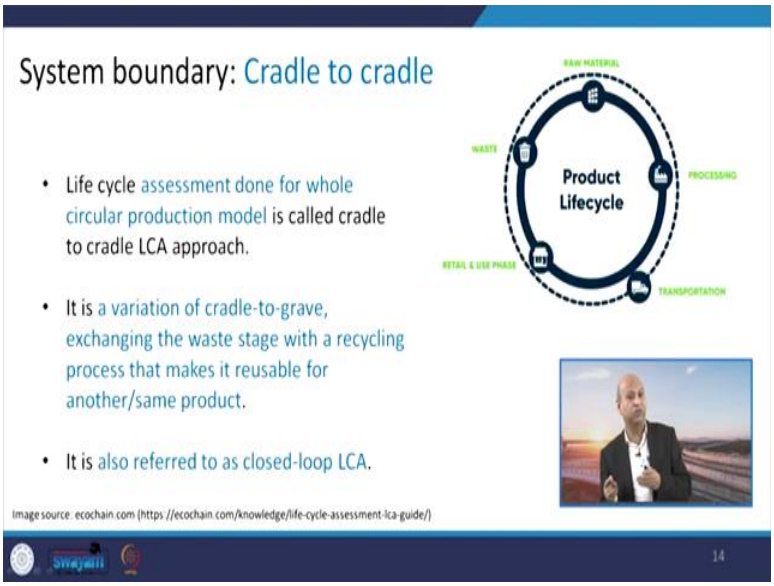

When we talk about cradle to cradle, this kind of means the complete cycle, the initial point, go and come to the initial point, so that is the cradle to cradle basically, so some cradle to grave we talk about then we are also taking some advantage of those reusable parts then we can say that it is cradle to cradle.

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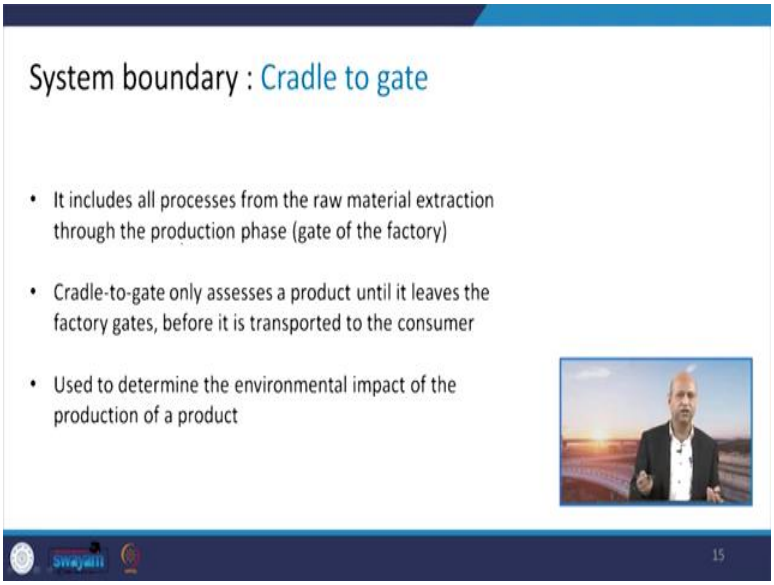

Cradle to gate we have just discussed that, it is only from raw material extraction to the factory gate, production, when something is produced and it goes out of the gate. So from cradle to gate.

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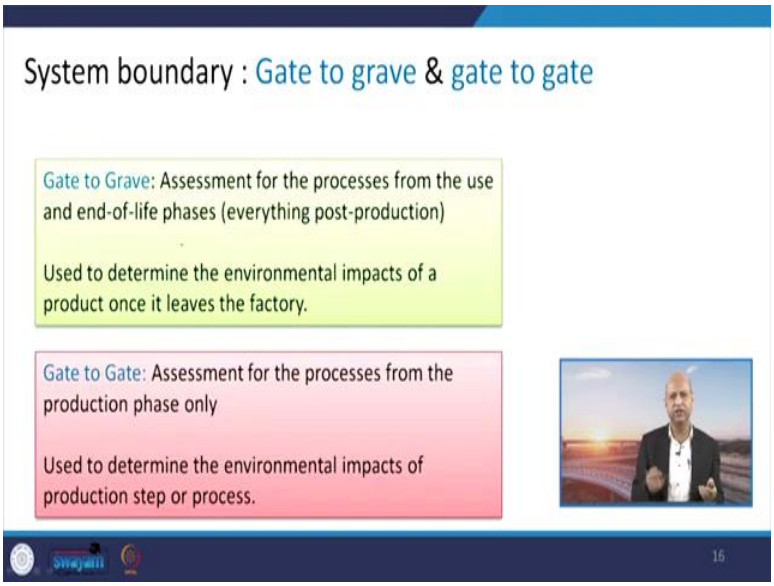

Gate to grave and gate to gate we have just discussed. So you can just see its definition in text form, otherwise I have already discussed what is the difference between gate to grave and gate to gate.

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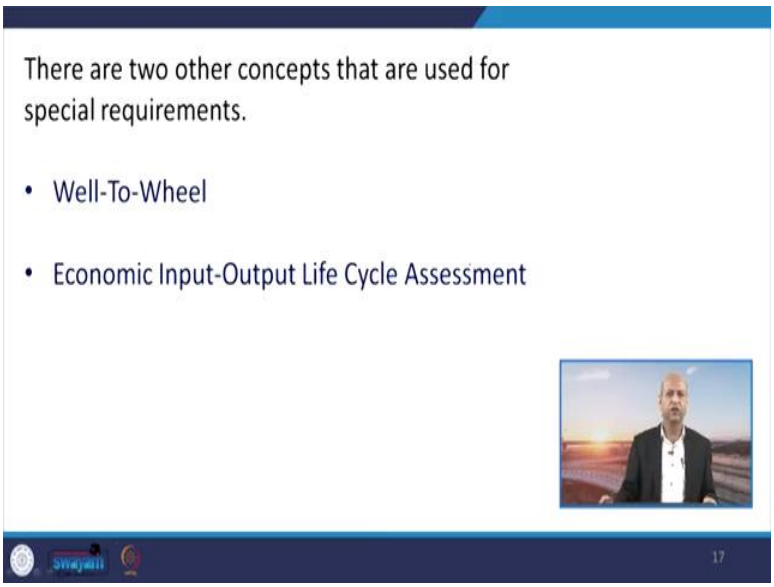

Well there are two other concepts beyond these four, which are very useful in particular requirements or contacts, like well to wheel, when some fuel is produced, like fossil fuel is being produced at some oil well. It is extracted then refinery and it comes to the transportation or

wheel. So means we are using for transportation purpose in a vehicle. So that is known as the well to wheel. Economic input-output life cycle assessment, this is another approach so we will see.

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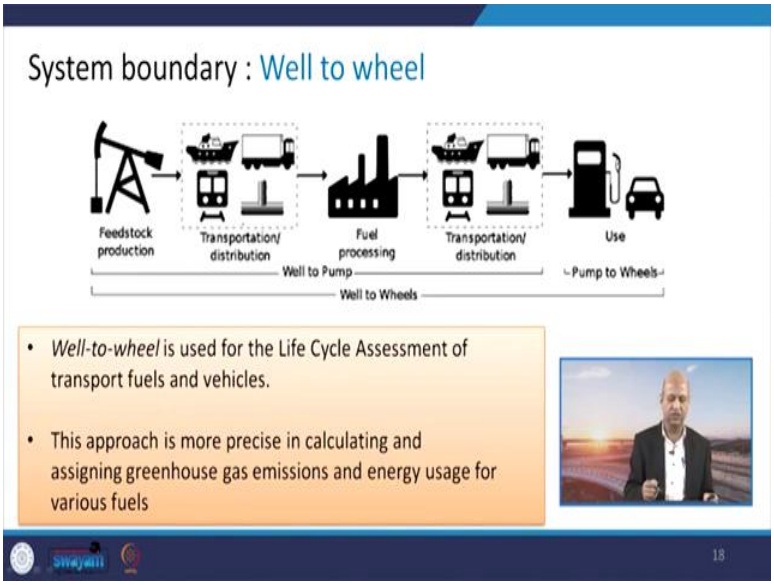

This is like well to wheel you can see. This is the production of the oil, then it goes to distribution system, fuel processing and then the production and distribution and this is the distribution of a foil to the refineries, then fuel processing at the refinery, then it goes to the petrol pumps and wherever it is utilized, then it is used by the cars, etc.

So this is from well to wheel basically. So this particular life cycle assessment of this stretch is known as the well to wheel. So in transportation sector basically it is very useful for deciding some quantities and inventories and their impacts like if you want to change some logistics' way to reduce the impact. So it can help in that sense.

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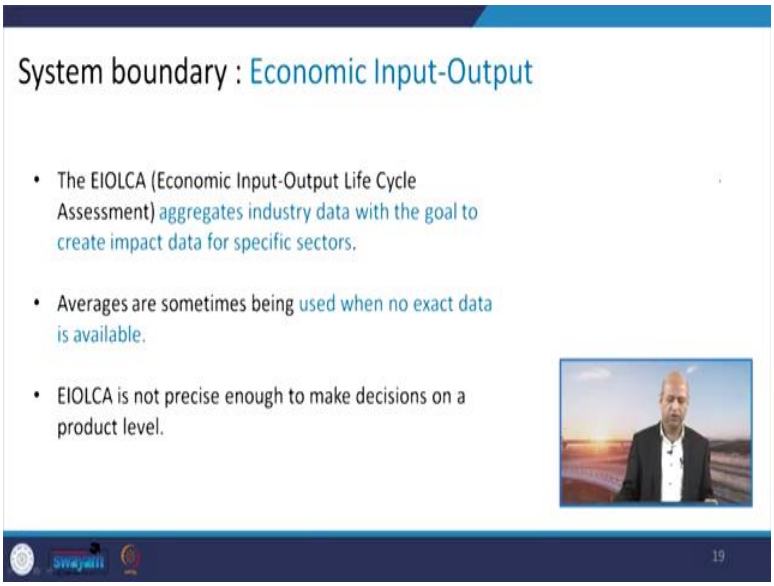

When we talk about economic input and output kind of thing, so then also some aggregated industry data when we want to create some impactful data for specific sectors, whatever sector it can be, but there are some limitations of this, because we use some average values and it may not be so precise or exact value but for kind of planning purpose it can be very helpful, for decision making for production level.

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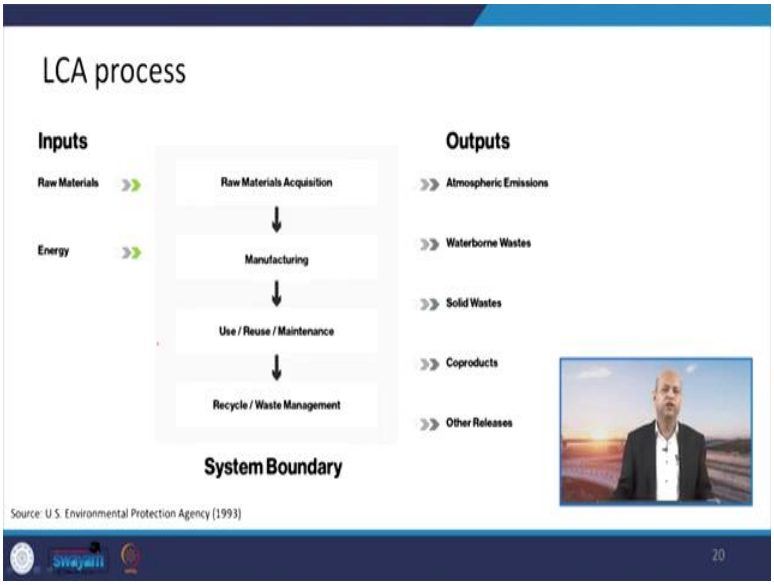

When we talk about the LCA process, so like input raw material and energy, so material and energy source, we see, although energy you can also say that it is also material like oil or whatever, but in energy terms also, because we see efficiency is dependent on several technologies, same fuel, energy utilization may be different. Like only 30 % or 20 % depending upon the technology.

So the raw material acquisition, then manufacturing, utilization, recycling the system boundary and output what will be, these externalities like atmospheric emissions, somewhere this waterborne waste may be there, solid waste or some co-products means additional one and other releases. So these outputs have to be seen as externalities, we have already discussed what are the negative environmental externalities. So these are the things which have to be taken into account when we are doing the exercise of LCA.

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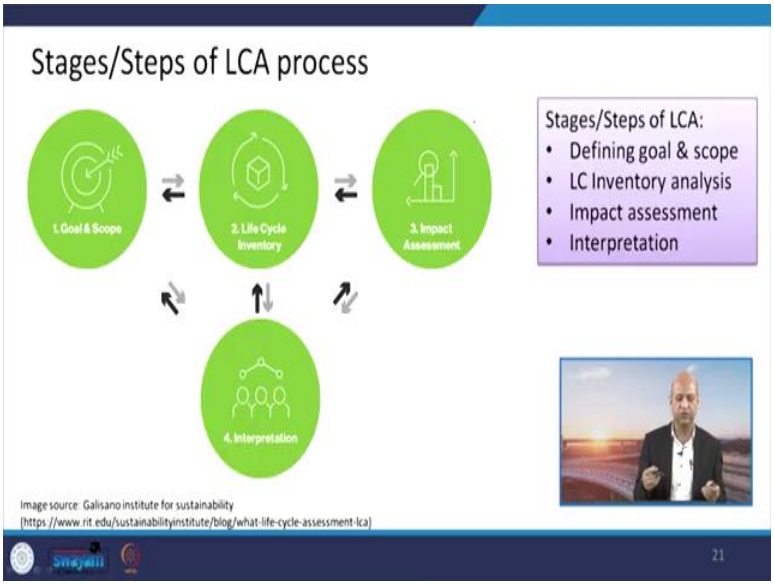

So when we talk about different steps or stages then there are like, we divide it in two different exercise like goal, we set the goal and what is the scope of the LCA, depending upon what kind of stretch we are taking. Then the inventory because data is collected for quantification of certain values, so that life cycle inventory has to be there and analysis has to be there, then impact assessment is done based on those inventories, and we also interpret the data.

So these impact assessment and the inventory related and these goal and scope all these are integrated or interrelated to each other. They play some role. So first of all we need to define the goal and the scope of the LCA. It may depend up on the objectives and purposes, also it depends on the industry to industry also. Then as we do the inventory and analyze the impact assessment and interpretation so these four steps or stages are very important for the LCA.

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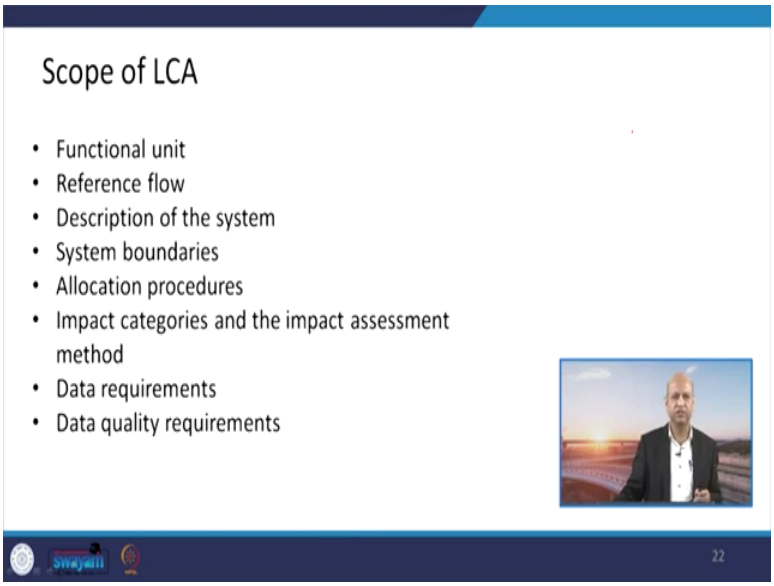

When we talk about the scope, when we set the goal and we talk about the scope of the LCA. So then again different steps are there, like functional unit related boundary definition and system description and allocation of different procedures, impact categories and impact assessment method, which kind of method we are using, what kind of data we need for this and the quality of data check through different techniques. What are the uncertainties in those data, reliability of those data, all those things are part of this setting the scope.

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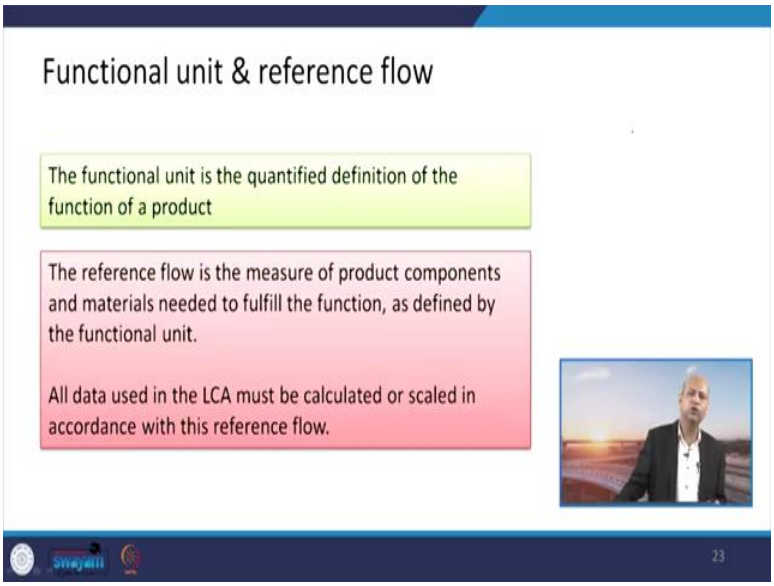

When we talk about this functional unit and the reference flow then we are basically talking about quantifying things and so this product components or whatever material we are needing so these are calculated. Their requirements, their mass or energy related quantities, all those quantities are to be quantified and tabulated properly.

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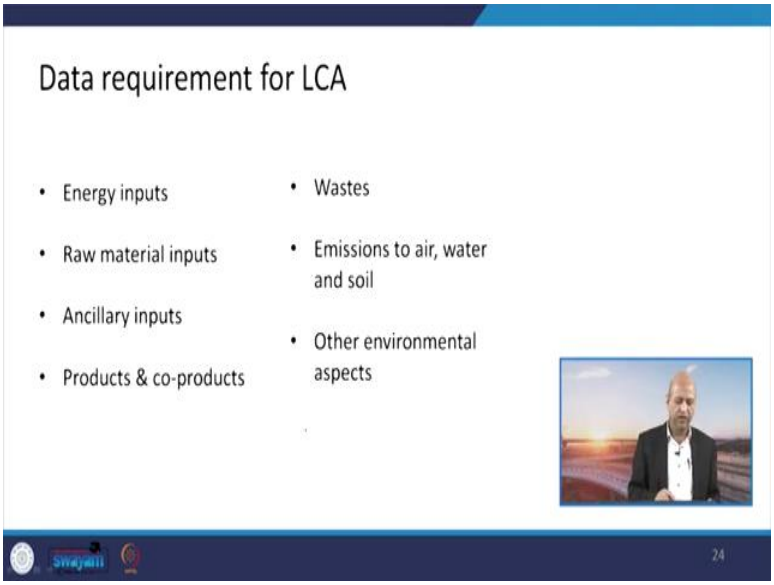

Data requirement for LCA if we list then like energy inputs, raw material inputs, so these input values we need what input values are going to be used, then ancillary inputs and then products

and co-products after those particular utilization of these input values and then waste will be there, emissions will be there, water related or air related or soil related and other environmental aspects will be there.

So, all this quantification has to be there for data requirement. So we have to collect it or we have to estimate it. There may be some models which are used for estimation purpose, otherwise primary survey you need to conduct or you can get secondary data also, from the published literature, some reports, etc.

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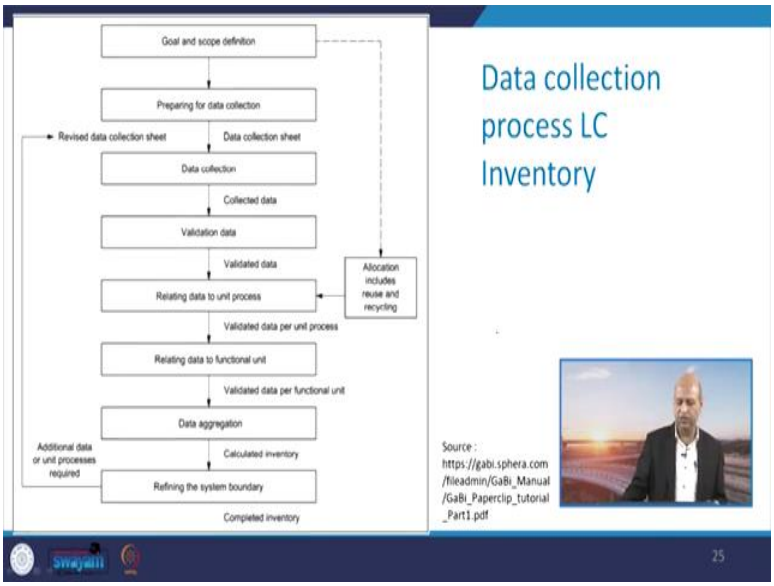

We see the flow diagram of this data collection process for life cycle inventory. So you can see this goal and scope definition we have done, then we do preparation for the data collection, proper preparation is needed, questionnaires are set, then data collection sheet is to be prepared, we do the data collection, then collected data is validated.

There are ways to validate it. For example you are developing emission inventory, so how far this emission inventory is nearer to the truth. So you can compare it with fuel consumption. You can compare it with some air quality parameter, so validation has to be carried out, otherwise whatever you are estimating it may be approximation and it may be quite away from the reality or real values.

So valuation is to be done. Then we need to relate the data to some unit process. Different unit process are there as you know. The validation of data as per unit process has to be carried so that more precision is to achieved. Then data functional unit and validation, data aggregation, calculation of the inventory and then refining of this system boundary depending upon the feedback, it is to be done. This full flow chart is to be used.

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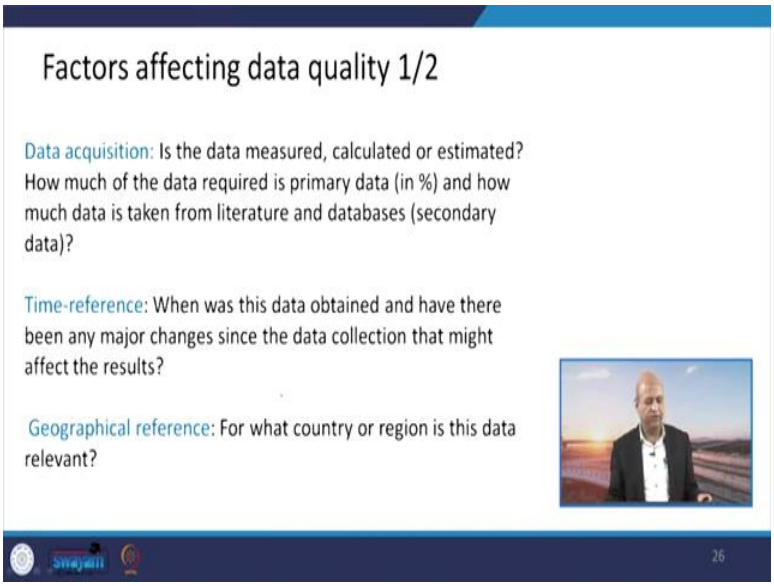

Those factors which affect the data quality are like how do we acquire the data or acquisition of the data? So, different techniques to estimate or whether primary data or secondary data; so that will also influence the quality of the data, then the time reference, if you are having a lot of data for several years. Then some good data may be there, which can give a good insights, but if there are limited data then you do not know whether it is good or bad and there may be issues.

Then geographical reference also, because for example if you want to get data related to transportation studies or air pollution studies you will get a lot of data for mega city Delhi. So many studies have been carried out. If you want to carry out such a study for remote area, so geographical area, maybe quite remote, nobody have conducted any study there. So you will struggle for having those data, then you have to conduct primary survey.

So those things are there to influence the quality of the data. Technology of course like as we said secondary data related from the literature and what kind of technologies, sometimes it is not

available whether carburetor is being used or some other technology is being used. Ignition is the technology, or what is the technology for the engine which is giving some emissions. So if it is not available then there is a gap in the data.

Precision also an issue, because if you do not have those kind of statistical parameters to know what is the precise data is there, then also there may be some gap. Then completeness, some gaps may be there. That is why there are like European models of emission inventory or U.S.A. models which we cannot use in India, because we do not have much data. Those models are very data intensive. So the completeness of that data, if it is not there, then you have to develop some other strategy.

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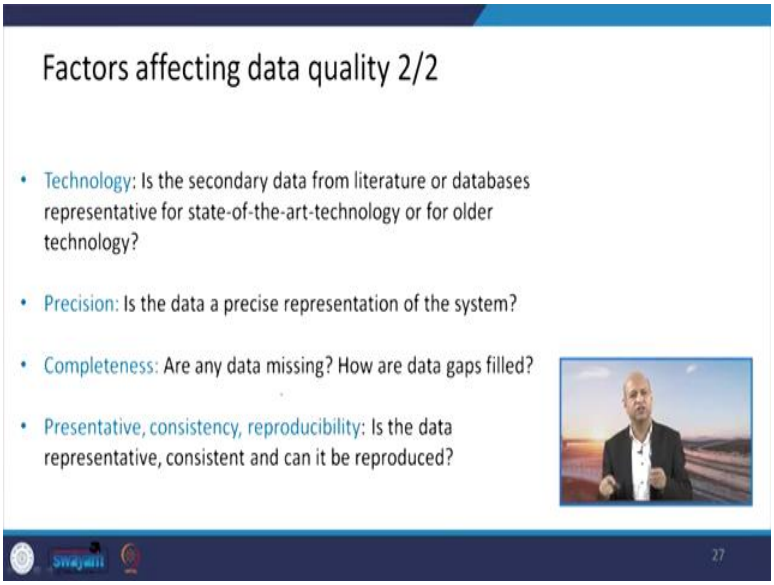

Then representative and consistency or reproduce-ability of those data are also important aspects.

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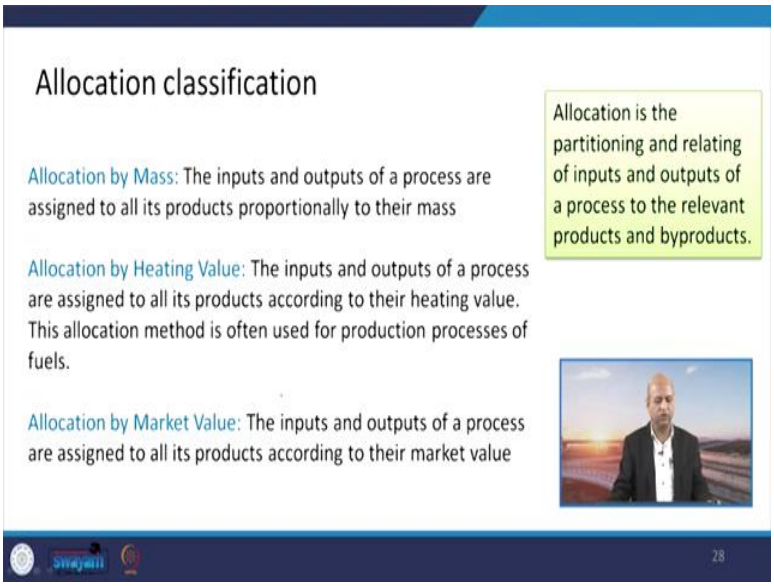

So we do some like allocation, classification, based on inputs and outputs of the processes and also their energy related aspect like heating value and then we also do like market value depending upon the input, output values. So that way we come with some picture of some quantification of the tabulated form, which will give us the information for carrying out the inventory analysis.

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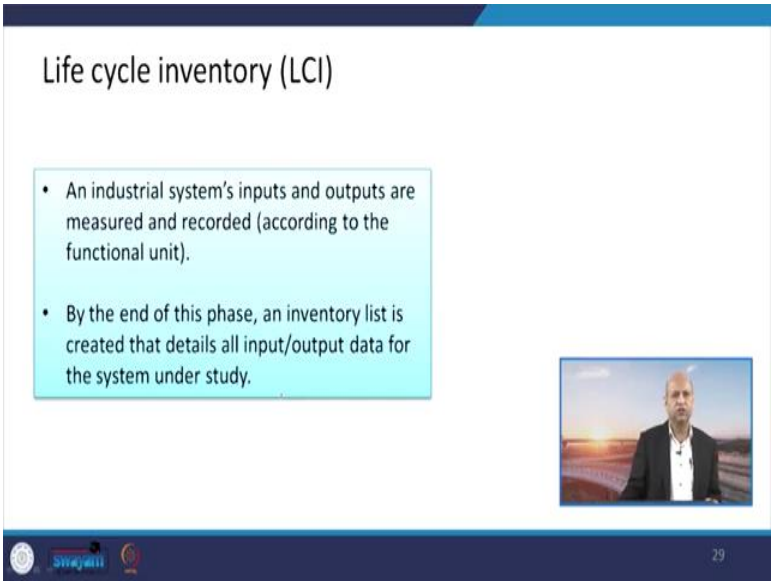

So the life cycle inventory when we are having, then we do some sort of analysis based on what kind of quantities we are having. So it should be converted into certain units so that you can compare. If you are having data but different units, so values may be different and it may be confusing. So in a certain unit it should be there.

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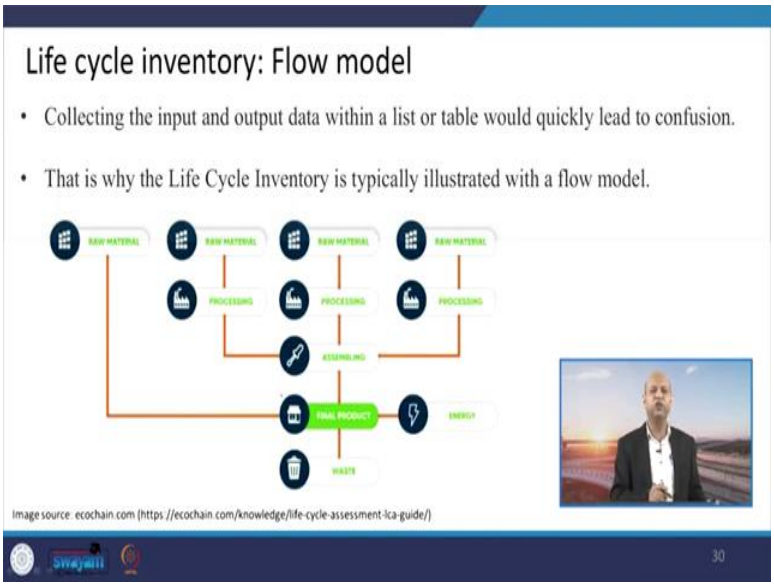

This is the model for life cycle inventory collection of the data input and output and this inventory related, like raw material related values we have, processing related value you have and then the final product, energy related, waste related all those quantities so flow chart sometimes, not only sometimes but it really helps us to categorize in different ways.

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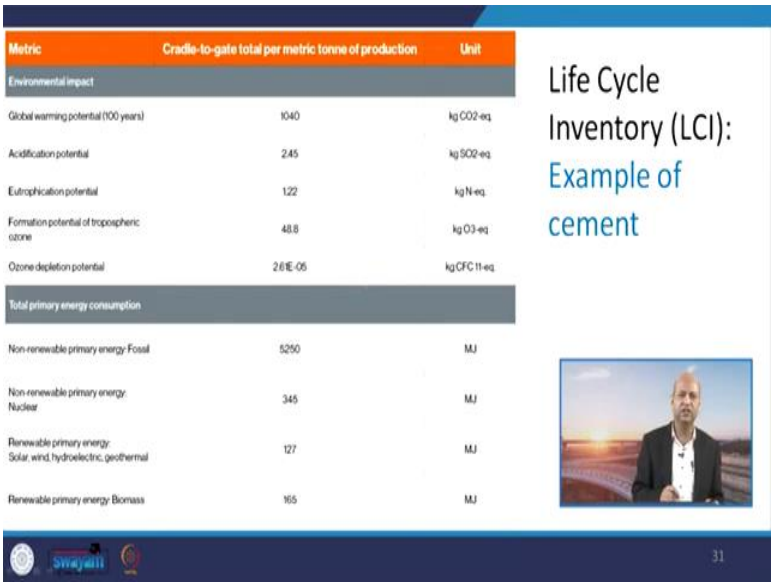

So as I said that some units have to be decided for example for a cement related, cement is a product and if you want to do the LCA for the production of the cement so you can get some data and you can convert it into, for example how much contribution is there in terms of CO2 at different stages. Like these are the quantities and you can convert it into kilogram of CO2 equivalent.

If you want to carry out calculations related to acidification potential so kg of SO2 equivalent, even if it is NO2 you can convert it into SO2 kind of equivalent. Eutrophication so nitrogen related different parameters may be there, but you can convert it into kilogram nitrogen equivalent. Similarly smog related issues or tropospheric ozone, so kilogram ozone equivalent you can do.

Then ozone layer depletion related potential if you want to estimate then you can convert it into kilogram CFC equivalent, those kind of units you can use, so that there is no confusion and all different parameters are converted into single unit and you can easily compare. Similarly this total primary energy consumption you can convert into one unit like joule or something like that rather than having different units.

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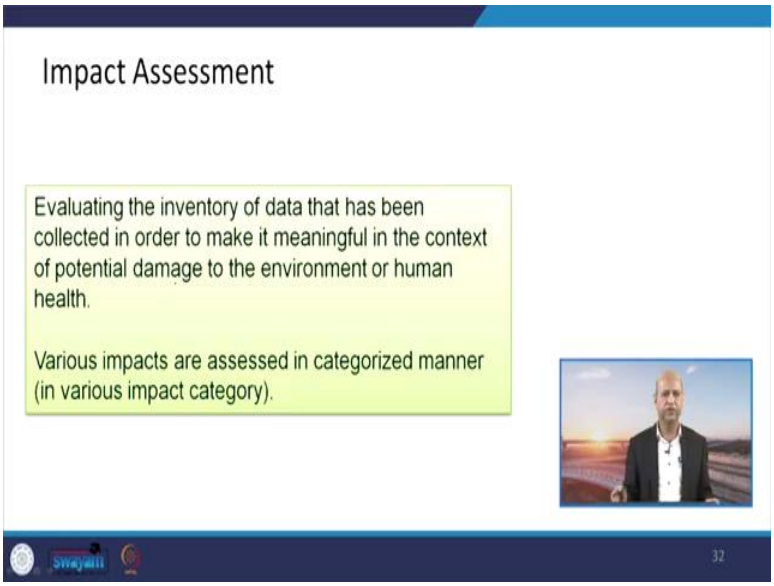

Then we carry out the impact assessment basically. So impact assessment is basically the evaluation of the inventory data which we have collected and analyzed, so that helps us to assess the impact in different category manner and different impact category can be divided, air, water waste, soil, those kind of things.

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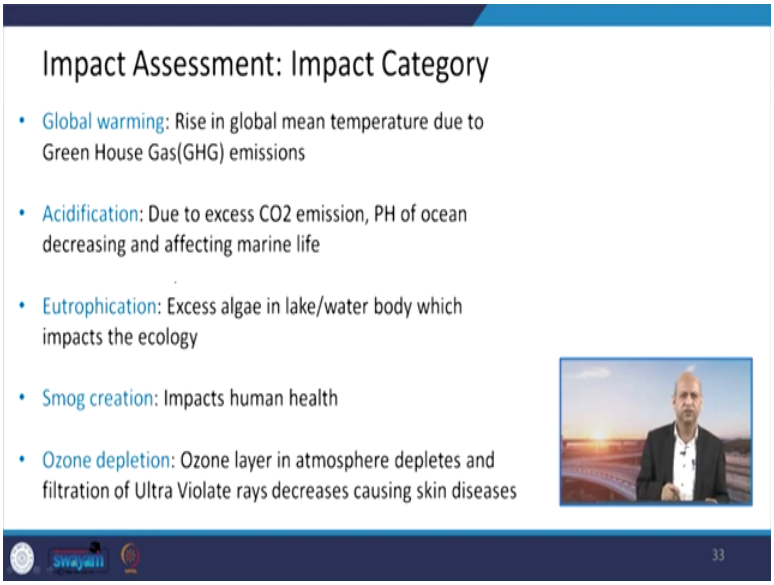

Like for example we can divide it into what is the global warming potential of a particular activity. What is the impact on the acidification, what is the impact on eutrophication or smog

creation, ozone depletion or health risk, heavy metals, so as per the activity you can list many kind of categories and see the impact or toxic gases or some other categories you can define.

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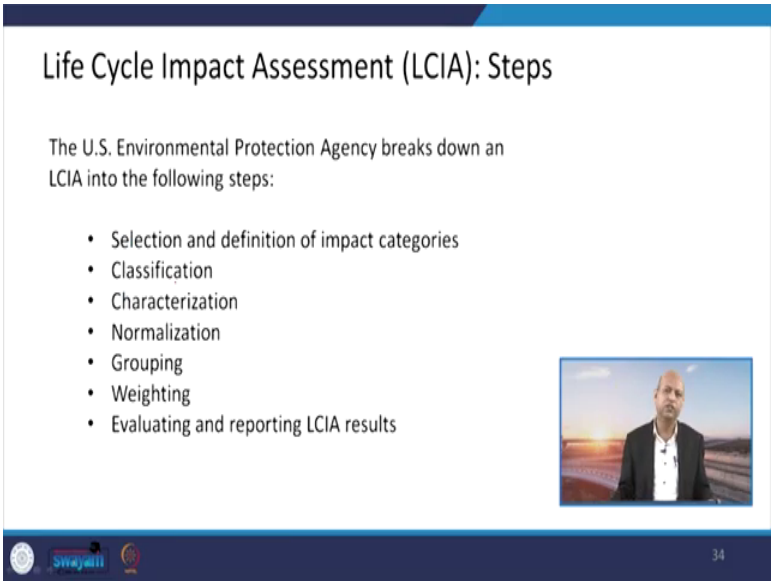

Then different steps again, we can list out like selection of this EPA has given this break down of different steps for carrying out life cycle inventory assessment. So for inventory assessment selection and defining impact categories as we have seen, you can add into that, that is only the representative kind of list.

Then classifying and characterizing, then grouping and giving some weightage, because everything is not so critical or important. So something is bearable you can give them less weight, if something is very critical, for example some activity is producing poisonous gas so you have to give more weightage to that, to convert it into impact, and then we evaluate and report to the results.

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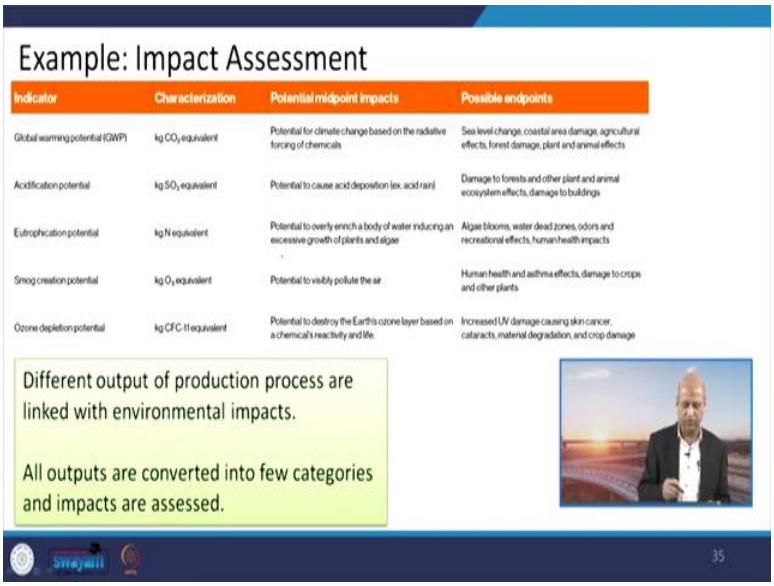

This is one tabulated form, impact assessment related exercise, again all those indicators which we have discussed like global warming potential acidification potential or eutrophication potential or ozone depletion potential or smog potential, so what are the characterizations equivalents which we have already discussed.

So then midpoint impacts and the possible end points in different steps, all those are to be tabulated so that picture is very clear and you can easily report them in a, you can communicate in a nice way. There is no confusion, it is lucid and complete clear picture, emerges out of those analysis.

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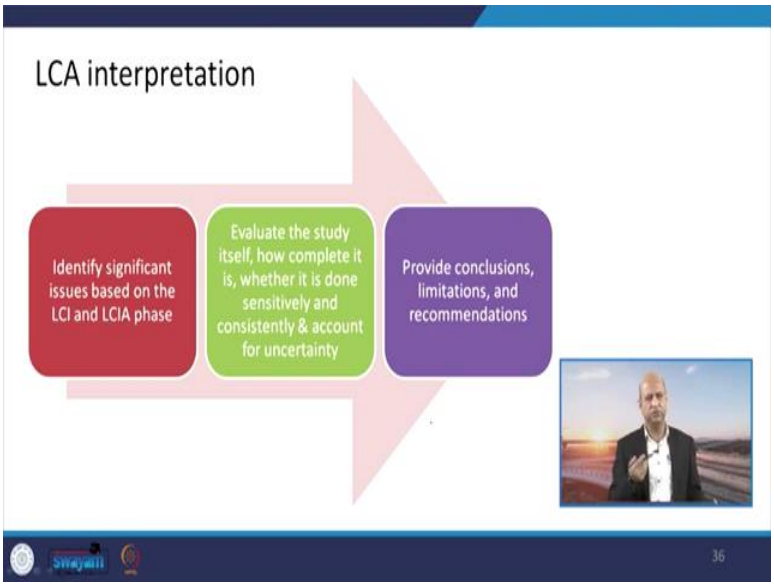

So interpretation is very important exercise otherwise if you are not giving some sort of insights and good interpretation and description, then again there is no use of that data, because policy makers need very simplified way of interpretation and conclusion kind of a thing.

So, need to identify significant issues based on this life cycle inventory and life cycle inventory analysis, those phase. And we have to evaluate and complete it in all aspect and sensitivity related or uncertainty related analysis has to be carried out, then we can provide the conclusions, limitations recommendations all those can be listed so that it can help policy makers to have the informed decision.

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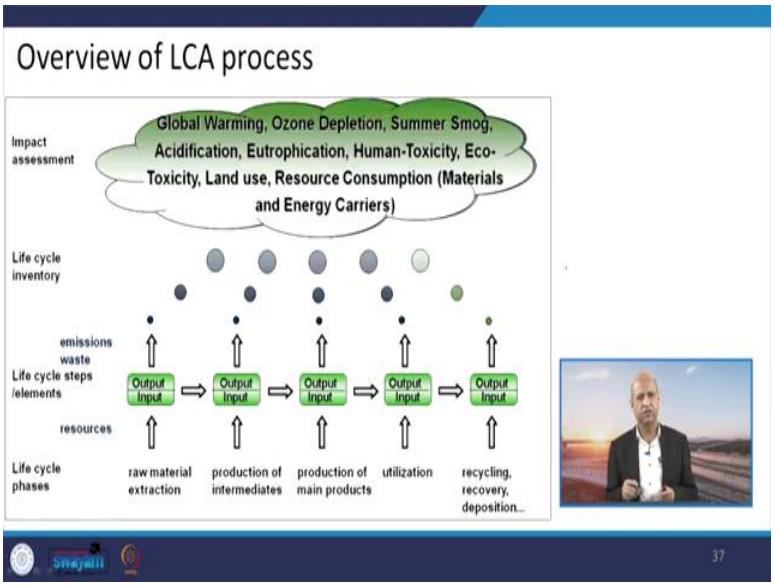

So, in an overview if you want to see the LCA process so you can see like life cycle phases are raw material extraction, production intermediates then main production and then utilization recycling then all these go and they create some sort of input, right?

So then these inputs will be there, in terms of some emissions, the output will be there and ultimately this inventory will be there and we will see different kind of values like acidification related emissions or global warming related emissions or toxic material related or heavy material related emissions, those kind of tabulated form is there of inventory, and we carry out the impact assessment as we have just discussed.

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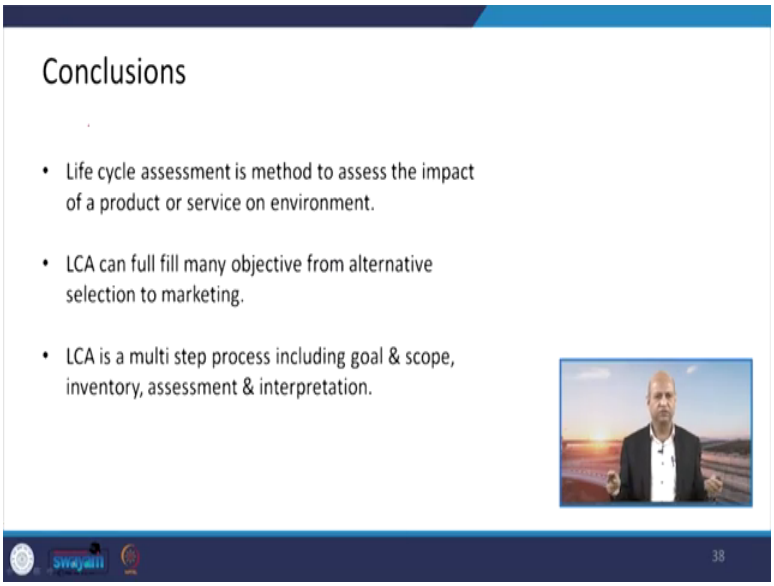

And that way we can conclude that LCA exercise is very important, it is methodological and it gives entire picture from a particular point to another point and it can be divided into as we have seen from initial cradle to grave or cradle to cradle if you are recycling or reusing something and in between also like gate to grave or cradle to gate or gate to gate, depending upon what kind of step or situation you are considering.

And then it can also help in assessing alternative marketing strategies or product related options. So there are several uses of the LCA, because it provides a complete picture, and that way this multi-step process, which includes all kind of defining goals and different kind of scopes and inventorization and assessment and interpretation.

So this is the way we do the LCA and this is all for the today's introduction of the LCA. Of course we will have two more lectures on this, so you will learn. Even we will have the case study that will give you better picture how to carry out the LCA in real sense, in real world. So up to then I take the break. So this is all for today.

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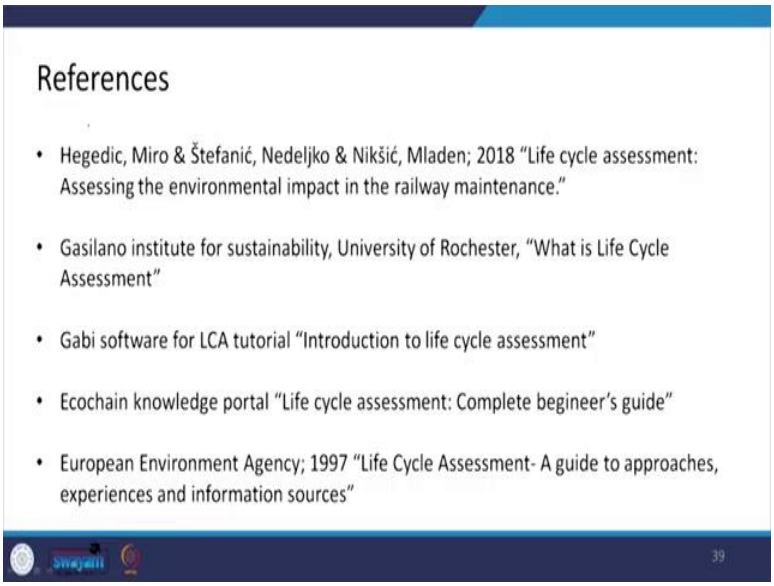

And you can see the references which we have used. So for additional information you are always welcome to visit those references. So thank you for your kind attention and we will continue this particular series of LCA next time also, thanks again.