Business and Sustainable Development
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Lecture - 11
Life Cycle Assessment

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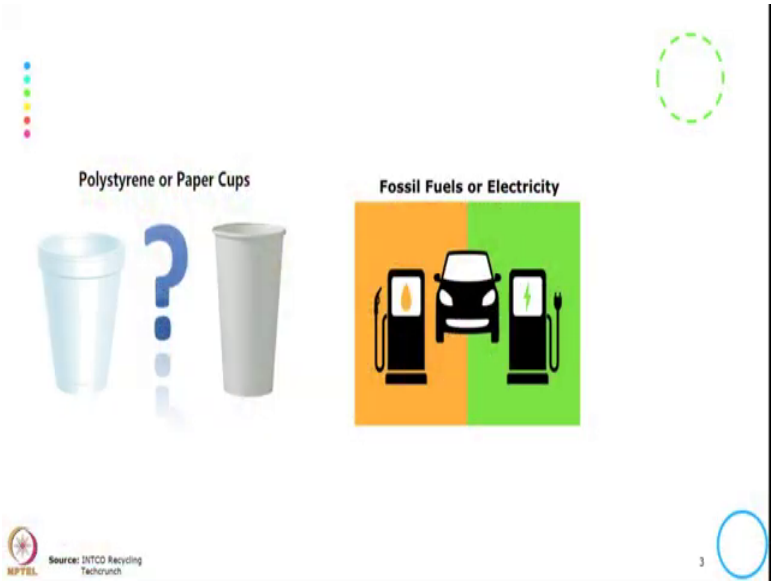

Hi. So, if you look at the pictures what is being display in the slide given a choice which one you would like to pick among the cups or the source of the fuel and the understanding for us over here is that we know that one source is clean other source is not so clean or one cup is less damaging than the other cup.

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The same story with the next slide also whether we should go for a liquid soap or whether we should go for a bar soap, and which one is more environmental friendly or whether we should go for a bio-fuel whether we will go for a solar whether we will go for a petrol so, based on that on what basis, we make a choice. Possibly being the environmental conscious consumer or being the pro-environment, we think that where the impact is going to be the less, but how do you know where the impact is more, or impact is less.

So, the tool what we use to understand the environmental impact of a product is life cycle, analysis and in this class, we are going to understand what is life cycle analysis and how it is being used to understand or to quantify the environmental impact associated with a product.

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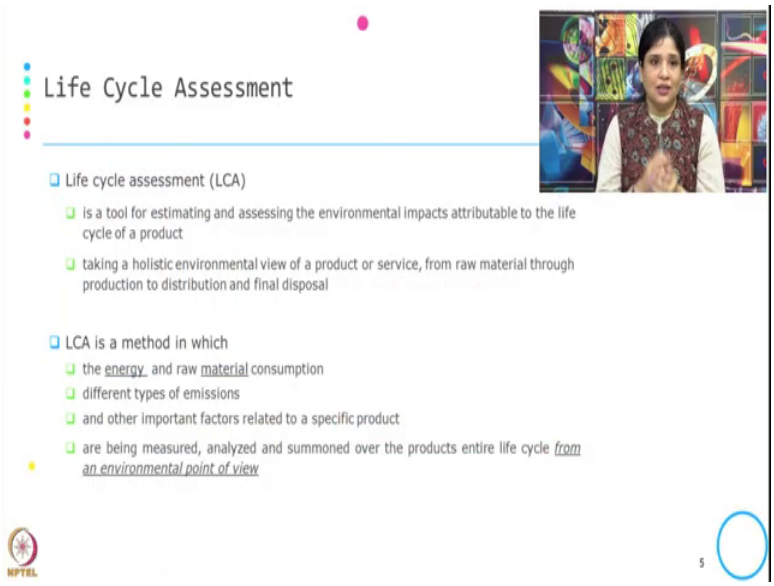

So, life cycle assessment is a tool for estimating and assessing the environmental impacts attributable to the life cycle of a product. So, in your entire product life cycle, how much is the environmental impact, this we can get through the life cycle assessment of tool. So, in case of life cycle assessment, we assess the environmental impact by taking a holistic environmental view of a product or services from the raw material to the production to the distribution and to the final disposal.

So, life cycle analysis or life cycle assessment is a method in which the energy, raw material consumption, different types of emission and other important factors related to the specific product is being measured, analyzed, summoned over the product entire life cycle from the environment point of view.

So, in simple word, LCA is the tool which helps us in assessing and estimating the environmental impact of a product in the different stage of the production starting from the raw material, sourcing of the raw material till the end-of-life disposal.

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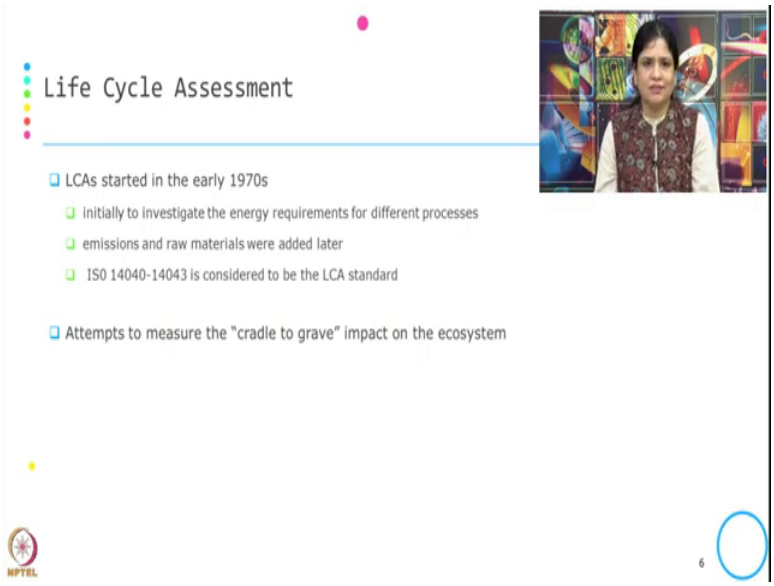

This started in 1970s and initially, this LCA was used to investigate the energy requirement of the different processes. So, just to initially when early 1970s it was started, it was for the understanding the energy requirement.

Then, the emission and raw materials were added later, and ISO 14040 to 43 is considered to be the LCA standard, we will know more about the ISO standard in the next week, but for the time being, let us understand that this standard is linked to; this series of standard is linked to the LCA standard and this LCA attempts to measure the cradle to grave impact on the ecosystem.

In the next slide, I will tell you what is cradle, what is grave and typically, how we use the variant of cradle to cradle or cradle to grave or cradle to gate in the product in the context of different product.

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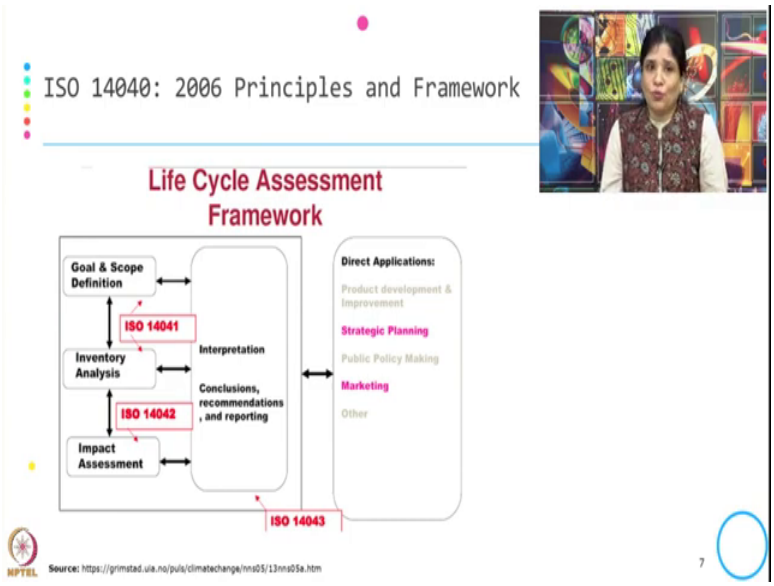

So, this is the principle and framework which was developed in 2006 that is the ISO 14040 series and this gives the life cycle assessment framework and what is this framework?

The framework involves goal and scope definition, inventory analysis, impact assessment and after doing the impact assessment finally, the interpretation, conclusion, recommendation and reporting and it can be directly whatever the impact, whatever the interpretation it can be directly applied to product development, improvement in product, product development, strategic planning, public policy making, marketing and the other domain of the business.

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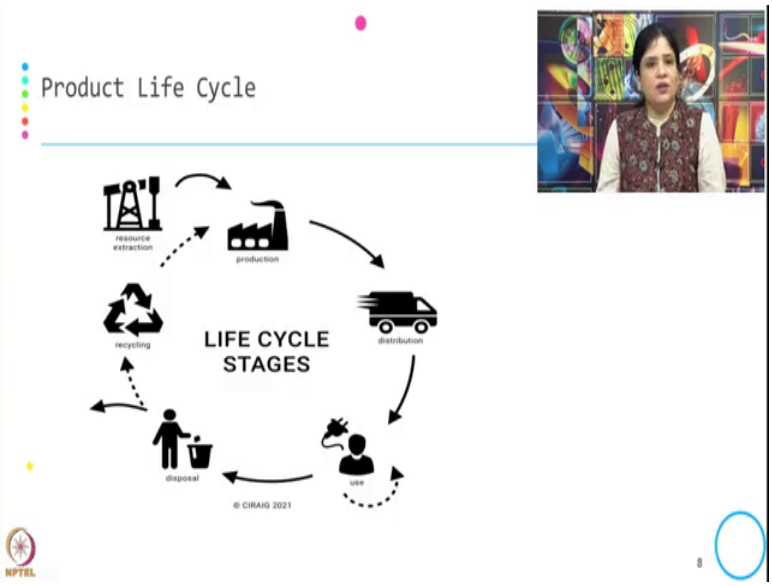

Now, this is the example of a product life cycle. So, you will find that it start from the getting the resource, getting produce, getting distributed, getting used, disposed and finally, the recycling. For every product, typically this is what the life cycle we get the raw material, we produce, we distribute to the end users, the end users use that, they dispose it off and then, it gets recycled, part of it get recycled, part of it gets into the final disposal.

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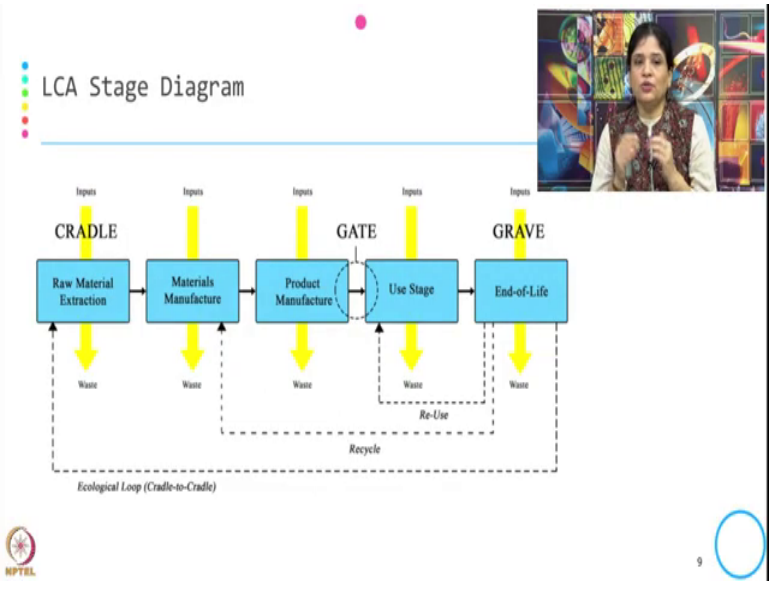

Now, here, we use the term cradle to grave to understand the different part of the life cycle of a product. So, when we say getting the raw material that is the cradle, the beginning of the product, the loop of the product life cycle and gate is the terminology we use where the product gets manufactured and goes out of the gate of the firm, then we get into the use stage which is part of the which is typically the consumer responsibility and finally, the end to life is called grave.

And there are different variation, there are variation of this LCA so, you will find cradle to the analysis when it is restricted or the impact of the product is being only assess estimated from the raw material sourcing to the product manufacture, then this variant of LCA is known as cradle to gate.

If the environmental impact of the product is estimated from raw material to the end-of-life disposal, then this variation of the LCA is known as cradle to grave or if the environmental impact of the product is estimated from the raw material till the time the waste is not recycled and going back again to the loop of the raw material, then this is known as the cradle to cradle.

So, based on the scope of the product that how whatever the scope of the environmental impact we are analyzing, typically the variant changes from cradle to gate or cradle to grave or cradle to cradle. And typically, the ecological loop is cradle to cradle it means whatever after using the product, when we dispose it off, again recycling bringing back to the source of the product life cycle to the raw material stage typically that is known as the ecological loop or the cradle to cradle.

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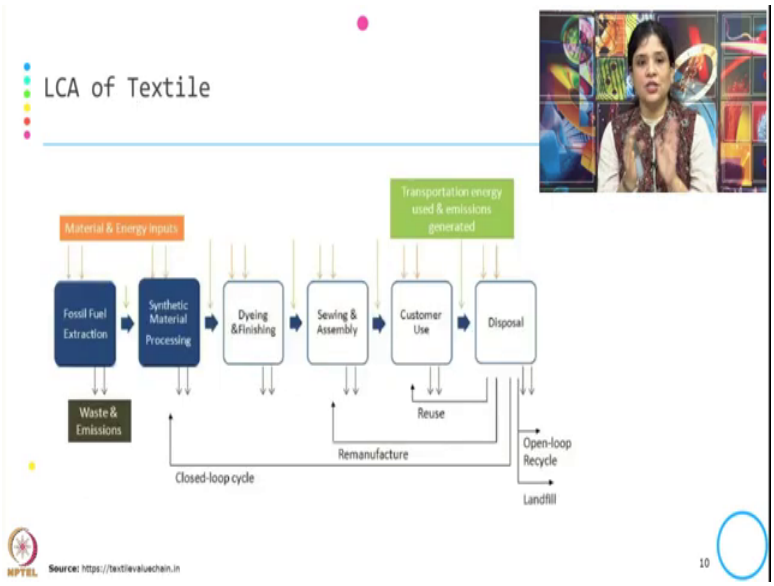

So, this is the example of a typical life cycle assessment of a textile where the product life cycle is being explained. So, if you look at for each of it, there the each process there are two inputs, one is raw material, second one is the energy inputs and what they are getting is the outcome of each process that is waste and emission.

So, whether you start from the fossil fuel till the time you get into the disposal, in each stage, the inputs are material and energy inputs, and the outputs are waste and emission.

So, if you are from the disposal, if you are reusing and bringing back again to the; bringing back again to the initial loop of the product life cycle that is the processing, then this is a closed loop cycle and open loop is that when the disposal is getting disposed either it is going for landfill or going for the open loop recycle, then it is a open loop cycle, but if it is a closed loop cycle, whatever the disposal happened that get recycled and go back again to the product life cycle that is closed loop cycle.

So, when in; when in some cases, it is not easy to recycle everything brings back to the product life cycle again, you will find some of them are getting into the landfill and some of them are going into the open loop recycle. So, this is just to understand that how it works typically the product life cycle, what are the inputs, what are the outcome, how it can be reused, recycled and bring back again to the product life cycle.

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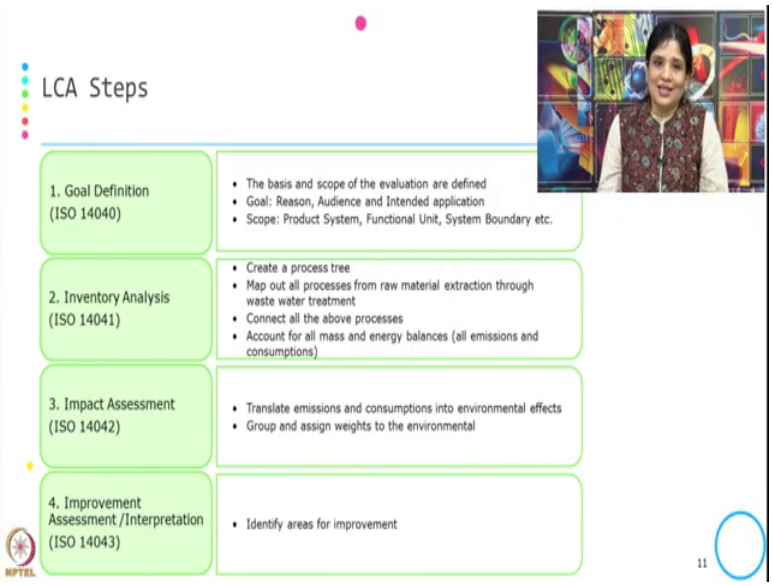

These are the steps for LCA. So, the first step is goal definition which is ISO 14040 standard. Here, the basis and scope of the evaluations are defined. Here, the goal is defined to understand what is the reason for doing this LCA, who are the audience, who are going to use this and what is the intended application of this LCA. Then, in case of scope typically, the product system, the functional unit and the system boundary etcetera is identified.

In case of inventory analysis, the process tree is created. Map out all the process from raw material to wastewater treatment this is what I was showing in the previous slide in case of a textile. Then, connect all the above process, account for all mass and energy balances it is like all emission and consumption.

Then, the next step is that once we create the inventory of the raw material usage, energy usage, whatever the outcome we are getting then we get into the impact assessment and what is impact assessment? In this stage, we translate the emission and consumption into the environmental effect, and we group, assign weight to the environment. Then, in case of the last step that is improvement assessment and interpretation, typically the areas of improvements are being identified.

So, there are four step of LCA: goal definition where the goal and scopes are being identified, inventory analysis where the entire material energy used in the production process in the different process, this different part of the process those are being those

are being created and impact assessment, how whatever is being used, what is the environmental impact of those inventory what is being listed and step four includes, where the areas of improvements are being identified.

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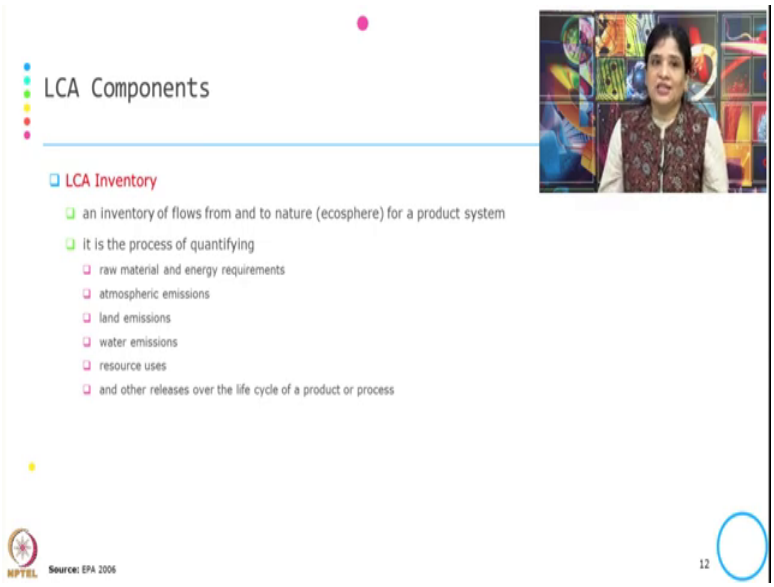

Now, what is done in the LCA inventory? An inventory of flow from and to nature of for the product system is being done and it is a process of quantifying raw material energy requirement, atmospheric emission, land emission, water emission, resource use and all other religious, all other impact that is being created in the life cycle of the product or the process.

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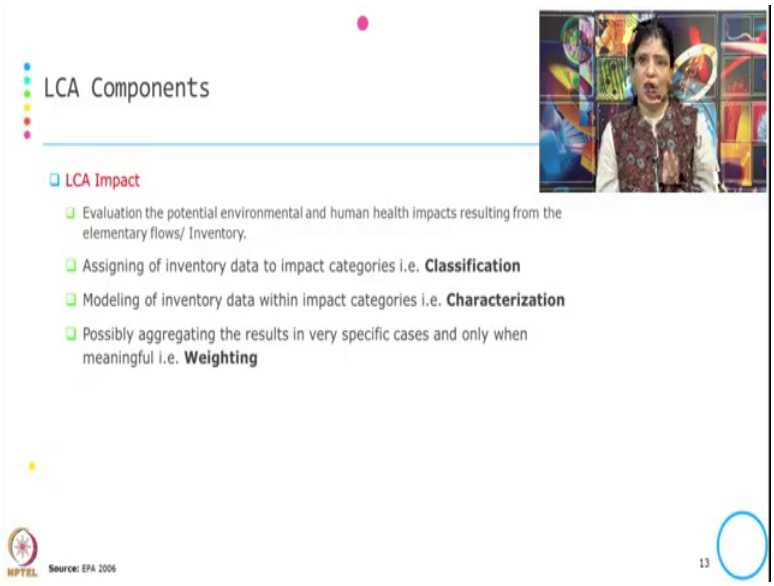

Then, in case of impact, typically here we do the evaluation of the potential environmental and human health impact resulting from this inventory what is being listed and three things happen over here.

When we assign the inventory data into the impact category, this is known as the classification. When we model the inventory data with the impact category, which is known as the characterization and possible aggregating result in very specific case only when it is meaningful, we call it is as the weighting.

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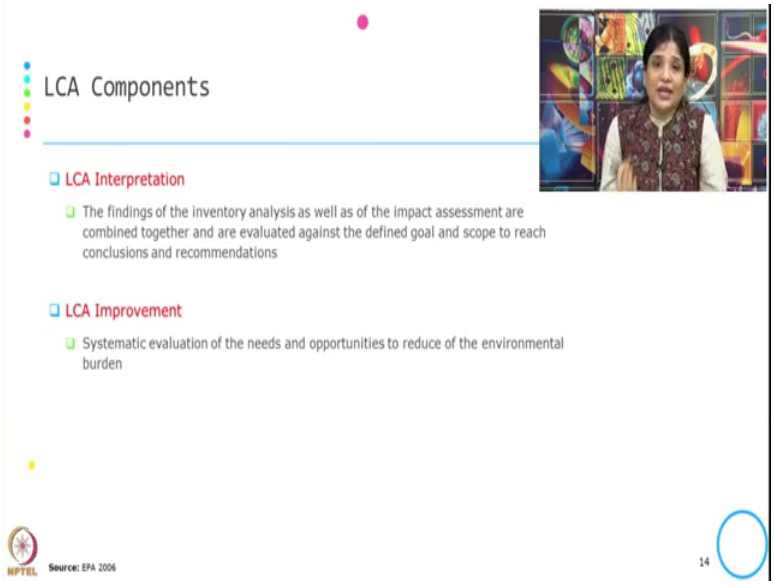

After that we do the interpretation and how do we do the interpretation? The finding of the inventory analysis as well as the impact assessment are combined together, evaluated against the defined goal and scope to conclude and recommend. and in LCA improvement, we do the systematic evaluation of needs and opportunity to reduce the environmental burden.

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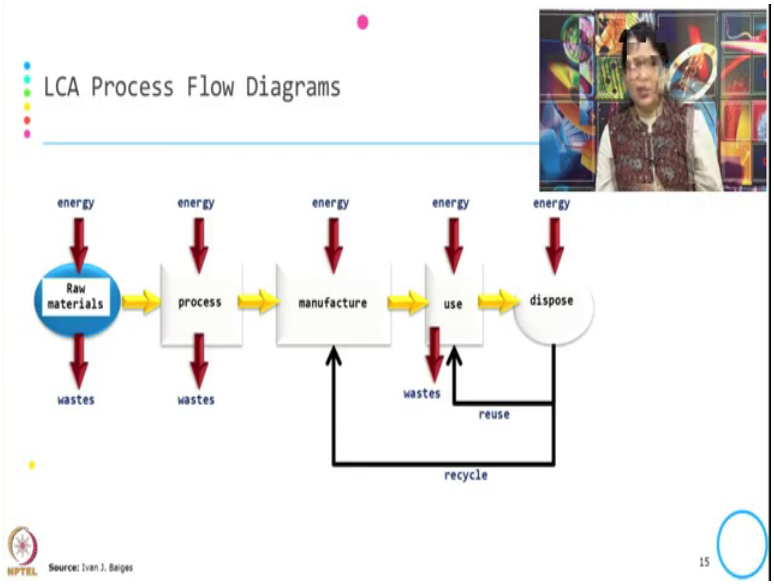

Now, this is what the typical. So, if you remember in the beginning when I was showing you the picture and asking, which source of energy you will choose or you will prefer to use which source of energy? This LCA process flow diagram is we will see in the next that how the different kind of energy, the process flow diagrams typically changes.

So, the basic process flow diagram is that getting the raw material, processing it, manufacturing it, using it and disposing it and what are the inputs in each cases? The inputs in each cases is energy and other materials those are being used and the output is; that whatever the wastage generated from each flow.

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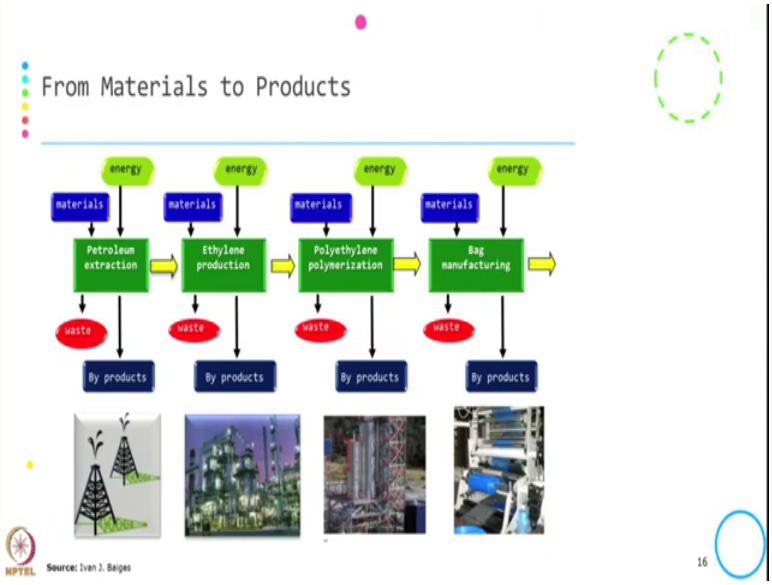

Now, this is what the typical example from materials to product. Let us say you start from petroleum extraction till the bag manufacturing. So, in each stage, there are three things to be checked: one what are the inputs being used energy and materials, what is the byproduct and whatever the waste coming out of it. So, getting from petroleum extraction to the bag manufacturing in each case, there are some inputs, there are some waste generated out of it and there are some byproduct.

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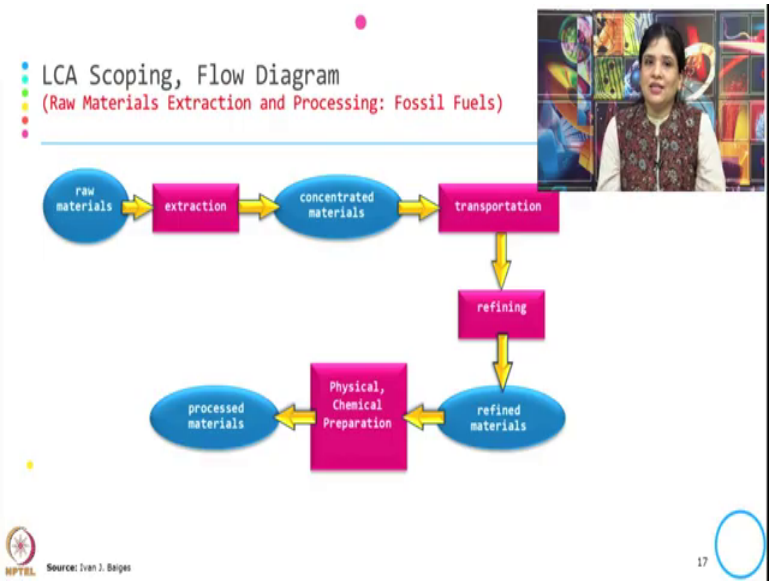

So, this is the LCA scoping and flow diagram of fossil fuel. So, it start with raw material, extraction, then get into the concentrated material, then getting into the transport getting transported for refining, then; then we get the refined material, then we do the physical, chemical preparation finally, we get the process material. And in this case, in each case, there are some inputs, there are some waste generated out of this.

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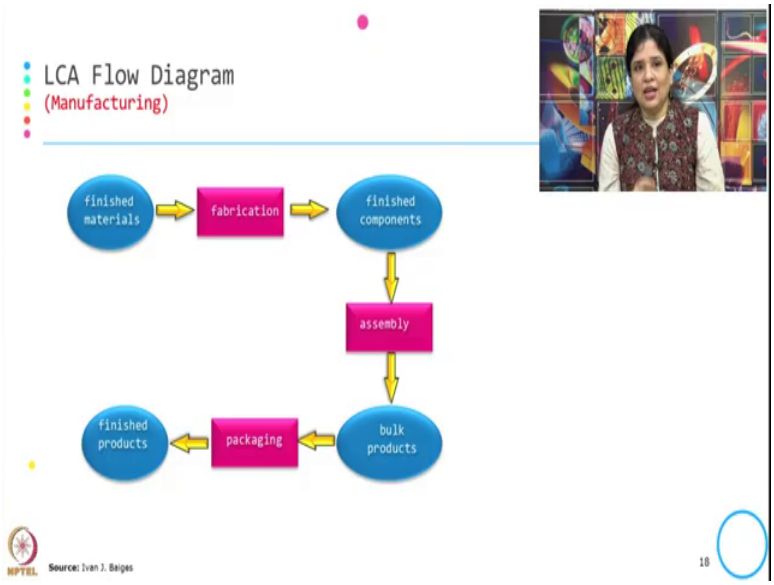

Similarly, for manufacturing from the finish material we get into the fabrication, finished component, assembly, we make the bulk product, packaging and finally, the finished product and similarly in this process flow also, there are some inputs, there are some waste which has the environmental impact.

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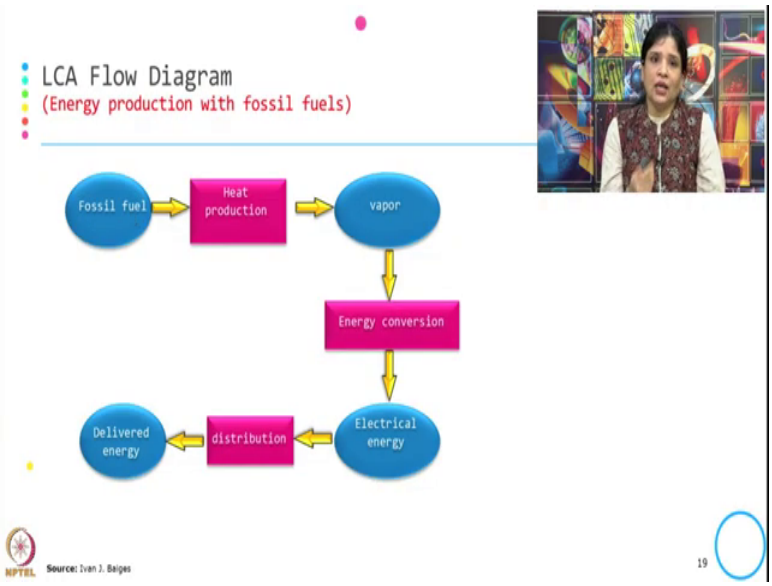

This is the energy production with fossil fuel. From the fossil fuel, we do the heat production, vapor, energy conversion, electrical energy distribution and deliver energy. This is this entire energy flow diagram what we are discussing this is taken from Ivan J. Baiges and this is through his presentation about doing the LCA analysis of the different sources of the energy.

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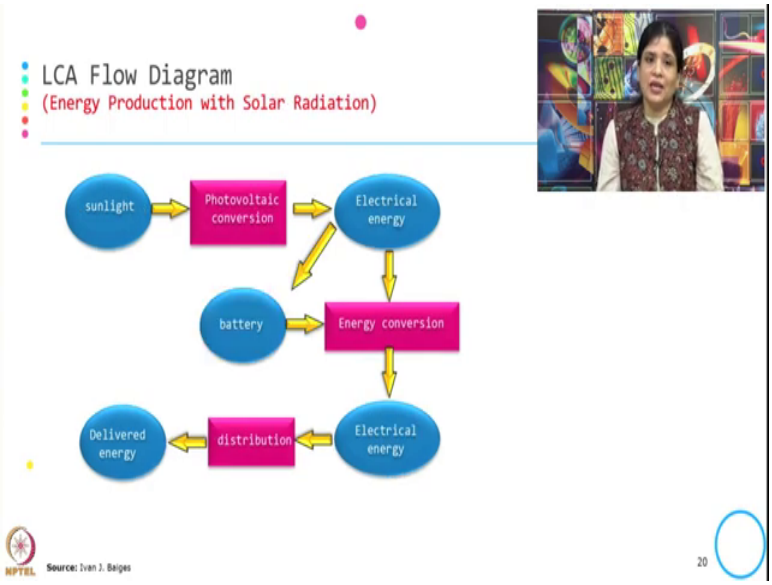

Similarly, energy production with solar radiation that is from sunlight you get into the photovoltaic conversion, then electrical energy, then part of it gets the battery, then part

of it energy conversion, then electric I think, I sorry I missed it over here so, it is from the photovoltaic conversion, then we get into the electric energy, from there battery, from there we get into the electrical energy, distribution and finally, it is the deliver energy.

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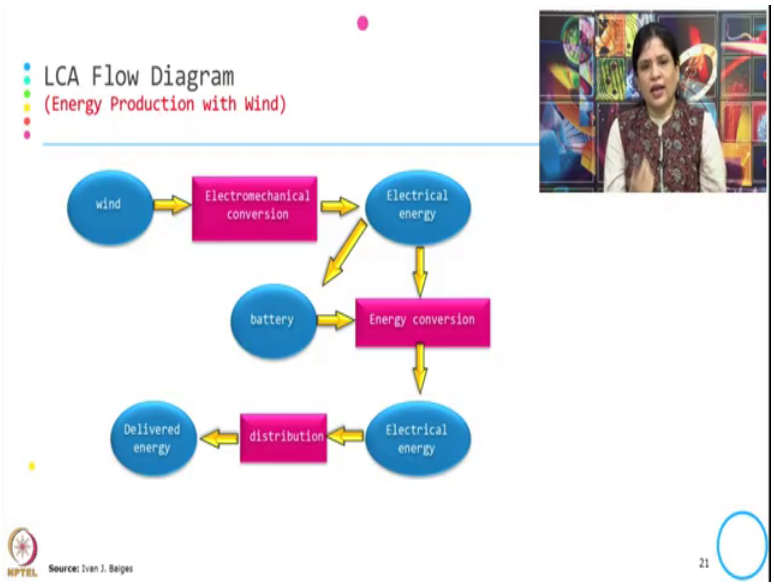

Then wind, the entire process flow of wind the different process what we used to get into the final energy sources from the wind.

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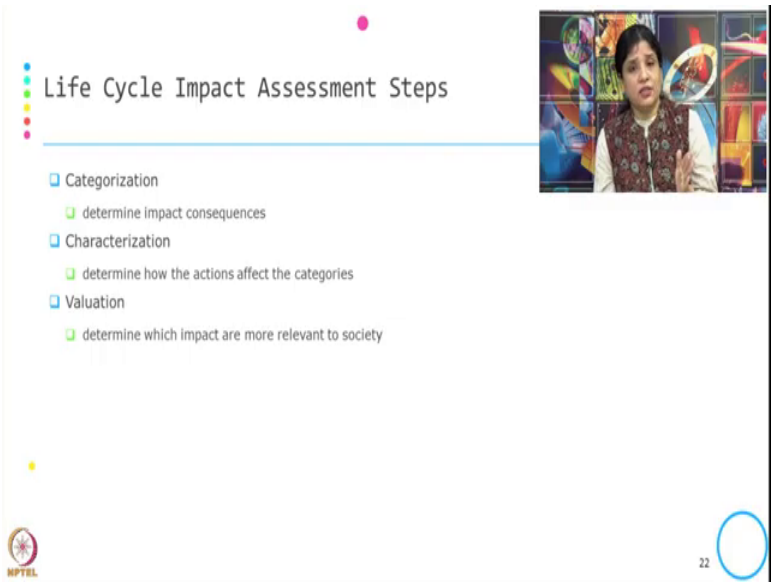

For this, regardless the types of energy what we use or the types of inputs what we use to get the end product, then again we do when we do a impact assessment, we do this three impact assessment step that is categorization, we determine the impact consequences, characterization, we determines how the actions affects the category and valuation which is more important is that determine which impact is more relevant to the society.

Because for everything there would be impact, but what we need to address first is that whatever the negative externality that is created for the other stakeholders which impact are more relevant to the society.

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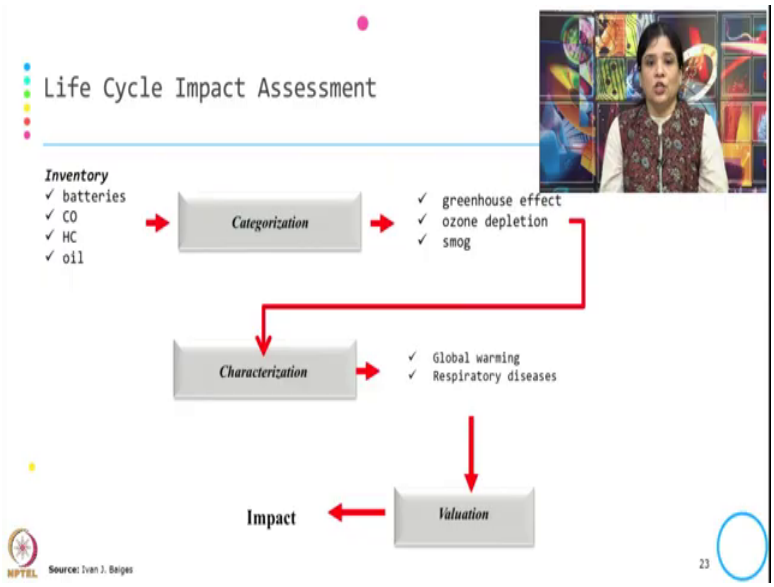

So, here if you look at the inventory is being done so, there is a battery CO, HC, oil these are the inventory being created. Now, when you do the categorization of it, then what it gives? It ends up in giving us the impact in term of greenhouse impact; greenhouse effect or ozone depletion or it is smog.

When this, when you categorize this impact and you do a characterization of this impact, then it is global warming, or it leads us to the respiratory disease. When you do the final valuation, you know that both are very high impact for the society. So, if you look at in this one slide, entire thing is being summarized.

You do a inventory from the process right, the inventory is that you in the previous examples when we are getting the energy from the different sources, these are the inputs

those are being used for getting this final deliver energy. So, these are the inventory. When you categorize them, the how do you categorize them? To find out what is the environmental impact of this inventory. What are the environmental impact of this inventory? Greenhouse effect, ozone depletion and smog.

Now, the next step is characterizing them. How do you do the characterization? To find out what it leads to. So, if there is a greenhouse effect, then it leads to global warming, if it is smog, then it leads to respiratory disease. Now, doing the valuation of this characterization that becomes the impact for the society and we know in this example, both of this thing global warming or respiratory disease is impacting the society at a very high scale.

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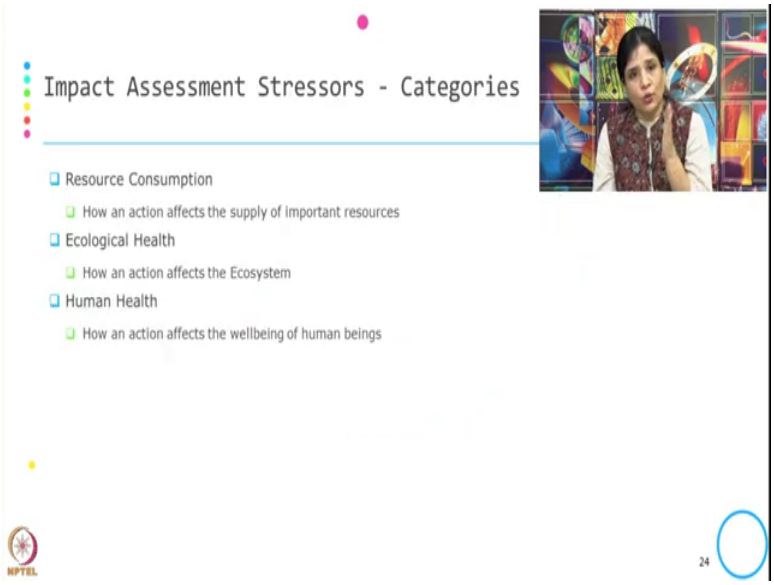

So, when we do the impact assessment stressor, when you categorize them, typically if you look at in the previous slide this is what we are trying to see when we are categorize them, you see that whether it is in affecting the resource consumption, whether it is affecting the ecological health or whether it is affecting the human health.

So, when you are doing the categorization or when you are doing the, what it leads to because of this inventory, because of this raw material usage, because of this energy usage or because of this usage, because of this process what it creates the stress? The stress can be whether the stress is on resource consumption, whether the stress is on ecological health or whether the stress is on the human health.

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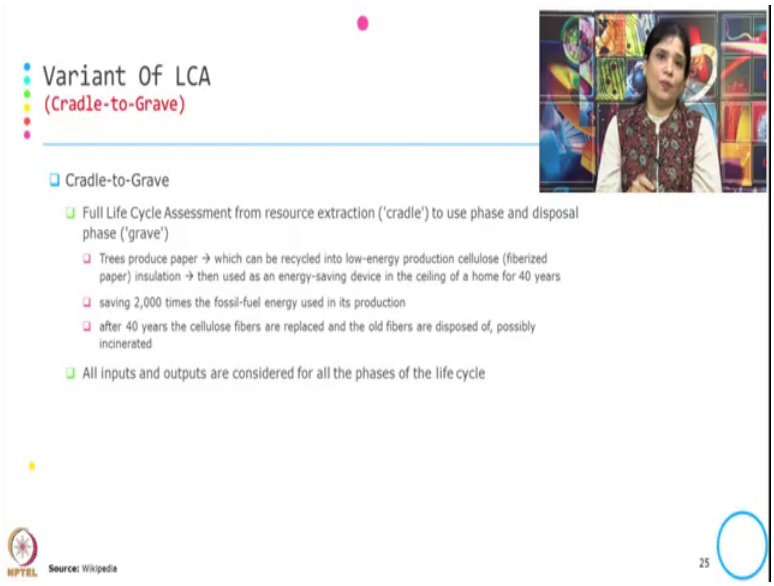

Then, we will see the different variant of LCA. The first variant of LCA is cradle to grave.

In this case, we do a full life cycle assessment from resource to use phase and the disposal phase, which is typically name as the; name as grave and the example what we take over here is that if you are just taking it for the paper, trees produce paper, which can be recycled into low energy product cellulose, that is the fiberized paper insulation, then used as the energy saving device in the ceiling for home for 40 years, saving 2000 times fossil fuel energy used in production and after 40 years, the end of life disposal is this.

So, in this case, when you are doing this life cycle impact of this, you start from getting sourcing it from the tree till the time the final insulation happen after the after you use the product. So, all inputs and outputs are considered for all phases of the life cycle, when we do a cradle to grave variant of the LCA.

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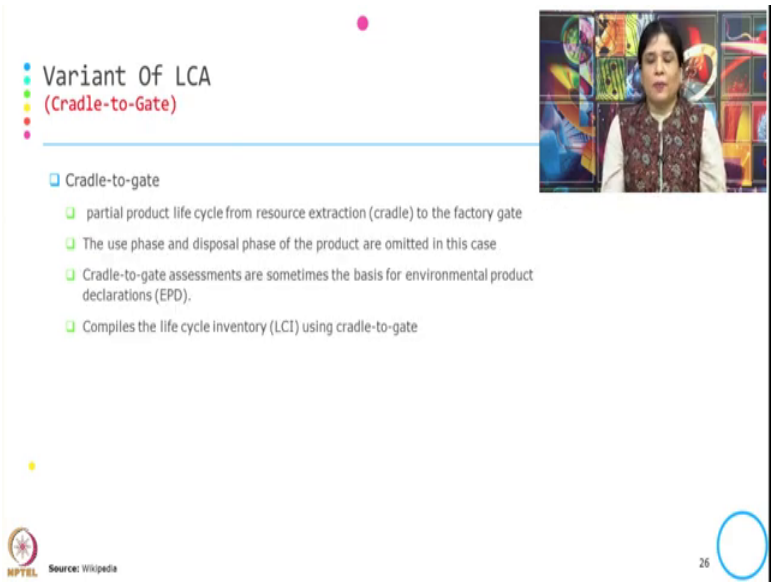

Then, cradle to gate. This is a partial product life cycle from the resource from the getting it from the resource to the factory gate. The use phase and disposal phase of the product are omitted in this case and this cradle to gate assessment is typically the basis of EPD and it compiles the life cycle inventory using cradle to gate.

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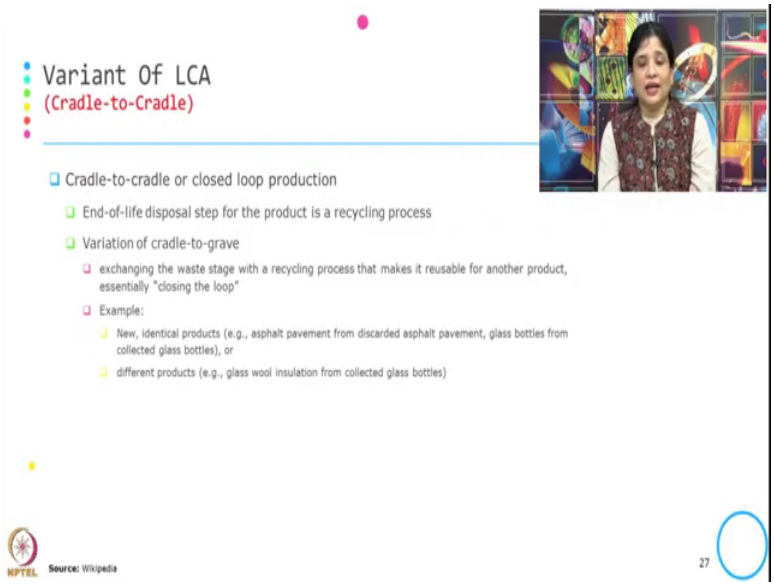

Then, cradle to cradle. This is typically as the closed loop production in one of the example we are checking that. So, this is the end-of-life disposal step for the product typically it also includes the recycle. And there are variation of this cradle to grave. So,

you exchange the wastage for the recycling process that makes the reusable for another product, because you have to close the loop in case of the cradle to cradle.

And closing loop can be two option, one from this you create from the reusing, recycling and reusing, you create a new or identical product or you create a different product.

If you if the capacity of whatever is the reuse or recycled material cannot go back into the production process of the same product, it can be different product can be created, but in both these cases, this is the example of closed loop because whatever is being wasted, those are recycled and reused either for producing the identical product or for producing the different product.

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Then, gate to gate. Gate to gate is partial LCS looking at only one value process in the entire value chain. So, you receive the raw material at the gate of the factory and the impact assessment starts from there, the raw material sourcing is not being added and it only takes care of the impact associated with the production of the product because it stops at gate, the use phase and disposal phase is not being added over here.

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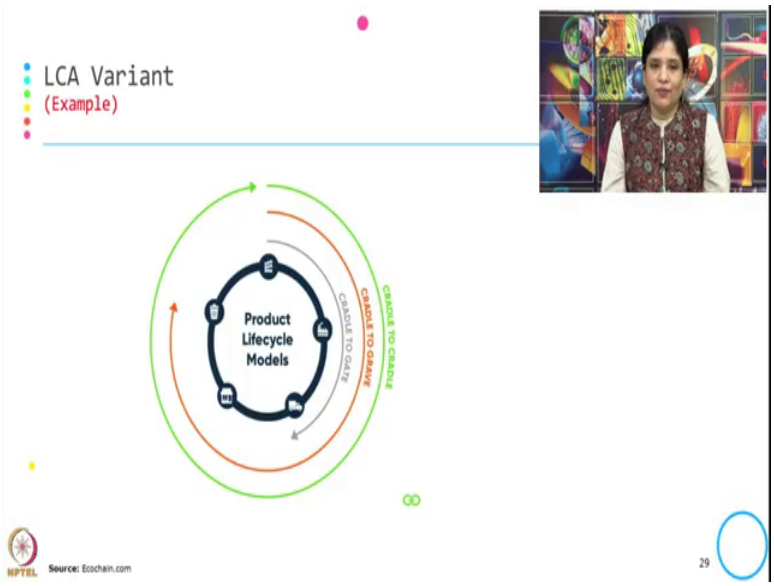

So, this is what the LCA variant showing through the product life cycle. If you look at the cradle to cradle, it goes the entire life cycle of the product. If it is cradle to grave, then it stops at the disposal and if it is cradle to gate, then it start from the raw material till the time sourcing of raw material, till the time the product is ready and leaving the factory gate.

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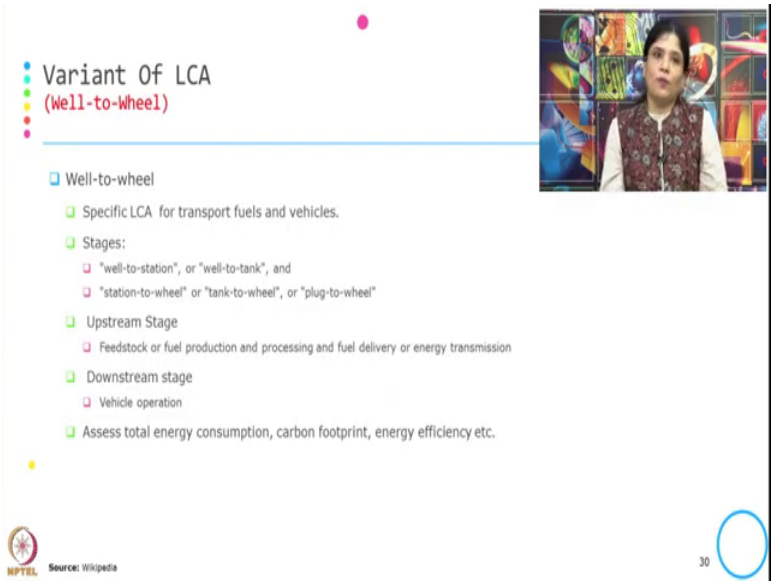

Then, there are few more variant of LCA that is one is well-to-wheel that is specific LCA of for transport fuels and vehicle and here the stages are you take well-to-station getting

it fuel from well to station, well-to-tank, station-to-wheel, tank-to-wheel, plug-to-wheel depending on the goal and scope, typically the variant of LCA is being taken from the source until the time when it is end.

Then, the upstream stage typically consist of feedstock or fuel production and processing or fuel delivery or energy transmission and downstream stage is typically consist of the vehicle operation and regardless in all the variants, the tool assessed the total energy consumption, carbon footprint and energy efficiency.

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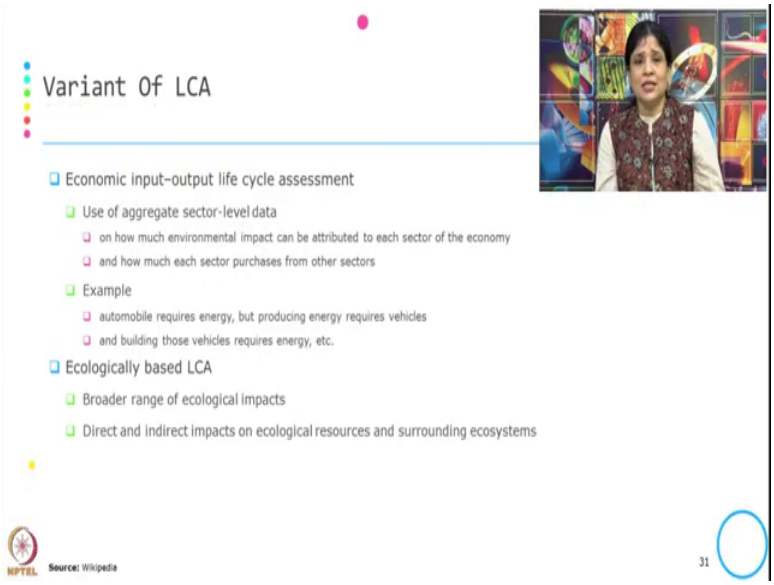

Similarly, we have two more variant, one is economic input-output life cycle assessment, use the aggregate sector level data to understand how much environmental impact can be attribute to each sector of the economy and how much each sector purchase from the other sector, this is typically through the input-output life cycle assessment because output of one sector can be input for others like automobile requires energy, but producing energy requires vehicle and building those vehicles requires energy again.

And the second variant is ecologically based LCA. Here, typically we consider the broader range of ecological impact, and we consider all the direct and indirect impact of the ecological resource and the surrounding ecosystem.

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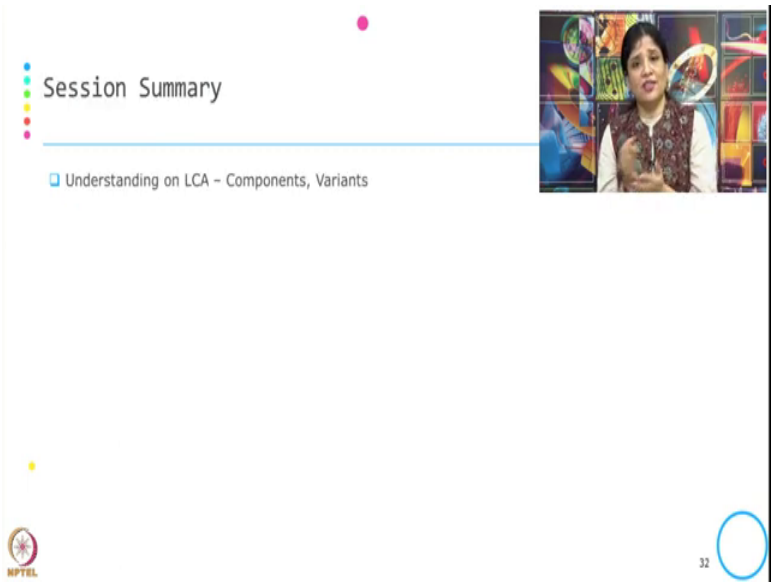

In the next class, I will show you few example of LCA considering all the variants. So, in this case in this class, we have tried to understand what is LCA, where it is used, what are the different component of LCA and what are different variants of LCA.

So, the different variant there are many more variant of LCA and typically, the variant depends on how much is the goal and how much is the scope of the impact assessment and the variants what I was discussing in the previous few slide, those are from the Wikipedia listed from the different sources.

And next class, we will see what are the few of the example with respect to different variant and how impact is being calculated?

Thank you.