Life Cycle Assessment
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Lecture – 38
Summary and Case Studies
(Contd.)

Hello, welcome back to the third module of week 8. So, as we know this is the last week and I showed you few examples in the previous module, we looked over the two examples again these are the case studies from actual projects which has been done either research project or the student projects that we have looked at.

So, again today we will try to go over three projects again I will give you a quick overview, and these materials will be available to you can go over that in more detail and this is kind of repetitive because we do the same stuff again and again in terms of goal and scope definition, functional unit life cycle inventory, as well as the impact assessment and those calculation.

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Science of the Total Environment

ELSEVIER

A comparative life cycle assessment of conventional hand dryer and roll paper towel as hand drying methods

Tijo Joseph, Kelly Baah, Ali Jahanfar, Brajesh Dubey

So, the first module as you can see this is on we are looking at a comparative life cycle assessment, this is a competitive life cycle assessment of conventional hand dryer and roll paper towel. So, this was a study which was done couple of years back, and this was a study funded by a campus it was a university many university campus is now have sustainability office. So, this particular we this particular study we looked at whether in a washroom if you go for after you use the washroom you have to dry your hand. So, while drying the hand should we go for a paper towel this dispenser unit, with a paper towel in there or should we use a hand dryer hand dryer which is electrical the hand dryer you go to any airport today and you find that, you find the hand dryer and you also find paper towel at many places.

So, when you compare these two again you have to kind of think about what will be the function, what is the functional unit. So, this particular study was done as I said few years back and here we looked at this one. So, when we started looking at this particular study the question comes is how will you do it. So, as you can I will try to explain it using some of the figures from here. So, as you can see on this particular figure there are.

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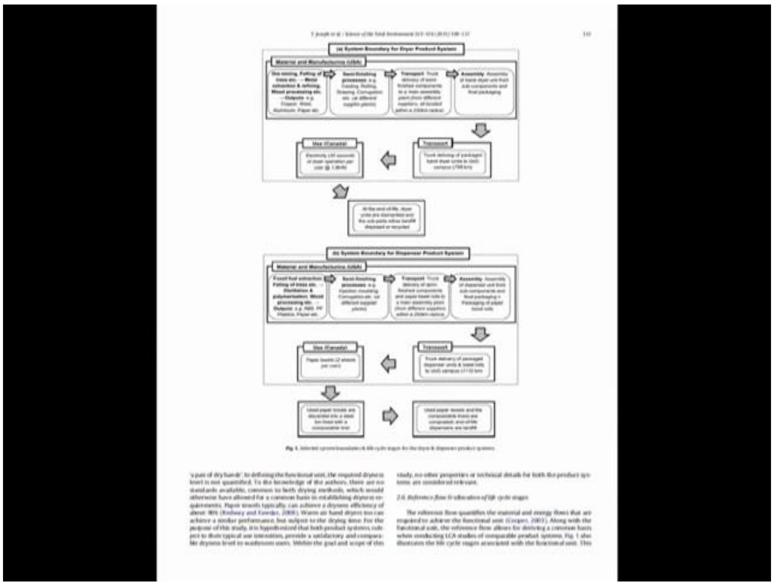

If we had two systems we have a system of android and the other system is paper towel. So, for both of this system we need to come up with a functional unit. So, the function unit for this is a essentially what is the function? If the function is to dry the hand after the usage of washroom.

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HIGHLIGHTS

ARTICLE INFO

ABSTRACT

So, when you are trying to dry the hand it is essentially your pair of hands. So, this is the pair of hands is our functional like a functional unit. So, drawing of a pair of hand could be a functional unit in this case. So, for both of this product the function that it provides is drying the hand and, functional unit could be a set of drying hand. Now with that functional unit we are either using the paper towel or we are using the hand dryer. So, we can use either of them two. So, we have now two different systems. So, what for these two difference in this particular figure we are trying to show that in terms of a system boundary again it will be you your material acquisition, you are like a transport and since this work was done in Canada and so we and the material this particular product was made in US. So, we assume that all the manufacturing in USA and the transport to Canada to this particular campus unit.

So, when you try to go for life cycle inventory as you know we have to go for the life cycle inventory.

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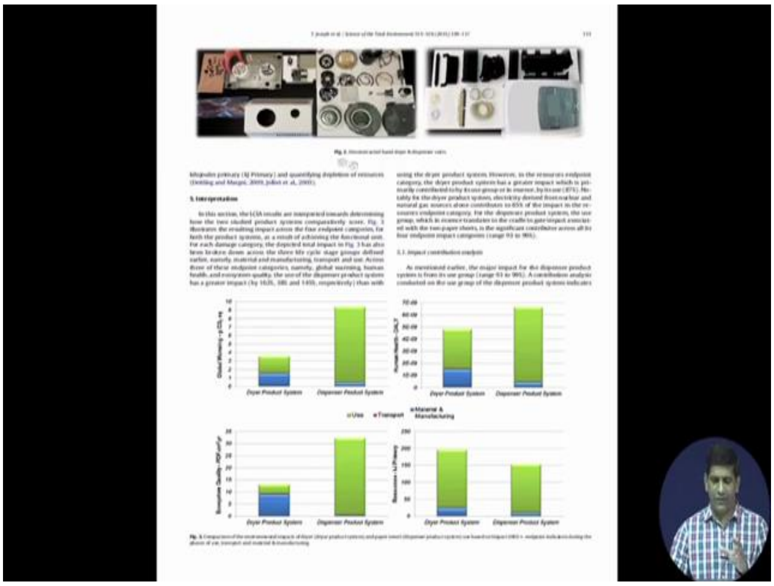

So, for the life cycle inventory as you can see over in the picture on the top here, we are all we did not knew what is there in the material. Of course, you what you will do is a this is two different products you can go to their website and try to find out the composition, when you try to find the composition you have to actually look at each and every item which is present in that particular product, but many times you do not have that information or what happens is the company will not give you the information because of the proprietary reason. So, in that case what you could do which was done in this particular study is we have we took one of paper dispenser, and we also took it this one.

So, I like a hand dryer electrical hand dryer we took it apart as you can see in this picture on top here this is the how we have actually taken apart the hand dryer as well as the dispenser unit, now each and every way to each and every item present here like how much is a plastic how much is a metal. So, all these materials all these items waved and then after waving these items, we could come with this life cycle inventory. There were certain materials which we were not sure what they are. So, there you need to get the help of your material science professors on campus or your material science colleagues and they can help you to find out what are those material out there, the other way you can go for xrd or xrf for those kind of analysis to come up with what kind of material is it. So, bottom line is that for each and every component which is present in a significant way, if you are many times what we do if it is a small screw a small very small part of like a piece which is we are not sure what it is you can ignore that, but for most part you can we should able to we should be able to find out. So, that becomes your life cycle inventory.

Now, for this life cycle inventory of the product you can use it you can use a software and this particular studies sima pro was used as a software that is one of the software sima pro is as said I thing in the previous classes well you can download sima pro there is a student version of the sorry demo version of that software available which lets you play with that a little bit it, also has a manual which comes with that and also has like a it is a software manual as well as there is a l c manual which comes, with a certain solved example which you can walk through in using that software. So, it is a good tool with those two documents actually you can learn the software part of it, which unfortunately we could not cover in this class that much because of we did not have any lab. Usually if we have a lab in a course if I am teaching course like a regular course in campus you will be lab associated with that and we cover the software part in that lab.

So, coming a. So, once you have this LCA inventory then you have the standard way of in putting all this LCA inventory data into the software then that will give you the then it will give you that different impact categories.

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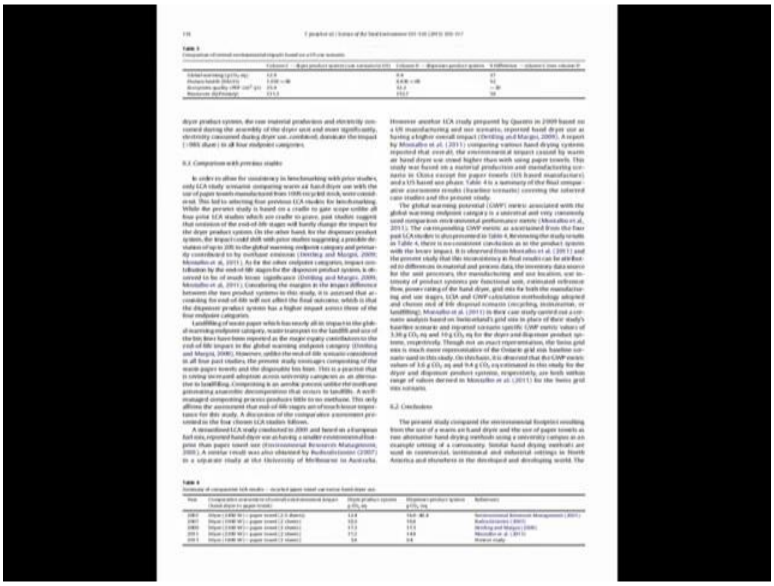

So, you look at the impact categories of the differ of the system and you come up with all the up what is the impact in terms of the global warming as in this particular table on top you can see the global warming potential, human health equality resources, and what we found is this if you are using the recycle paper and if you are using this; if you are whatever is the paper coming after the usage if you are compositing that particular paper this paper towel came out to be a better option than the hand dryer unit. And again the hand dryer unit energy is the major consumption, so energy you have to be careful what kind of energy you are using, is it a coal based thermal power plant, is it is a hydro, is it a nuclear power. So, based on that your answers will change, but for this particular setting in the province of Ontario in the southwest Ontario, again the geographical region means is a very very important in terms of looking at what will be what is the like a output for that particular system.

So, geographical region does play a good role in terms of deciding what is how the output will be. So, in this particular case Ontario, southwest Ontario this was a (Refer Time: 08:12) university setting we found out that this in this particular case of that paper towel with was came out to be a better option, and assumption was paper towel is recycle paper towel and the residue after the usage is going to a compost facility. So, this is and again that this material is available.

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And we have made this available to you. So, you can I say part of the week eight material you have access to this. So, you can have a look at that in as a reading material. So, this is one example. So, I will kind of go through two another two examples quickly which is kind of related to each other. So, these days we are going a lot in terms of looking at looking for a in a bio bioplastics.

So, that is another example where you can use it. So, here this is a plant based plastic water bottle. So, whether is it a green washing, or a small step in the right direction. So, if you are trying to do this life cycle assessment of environmental profile of PLA and PET water and PET PLA is the pop, it is bioplastic and PET is the regular plastic bottle that we use.

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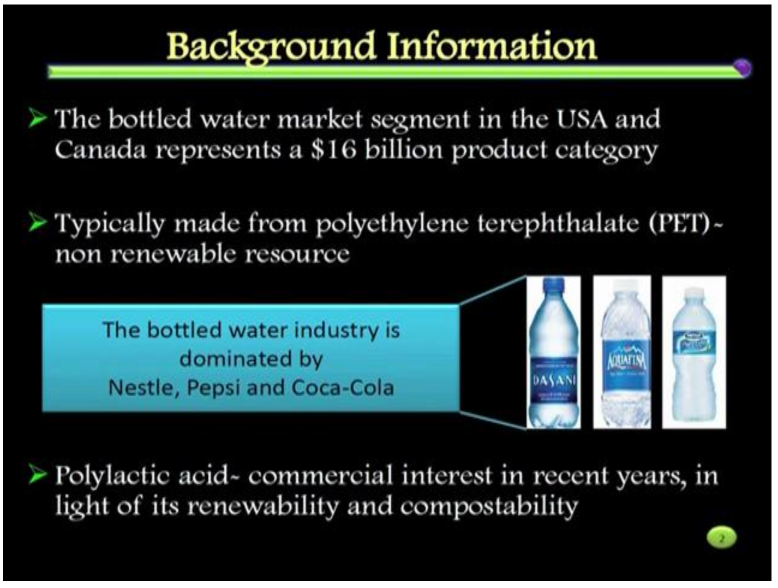

So, here some background we know the bottled water industry is dominated by the different companies bottled water is becoming a big (Refer Time: 09:34) in some sense you can also say it is a big new sense actually in today in terms of what is happening in the industry. So, even if you are in any meetings we go today in any conferences or any even a small meetings you see lots and lots of plastic water bottle, and this water bottles are becoming a new sense in terms of plastics into the environment, with huge amount plastic waste coming to the environment.

So, there has been push in terms of rather than using this plastic water bottle, we can we go for a bioplastic where we can use this bioplastics for instead of this traditional plastic.

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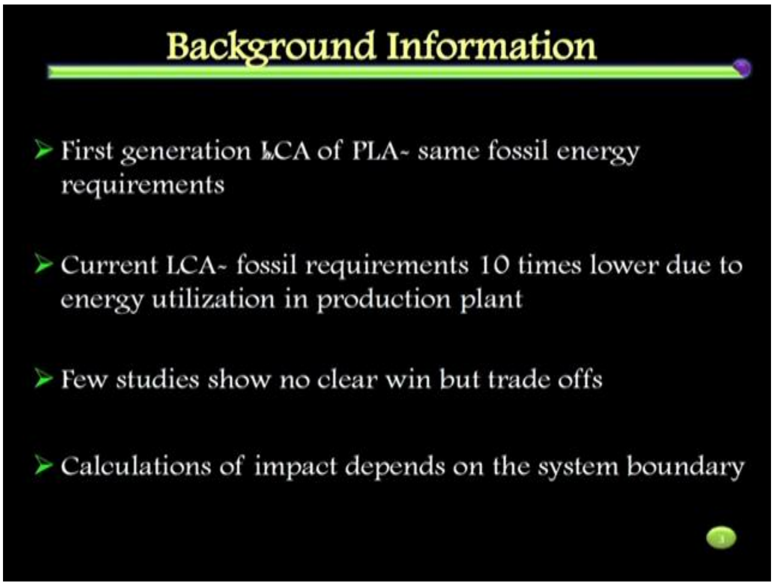

So, in first generation of LCA of PLA is same fossil fuel requirement was there. So, there it was they were looking at, but the fossil requirement was ten times lower than what is required in to in terms of regular plastic, there is no there have been few studies which shows no clear win or trade off. So, we try to do say study here and as I said earlier in the lecture material that system boundary plays a major role in terms of how you are looking at, what kind of impact to you see it depends upon the system boundary. If you can play with the system boundary and you can make looks something very good or you can make look something very bad as you play with the system boundary.

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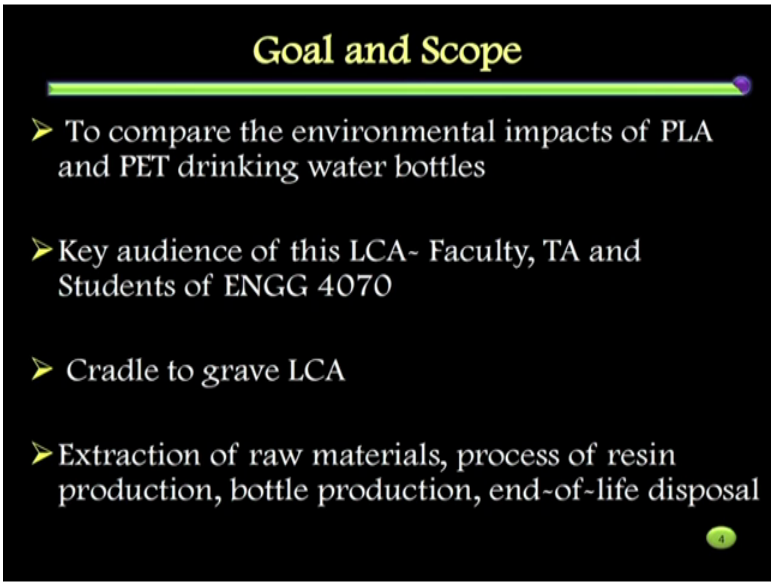

So, in this particular work again this was a kind of a project the student driven project where one of my student has done it, it is a hot slide. So, if they compare the environmental impact of PLA and PET to drinking water bottle here the cradle to grave LCA was done.

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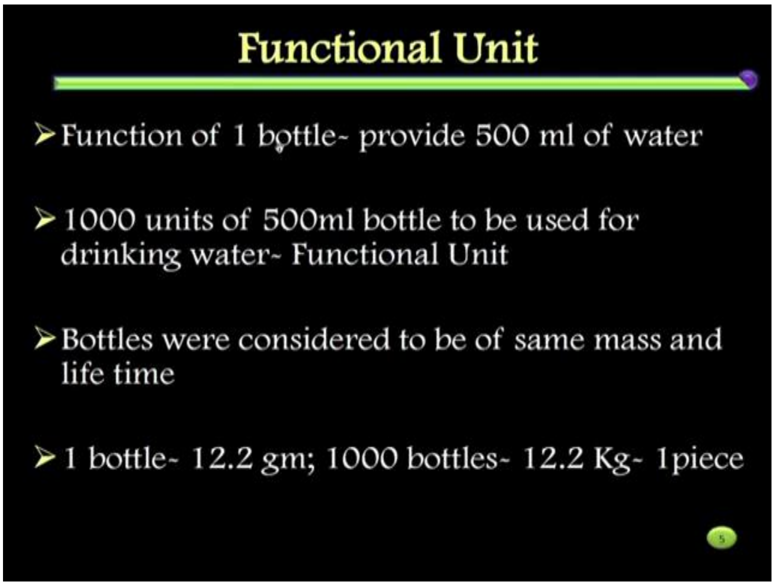

And from extraction of raw material, process of rays in bottle production end of life disposal all things was done. So, in terms of the funds again we have to after having the goal and scope next thing is functional unit. So, here we use the function of one bottle like a 500 ml bottle which is not the one liter bottle, which if you have 500 ml bottle. So, provide 500 ml bottle of water. So, we have we take thousand units 500 ml bottle just you could take one unit as well, we use thousand units of 500 bottle as the functional unit, and the bottles where considered to be of the same mass and life time.

So, it is one bottle was around 12.2 grams. So, thousand bottle becomes 12.2 kg, so that is our functional unit in terms of this particular exercise.

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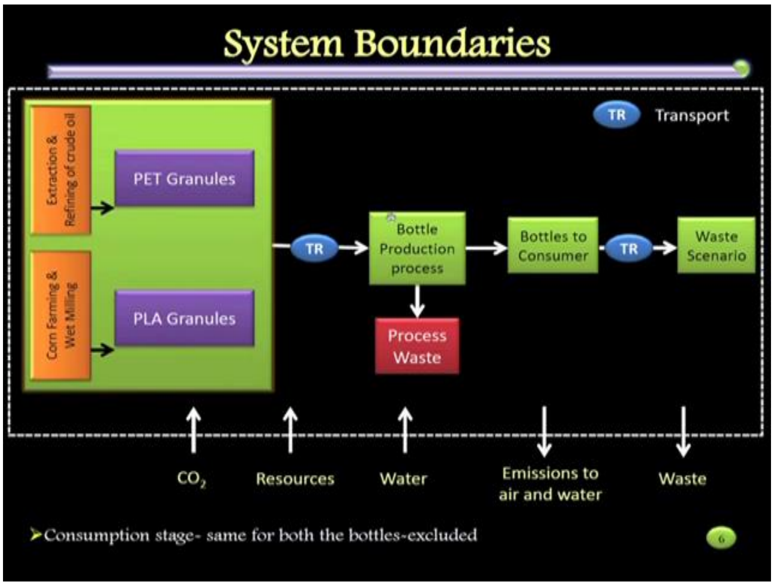

So, this is how the system was look like, we had extraction and refining of crude oil to get the PET granules, then corn farming and wet milling to get the PLA, PLA granules and then it will be to be transported to the bottle production process, there would be some waste being produced then you have the bottles to send in going to the consumer some transportation further and then you have the waste which is which waste scenario that has to be that has to be managed. So, and then in which process we have the in terms of corn farming we have CO2 as the input, some resources as the input, water also as a input, emissions to air and water and the waste that is being produced.

So, this is as. So, consumption stage in terms of the consumption of the water sensors both since it will be same for both whether it is a PET or the PLA we have excluded that; as I have mentioned earlier if you remember in earlier lecture I said that if certain processes are same in comparative LCA you can eliminate one particular process, you do not have to include that because for product a verses product b the impact would be the same. So, rather than doing that exercise you can exclude that exercise and do it on the a stuff which is not common between product a and product b.

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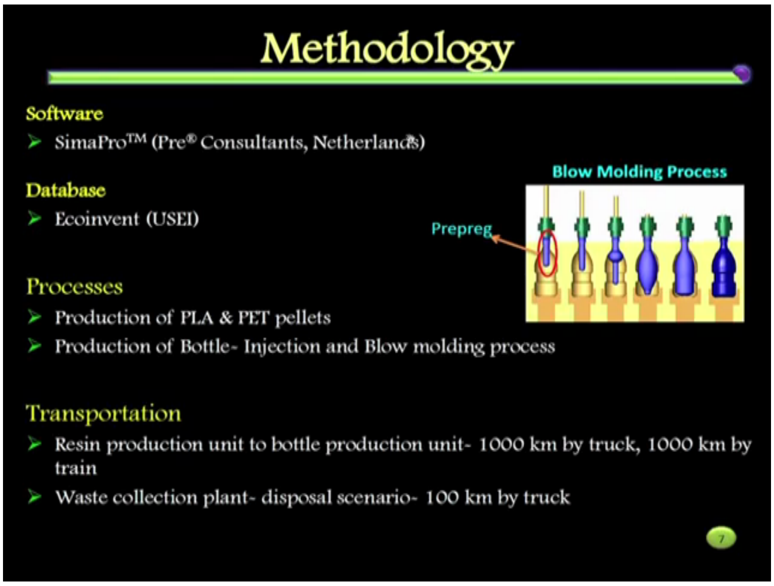

So, then in terms of the methodology that the software was used sima pro again was used for this, there is an sima pro is actually I have sima pro license that is why you see that most all the examples I am showing you we have we have you use sima pro, but you do not have to you see sima pro, it is not that we have to it is that that is the only software out that I am not indorsing a particular product here you can use (Refer Time: 13:39) you can use open, LCA or you can use any product of it is very simple LCA we can do it using excel spreadsheet.

So, it is all depends on you what you want to do, but in most in th since I have license of sima pro. So, that is why you see all the examples coming using that sima pro software. So, just wanted to make that clear and then data this software come with ecoinvent database which we talked about earlier and then we looked at production of PLA and PET bottles production of bottle injection and blow molding process, then transportation and all those factors came in picture.

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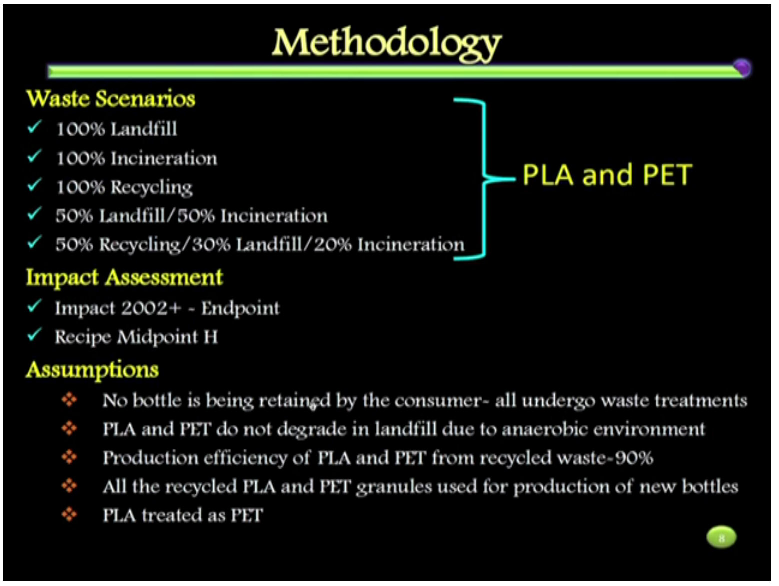

So, in the waste scenario we assumed different cases 100 percent landfill, 100 percent incineration, 100 percent recycling, 50 percent landfill, 50 percent incineration, 50 percent recycling, 30 percent landfill, 20 percent incineration. So, different scenarios we are looked at, and there are different impact assessment if you remember we talked about that. So, here we use both impact 2002 plus as well as the recipe midpoint H. So, both use certain assumption where made as you have to do in any of these LCA exercise there will be certain assumption that you have to make.

So, no bottle is being retained by the consumer. So, that is one exemption, they do not degrade in a landfill and anaerobic environment, production efficiency of recycle waste is around 90 percent, and all the recycle PLA PET used for production of new bottles PLA are treated as PET in terms of like it is a usage.

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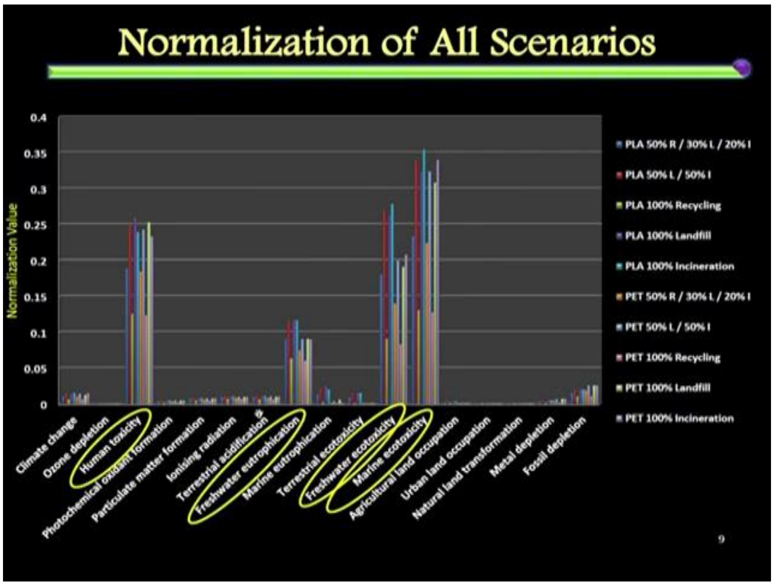

So, in terms of if you look at the different once you put the all these data into the software, and then you look at and then you go for the impact categories what we found that the human toxicity, freshwater eutrophication, freshwater ecotoxicity, marine ecotoxicity those for your kind of coming out to be the major ones for the different scenarios; then in terms of the midpoint we saw climate change, agricultural land occupation fossil depletion, and the end point we saw the carcinogens and the non renewable energy. So, those were the once which was coming out in terms of the normalization of the different scenario.

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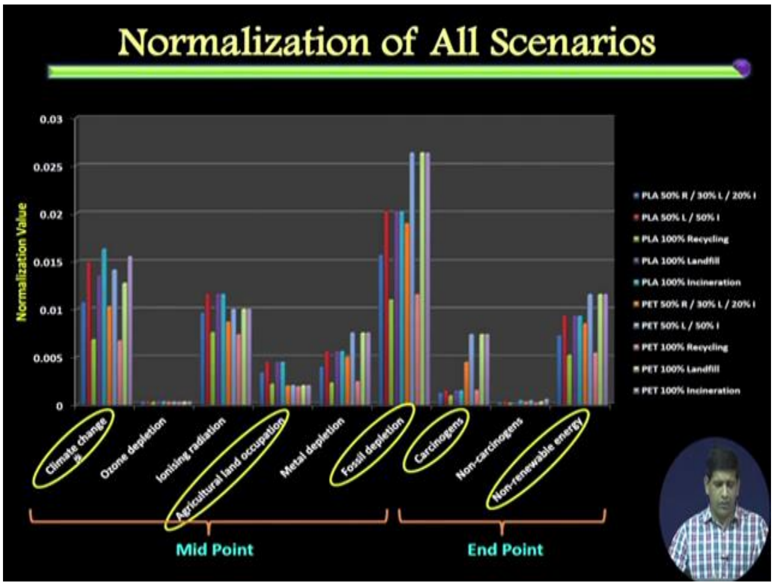

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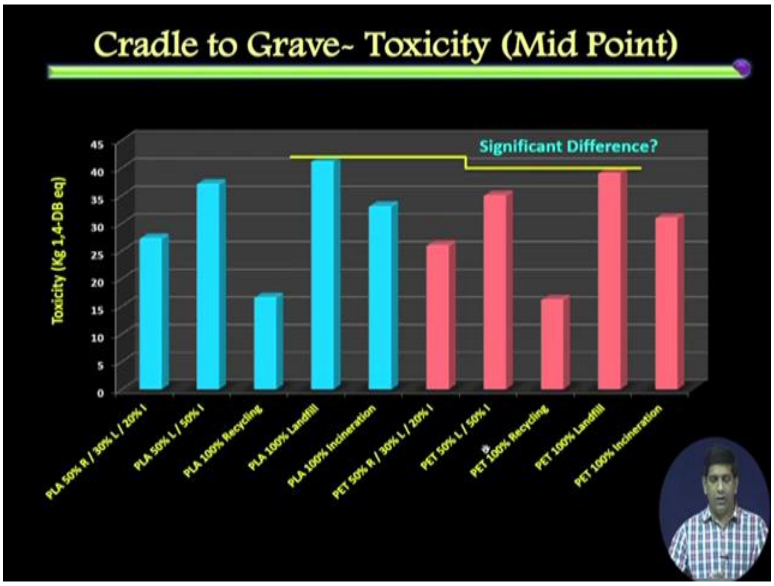

So, what we saw is that there was a significant difference like a we in terms of the we are not kind of there was some sort of difference was found will may not be significant if you do the statistics on that, but there was some different in terms of PLA and PET where we found that PET to be little bit more toxic.

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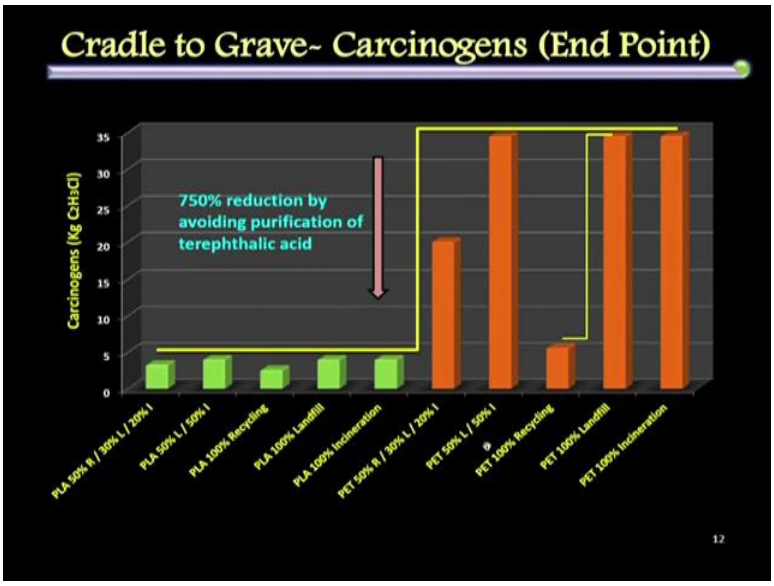

And as there was in in terms of if you look about the PLA there was 75 percent deduction by avoiding purification of terephthalic acid. So, that did in PET case we saw high impact in terms of carcinogens, PLA shows less impact 7700 and 50 percent reduction.

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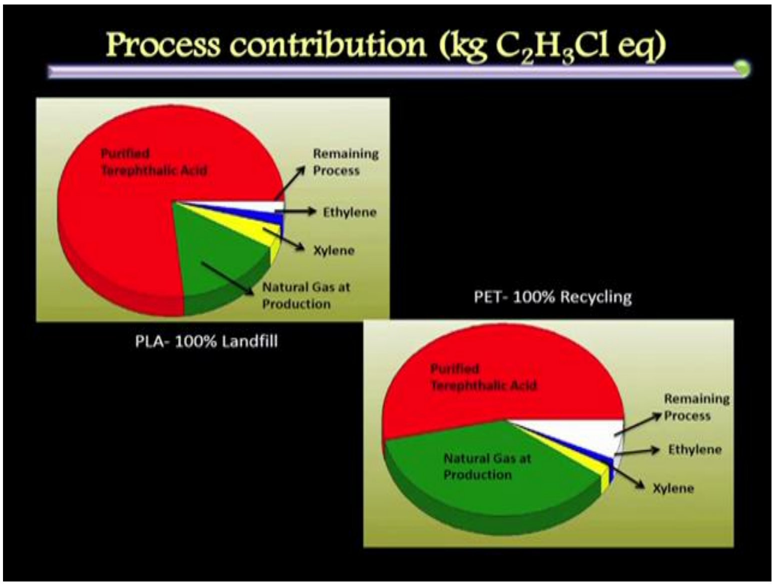

And there is some PLA if you goes to 100 percent landfill PET 100 percent recycling, what will what are the different process we looked at that. Then in terms of the cradle to grave fossil depletion a reduction of 18 kg of oil equivalent in case of PLA, now reduction in terms of cradle to grave energy non renewable energy we saw reduction of 341 mega joule of energy for PLA.

So, again you as you can see we had in all these categories PLA came out to be better than a PET and, but in terms of the climate change in terms of the cases we have to equivalent we saw the reduction around 14 kg CO2 equivalent if we use PET rather than PLA. But here you have to we have not taken the consideration that the CO2 that is being used for production of PLA is those biogenic CO2. So, if we take that factor into account this number will change; then land use since PLA is used is a based on bios during more land, so in land use 360 percent increase in land use. So, for the land use categories actually PET came out to be better.

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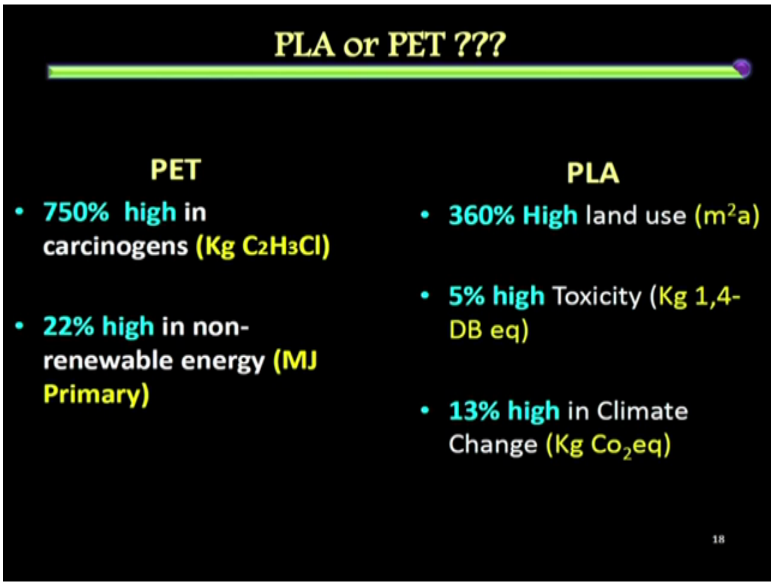

So, that is. So, PLA or PET as a summary in PET we saw 75 percent high in carcinogens 22 percent high in nonrenewable energy. PLA 35 30 60 percent high in land use 5 percent high toxicity 13 percent high in climate change and again here.

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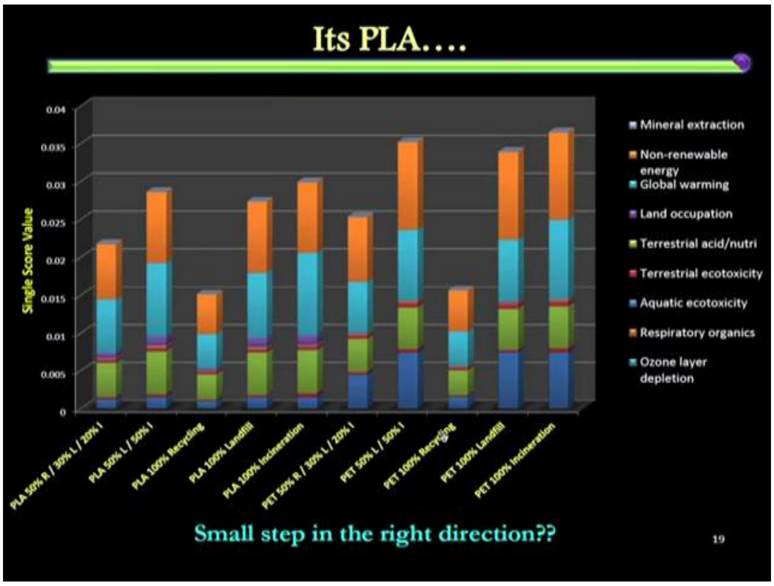

So, these are the stuff so, but if you look at the in terms of a single score value what you see is the PLA comes out to be less than PET, when you try to go for the comparison between the two and it kind of gives us a indication that yes it is a small step in the right direction where we are trying to go towards from PET to PLA.

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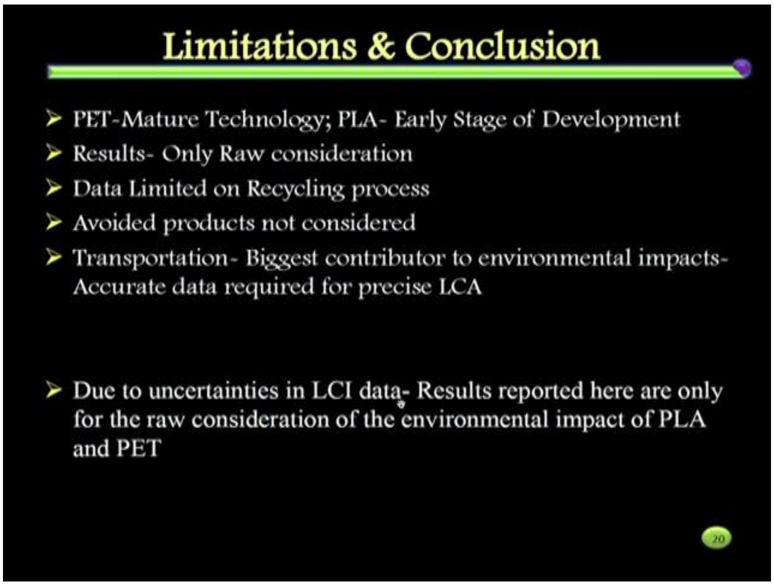

So, that is but there are certain limitations and conclusion we already due to uncertainty result reported here for the raw consideration of environmental impact of PLA and PET data is limited avoided products not considered, transportation we essentially assumed to be the same so those things where there in terms of for this particular project.

So, then again one another example to just to show you how this system can be used, so now, we will get to the last example which; again this is a case study of where we have this is a actually real project one of our M.tech student just finished in six around eight months back now and he had won on this he worked on this particular case study, where it was an LCA of an algal biomass plant microalgae to biofuel. So, this work was this is a we have a Nalco plant and national aluminum company which is an angul. So, this was based on work being done at Angul facility of Nalco.

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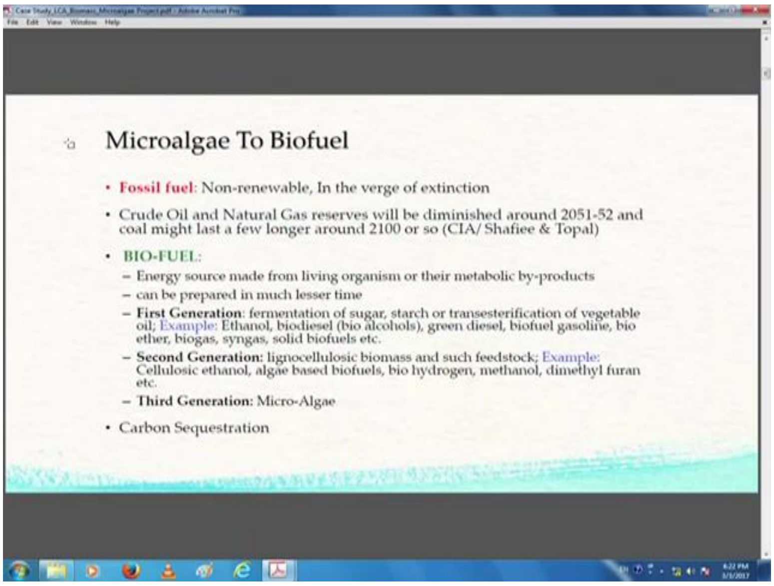

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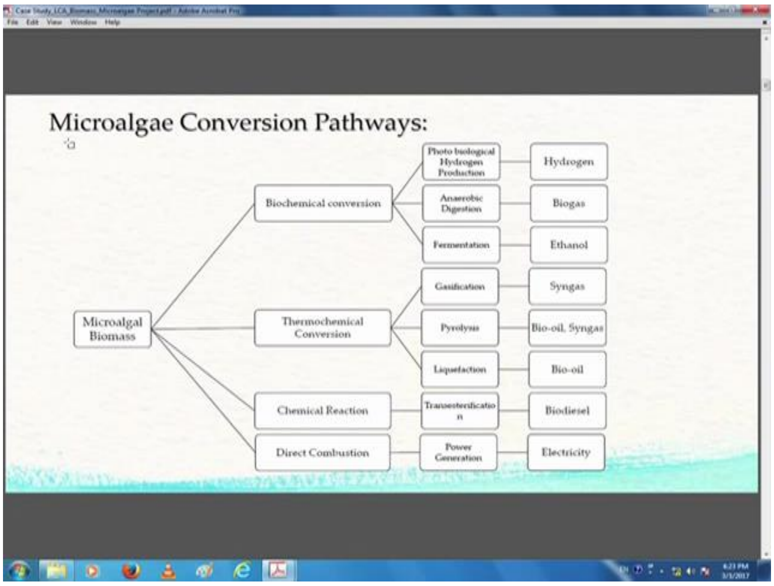

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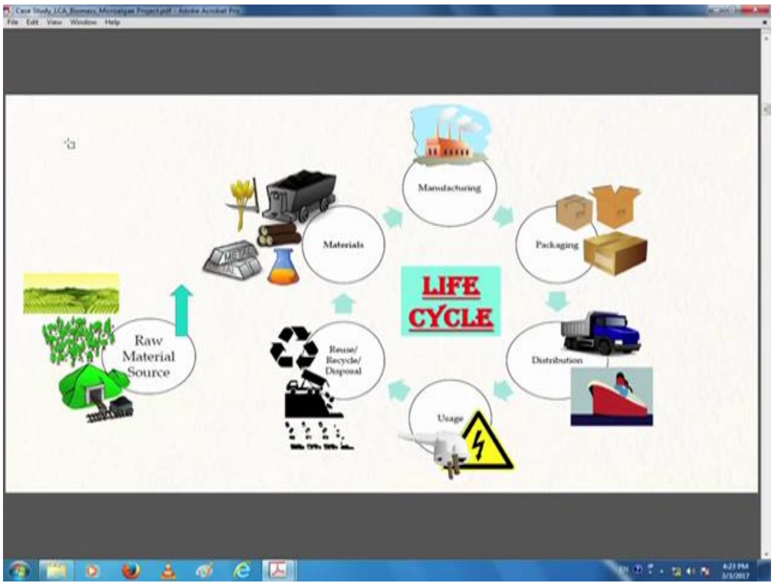

So, what here it was and some background we will not worry too much about that I will just go to the essential of the problem. So, the from the microalgae is let us go to this. So, this, these are some of the background information how the life cycle is done.

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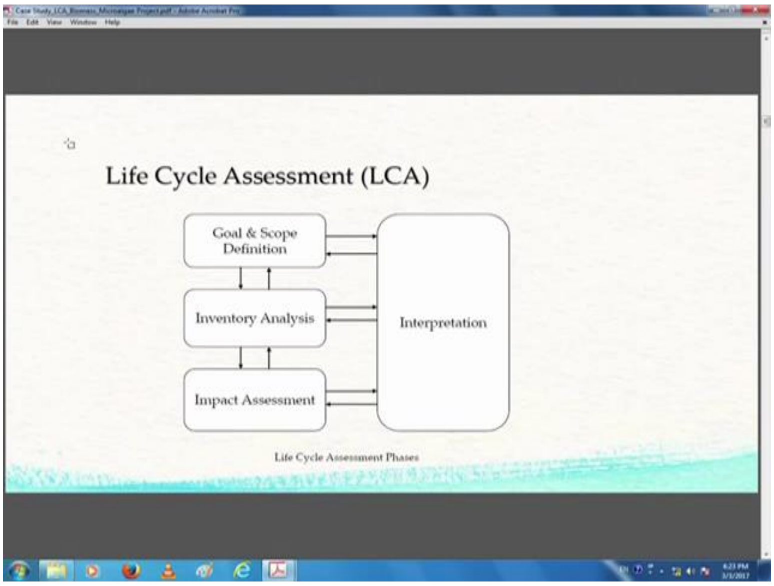

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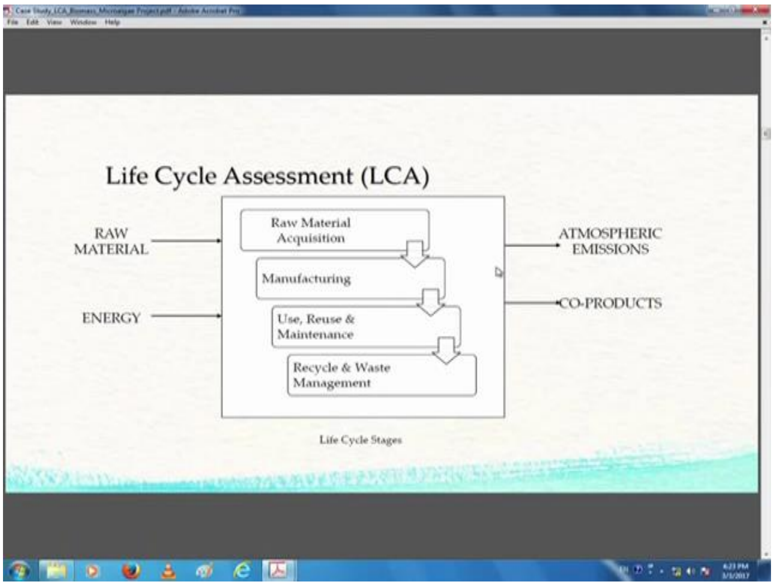

And all that you already have information on it this is your classical ISO diagram goal and scope definition inventory analysis impact assessment and the interpretation part of that. So, and this is your life cycle stages craft. So, these are all your kind of summary of the previous one.

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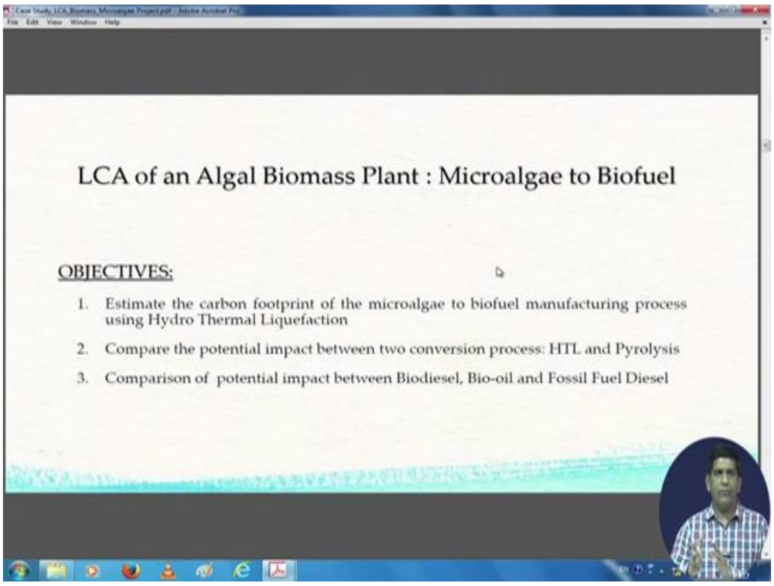

So, in this particular project our objective was to estimate the carbon footprint of the microalgae to biofuel manufacturing process, using the hydro thermal hydro thermal liquefaction then we also compare the impact between the two conversion process which is the HTL, which is the hydrothermal liquefaction and Pyrolysis then we also compare of our potential impact between the biodiesel, bio oil, fossil fuel diesel that was done as well.

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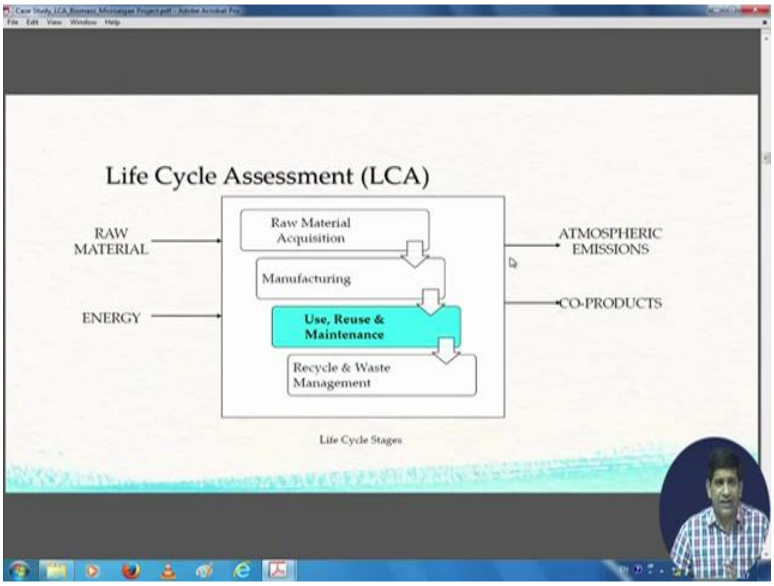

So, in terms of life cycle assessment what we were more worried about is the use reuse and maintenance part because that is what kind of the focus of it.

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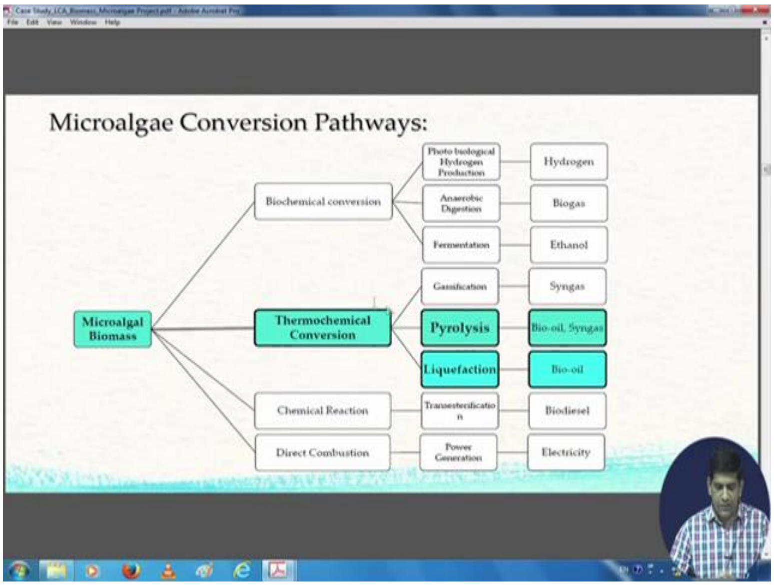

So, if you look at the microalgae conversion pathways there are different pathways out there, but in this particular project the focus was what you see in the blue or light green colour, a boxes that you see there microalgae biomass to thermochemical conversion pyrolysis and liquefaction, where you have the bio oils in gas and the other bio oil which is present.

So, as the first objective was to find out the carbon footprint. So, we are not doing a comparative LCA, this is the standalone LCA as I said earlier in the course as well you do not have to do comparative LCA all the time. This is a we essentially we are trying to find the carbon footprint of this particular process, that we can do for any process or any product; as I said earlier to say even for a pen like this if you want to find out the carbon footprint of this pen you can do it and use using the same step. So, the goal here is to find the carbon footprint of this pen, similarly in this particular project here we have to find a carbon footprint of the microalgae to biofuel manufacturing process, and the process was using the HTL which is the hydrothermal liquefaction.

So, how will go about that? So, first any project like this what you will do, you have to come up with the process diagram. So, you do not have to be too much fancy make boxes are clean neat boxes and write down all the processes that will happen.

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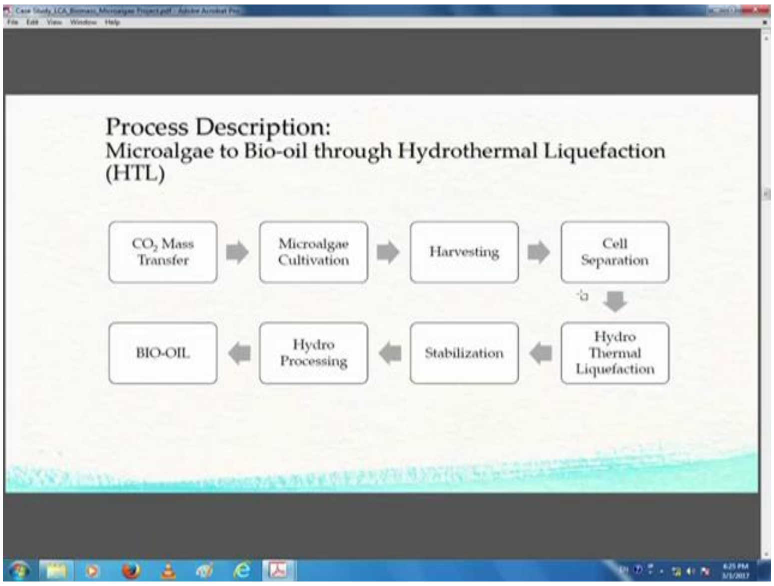

So, you can see in this particular image over here, you start with what are the process CO2 we take the CO2 mass transfer we grow microalgae, we harvest the microalgae, separate the cell, do the hydrothermal carbonization is stabilized hydro process it, and then produce bio oil. So, that is very simple process which is going on and other CO2 is coming from the cogeneration plant at the site. So, rather than remove releasing that CO2 into the atmosphere it has been used to cultivate microalgae and in the process to produce the bio oil.

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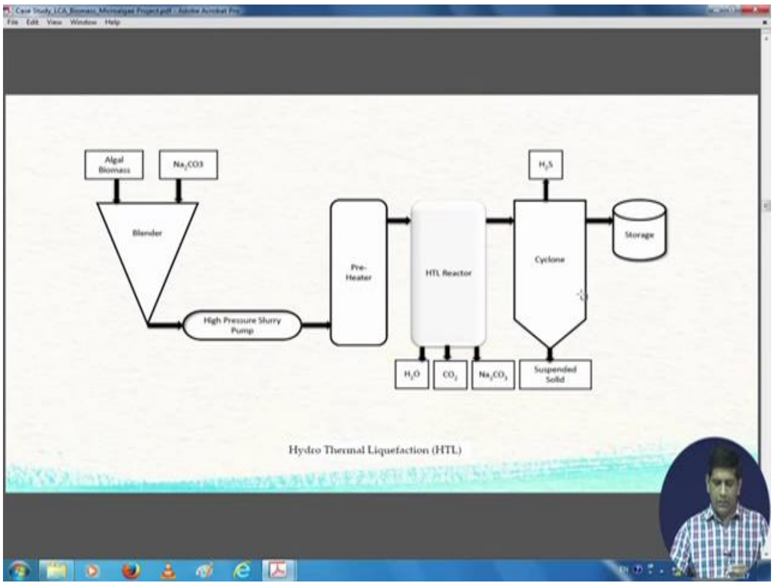

So, and this is a like a since we are using HTL this is a process diagram for HTL, where you the blender, algal biomass and sodium carbonate high pressure solid pump then you have your pre heater HTL reactor cyclone and all that things which is being used as a diagram for HTL.

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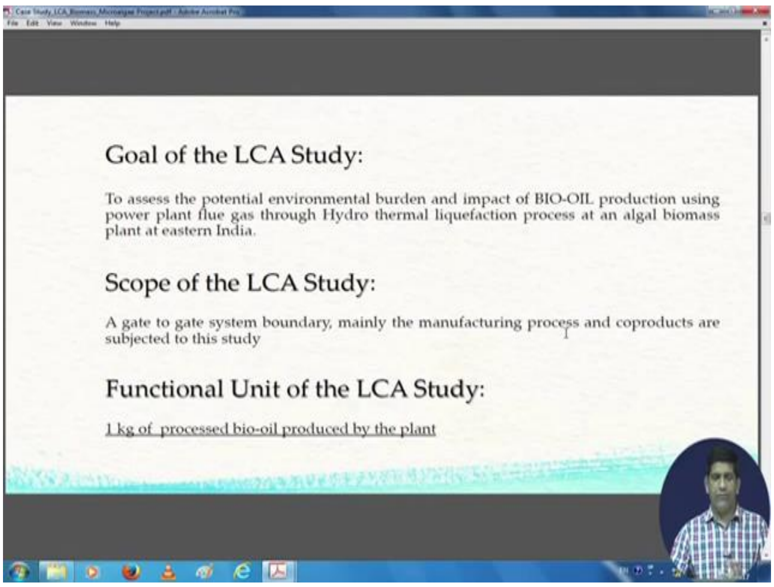

And the goal of the study to assess the potential environmental in burden of the bio oil production is scope is gate to gate system boundary we have a gate to gate, not cradle to gate or cradle to grave and the functional unit is one kg of process bio oil, so again goal and scope functional function and functional unit so this is you that is the number one thing that you have to do in any LCA exercise, and as we have talked earlier for any of these exercises.

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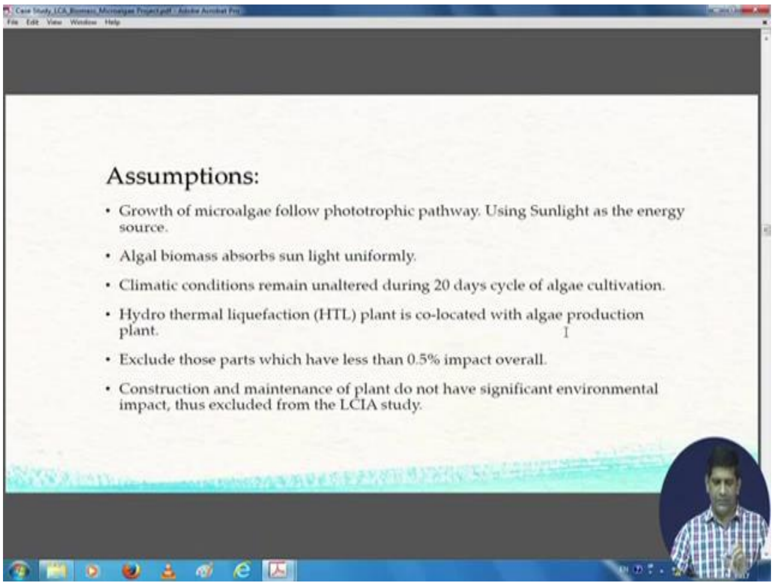

There will be certain assumptions that you have to make, assumption was the growth of microalgae follow phototrophic pathway they using sunlight as the energy source, algal biomass absorbs sunlight uniformly, climatic condition remains unaltered during 20 days of cycle the algae cultivation, HTL plant is co located with algae production plant. So, no transportation much involved. They we exclude any process which has less than 0.5 person impact over all construction and the maintenance of the plant do not have significant environmental impact that it reproducing I excluded from LCA study.

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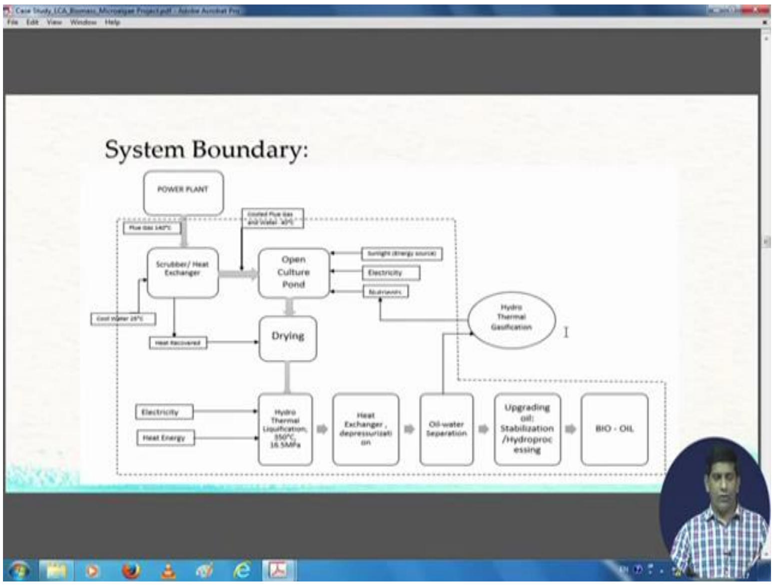

Then you come up with the system boundary that is your system boundary from the power plant the CO2 is coming it is going to scrubber and heat exchanger open culture pond, and dry then HTL, heat exchanger oil water separation bio oil production. So, this is the whole system boundary of the system then you do your life cycle inventory.

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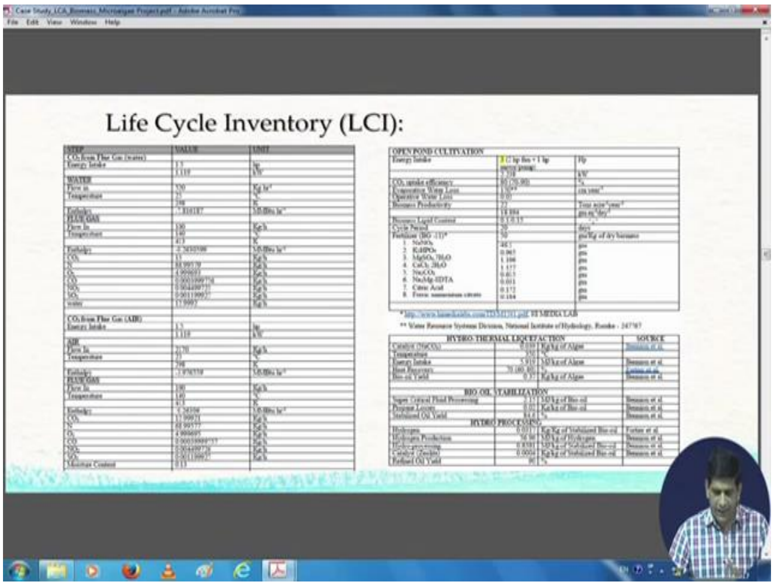

So, the life cycle inventory data for this particular exercise was either collected from the plant after visiting the plant and collecting the data or getting the data from where, or some of the data which was not available as you can see in the with the plant in this particular table on the right hand side at the bottom, this were mostly reference data from the literature. So, these data we calculated that these are the reference data rest of others where all our like data from the particular plant itself.

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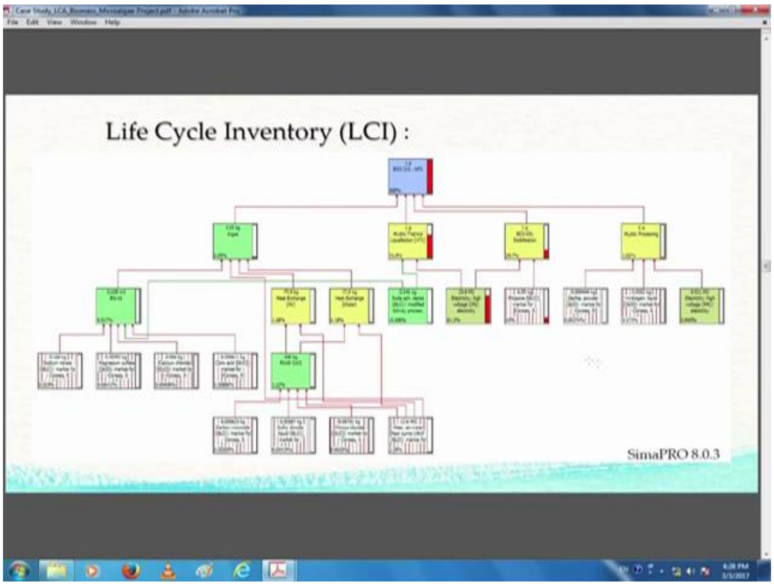

And then you put them in the life cycle inventory this is how it look slide in the software, on the screen of the software again to sima pro 8.0.3 and you can have your bio oil HTL algae hydrothermal liquefaction bio oil stabilization hydro processing that reach within each you have the different unit process and for each of these unit process we have the input and output coming in.

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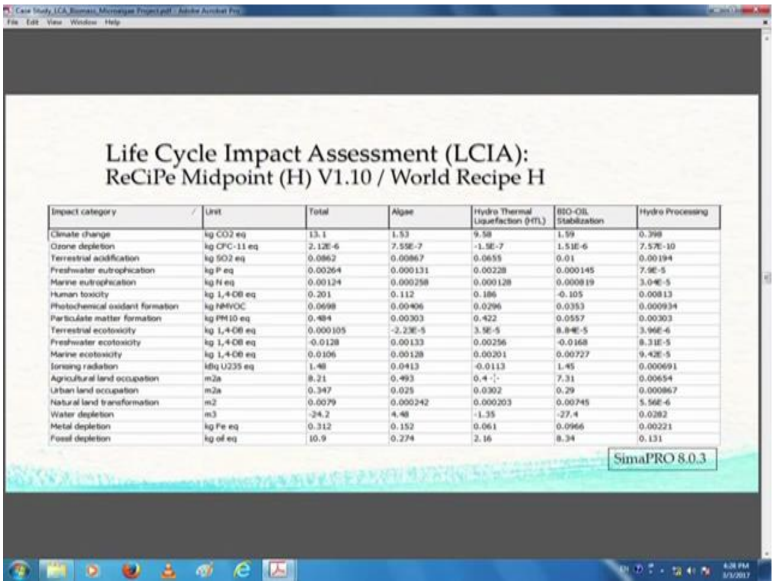

Impact category	Unit	Total	Algae	Hydro Thermal Liquefaction (HTL)	BIO-OIL Stabilization	Hydro Processing
Climate change	kg CO2 eq	13.1	1.53	9.58	1.59	0.398
Ozone depletion	kg CFC-11 eq	2.12E-6	7.55E-7	-1.5E-7	1.51E-6	7.57E-10
Terrestrial acidification	kg SO2 eq	0.0862	0.00867	0.0655	0.01	0.00194
Freshwater eutrophication	kg P eq	0.00264	0.000131	0.00228	0.000145	7.9E-5
Marine eutrophication	kg N eq	0.00124	0.000258	0.000128	0.000819	3.04E-5
Human toxicity	kg 1,4-DB eq	0.201	0.112	0.186	-0.105	0.00813
Photochemical oxidant formation	kg NMVOC	0.0698	0.00406	0.0296	0.0353	0.000934
Particulate matter formation	kg PM10 eq	0.484	0.00303	0.422	0.0557	0.00303
Terrestrial ecotoxicity	kg 1,4-DB eq	0.000105	-2.23E-5	3.5E-5	8.84E-5	3.96E-6
Freshwater ecotoxicity	kg 1,4-DB eq	-0.0128	0.00133	0.00256	-0.0168	8.31E-5
Marine ecotoxicity	kg 1,4-DB eq	0.0106	0.00128	0.00201	0.00727	9.42E-5
Ionising radiation	kBq U235 eq	1.48	0.0413	-0.0113	1.45	0.000691
Agricultural land occupation	m2a	8.21	0.493	0.4 [illegible]	7.31	0.00654
Urban land occupation	m2a	0.347	0.025	0.0302	0.29	0.000867
Natural land transformation	m2	0.0079	0.000242	0.000203	0.00745	5.56E-6
Water depletion	m3	-24.2	4.48	-1.35	-27.4	0.0282
Metal depletion	kg Fe eq	0.312	0.152	0.061	0.0966	0.00221
Fossil depletion	kg oil eq	10.9	0.274	2.16	8.34	0.131

So, if you when you go through that after you look at the all these impact categories and for the like in different units we have the total we have the like the total impact from the one from Lg HTL bio oil stabilization and hydroprocessing. So, basically you add them up and then you get your total impact for each of these categories.

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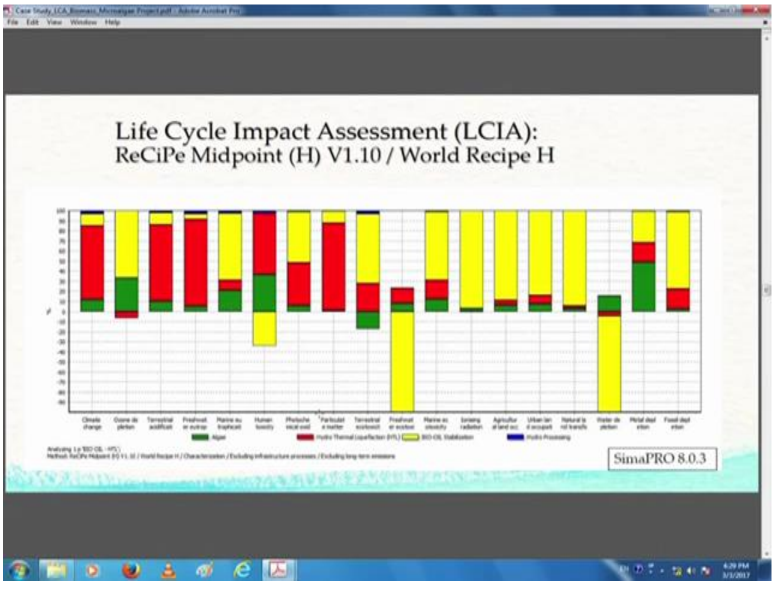

And then you can plot it and as you can see the yellow part which is the bio oil stabilization kind of has the biggest share of the impact that we see followed by the red colour which is the hydrothermal liquefaction. So, based on the recipe midpoint h method.

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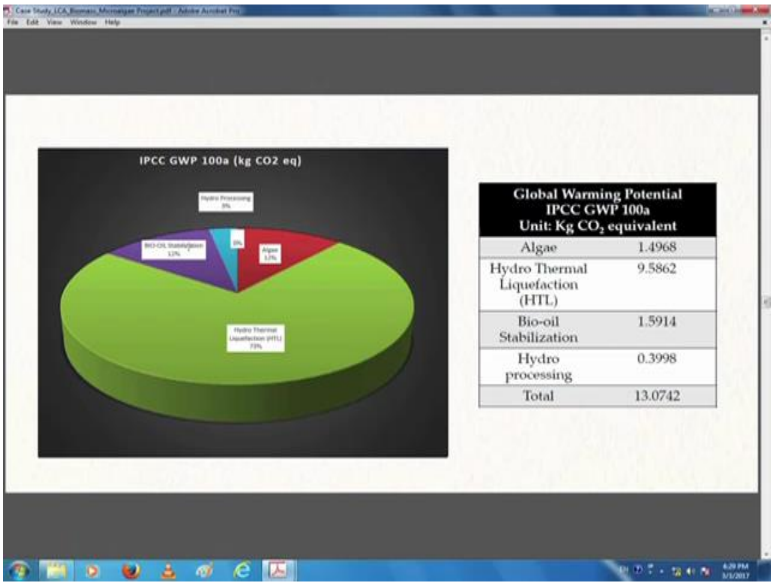

So, in term of the IPCC global warming potential what we saw that the HTL had a higher contribution, and then followed by bio oil stabilization in algae production and then hydroprocessing. So, that is how it was; it was found on totally it was around 13.07 kg equivalent.

So, that gives us the carbon footprint; that gives us the carbon footprint of the whole process now the second part objective of this was to compare the potential impact between HTL and the Pyrolysis.

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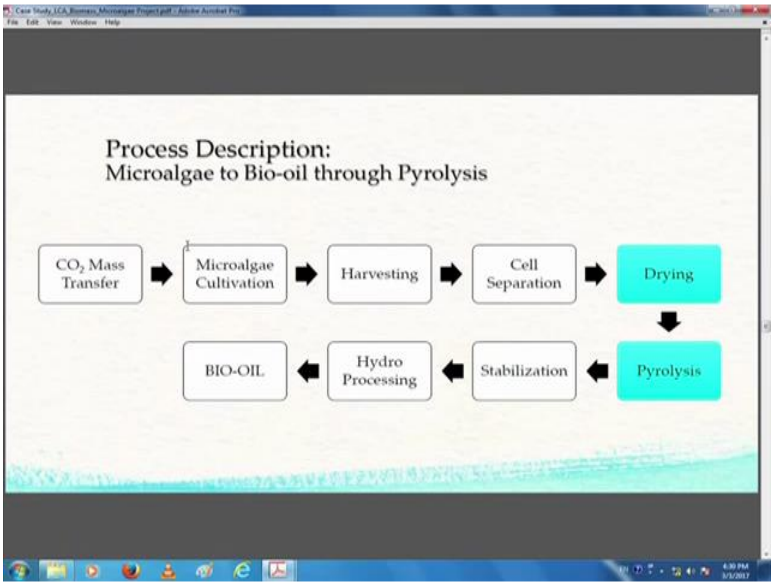

So, if you want to compare these two particular process how we can do it, again you go back and look at your process flow diagram only thing is the drying and the Pyrolysis these two are what is the kind of changing whereas, compared to earlier.

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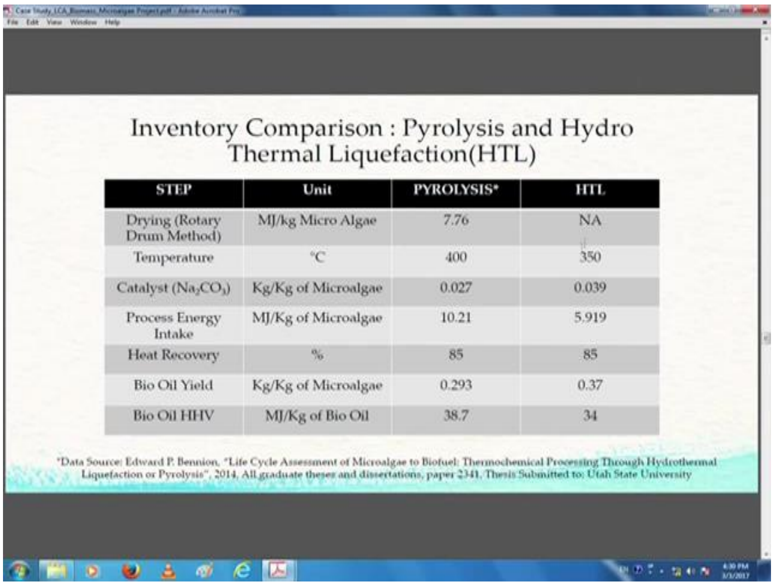

So, you do you look at the step for the Pyrolysis and the and the hydrothermal liquefaction, you look at different units sorry the steps like the drawing temperature catalyst process energy impact, heat energy, bio oil, bio oil, real bio oil (Refer Time: 27:07) and then you look at there what is the in terms of parameters for both Pyrolysis and HTL; and some of these data was available from the literature again you put that into the life cycle inventory Pyrolysis sima pro, and then you get your unit processes and you get in terms of it like a clamp impact into for bio oil HTL and bio oil Pyrolysis for the different categories, and as you can see for some cool climate change bio oil Pyrolysis is much higher and foremost of the most of the categories you see the bio oil Pyrolysis to be higher than bio oil HTL.

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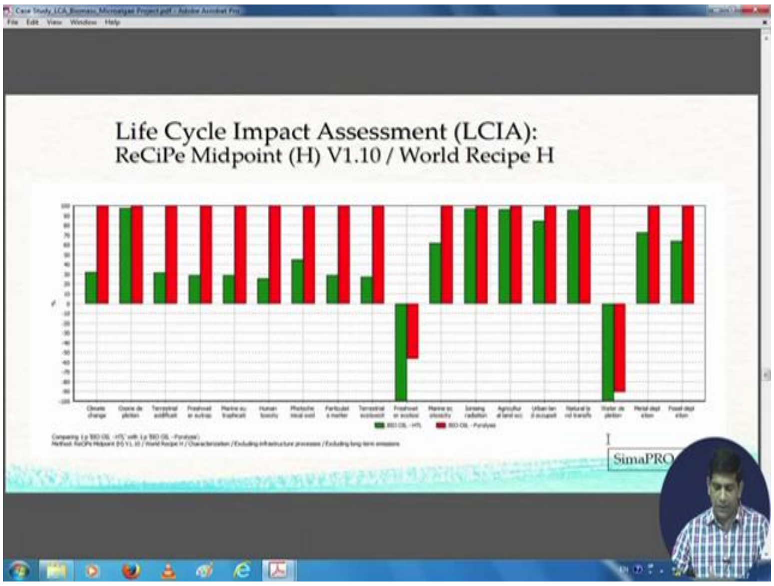

And which you can see over here as well the bio oil Pyrolysis is the red colour, and bio oil HTL is a black colour and you see that they compare the different impact categories between them.

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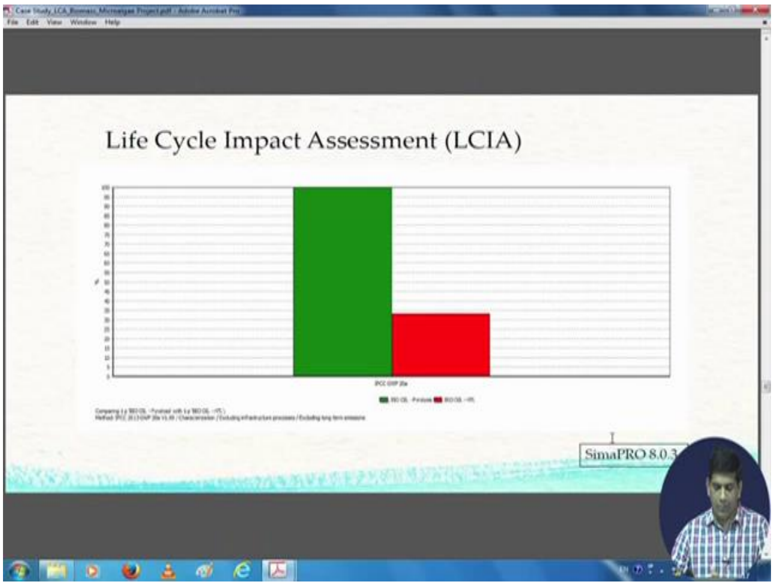

So, here what we found that bio oil Pyrolysis is if we normalize that to 100 percent, the impact for bio oil HTL was somewhere around 35 percent. So, it is almost nearly one third of that. So, that is the comparison between the two then if you compare between biodiesel bio oil and fossil fuel diesel.

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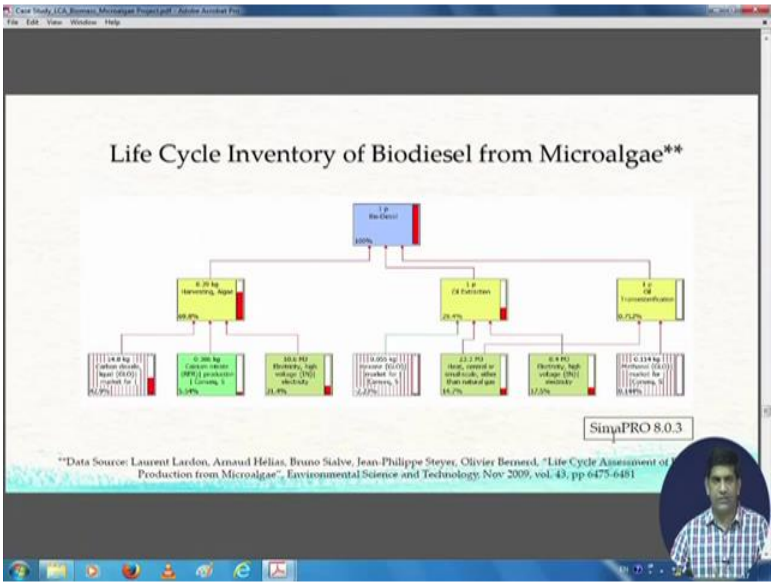

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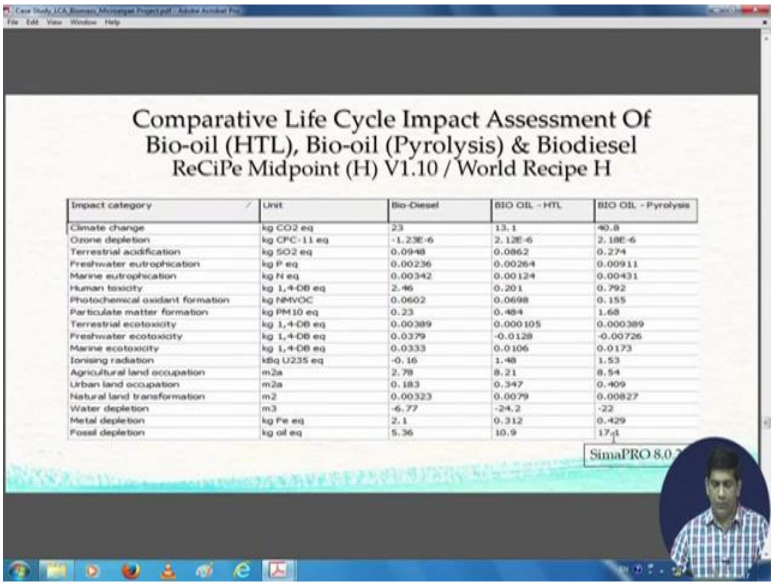

Impact category	Unit	Bio-Diesel	BIO OIL - HTL	BIO OIL - Pyrolysis
Climate change	kg CO2 eq	23	13.1	40.8
Ozone depletion	kg CFC-11 eq	-1.23E-6	2.12E-6	2.18E-6
Terrestrial acidification	kg SO2 eq	0.0948	0.0862	0.274
Freshwater eutrophication	kg P eq	0.00236	0.00264	0.00911
Marine eutrophication	kg N eq	0.00342	0.00124	0.00431
Human toxicity	kg 1,4-DB eq	2.46	0.201	0.792
Photochemical oxidant formation	kg NMVOC	0.0602	0.0698	0.155
Particulate matter formation	kg PM10 eq	0.23	0.484	1.68
Terrestrial ecotoxicity	kg 1,4-DB eq	0.00389	0.000105	0.000389
Freshwater ecotoxicity	kg 1,4-DB eq	0.0379	-0.0128	-0.00726
Marine ecotoxicity	kg 1,4-DB eq	0.0333	0.0106	0.0173
Ionising radiation	kBq U235 eq	-0.16	1.48	1.53
Agricultural land occupation	m2a	2.78	8.21	8.54
Urban land occupation	m2a	0.183	0.347	0.409
Natural land transformation	m2	0.00323	0.0079	0.00827
Water depletion	m3	-6.77	-24.2	-22
Metal depletion	kg Fe eq	2.1	0.312	0.429
Fossil depletion	kg oil eq	5.36	10.9	17.1

Just to again similar stuff you go back and then put this into the sima pro, you get your output and two different impact categories, and here bio oil Pyrolysis again leads in terms of climate change for followed by bio oil diesel, and then you have your for the different categories looks like.

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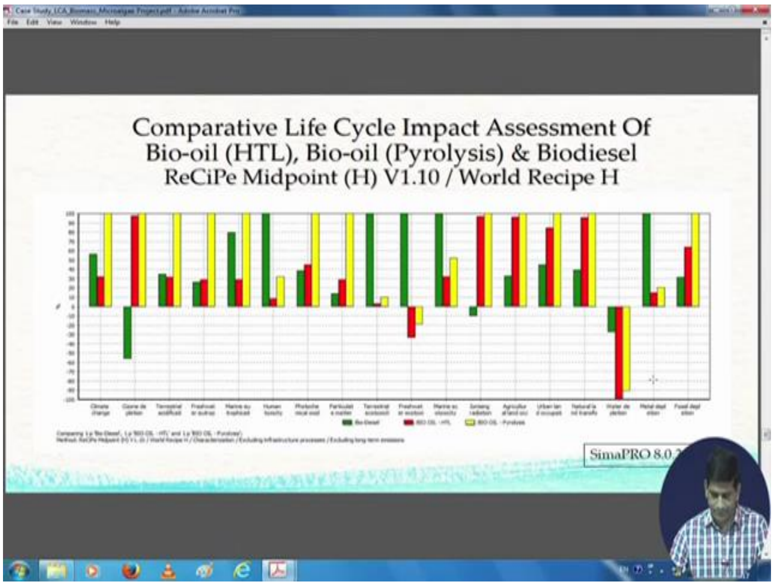

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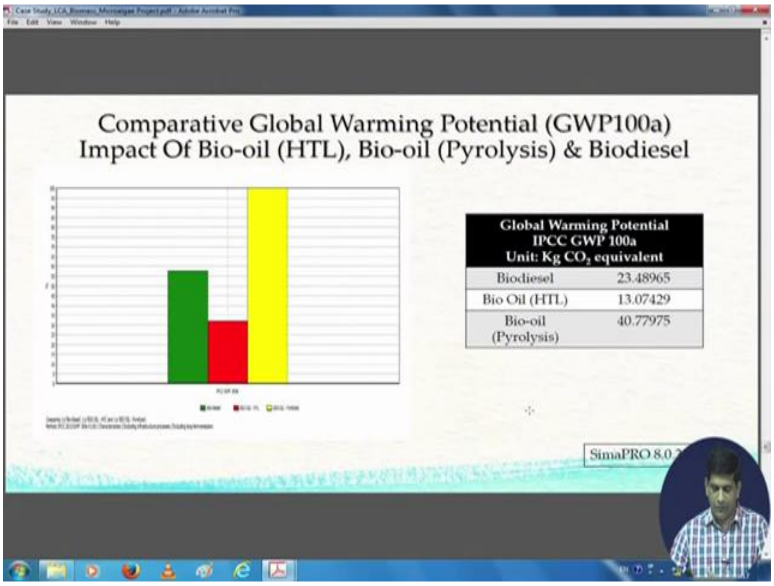

If you plot them out, you see this bio oil Pyrolysis is kind of shows higher as then the bio oil HTL and then finally, if the biodiesel. So, biodiesel sorry bio oil HTL was kind of in the middle. So, in summary you see that your bio oil Pyrolysis the yellow one which is has a higher the global warming impact followed by biodiesel which is black one and this red colour is we have this bio oil HTL which is kind of in the middle.

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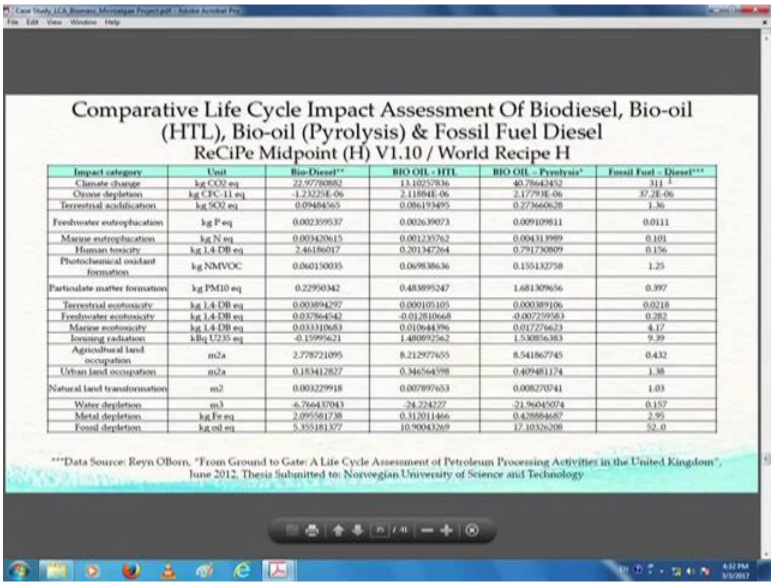

So, in terms of a compare that for the different impact categories different unit different processes that we get here including that fossil fuel, and what we found the different you can put you can even your represent your data you can represent in this particular way for the different impact categories you can see different units for different impact categories, you can convert all this unit to CO2 equivalent at some particular point of time as well.

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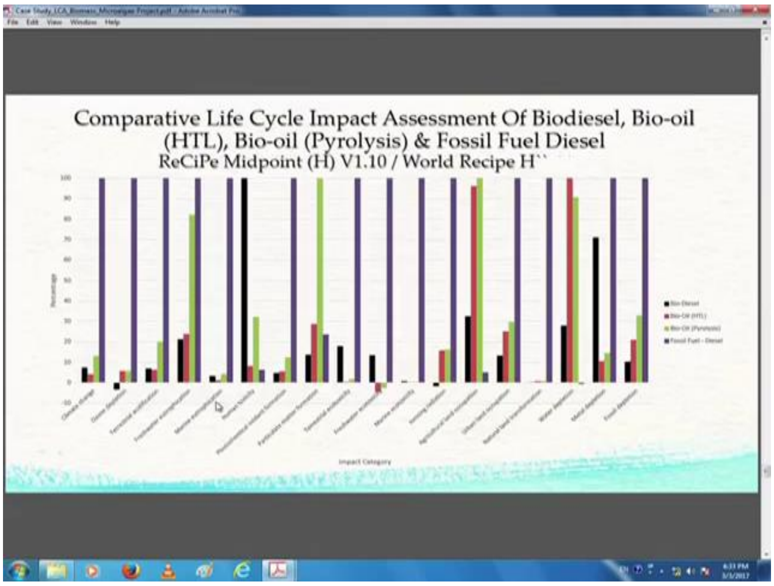

So, and then the same data has been plot in the next graph, the table that you see here is the next slide shows the graph for that. Where water has been this one particular category the biodiesel no sorry the fossil fuel diesel has been put at 100 and the others is based on that particular impact based on that, and as you can see where the fossil fuel diesel then we have our bio oil Pyrolysis followed by bio oil HTL, and biodiesel and some categories.

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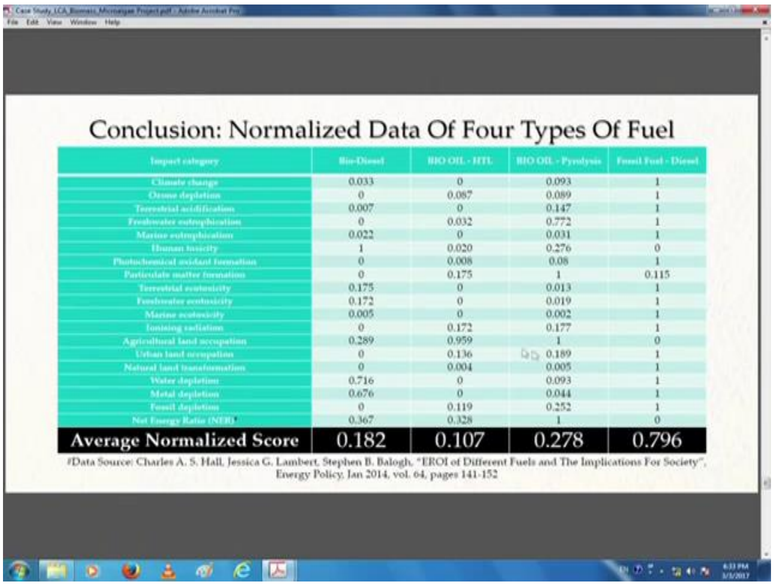

You see the difference as well in terms of and then finally, if you normalize all the four types of fuel and with taking fossil fuel as number one or any other which is sources as number one, whichever is the highest data is considered at number one and then if you can normalize for different impact categories what we found is the fossil fuel diesel was the highest in terms of impact and the lowest impact was from bio oil HTL followed by the bio oil diesel.

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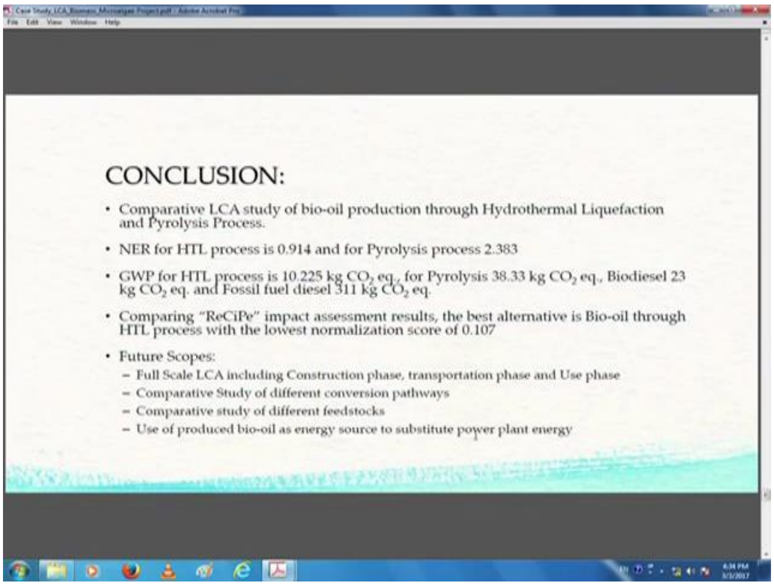

So, that the conclusion was we found that bio oil HTL was the environmentally friendly process followed by the biodiesel, follow and then for bio oil Pyrolysis, and ultimately last one was the fossil fuel. So, it is that we can. So, this particular exercise I showed you standalone LCA I also showed you a comparative LCA between the two process, then a comparative LCA between the four different products. So, you can again this material are available to you and you can go through these slides in more detail it has a step by step information is provided, the paper is already available to you which I showed regarding the paper dryer and the hand towel. So, this is kind of these different examples today this particular video and the previous model that we covered and. So, that gives you a good idea about how the LCA is really applied in field scale or in the lab scale.

So, I hope that this will help you and your masters project in your PhD research or any other project that you are involved with in your LCA exercise. So, this kind of comes to an towards the end of the like a lecture part and the then the next module we will try to cover some of the solved example, and in your exam which is some many of you have registered for the exam.

So, for your exam there will be some problems and we did covered some solved examples in the during the lecture module, but the (Refer Time: 32:08) is they will come up in next two videos and they will walk you through some of the example problems, so that you can prepare that will help you prepare for the exam and kind of gives you some idea about how to approach some of the problems which we did talk about in the theory with some examples in between, but kind of a recap of the problem side will be done in (Refer Time: 32:30).

Again thank you very much for taking this course, and this is the last time you are seeing me for this particular course, and again any question feel free to put it on the discussion forums we will be happy to answer, we are keeping an eye on the discussion forum as we are making progress in the course. We look forward to hearing from you any feedback that is also appreciated, and then again all the best those of you have registered for the exam and thank you and I will see you again in future at some other forum.

Thanks.