Advanced Green Manufacturing Systems
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Lecture – 32
Design for Environment (Part 4 of 4)

Good morning welcome back to the design for environment lecture in the course Advanced Green Manufacturing Systems. In this lecture, we will discuss the implementation strategy for Design for Environment.

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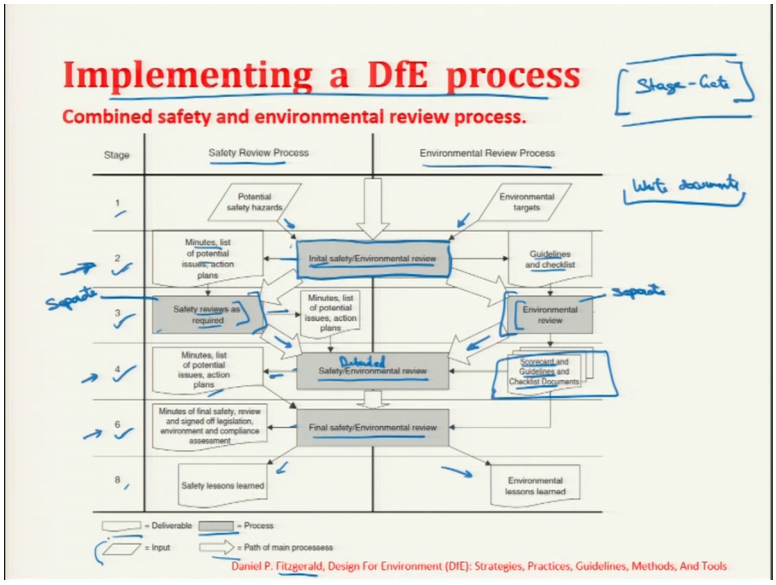

So, this is one of the methodology to implement design for environment which is developed by Fitzgerald this research was done by this person in 2007 and as I discussed in the previous lecture the safety review process and environment review process has to go hand in hand. They worked on the stage gate process, there are 8 stages and at each stage when the work is complete there is a gate to exit this is the phenomena that works on working and stage is an specific steps.

So, there were 8 stages and these are the stages where safety environmental review came into existence in series 1 2 3 4 6 and 8, in stage 1 the safety review is just potential safety hazards were to be identified. So, initial safety environmental review this is the legend

for this this colour box is the process this is input this is something deliverable and this is arrow is showing path here. So, from the environmental and safety review process the input to the environmental and safety review here this process input this process is potential safety hazards and potential environmental targets. So, these what a stage want that just a defecation then for safety hazards minutes list of potential issues and action plans who are the deliverables that goes into the safety review which were required in the stage 3.

So, these then they have to developed in minutes of potential this is the next sense which help to get the safety environment review this is a kind of a detailed review this is initial review initial this is detailed and how it is detailed, we have the final safety review required for the final environmental review required which is based upon the guidelines or the minutes in the safety and guidelines for environment targets and checklist in environmental view these acts as inputs to get the detailed safety environmental review. They help to develop another list of the plant that action plants and we get the final safety environmental review after inculcating a scorecard system.

Scorecard system it is the subjective importance identification system in which we get the what are the important attributes does we need to address in the environment review. Finally safety lessons in order to say environment lessons not were gotten at stage 8 just to discuss this in short this is allegedly produced by this author fitzgerald and they claim that this is going to be implemented it by black and decker now black and decker has safety review during stages 2 and stage 3 and stage 4 and stage 6. So, these are the safety reviews and the safety reviews are the meetings that intended for viewers to evaluate the assessment action and process for design team in addressing product safety.

Then the design for environment process adds an environmental review to agenda of a safety review held during stages 2 4 and 6. Here environmental review 2 4 and 6 here environmental review comes into play a separate environmental review is held during stage 3, which is not the part of safety review which is not the common and in the after safety review the separate reviews are here this is a separate review this is a separate review. So, this is the way they tries to implement the design for environment and when the design for environment process is first implemented the design team will have to fill out the environmental scorecard only during stage 6.

So, if score card is prepared here it is go that goes as input in stage 6, when the design team becomes more familiar with the process the scorecard will be completed 2 or more time during stage gate process in order to trap decision changes that may influence the environmental metrics during the development process.

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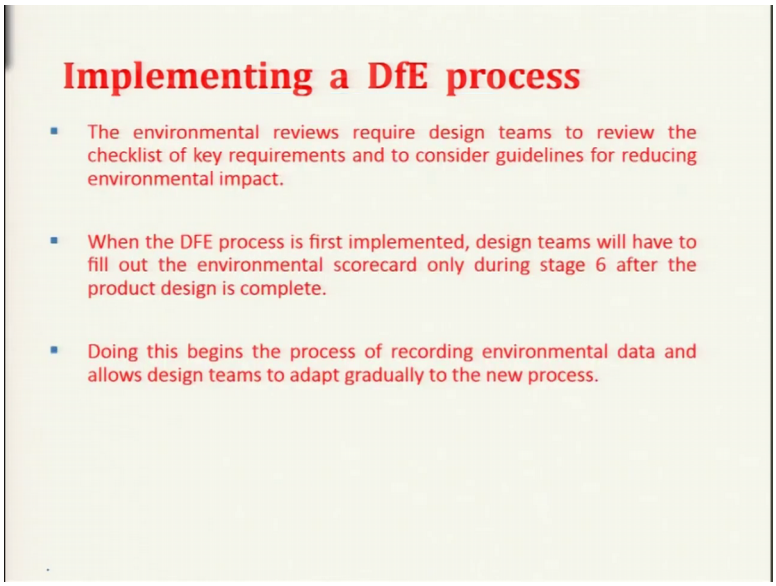

So, let us try to see a few lines on this the environmental reviews require design teams to review the checklist of key requirements and to consider guidelines for reducing environmental impact this is general. When design for environmental process is first implemented design team will have to fill out environmental scorecard as I just mentioned only during stage 6 after the product design is complete.

So, this product design is already complete and the scorecard for working on the requirements what are the specific requirements of the score of a different guidelines that is filled in stage 6. So, doing this begins the process of recording environmental data and allows design teams to adapt gradually to the new process. So, this is essentially the implementation of design for environment in a scenario where it was not before. So, safety review was only there and DFE, then came into the play and then the teams have to understand both the teams together.

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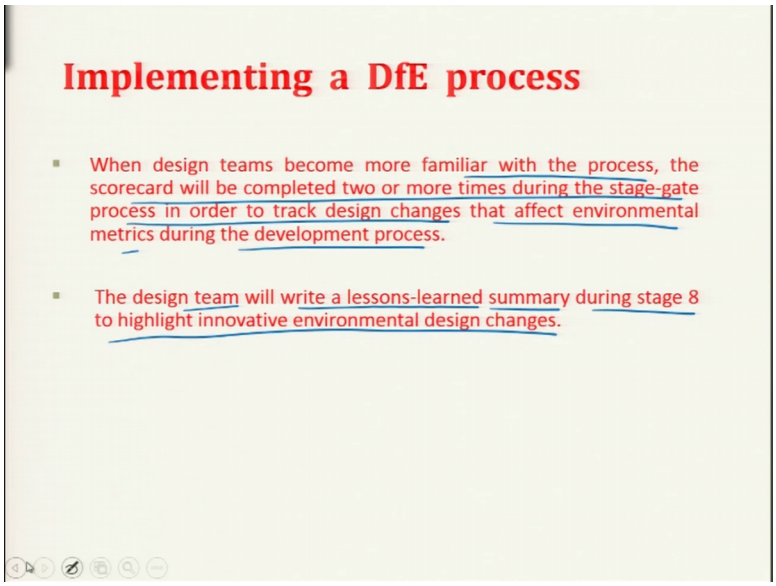

When design teams become more familiar with the process the scorecard will be completed 2 or more time during the stage gate process in order to track design changes that affect environmental metrics during the development process. The design team will write a lessons learned summary during stage 8 to highlight innovative environmental design changes. What essentially is here we will have to develop or write documents, these what as review these are actually documents initial environmental review safety environmental review these are the process and the process documents are to be written so what are these documents.

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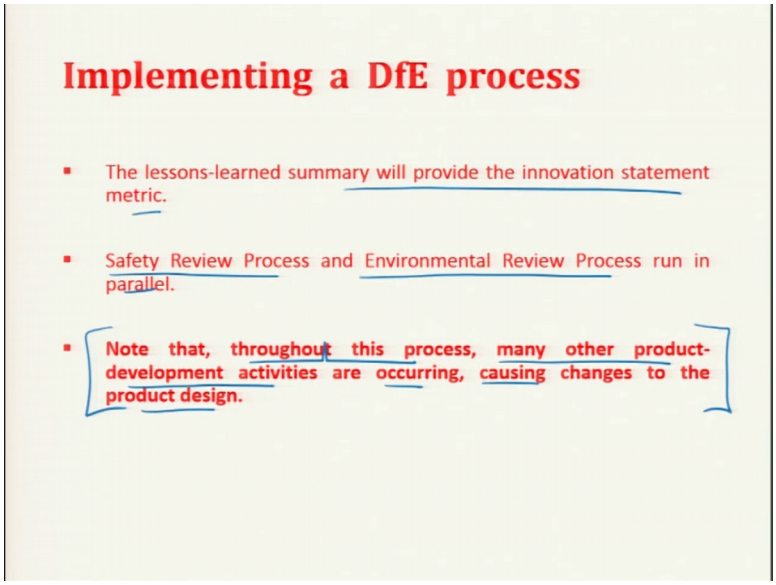

We will see in the next slides and the lessons learned from summary will provide the innovation statement metric, safety review process and environmental review process run in parallel we need to note that throughout this process many other product development activities are occurring causing changes to the product design. So, this is not only the safety environment that is going on many other things availability the difference between the schedule and the actual performance all those things are going on safety and environment are added to the basic production plan here.

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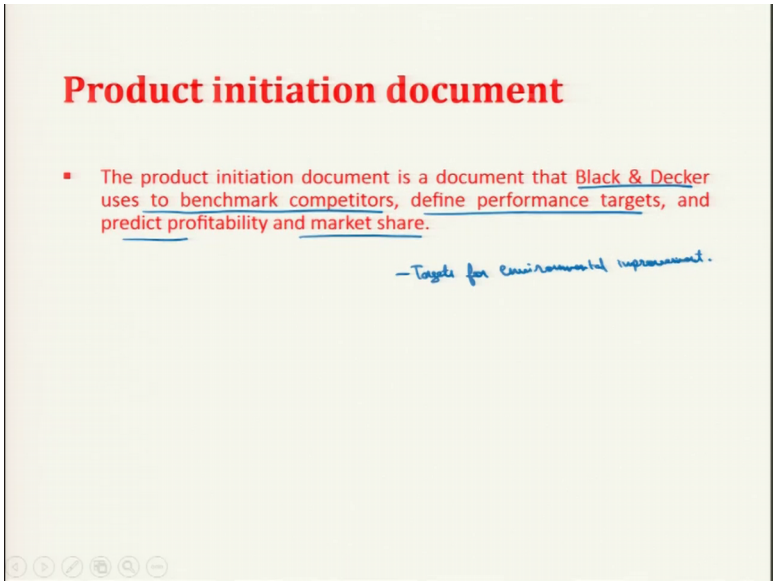

Now, what are the documents those are needed to prepare here first is the Product initiation document, product initiation document is a document that this company black and decker uses to benchmark competitors define performance targets and predict profitability and market share. So, it is initiation that from where or from which point the product has to start it is this document that is eventually this thing. The product initiation document will also address environmental regulations and trends and opportunities to create environmental advantage as I said here. So, targets for environmental improvement will be included, so this gives the targets for environmental improvement right, so this is the output of this document.

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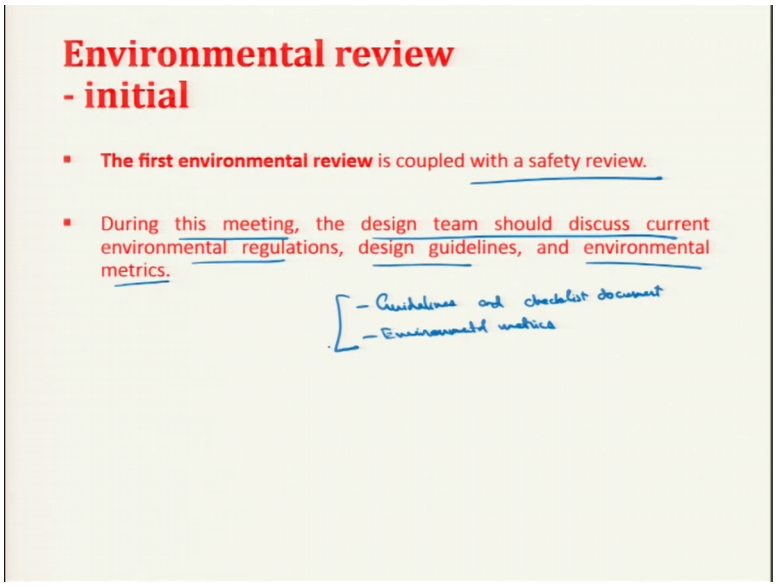

Then Environment review initial environmental review that was there in the initial stages the first environment reviews coupled with a safety review during this meeting the design team should discuss current environmental regulations design guidelines and environmental metrics this is what he suggested. So, there is a meeting that is to be held in the stage 2 where we have the initial environmental review.

Here we have initial government reviews in stage 2 this meeting discusses about the environmental regulations design guidelines and environmental metrics. In the first environmental review the list of regulations and design guidelines can be found in the guidelines and checklist document, so guidelines and checklist document is prepared here in the first environmental review also the environmental metrics are located in the environmental scorecard ok. Now in the lessons are learned from the old documents from the similar products let the previous or the past data is taken and so a pass products are reviewed in this meeting to facilitate the environmental design ideas.

The result of the meeting is an initial assessment plan, so overall we have an initial assessment plan there were a reliability representative will write the assessment plan and the list of ideas of brainstorm for environment improvement as we discussed in the valuing change or a creativity presentation.

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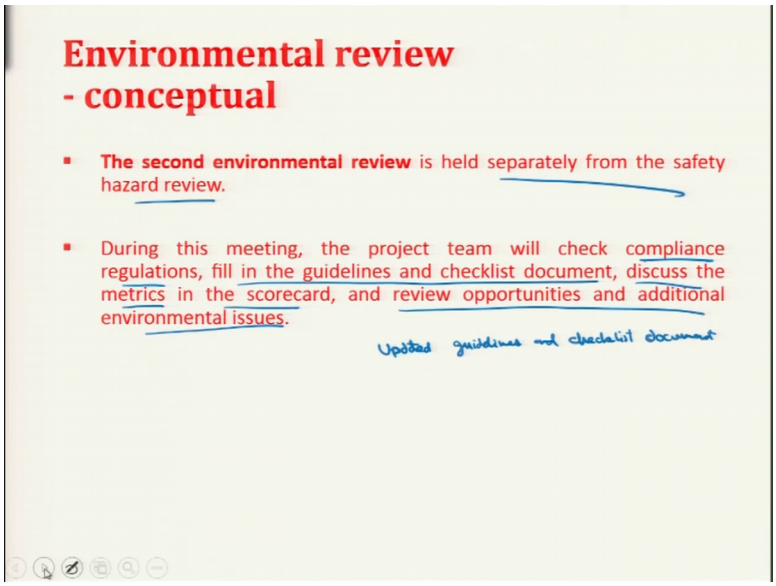

Next is second environmental review is held separately from safety hazard review, now safety is inculcated here in the initial document but second environmental review is taken separate. So, during this meeting the project team will check compliance regulations fill in the guidelines and checklist document discuss the metrics in the scorecard and review opportunities and additional environmental issues.

If you have any questions on the scorecard etcetera you can indefinitely read the paper published by Fitzgerald in 2007. So, it has retailed our scorecard in which multiple inputs were there multiple metrics are putting the scorecard the metrics can be the total product or packaging volume or weight then recyclability disassembly rating, then flat material or material used in the product then maybe energy consumption innovation statement all those can be the metrics to conduct this environment review.

So, in this case the guidelines and checklist are updated to get the updated guidelines and checklist document then reliability representative will update the guidelines and checklist document and write the minutes and lead engineer will update the scorecards for the next meeting and the next meeting is the third Environmental review which is coupled with the safety review again.

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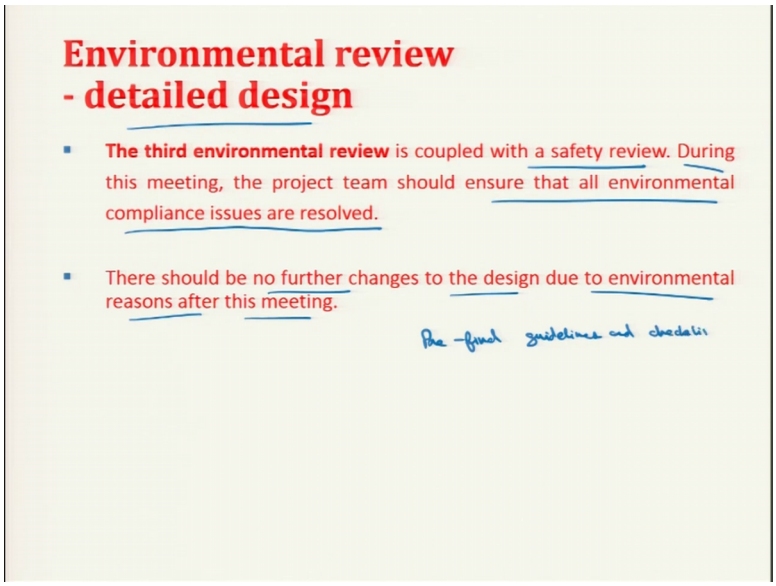

During this meeting the project team should ensure that all environmental compliance issues are resolved, there should be no further changes to design due to environmental reasons after this meeting. So, this is the detailed design when we are when we are go out the input from the separate this is separate environmental review and a separate safety review detailed safety environmental review document is prepared now. So, result of this meeting is an updated guideline and checklist again than the previous one, so we get the pre final guidelines and checklist why it is pre final because final phase says to come for the.

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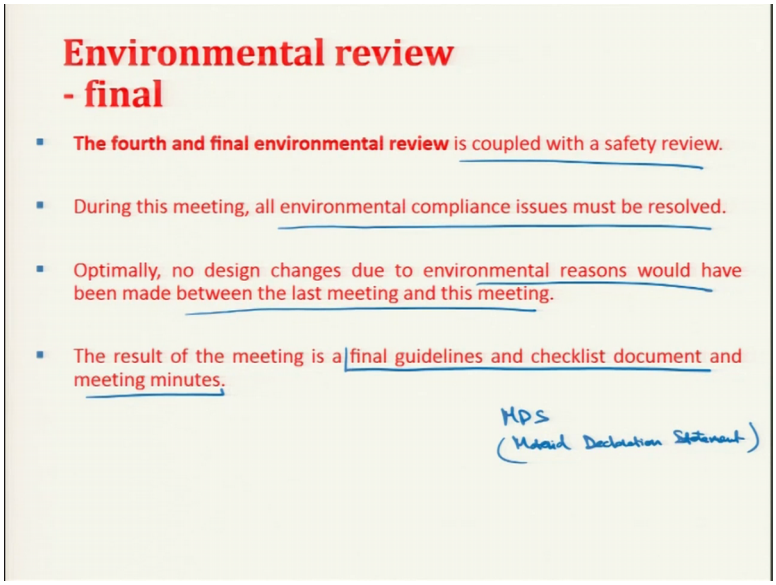

In the final phase of the fourth and the final environmental review this is again coupled with a safety review during this meeting all environmental compliance issues must be resolved, optimally no design changes due to environmental reasons would have been made between the last meeting and this meeting result of meeting is final guidelines in checklist document and meeting minutes, so this is the final that is to be delivered. So, the reliability representative will now finalize the guidelines and checklist document the lead engineer will now finalize the material declaration statement, this is material declaration statement this is made by the lead engineer where to work in production.

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After this we have post launch, in post launch what is there we just need to see that what went well with the project what did not go well with the project reasons why the product did not meet the targets which was set in the trigger document. So, this is the post launch or the feedback document the lessons learned summary will include the environmental design innovations, which are realized during the product development process for the maybe publicity or for the customer questionnaires, so these are helpful post launch things. So, an example of an item to be included in the lessons learned summary is a material selection decision.

In this post launch details should include what materials were considered and the rational of the decision the reason for using the materials. So, lesson learned summary is very important part of the design for manual process, because it provides the future design

themes with the environmental knowledge gained by the previous engineers. So, this is a document known as Feedback document it is also called as lessons learned summary this is post launch. After that we have feedback loop that has to run the completed guidelines in checklist of documents and Lessons learned summaries create a feedback loop of DFE process.

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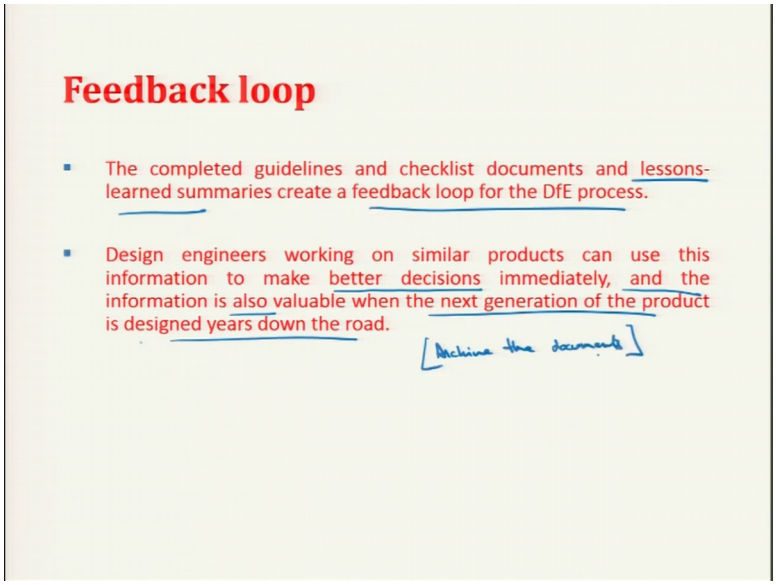

So this is a loop that is a cycle that has to go on and on the design engineers working on similar products can use this information to make better decisions immediately and information is also valuable the next generation of the product is designed years down the road. The design engineer will look or what environmental issues were made and why there we made it is a decision information scorecards comments on the guideline documents checklist all are archived here are archive the documents.

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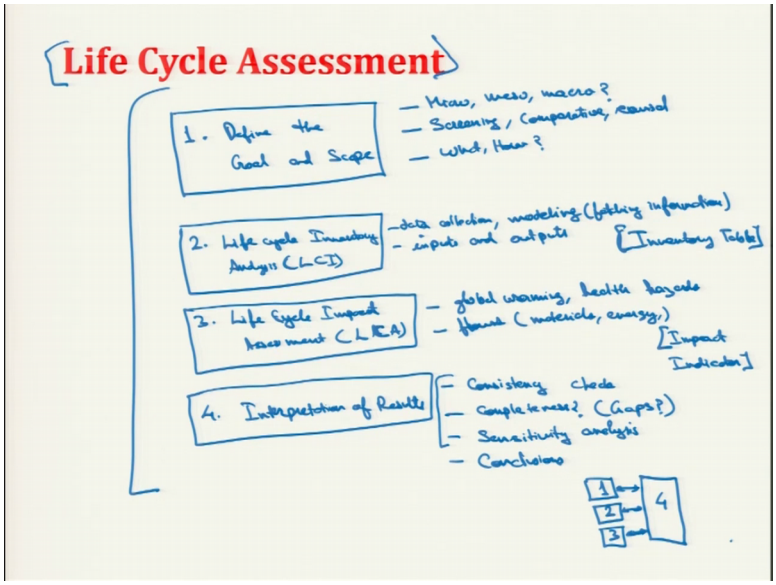

Now, in design for environment I said the most important part is the Life Cycle Assessment, life cycle assessment be a certain steps and how do we conduct the first step is we define the goal and scope of the assessment that what we are going to do right in defining.

Next step is the Life Cycle Inventory this is also known as LCI, third step is we now conduct the Life Cycle Impact assessment is known as LCA in a way and finally we have the interpretation of the results right. So, in the first step we define the scope, scope can be whether it is a product or component or the whole system or maybe for the whole economy we are thinking of what is the total globally issue original tissue product wise micro meso macro that I have discussed in the previous lecture. Then life cycle inventory analysis nothing but it is this is actually data collection only ok.

Life cycle backed analysis is the results of the LCI or the life cycle inventory analysis are transform into environmental impacts, then weights are given to them in interpretation of results we identify the most important environmental impact and limits and uncertainties for that. So, these threes are conducted here and for goal and scope the life cycle assessment models a product service or system life cycle. So, we actually tried to build a model that what will happen in reality, so this model is simplification of the reality and as with all a models and that it tries to simplify that happens in simulation as well they are distorted in some way. The challenge for a good life cycle assessment practitioner is

to develop the model in such a way that the simplifications which are made and a distortions do not influence the result too much.

The best way to so here is to define carefully what is the scope of the product, scope can be either micro meso and macro scales that I have just mentioned ok. I can either put whether it is micro meso or macro scale the scope can be whether we are working or till what we will have use are we going on whether it is before use during use after use most of the time where life cycle assessments. When you are doing generally most of the software's do it for the before you start before uses from the extraction of the ore to the final delivery of the customer. If there the ore can even be defined like in a life cycle like in EIOLCA economic input output life cycle assessment that will that just discussed the online tool is there.

There are two kinds of price is there purchasers price and producer price, purchaser price is that when purchaser is processing that that means after production after the factory the work is there before use after the production from the production point to the customer point is delivery transport is also included. So, this can be a scope like there is manufacturing and transportation at richest customer scope can even be the producers price that is just production at this point it is limited transportation is not included. So, that scope has to be defined very clearly when we have to start the life cycle assessment so this is one above one.

Also in defining this scope we need to say whether it is a screening life cycle analysis what is kind of life cycle analysis, it is just screening or just the assessment or it is comparative that whether we are comparing 2 different products or it is a complete product and mitigating results with that, what do we also need to put the causes of that I can put causal or the reasons. So, it can be external or internal certain review verifications can be there, so this is defining goal and this scope. So, in the goal and scope also we need to know who is the intended audience what are the primary intentions who are the involved parties. So, definition of product system what this what is definition of the function of functional unit that we are considering.

And all these points need to be addressed here there are certain question that need to be answer, what is the reason of carrying out the study that is one putting the causal we will need to put on that then what is the internet application what to analyze and how to

analyze yeah this is important what and how this is important. Why it is because we need to know the life cycle assessment it is ok, but these are important questions here next comes the life cycle inventory analysis that is essentially the collection of data and along with collection of data we have data collection and data modelling and modelling is actually the putting the data and the formula of information yeah it is not the complete modelling.

For about this whole life cycle assessment, this whole is a complete modelling itself this is just actually fetching information can this result say can be inventory table extensive list of environmental, interventions those are there then these things are there in the step number 2 where we look at the environmental inputs and outputs output inputs and outputs. So, which are associated with a product or service such as the raw materials energy emission pollutants total pollution waste streams, so this is where we get the complete picture that what is the status we have just define the goal and scope in the first step and here we get the overall view that what is there. Now we need to conduct the third point that is lifecycle impact analysis.

A life cycle impact analysis we draw the conclusions that allowed to make better decisions we classify the environmental impacts evaluated them by what is important to the company or to the economy that we are talking about and to we need to transmit them to environmental themes such as global warming human health. So, those are the broad terms global warming health hazards we need to quantify them in this way, the third step we need to actually determine the environmental impact of the reference flows a certain flows of what materials energy and we have emissions. So, what they are in this case actually we are translating the inventory table we get a inventory table here.

Inventory table this is now translated into an impact indicator impact indicator, now the results right but this is not the end. Now we need to interpret the result as well while interpreting the results which is the last step conclusions are well established the conclusions are to be made, the If standard describe a number of checks to test whether the conclusions are educatory supported by the data or by the procedure which are used. So, in this way one can share one result and improvement decisions with the world without any surprises, so the conclusions are to be made and second checks like consistency check ok.

Then completeness check that whether it is complete or not or we need to identify the gaps, then we need to see this sensitivity analysis sensitivity analysis that whatever we have conducted as a conducted study on the specific set of the data, is it replicable or is it possible to produce some general conclusion out of that or not or within our limits what will we can we can put here. So, next is finally we put conclusions, if we take off the conclusions from here and just consider these 3 parameters, so people even defined it in a way that the interpretation of results go hand in hand with the first 3 steps for instance this is step 1 2 and 3 step 1 is would be defining the goal step 2 is life cycle inventory.

Then this is life cycle impact analyses the 4'th step is here that is interpretation of results that go hand in hand at each step at each step we need to interpret or we to need to see that whether whatever we have got we have got the information given this scope a goal whether it is good or not or whether it is acceptable to our work according to that boundary that were designing or not. So, life cycle assessment helps to have in sites in the environmental impact the company's clients or investors want in sites in the environmental impact of the products or the production process and cost reduction happens.

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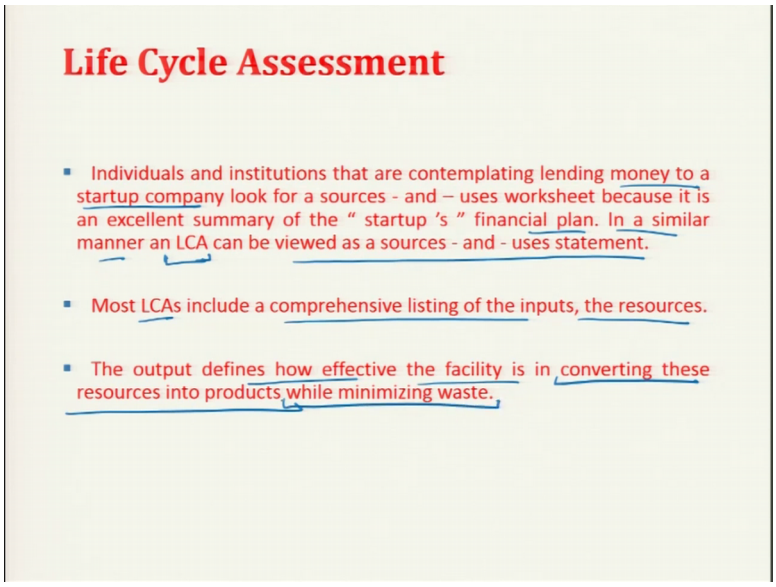

So, let us read a few lines on life cycle assessment, so this is some information about the life cycle assessment now individuals and institutions that are contemplating lending money to a startup company look for sources and uses worksheet because, it is an

excellent summary of the startups financial plan. In a similar manner life cycle assessment can be viewed as a sources and uses statement because, the customers are demanding the green product these.

So, these insights in an environmental impact once clients and investors who like to have insights a customer would like to see the production process in a way. So, that is important so most life cycle assessments include a comprehensive listing of inputs and resources the output defines how effective the facility is in converting these resources into products while minimizing waste this is important.

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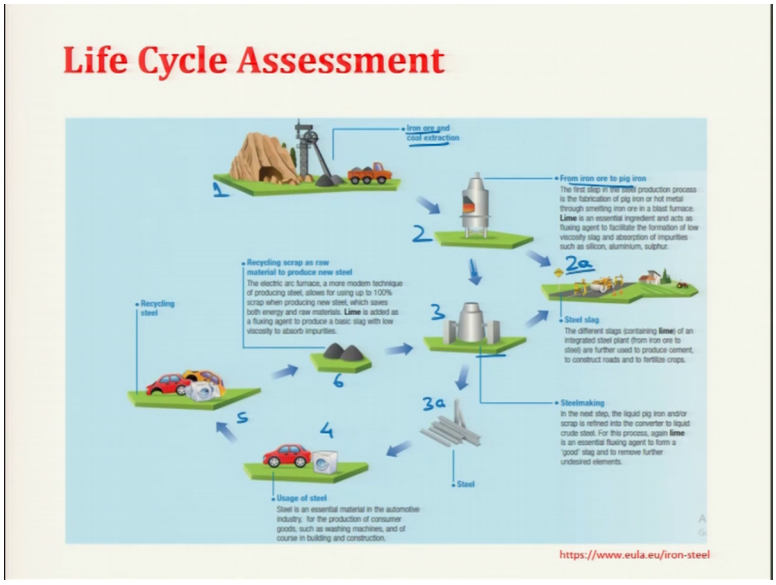

This is an example of the material flow in life cycle assessment that how production of steel and finally we get the goods we use them and it is recycled this is the material flow the same thing that I showed you in the block diagram how recycling remanufacturing and reuse happens reuse is not here. But recycling is essentially here this is actually extraction of the ore which was the first step, from extraction of ore first is the we get pig iron this pig iron is then help then has to produce steel here. We get steel here in third step this is step 1 this is step 2 this is step 3 this thing we get steel in step 3 this is the product of step 3 this second put step 4 finally get the product step 5.

We send the product after the service life to scrap and from that from that this recycling scrap is again taken this is step 6 that again goes as an input to step 3. Now we can see something here this is as I said industrial symbiosis in industrial symbiosis what happens

this is I can say not a step this is a step I would say 2.2 a this is 3 a, in 2 a what happens the cement is produced let us try to see the step 2 see any example in steel manufacturing for life cycle material flow. So, this is taken from the reference here so iron ore coal extraction is there first pig iron is produced.

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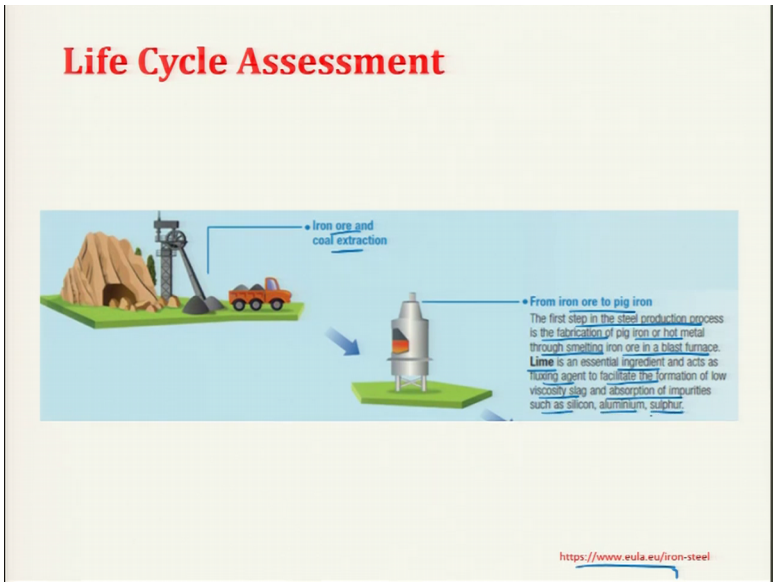

The first step in the steel production process is a fabrication of pig iron or hot metal through smelting iron this is a blast furnace, from which this is a blast furnace from which lime is essential ingredient that act as a fluxing agent to facilitate the formation of low viscosity slag and absorption of impurities such as silicon aluminium, sulphur and so on.

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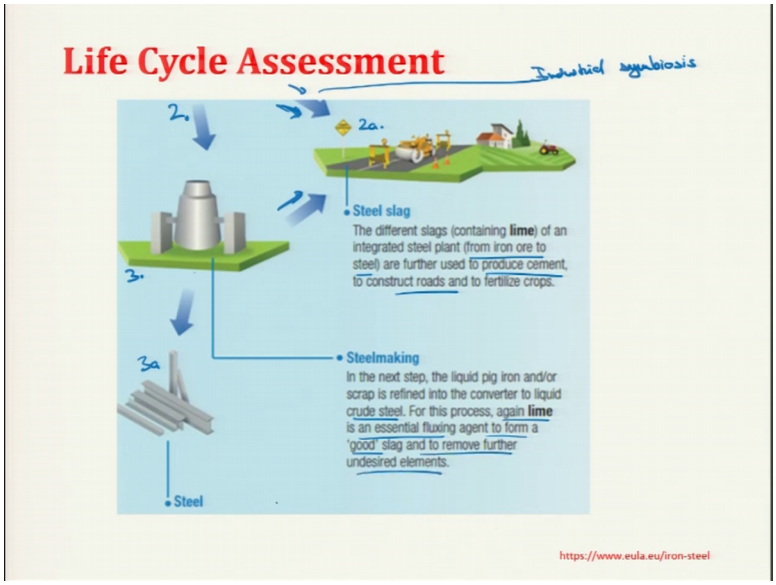

This slag can be used to produce cement this slag comes here this has to produce cement here, the different slag's containing lime of an integrated steel plant from iron ore to steel are further used to produce cement to construct road, from here the next step come is the steel making.

Steel making also produce slag which also goes here, so this is an example of industrial symbiosis, different slag's containing lime of an integrated steel plant from iron ore or steel are further used to produce cement this is from iron ore this is from steel. So, actually from step 2 step and step 3 this is step 2 a, so this is step 3 where we get the steel that is ready in steel making what happens the again the liquid pig iron scrap is refined into converter to liquid crude steel for this purpose again lime is an essential fluxing agent to form a good slag and to remove further undesired elements.

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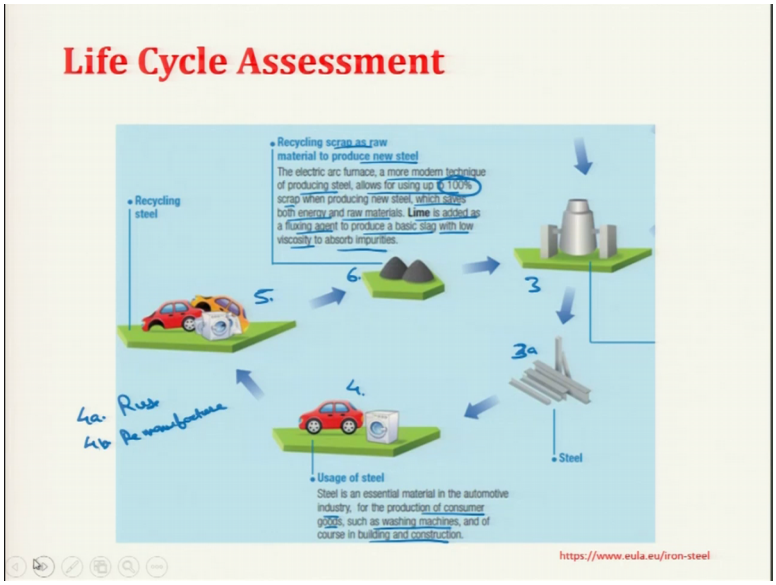

Next is after this step 3 and 3 a step 4 is the final use the usage of steel is an essential material in automotive industry and the production of consumer goods in the home appliances production of automotive the car is being shown here. They are used in production washing machines and of course in building and construction.

So, this is a use of a steel after the use you to go to step 5, step 5 is recycling we are not considering re use here that is a step in between I can put step 4 a is reduced or 4 b can be remanufactured. Now step 5 is when re it goes for recycling and re after recycling it goes as a scrap this steel scrap as a raw material to produce new steel electric arc furnace. That is a more modern technique of producing steel allows for using up to 100 percent of scrap when producing new steel which saves both energy and raw materials lime is added as fluxing agent to produce basic slag with low viscosity to absorb impurities.

So, this is a material so for specifically in the steel manufacturing that is taken as an example to illustrate that how the flow from the extraction of the ore goes to the customer then it get comes back to the manufacturing of the steel itself.

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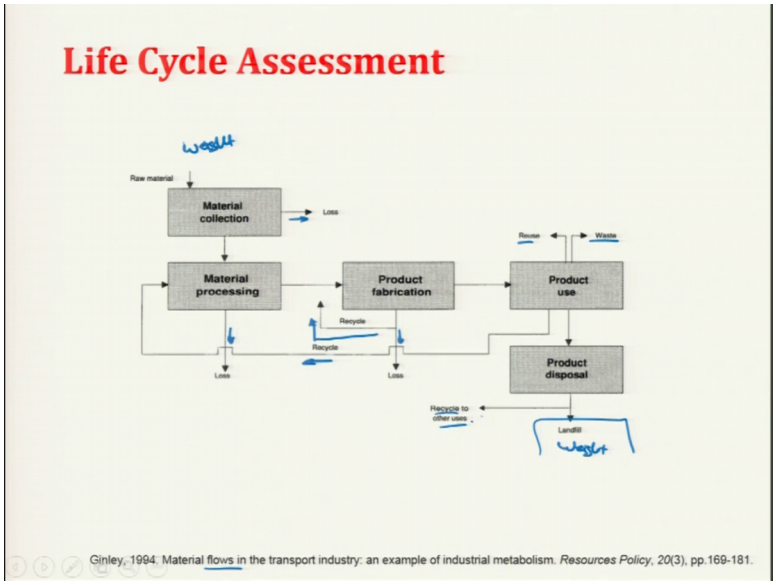

So, this is one of the examples now this is a study that is taken by Ginley on 1994 that is well sited by many people. In this case they connected life cycle assessment in a way that this raw material that is collected by weight of the raw material and the final that is that goes to landfill, what is the way that goes to landfill. So, in that way they take this is a detailed collection and what is the at each stage the series some loss when material collection is material collection is in a way collection of ore there is some loss ok.

In case of processing that is when manufacturing there is some loss this loss is again in the weight during production of fabrication there is something loss, which is the this is the manufacturing of automobile some laws and in this case some recyclability is also there. After this the product use is there after the use also there is some recyclability that goes here at each stage there is some loss and reuse also some weight is reduced and waste is also produced here, but this is disposal this is where the final landfill goes. That is the final waste or that is of no use, but it can also be recycle for other uses recycle is taken here in this case.

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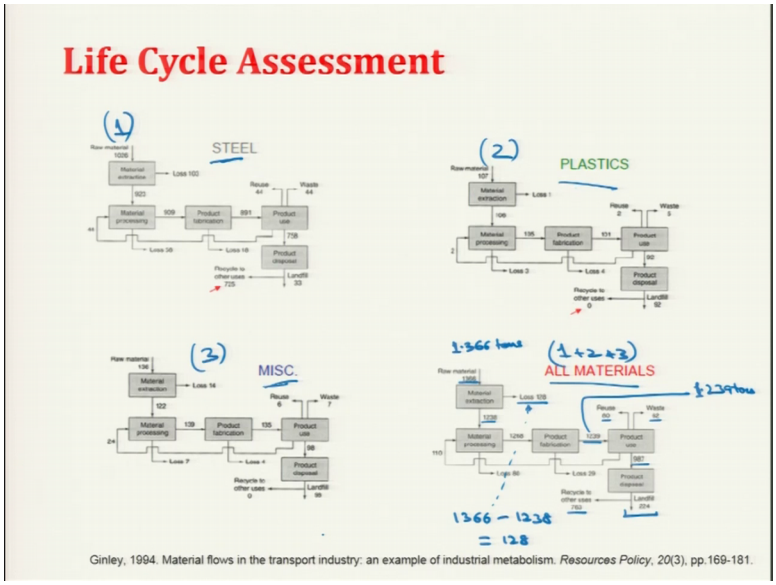

So, they have made this assessment for different materials this is steel plastics miscellaneous and all materials this is actually for all materials and this is I will put this as 1 2 and 3 this is 1 plus 2 3 all material is like this. So, what is actually going on here a an automobile is dismantle, this specific materials steel plastics and other materials are taken separate the total waste that is taken while manufacturing the automobile and the losses that happens those are studied and finally what is the weight that goes to the landfill that is taken care this is one of life cycle assessment that they did in 1994. This is around 25 years ago.

So, the total weight of the automobile was thirteen hundred and 66 kg I can put it is around 1.366 ton. So, this is the total weight the total loss in material extraction or the extraction of ore is 128 kg and a material that go that goes from material processing is this.

Actually how it is taken first the total raw material that is extracted is taken and total material get that goes for processing is taking this difference this 128 is 1366 minus 1 2 3 8 this is equal to 128. This weight comes here the loss in this and around 1200 kg of material goes actual fabrication where actual fabrication happen and the weight for the product that is used by the customer, the weight of the product that is the car that is delivered to the customer is around 1.239 tons ok. So, while using and we reusing 80 kg is consumed if waste is around 62 kg the total disposal weight is 987 kg of which 763 kg

is again recycled and in the first run 224 kg goes to landfill this is the total weight. This is the separate weight for steel plastic and miscellaneous.

Now, what one can determine from this the percentage is weighted now what is the total percentage of steel that is consumed, what is the total percentage of plastic that is consumed impact of these specific material that can be taken into account.

So, what is the material this can be normalized on the basis of percentages and the comparative statements can be made depending upon what is the carbon emissions total greenhouse gaseous emissions that happens during manufacturing before manufacturing so all things are considered here. So, this is one of the way or one of the studies on life cycle assessment that is taken by this researcher.

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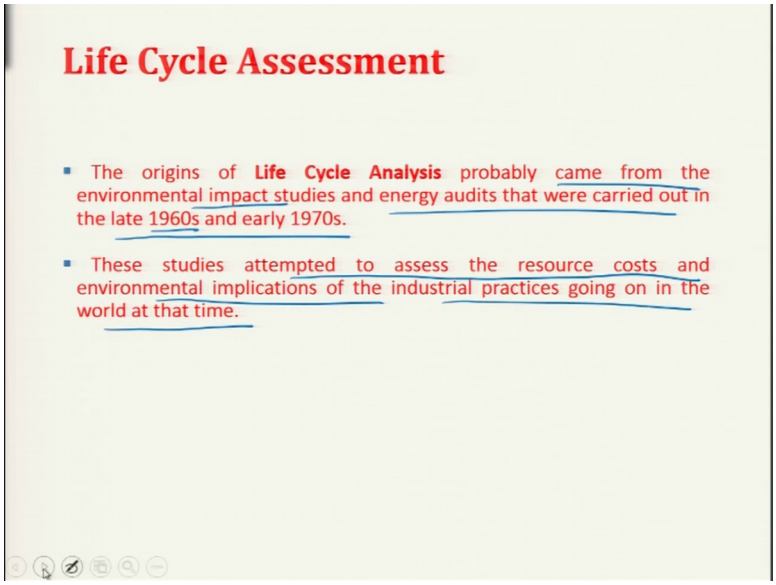

Moving on the origins of life cycle analysis probably came from the environmental impact studies and energy audits that were carried out in late 1960. And early 1970, these studies attempted to assess the resource costs and environmental implications of the industrial practices going on in the world at that time and it was started way back in 1960 and we have seen once study in 1994.

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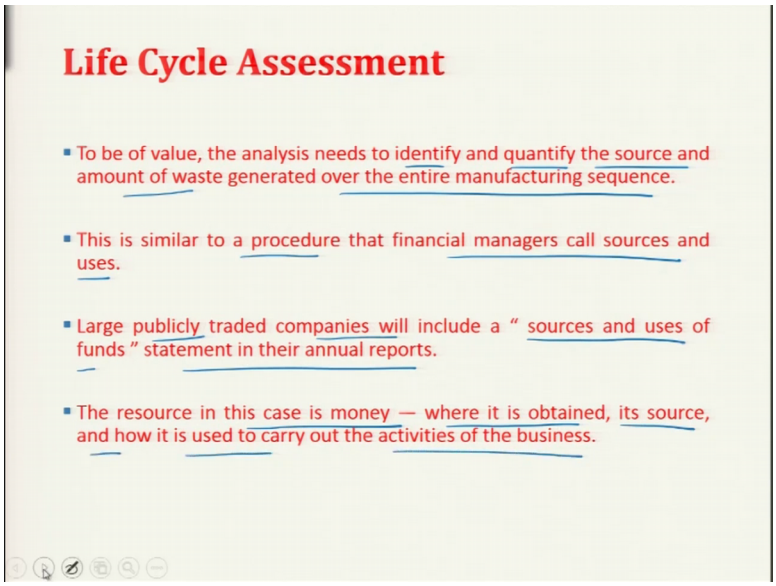

To be of value the analysis needs to identify and quantify the source and amount of waste generated over the entire manufacturing sequence. This is similar to a procedure that financial managers call sources and uses large publicly traded companies will include a sources and uses of funds statement in their annual reports. The resource in this case is money where it is obtained it is source and how is used to carry out activities of the business.

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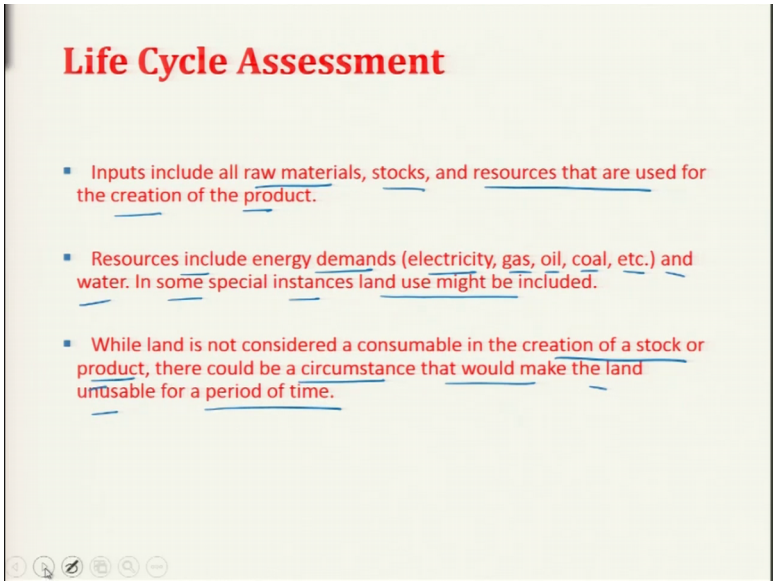

In the similar way, life cycle assessment in this case the inputs include raw materials stocks resources that are used for the creation of the product, resources include energy demand here the gas oil coal etcetera and water. In some special instances land use might be included while land is not considered as a consumable in the creation of a stock for product, there could be circumstance that would make the land unusable for a period of time that is why the land can also be considered as one of the resource.

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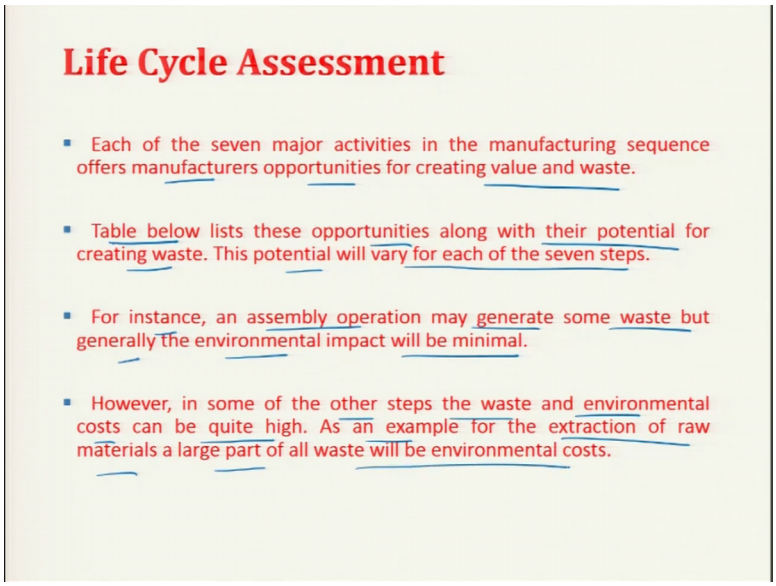

So, each of the 7 major activities in manufacturing sequence from the very extension of the ore to the final delivery with the customer offers; these activities offers opportunities for creating value and waste the table in the next slide lists these opportunities along with their potential for creating waste. This potential will vary for each of the 7 steps for instance an assembly operation may generate some wastes, but generally the environmental impact will be minimal.

In assembly there is not much energy used note no they are not there is not much pollution produced. So, environmental impact is minimal here but waste is there. However in some of the other steps the waste and environmental cost can be quite high as an example for extraction of raw material a large part of waste will be environmental cost.

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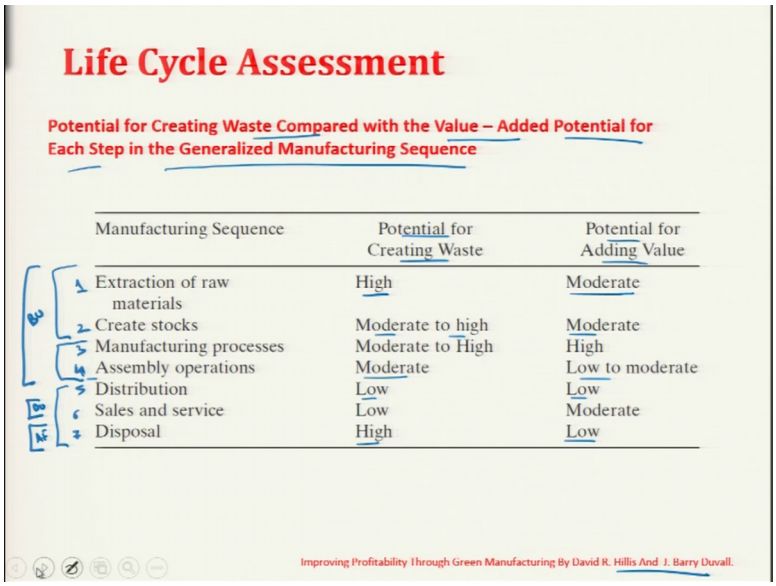

So, this is given in this table here this is again taken from a study the potential for creating waste compared with the value added potential for each step in the generalized manufacturing sequence. So, this is step 1 2 3 4 5 6 and 7 this is extraction of raw material the potential of creating waste is high, the potential of adding values moderate is not adding value adding value in a weight is telling that adding value in the terms of from the view point of the customer.

Adding value in a way means the total value that customer receives customer wants the automobile to be manufactured a what automobile to be economically right aesthetically looking good working properly giving good performance, these are the functions that customers need in that extraction of ore yes it is adding some value it is not flow. But because the material is there but it is not even high now create stocks from the extraction of materials the potential of creating waste is moderate to high and potential of adding values moderate manufacturing process this is actually manufacturing.

This is before manufacturing this is after manufacturing and specifically this is after use this is during use and this is before use I will put it this is before use this is during use this is after use. Now you can see in assembly operations there is a moderate waste, but low to moderate value is added and distribution the waste is low and the potential value added is also low in disposal the waste is very high and the potential value added is low

in the product. So, this is the generalized manufacturing sequence and the potential of the creation of waste and adding value which are compared.

Now, in this balancing the potential for waste against the potential for adding value has been a manufacturing tactic for years. Now the changes in technology is coming knowledge management these things are coming which requires to reorder the balance between the value added and the waste generated at a particular step, to the company that limit itself to only 1 step to understand the company would like to limit itself to tool manufacturing processes or for instance if company would like to limit itself to only assembly operations. So, that would be in 3 b simplifying it is business by focusing on just that function, but this limits the company to calculate the total value added in the step.

Alternatively to this manufacture should try to do all the 7 step at least for life cycle assessment maybe they are not in this business, but at least for life cycle assessment in order to on the value added potential from the raw material to the sale and disposal of the product. So, this has to be the approach in the present demand that is coming for the green products, also the company would have to develop the skills and expertise for all aspects of manufacturing sequence it is also required.

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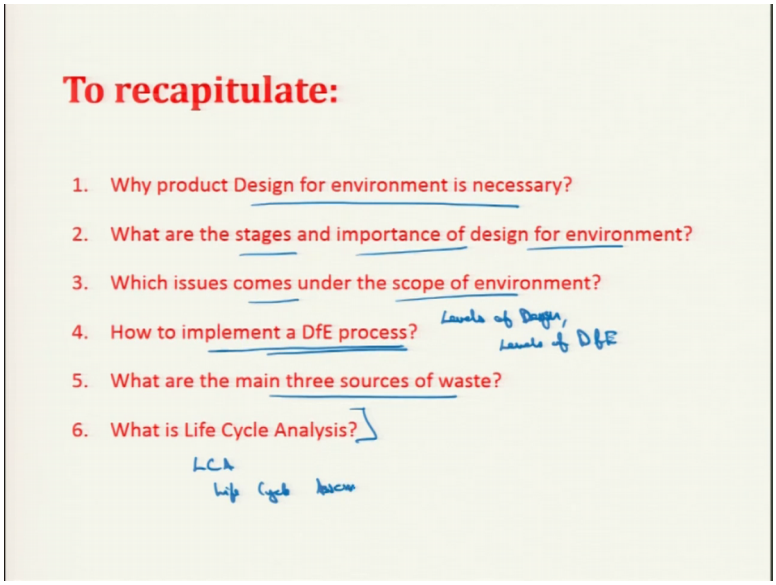

So, just to recapitulate we have seen in this presentation why product design environment is necessary, what are the stages and importance of design for environment,

which issues comes under the scope of environment. We have seen the scope in the these 2 3 lectures. We have seen what is designed for environment we have seen how to implement design for environment, we have seen the levels of design we have seen the levels of design for environment, then we have taken once study on implementation of DFE or one of the approaches that was taken by a researcher.

Then what are the main sources of wastes that we have seen, then we saw what is life cycle analysis and more than that we saw what is life cycle assessment. After this I would like to discuss the software tools one is an online tool that is life EIOLCA economic input output life cycle assessment that we will let us take in the next lecture. After that I will discuss gabi tool which I said I will just tell you what are the various software's available open source and the licensed versions and what are the software's on that you can just get an in an open source and work on. So, we will see and try to see the examples that what is life cycle assessment and what are the results those come and how to interpret those results.

Thank you.