Life Cycle Assessment
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Lecture - 24
LCIA

Welcome back. So, we will continue our discussion on life cycle impact assessment. So, we will look at how we like how we choose the LCIA method like I said earlier there are different methods out there the most common ones we are using right now is a impact 2002 plus and recipe 2009, but there are other methods out there.

So, we will look at choice of method choice of impact categories there are different impact categories which you have already seen like there was a list of impact categories and based on where you are. It does not have to be that many times you may not be using all the impact categories. So, there is a cut square the judgment of us as a research scientist or research engineer comes in picture, because we have to kind of decide which impact categories is relevant for us and which impact category is not. So, that is we make the choice. So, there is a peace stabilized choice of impact categories, there are category indicators characterization models and factors. So, those are those are there in terms of LCIA method.

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LCIA in practice

1. **Choice of LCIA method**
   (pre-established choice of impact categories, category indicators, characterisation model and factors)
2. **Classification**
3. **Characterisation**
   (calculation of category indicator results or impact scores)

$$S_j = \sum_i CF_{ji} \cdot m_i$$

where:

S_j Impact score for category j (ex. in kg CO_2 eq.)

CF_{ji} Characterisation factor of elementarey flow i for impact category j
(ex. in kg CO_2 eq./kg of i)

m_i Elementary flow realted to functional unit (ex. kg of i)

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So, and then there are classification associated with characterization like how do you calculation of the category indicator, then indicator results you take the impact score; many times you take you do a summation. For example, if you want to do impact score for category j. So, this is your S j which should be a summation of all characterization factors which is there for the elementary flow for that particular impact category. So, you elementary all characterization factors for elementary flow i for the impact category j. So, you basically add them up and then how the elementary flow is related to the functional unit; for example, k g of i.

So, that is how in terms of the first factor it will be k g CO2 equivalent per k g of i, and then your i is your elementary flow and then and the other part portion is elementary flow related to the functional unit. So, that is how much of the elementary flow is related to the functional unit. So, multiply the two add them up that should accumulate impact score for category j. So, that is much k g CO2 equivalent. So, that is how we do the calculation and I will show you one example right now where (Refer Time: 02:38) where we essentially do this calculation in this calculation in the next particular table.

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GWP for the incandescent light bulb

Emissions	Amount per FU (kg/FU)	CF (kg CO$_2$ eq./kg)	GWP (kg CO2 eq./FU)
Carbon dioxide (fossil) (CO$_2$)	19	1	19 (82%)
Carbon dioxide (biogenic) (CO$_2$)	0.60	0	0
Methane (fossil) (CH$_4$)	0.040	25	1 (4%)
Sulphur dioxide (SO$_2$)	0.074	0	0
Dinitrogen monoxide (N$_2$O)	0.0036	298	1.1 (5%)
Sulphur hexafluroide (SF$_6$)	0.000092	22800	2.1 (9%)
		TOTAL	23.2

Here again going back to our example of that incandescent light bulb, that we used incandescent light bulb. So, here we have carbon dioxide fossil CO2, biogenic CO2 will I will explain you biogenic CO2 after we go through this table, but there is a the explanation is needed, but let us finish this table first and then we will explain that. Then

methane fossil methane CH_4, sulphur dioxide N_2O, dinitrogen monoxide it is also called nitrous oxide then you have sulphur hexafluoride and these are this is not the complete list the complete list could have more emissions coming up, but for these particular stuffs, if you look at the amount per functional unit, the k g per functional unit that comes out these are the numbers associated with them and as I said earlier if you think about how much CO_2 is being released fossil versus N_2O, N_2O is much much much smaller that is why you do not hear too much about N_2O.

So, that was per functional unit. So, if you want to calculate k g CO_2 equivalent per k g. So, we can do that calculation this is a equivalent that we calculated earlier based on the (Refer Time: 03:55) manual remember 125 then we have 298, 22800 and then this two 0 numbers also I will explain you in a minute. So, and. So, then you calculate the green house potential. So, you have to get the greenhouse potential as 19 because 19 times 1. So, this is in the previous if you look at the previous slide, those are the two factors that is coming up from the previous slide those summation. So, here we are actually these are the individual factors and then we are summing it up. So, that is the final greenhouse gas potential k g CO_2 equivalent per functional unit.

So, 19 times 1 here since it is 0, we got 0 then if we multiplied by 25 you got 4 sorry 1, that is 4 percent and then you multiply these you get 1.1. So, actually if you see in terms of the impact in this particular case although methane is 10 order of 10 higher than this, but since 298. So, this is also order of more than 10 higher so that is why; see more impact from N_2O then from methane. So, 5 percent impact and sulphur hexafluoride because it is of a very high equivalent you get even 10 percent. So, it is actually twice of nitrous oxide and more than twice of methane. So, add them up you have a greenhouse gas potential of 23.2.

So, that is into how we calculate, that is what the previous slide was referring to when we do that summation of different components coming up. So, this is what the software does it for you so, but you need to understand again I have been telling it again and again and again you need to understand what is really going on within the software. So, that if it gives you a wrong number and you should be able to find out where the where could be the problem going on. Now look at some of these biogenic we said that we will explain it after we finish this table, what is biogenic? Biogenic CO_2 is assumed as CO_2 which is coming from the natural process.

So, coming from the plant based stuff from the biological stuff the CO2 that it is not fossil CO2 it is not the CO2 coming from the gasoline and other fossil fuel related CO2 it is a biogenic CO2 coming from the plant sources and since it is coming from the plant sources, we since the plant takes CO2 to make the food and then release CO2 as well, we do not take any impact associated with that. So, that is why the conversion factor and the second table that the third column that you see on this particular slide you have 0 for them; we do not take any impact associated with biogenic CO2 in terms of it is greenhouse gas potential. So, that is why you see a 0 and then you multiply 0.6 by 0 it gives you a 0 number.

Now, for SO2 also we have taken it 0 because sulphur dioxide does not have a greenhouse it is not a greenhouse gas. So, if sulphur dioxide is not a greenhouse gas, so that is why we do not include sulphur dioxide in the greenhouse gas calculation. So, they do relate it will SO2 will show as part of the acid rain. So, when we look at the acid rain impact it will show up there, but in terms of the greenhouse gas impact its impact is 0, that is why you see the 0 number for that and then when you multiply it comes out to be 0 there as well. Now sulphur hexafluoride has very very high in terms of the equivalent see it is very very high. So, even the concentration being so low, since the equivalent factor is so high you get a bigger impact.

So, it is very similar to what we talked about remember we talked about that toxicity is actually exposure times the potential of the chemical multiplied by the exposure very similar concept here, it is not only what is not important is what is the amount being released it is also what is it is potential in terms of the climate change or in terms of the greenhouse gas potential. So, that is a greenhouse gas although the greenhouse gas potential may be very high, but the emissions is very low impact may not be that much; and also at the same time if the impact is, sorry the conversion the greenhouse gas potential is very low and you have a huge emissions coming out again in this case you will not see much impact coming out as well kind of in the middle you will see more. So, that is kind of illustrate over here, you add them and you get the greenhouse gas potential. So, this is how the calculation is done.

So, whatever we have been looked at in the previous slide. So, this was the previous slide this particular equation, where you are looking at this is the characterization factor and this is your characterization factor multiplied by the elementary flow required for the

functional unit. So, we did that over here, and this is we got those numbers here multiplied them together added them up and we got this number. So, this is how this calculation is done, since most of is done (Refer Time: 08:54) software most of this is from the characterization the impact assessment part of it with that as well, it gets done within the software and that is kind of many times students do not really pay attention to it; because what they get the readymade answer they do not really think what really what the software did for us.

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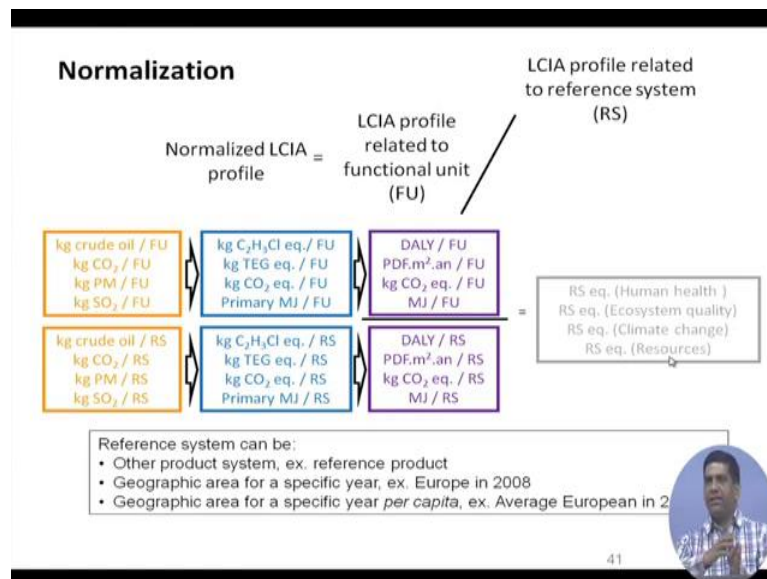
So, that is an important concept like how this impact assessments are calculated, then after you have this impact assessment this in terms of different emissions coming out; now you need to do some sort of normalization. So, now, you do a normalized LCIA profile what does that mean. So, because a you have v d a LCI profile related to a reference system, now in any environment it is not only the product which is having an. So, one particular product or process or a system is there, but it is a part of a bigger environment.

So, if say we live in a city or live in a town, we are focusing on transportation emissions, but transportation emission is one factor. Now in addition to that there are other factors associated with that too, and sometimes we really forget that I will (Refer Time: 10:01) very recent example of like when in Delhi, with this because of the vehicular population Delhi has lot of air pollution problem, and I totally agree with that that is air pollution

problem is there and needs to do we need to do something about it, but decisions such as bringing the like a diesel car overnight.

Diesel car yes they do contribute to vacuolar pollution, they do compute contribute to air pollution issues in Delhi, but we need to look at in terms of in the context of Delhi city what are the other factors of air pollution coming out, and what is the real impact coming just from this diesel powered cars; because if you ban this diesel powered cars overnight first of all I do not really understand why we allow this diesel driven cars first to be made and sold in India, because I left in overseas in different countries three different I lived in worked in four countries including one being India three other countries and for example, this Toyota, Honda they are they are s u v s where we are allowing them in India to serve like sell a diesel s u v; while in their own country of Japan they are not able there is no Toyota in nova diesel version in Japan, there is no Honda mobilio diesel version in Japan, how come they are allowed and being sold in India for that example tavera, bolero and all those different cars.

So, why we why do we first of all allow them there should not be there should not be if you really worried about air pollution from this diesel vehicles. Especially for the passenger cars I can understand for public transport or for the trucks and all that because we want diesel prices (Refer Time: 11:45) cheaper government will subsidizing diesel and so that is why we want to keep our food prices low, that is we want to keep our transportation cost low for passengers traffic, I can understand having the diesel vehicle there. But diesel luxury cars it is kind of why we need to have it? If we have if our concern is the emissions coming out from this diesel vehicles, we should not allow this diesel vehicles to run on the road for the first time, but is it that is the only source of diesel emissions.

If you look at in cities like Delhi and other places there are lots of things are running on literatal gensets though the power situation is improved, but there are cities in India where big big mall are running on electrical gensets, the AC in the mall is running on electrical gensets. So, electrical genesets is much more polluter than diesel driven car most of the cases. So, we need to kind of look things in more totality rather than just looking it on one because sometimes it is creates lot of news, that oh this vehicle is banned now from tomorrow no diesel vehicle in Delhi which is 10 years old or may be now brand new diesel vehicles are not also sold in such and such city it makes a good

news item, but it does it really impact on the ground. So, we need to kind of look at those things, and this LCA kind of exercise helps us do that because we lift we have to look at things more in totality to make a more judicious judgment, like more judgment based on science not based on emotions.

So, any policies or any like a specially when you are trying to reduce environmental emissions or reduce air pollution, all these things should be based on science or whether you want to go for a in waste management system as well, which should work better many times we are we are too much into compost in the country, and sometimes this compost is we are making the compost we are not able to sell the compost because there is no market. We are making the compost the compost quality is so bad that nobody is buying this compost and the compost ends up in the dump. So, that is not we are we are not doing any environmental good that way so, but I am not saying composting is bad, but I am saying is we have to really look at things; if you want to do compost your input to the compost needs to be really good to produce good quality compost and, but that we can discuss in a solid waste class.

But coming back here in a system there are lot of things going up there in a in a sini kind of system it is. So, there not only the vehicle are pollution from the car that we started with it could be pollution coming from this electrical gensets, it could be pollutions coming from fire agricultural fire, which is again a big deal in Delhi. Delhi contest especially during the winter months and then there could be pollution coming from other sources too. So, in that particular scenario that is the that reference system, what is the pollution coming from this particular product or process or system that we are looking at for LCA exercise, that is what we are trying to do in terms of normalization.

So, k g of crude oil per functional unit that is this different category per functional unit, the impact in terms of the emissions per functional unit, different then you have. So, we look at the other product system, we look at the reference product, we look at the geographic area for a specific year for example, Europe in say 2016 or 2008 whatever, and per capita average European emissions. So, based on that in terms of the reference system what is the average emission from all the other factors which is like a documented and done together, we try to find out what how they compare in terms of per functional unit the different categories of impact is compared to the reference system. So,

is it more is it less and based on that we will try to extra polite; basically we divide it. So, that is we here you see a middle line.

Now, you have your numerator is the impact coming from this particular LCI profile related to the functional unit, divided by the base line and that kind of gives you the reference system equivalent in terms of human health ecosystem quality climate change and resources. So, that is kind of then we are putting things in more in a big picture perspective. So, that is how we normalize our data, we our normalize data based on all the other things happening around in the system. So, it is that is how things are done. So, you normalize this data.

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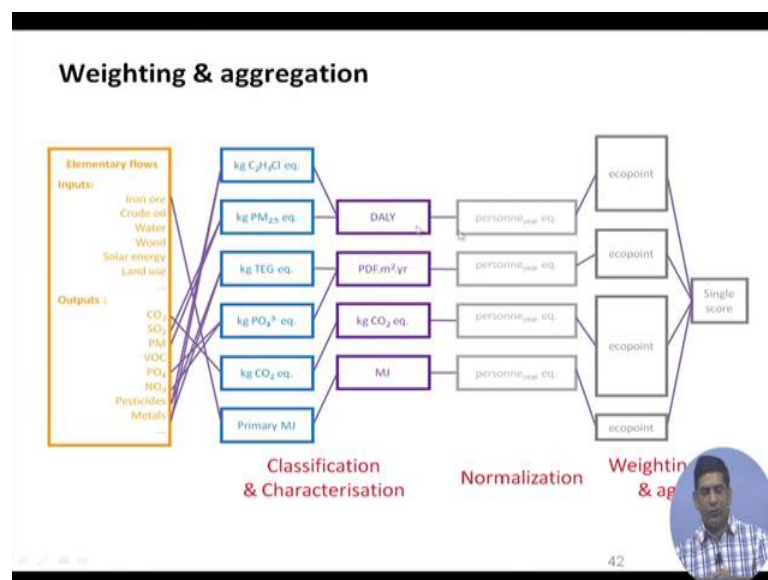
So, again if you look at the kind of in summary what we are doing, we had this elementary flow we had the input and output coming out; from there we quantify this in terms of emissions coming out different emissions coming out, from there we look at the impact categories, from the impact categories we are kind of trying to do we are trying to do the normalization.

So, here we did the classification and characterization, then we are doing the normalization from normalization we will try to do some weighting; because waiting factors and then ultimately we will take it to the single score. So, that is the whole how the interpret like a impact assessment is done. So, we will this is how this impact

assessment is carried out once you know the emissions coming out from there. So, this is again we will look at some examples.

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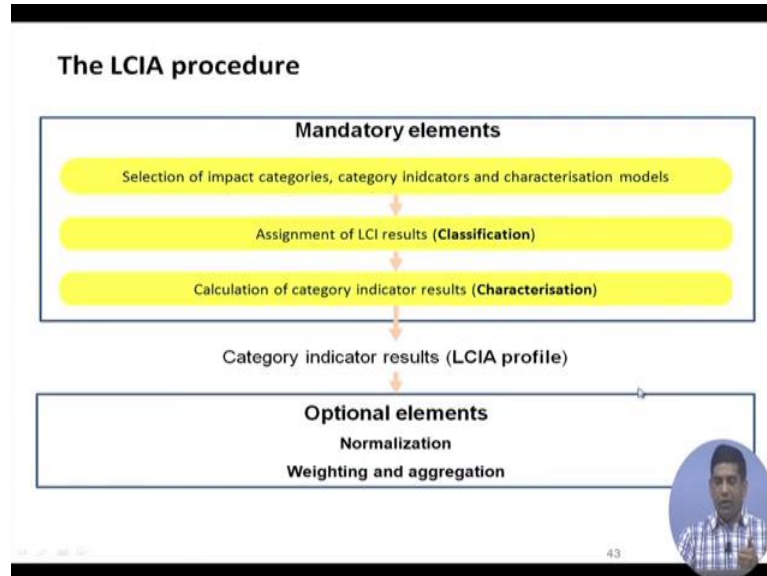
So, in future like videos as well, which will again kind of reemphasize that; so these are very these concepts are very very basic concepts in terms of the lifecycle assessment the different steps of life cycle assessment.

So, in terms of kind of summarize again same thing we put it in what we just explained in the previous slide, now put in terms of text over here in boxes. So, in terms of LCIA procedure life cycle impact assessment procedure, there are certain mandatory elements which you need to have you have to select the impact categories, category indicators and characterization model. So, impact categories as I said earlier there is a list you already saw those list in terms of impact category, it was there in previous few previous slide it is not over here it was there in few previous slide where you had like climate change, global warming, land use, acidification, eutrophication all those different impact categories out there, out of that you need to select which one is relevant for your exercise which one is relevant for your scenario. So, that you have to select those impact categories, you look at the category indicators for those impact categories what kind of category indicators you are going to choose, and then you use certain characterization model.

We looked at some of those characterization models then you assign them as part of the LCI results. So, classify them you characterize them you calculate category indicator results which we did for the incandescent bulb just few slides back, then based on that you come up with this LCIA profile that is your category indicator result. So, lifecycle impact assessment profile you come up, that leads to your optional element in terms of normalization weighting and aggregation into you come up you do those are the mandatory elements.

So, you cannot in terms of the LCIA procedure you go these are the mandatory that you need to do, and then you look many times you may see that some of the LCA results LCA reports they just leave at this particular this particular stage, they will come up with category indicator results give them LCIA profile, and then just go to interpretation directly; they will not go for normalization weighting and aggregation. And some of the that the box at the bottom these are optional, and most many times for the research kind of activity we look at this LCIA profile and then we kind of try to interpret from there as well, we do not go for normalization weighting and aggregation.

But if you are going for a policy kind of LCA study, if you are going to say if you give this indicator results to general public, they will get totally confused what you are talking about. So, (Refer Time: 19:38) for that matter our bureaucrats who are not familiar with this kind of area or like a to the ministers if I am giving a presentation to the ministers in other places if you put all this scientific term over there things will get confusing. So, we need to kind of put it in a perspective of something similar to water quality index or per quality index. So, BSE index like a stock exchange index. So, that people can easily compare which one is good which one is bad.

So, for that this normalization weighting and aggregation that really helps, and that but here in terms of normalization weighting and aggregation things does go subjective sometimes, you need to be careful how you want to interpret those information's.

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Available LCIA methods
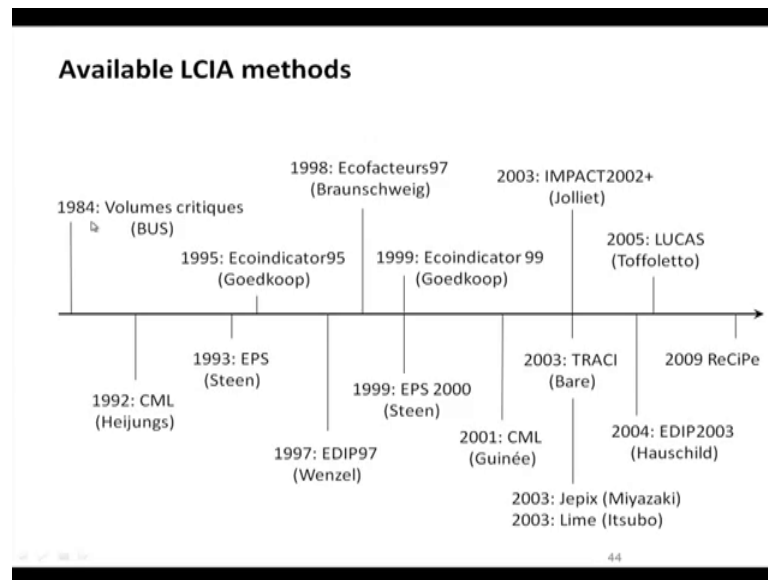
So, there are different LCIA method out there which have been used there are several LCIA methods which has been used in the past, and here are some examples. So, since we started with our LCIA exercise you saw that 1984 where 1980s if you remember that history of LCA slide, which we had in last week in one of the modules of last week. So, 1969 was when the coco cola did their it is first LCA study and then nothing happened for several years, and then 1984 when this was again the LCA as we know it today is started. So, 1984 of course, since it is LCA started in nineteen this exercise is started of course, the impact is impact assessment method also was developed the first one developed in 1984. And this some 1984 then 1992 CML that came up with another.

So, you do not have to remember all these different names, just kind of give you a perspective the historical perspective of how things have changed over time. Because as I said for anything you do knowing little bit of history and the background associated with that is always makes things interesting, you kind of feel you can relate to certain things in more in terms relate them better as when they make further progress. So, 1993, 1995 you see that every year mid 90s onwards there are lot of activities in terms of LCA in different method LCIA method there are lot of newer methods also coming up. So, 1995 the (Refer Time: 22:01) method came up 1998, which was ecofacteurs 97 improved upon to that method again the names are under the in the bracket gives you the name of either the author or those impact assessment method reports or the papers or the organization which worked on it.
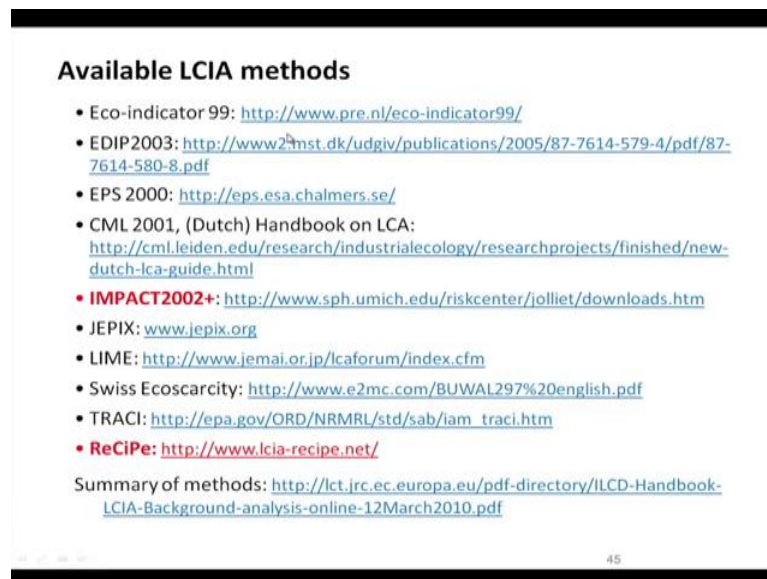
So, in terms of their popularity, if you look at 1992 CML came about one, and then 2001 they came up with a newer one. So, 2003 this CI came out which is a US it is a US based organization. So, they came up within 2003 and at the same time this impact 2002 plus came out, the impact 2002 was much more became much more popular and I would encourage you if you do not want to you cannot probably read each and every one of these, but there s a impact 2002 plus and this recipe 2009, if you can get hold of these two impact assessment method especially for those of you who are interested to do a kind of a mass test project or a PhD research even part of your PhD research on doing some LCA exercises associated with that, or you if you want to become a professional LCA as a LCA professional. So, I would rather say that. So, I would strongly encourage you to kind of get hold of this impact 2002 plus document, and recipe 2009 document which is may be available in your library or you can I think this 2002 plus paper I did find somewhere it is either on research gate or somewhere it was available as well.

So, you can you should download and you should go through that method, and it helps you to kind of gives you an understanding of how this impact assessment, what is the logic behind all this impact assessment. And again how this impact assessment method is is anything like a Bibber, anything like a it is not a set any stone. You can come up like you can read some of this impact assessment and then if you feel like that no this is this impact assessment method does not suit my requirement, my impact assess I need to do it little bit differently, you can come up with your own impact assessment method as well; but initially I would say that you sum up these and then when you become more confident while doing LCA, you can always come up with your own impact assessment method and that is one area of research as well.

Some of you if you want to do say if you want to do PhD in this particular area, one area where we can do really in terms of how to really interpret all these data in terms of the impact assessment in Indian scenario. So, I am just trying to hire some of you as a PhD student as well as part of you like when I am if you are really interested, if you have real interest in life cycle analysis concept and we do not have can we really look at how these impact assessment criteria should be done in a country like India, how with that that will be a still with I do not think we have any study like that done over here. So, that would be a really very good PhD research may be couple of PhD research, where nice PhD thesis with certain papers can come out of that journal publication.

So, if you are. So, those are there are for that of course, you need to read all these LCI method and try to understand the basics of all their (Refer Time: 25:34) again there are lot of methods out there I would encourage you to at least try to look at this impact 2002 plus and 2009 recipe method, those are the two methods which are most popular and used right now as we progress of course, there will be much more methods. So, if much more methods which will come up which should be in more like more elaborate more comprehensive than the previous ones.

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Available LCIA methods

- Eco-indicator 99: http://www.pre.nl/eco-indicator99/
- EDIP2003: http://www2.mst.dk/udgiv/publications/2005/87-7614-579-4/pdf/87-7614-580-8.pdf
- EPS 2000: http://eps.esa.chalmers.se/
- CML 2001, (Dutch) Handbook on LCA: http://cml.leiden.edu/research/industrialecology/researchprojects/finished/new-dutch-lca-guide.html
- **IMPACT2002+**: http://www.sph.umich.edu/riskcenter/jolliet/downloads.htm
- JEPIX: www.jepix.org
- LIME: http://www.jemai.or.jp/lcaforum/index.cfm
- Swiss Ecoscarcity: http://www.e2mc.com/BUWAL297%20english.pdf
- TRACI: http://epa.gov/ORD/NRMRL/std/sab/iam_traci.htm
- **ReCiPe**: http://www.lcia-recipe.net/

Summary of methods: http://lct.jrc.ec.europa.eu/pdf-directory/ILCD-Handbook-LCIA-Background-analysis-online-12March2010.pdf

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So, there are several methods which is available which you can be able to download say as I said here both actually recipe as well as impact 2002 plus, you should be able to download from these website, again this for all these slides that you are seeing and this these videos we will post the p.d.f version of that and I will make sure that this hyper link remains active on those p.d.f slides or all those you can copy this hyper link to your good browsers and go there.

So, eco indicator this is an impact EDIP. So, this impact 2002 and recipe those I have highlighted and read, and then others are also there, there is a summary of methods. So, there was a summary of methods done in this ILCD handbook which I showed you as part of that LCA history slide in the last in the material of last week. So, that also is you can that kind of gives you what all the methods that was developed until 2010 they have summarized it is like a review article. So, it is it helps you to lose kind of choose which

method will work that is best for you in terms of different LCI method, you can these you can go to this individual, but at least since there are several of those I will encourage you to at least go to the ones which is highlighted in red and try to read about those. And if you have any particular questions related to those impact assessment methods, you can always post things on the discussion board and I will be happy to answer those questions and since not all of you will be interested in such a great detail. So, I am not going to cover this impact 2002 plus on recipe in a great detail this particular course, because we have only 8 weeks to cover this whole material.

So, but if some of you who all really interested of course, you can join for your masters of PhD like we can do lot more things over there, but at, but just that was later on, but for now you can of course, put things on the discussion board and we will be happy to answer your question.

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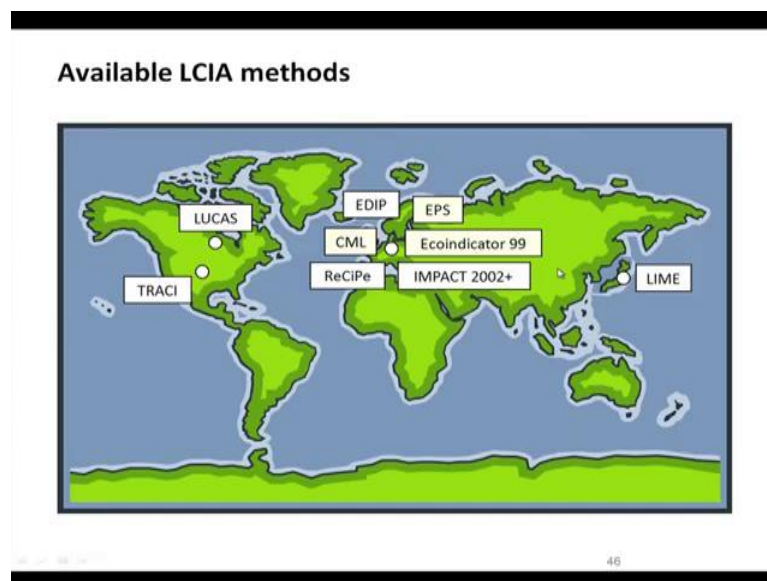
So, these are some of this and where in the world these have developed you see the method has been coming from pretty much everywhere in the world. So, this I will say impact assessment, but we do not have any method coming out from India. So, again if you are a energetic hardworking smart PhD candidate, do join and we will come out with your name and method for LCIA in may be three four years from now.

So, with that this is in terms of the impact assessment, then we will go in the next module we will try to look at the LCA interpretation and little bit on ISO method, this is

again we covered as part of the ISO method, but then I will show you some of the terminology which is used in ISO method and then we will have some good points of LCA and that will wrap up this LCA methodology section that we have been doing for last several videos we have been covering that. So, these are very important concepts very like a very basic concepts and I am reason I am spending so much time on this and going this going through this slides in such a slow phase is to help you understand I am repeating several things again and again to help you understand the concept because as a result these are the newer concept, many of you have not probably never took a LCA course even a part of course, like an overview of LCA.

So, for you it will be to understand that things are not that easy things do get complex. So, that is why the reason is we have been we are trying to do things step by step in a slow way, putting lot of examples there and hopefully you are understanding the concept, you are learning the material again watch the video again and again if you need to, but strongly encourage you to learn this material this is a new thing, and it will really help you in your job market. Because most of the companies if not today few years from now we will be looking for people who really understand this kind of subject as, because this is getting popular in India as well.

Thank you and I will look forward to see you again in the next video.