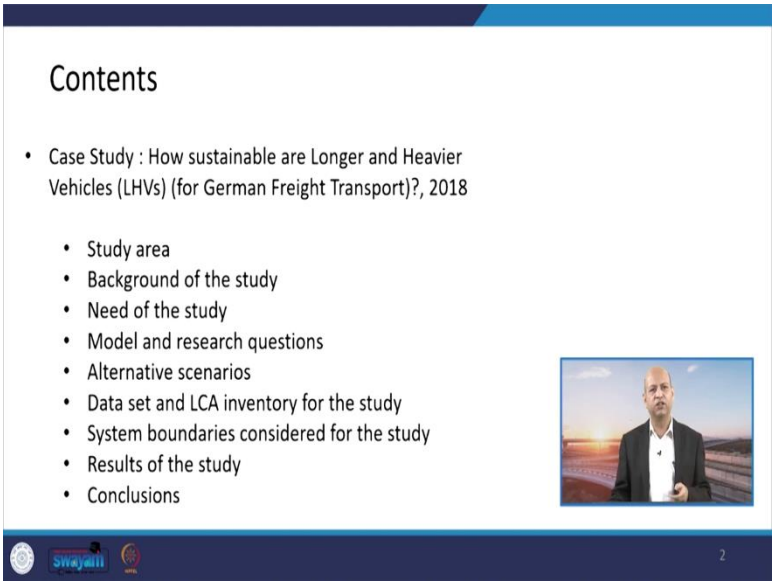
Sustainable Transportation Systems
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology, Roorkee
Lecture 56
OpenLCA Application – Case Study

Hello friends, so, you may recall last time we discussed about theory or basics of openLCA software which is used for lifecycle assessment of some activity or a process. So, today we will apply it in a case study so, that you can learn kind of hands-on training. So, that the steps are clear to that what are the different kinds of processes which are to be followed in this particular software?

What are the input data? How does it used for calculations? And what kind of results it gives? And how to interpret those results? So, that we can use this software for a decision-making process. So, the case study which today we will discuss is related to how sustainable are longer and heavier vehicles? That is LHVs in short form. And this study is focused in for German Freight Transport and study was carried out in 2018. So, first of all, we will discuss about a study area.

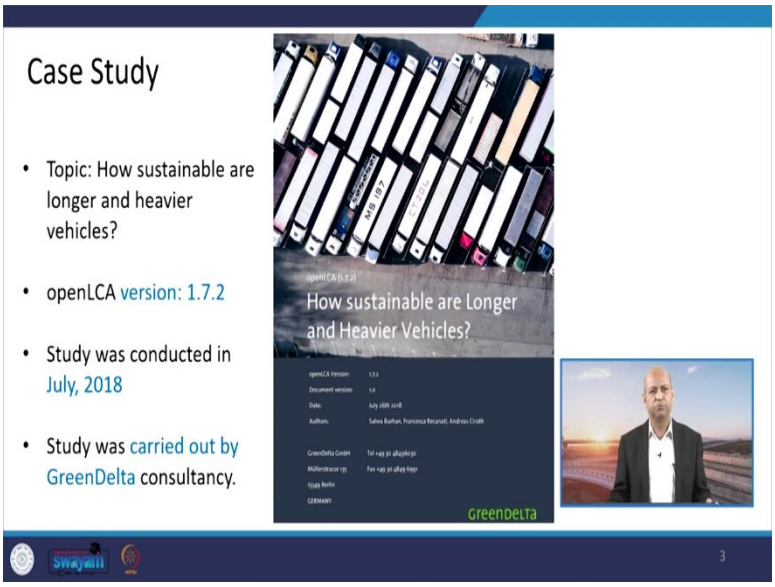
(Refer Slide Time: 01:33)



Then the background of the study briefly we will touch and what was the need of the study? Why it was carried out? That will be discussed and then the model and research questions which are related to this particular study that we will focus on and then we will see the alternative scenarios. So, that different kinds of situations we have to see to learn about the best possible scenario.

Then, this data set and LCA inventory for the study where it has to come, where we have to borrow or download and use then system boundaries considered for the study, because, whenever we do some sort of modelling, we have to define the system boundaries in a particular context only we use the model basically. Then we will see the results of the study and ultimately, we will conclude how these results are interpreted. And what are the implications.

(Refer Slide Time: 02:21)

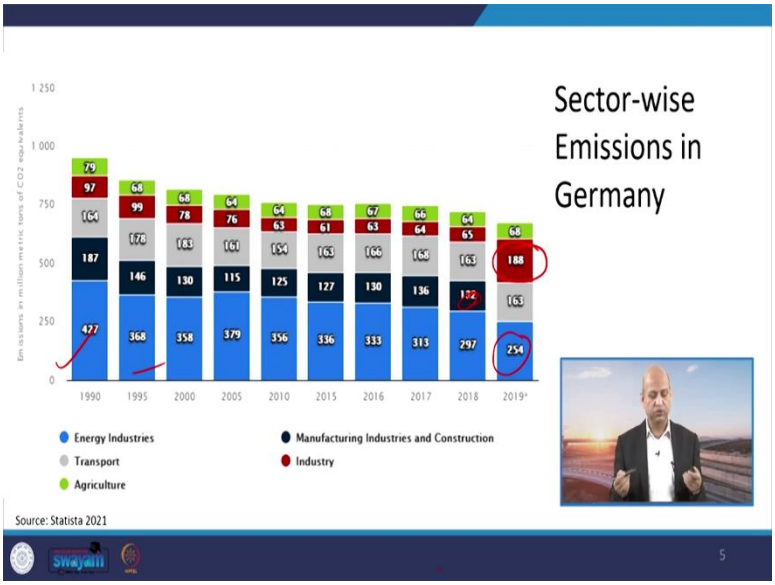


So, the case study this is related to how sustainable are longer and heavier vehicles and the software which we have used is openLCA and the version of this software is 1.7.2, because every time it is improved by the open software community and new versions are launched so this particular version was 1.7.2 and this study was conducted in 2018 July 2018 basically, and it was carried out by GreenDelta consultancy. So, that was a big project and this particular firm took this study undertook this study to see the impact of different options.

(Refer Slide Time: 03:08)

The study area is Germany and you know that Germany is one of the most industrially developed countries in Europe and it has very dense and efficient network of roads, railways, waterways, ports, airports, and it is one of the global leaders in freight transport and logistics. And the increased demand for the freight traffic due to the rising globalization and international trade. It could translate to more emissions of the pollutants and the greenhouse gases including carbon dioxide and then the more noise and more land use. So, these are the basic background.

(Refer Slide Time: 03:51)

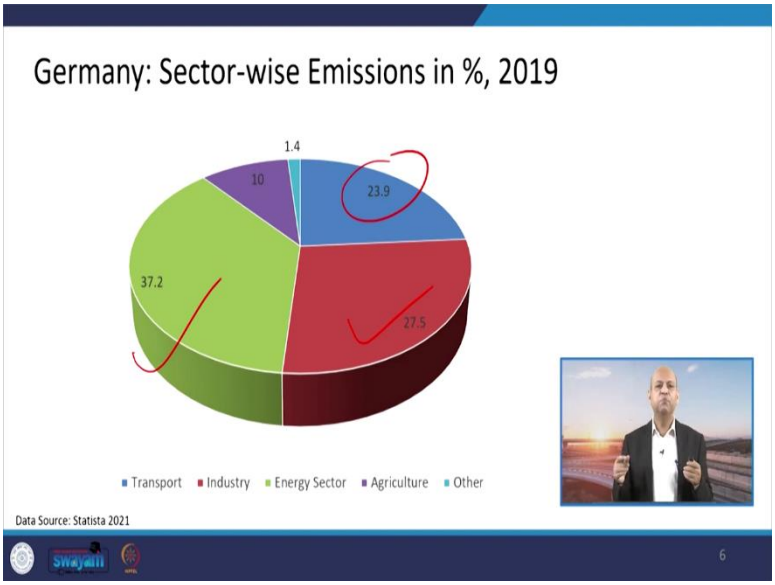


If you see the sector wide emissions in Germany, then the biggest emitter is the energy, energy industries, this much this is. Over the years although you can see that trend is decreasing the total emissions are reducing that means their policies and technology interventions are good. So, in total they are decreasing the emissions. But still, if we compare different sectors, the emissions of the different sectors then we have to compare about their contribution.

So, the biggest contributor is from energy industries. And then the second one you can see is this manufacturing industries and construction activities. And then the third one is the transport sector basically, and this maroon colour is about industries. But in 2019, you will see there is no this manufacturing industrial construction. Because this industry includes this sector also.

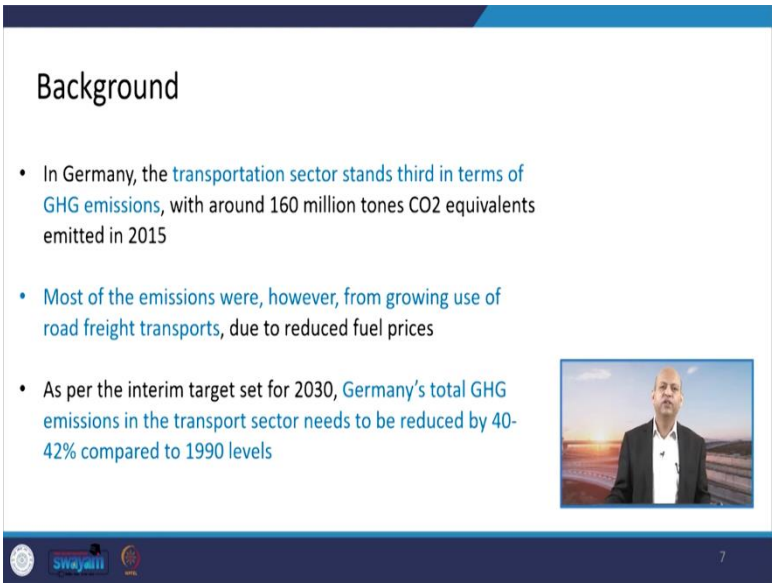
So, in 2019 basically this figure is industry which is including the manufacturing industry and construction activities also. So, in that sense it is the still the third one because this is second 188, 163 is up to 188 and 254 is the maximum from the energy industries or energy producing sources.

(Refer Slide Time: 05:22)



Well, if you see in percentage, the date of 2019 then again this is clear that the maximum emissions are coming from energy sector. The second one is from industry and third one is the transport sector. So, third biggest emitter is the transport sector that means, if we can intervene if we can make some changes in this sector to reduce the emissions the big impact can be observed.

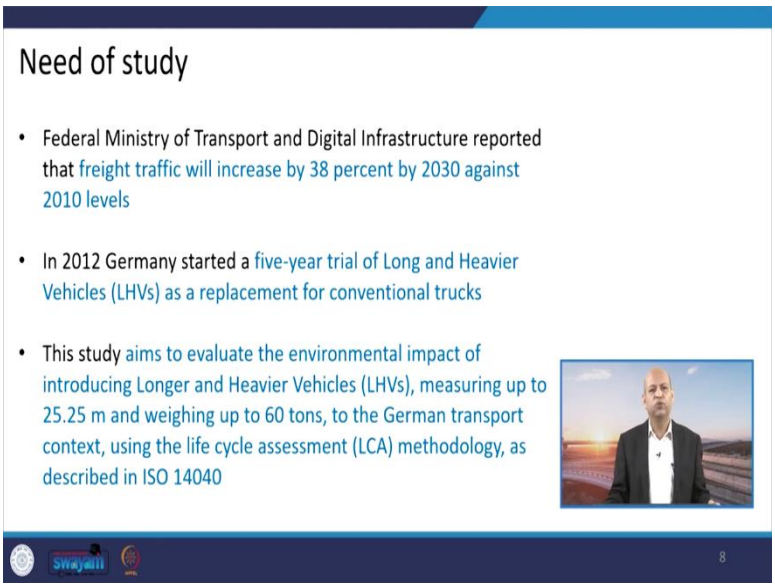
(Refer Slide Time: 05:51)



Well, the background is this transport sector stands as we have seen third in the category of greenhouse gas emissions and the most of the emissions are basically from the growing use of the road freight transport. Because transportation sector includes everything like railways, roads, inland waterways, etc. But because we when we see within the transport sector different kinds of modes of transport, then we see that the road transportation is the biggest contributor.

So, as per the interim target set for 2030 the total emissions greenhouse gas emissions in the transport sector needs to be reduced by 40 to 42 % compared to 1990 levels. So, that is the target. So, big target it is there. So, a lot of interventions are needed

(Refer Slide Time: 06:40)

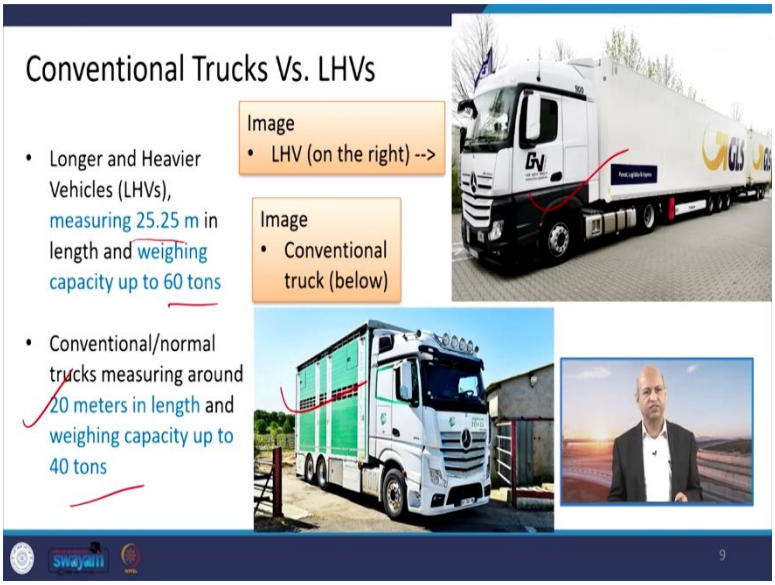


Then the need of the studies also based on like federal government of Germany they have this Ministry of the Transport. So, the ministry of the transport and digital infrastructure has reported that freight traffic will increase by 38 % by 2030 against 2010 levels. So, this is a big jump you can see this trend remains the constant.

In 2012, Germany started a five year trial of long and heavier vehicles that is in short known as LHVs as a replacement for conventional trucks so, that the more load can be transported in one go and also the emissions can be reduced. Because a smaller if you distribute in smaller vehicles then the total distance travelled will be more and more emissions will be there.

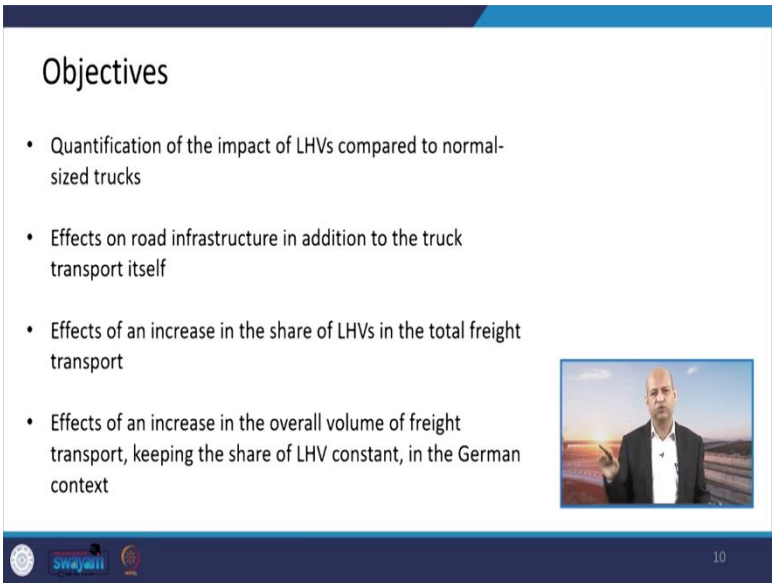
Then this study basically aims to evaluate the environmental impact of the introduction of these LHVs and the measuring up to this LHVs the dimensions is quite big, it measures around 25.25 meter and it weights around 60 tons and in German context basically, it uses the lifecycle assessment methodology for this particular study and as per the ISO 14040.

(Refer Slide Time: 08:11)



Well, the conventional trucks and these LHVs if you compare then these are the longer and heavier trucks or vehicles and these are the conventional ones. So, you can see the size these are very big as I said around 25 meter and weighing 60 tonnes. Whereas the conventional were 20 meters and weighing around 40 tonnes. So, in weight it is 1.5 times you can say.

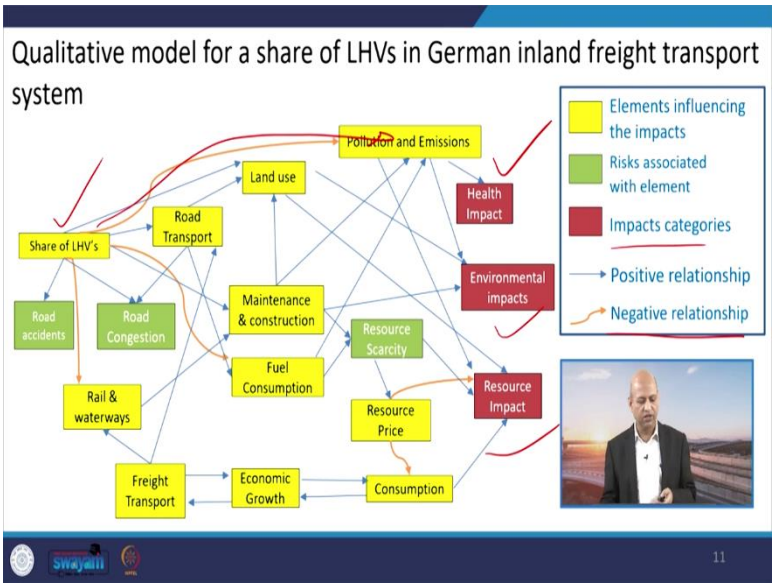
(Refer Slide Time: 08:39)



The objective of the study is basically to quantify the impact of these longer and heavier vehicles compared to the normal sized trucks or conventional trucks and the effects on the road infrastructure in addition to the truck transport itself. So, we have to see like, because you have longer trucks, heavier trucks, then the manufacturing technique has to be changed their layers that strata all things have to change and the new roads may be constructed all those impacts are there.

Then effects of the increase in the share of these LHVs in total freight transport, we have to see and we have also to observe the effects of an increase in the overall volume of the freight transport, keeping the share of LHV constant in the German context. So, different kinds of scenarios, we have to basically observe.

(Refer Slide Time: 09:29)

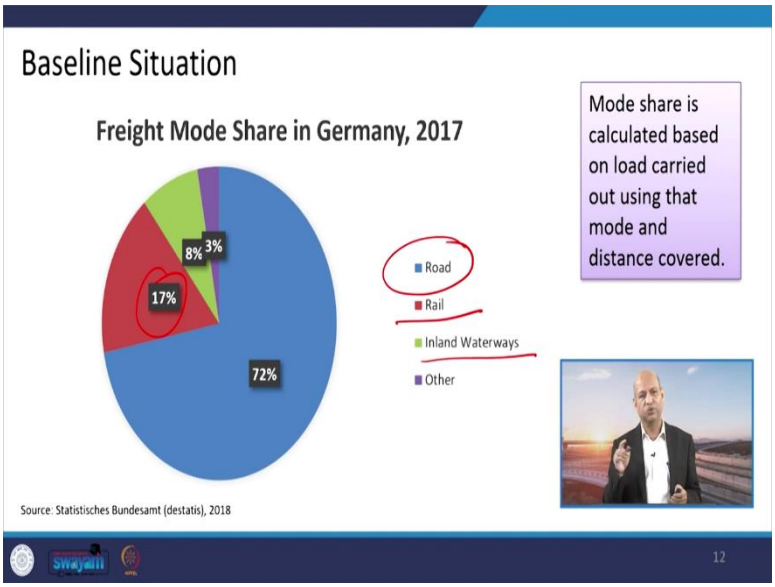


If you see this qualitative model for the share of LHVs in German inland freight transport system. So, you can see this is the yellow colour elements for influencing the impacts and the green is risk associated with these elements. For example, resource scarcity may happen, road congestion may happen if this number of vehicles increase, the road accidents may also happen. These are the impacts risk you can say.

And the impact categories are like health impacts or environmental impacts in total air, water, soil and the resources impact which are related to like a scarcity of the resources and the price of the resources. And if you see the relationship in blue arrow lines, these are the positive relations means something is contributing to that direction.

So, you can see, if share of LHVs increase the chances of the accident may increase, road congestion may also increase. But at the same time, it will reduce the pollution and emissions. So, this is the negative relationship or inverse relationship this brown is these arrows. So, that kind of relationship are shown in this particular figure which you can study in detail.

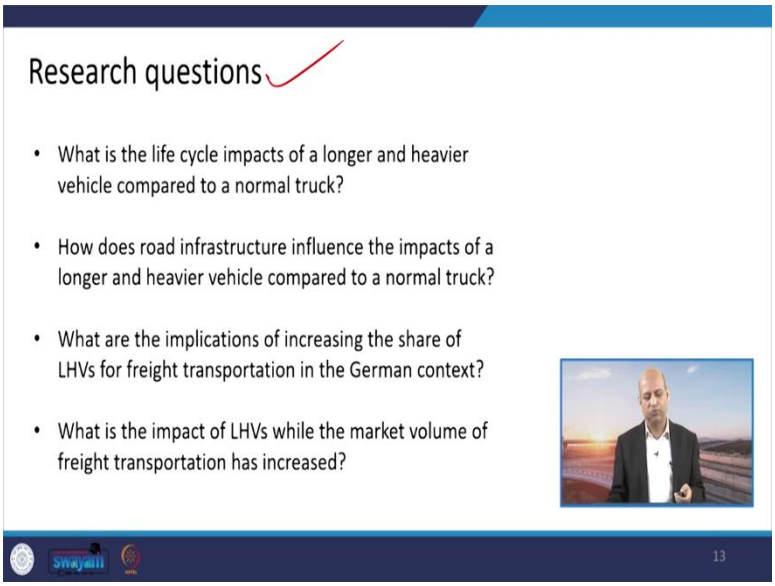
(Refer Slide Time: 10:42)



Well, the baseline situation because whenever we do the modelling, we have to see the baseline scenario. So, our 2017, fright mode share has been taken as the baseline and this mode share has been calculated based on this load carried out using that particular mode and the distance covered. So, if you see the 72 % is from the road and the 17 % is from the rail. So, the freight modes here is biggest from the road transportation you can say.

Second is the rail and then the third one is inland waterways 8 % and others are 3 % like air, etc. So, this is the distribution that means the biggest scope is on road transport or road freight transport.

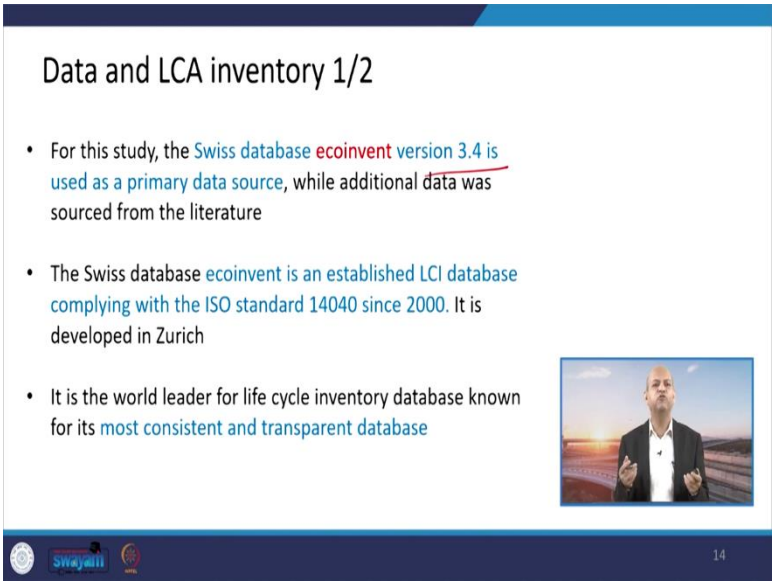
(Refer Slide Time: 11:33)



Well, these are the questions the research questions you can say. So, basically, we have to see the answers of these questions when we are doing the modelling. What is the life cycle impact of a longer and heavier vehicle compared to the normal truck? So, this is the first research question the answer we want to find. How does road infrastructure influence the impacts of longer and heavier vehicles compared to a normal truck?

Then what are the implications of increasing the share of LHVs for freight transportation in German context? And what is the impact of these LHVs while the market volume of freight transportation has increased? So, all these question's answers, we have to see by running the model with the different scenarios.

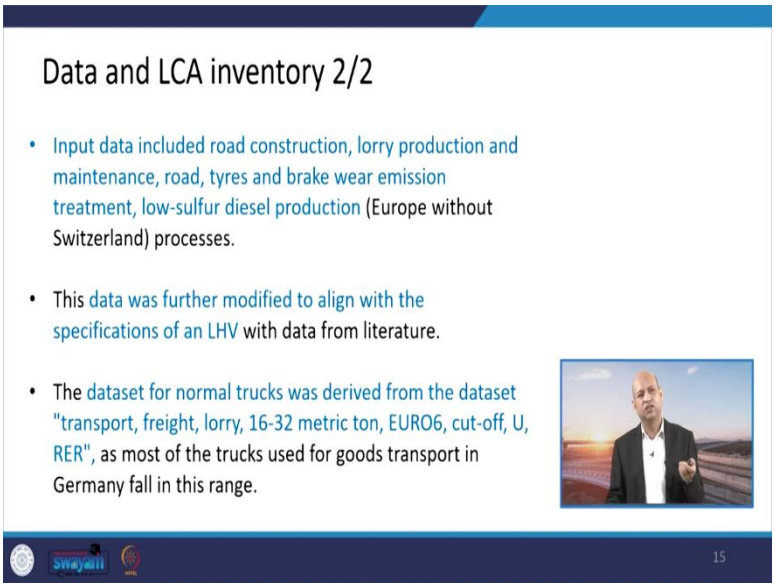
(Refer Slide Time: 12:18)



But the data and the LCA inventory. So, we have to see like this is study uses this ecoinvent database which is very popular and freely available. But some fine data you have to pay and this version 3.4 data has been used for this particular study. So, primary data source is ecoinvent and some additional data needed that is used from the different literature or secondary sources you can say.

The Swiss database of ecoinvent is an established, this lifecycle impact database which is complying with ISO standards 14040 since 2000 and it is developed in Zurich and this is, very robust data people, use it quite frequently. It is the world leader for the lifecycle inventory database known for its most consistent and transparent database. So, these are the issues means, you can always check and see where this data has come, what is the basis of those values. So, that way the confidence is there to use this data.

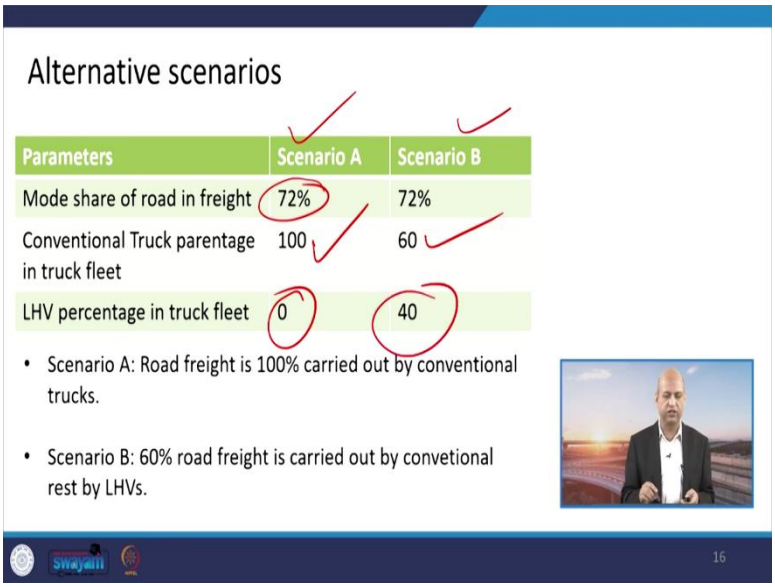
(Refer Slide Time: 13:23)



Well, then input data which are included like road construction or the lorry production that the trucks production then the maintenance of the roads and then the tires or the road surface, brake wear emissions treatment, low sulphur diesel production, this Europe the whole Europe this data can be used without the Switzerland processes. All those processes are linked with these kinds of activities.

Then this data was further modified to align with the specifications of LHVs with data from the literature. So, some modification has been done as per the context otherwise, there will be some kind of mismatch of those data and values. The data set for normal trucks was derived from the data set. Transport, freight, lorry and the 16-32 metric ton, EURO6, cut-off, U, RER. So, these are the specifications of those data which have been used. So, that way you can always see. This is completely transparent to study and you can compare you can rerun rather rather on the basis of these particular input data.

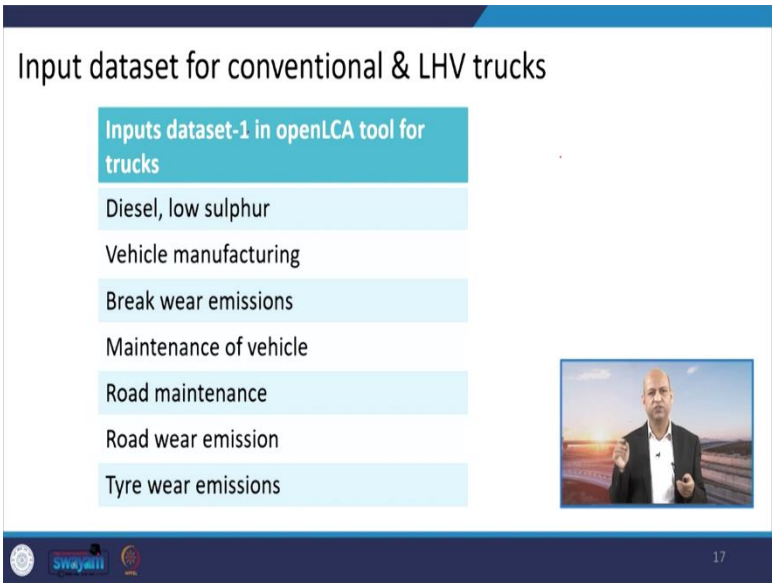
(Refer Slide Time: 14:29)



Well, the alternative scenarios which have been considered are scenario A and scenario B. In scenario A you can see like the mode share of the road freight has been considered as 72 %.

Beyond that, because this is the base data which we have seen and then in scenario A basically the conventional truck this percentage in truck fleet has been kept as 100, and in scenario B it is 60 and this LHV percentage it is 0 in scenario A. But it is 40 in scenario B. So, that kind of scenario A and scenario B you can see which have been used for modelling efforts.

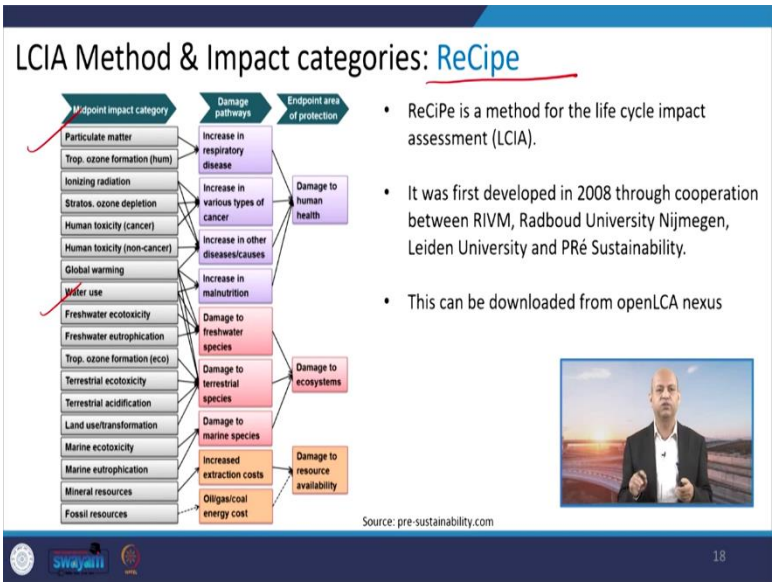
(Refer Slide Time: 15:12)



Then the input data of the conventional and these LHV trucks are basically like the lead diesel, low sulphur related values that vehicle manufacturing year of the vehicle because that

will also influence the emission factors. Break wear emissions then maintenance of vehicles, road maintenance, road wear emissions, tire wear emissions all these things have been included as the input data. Because we are considering environmental impact of these particular activities.

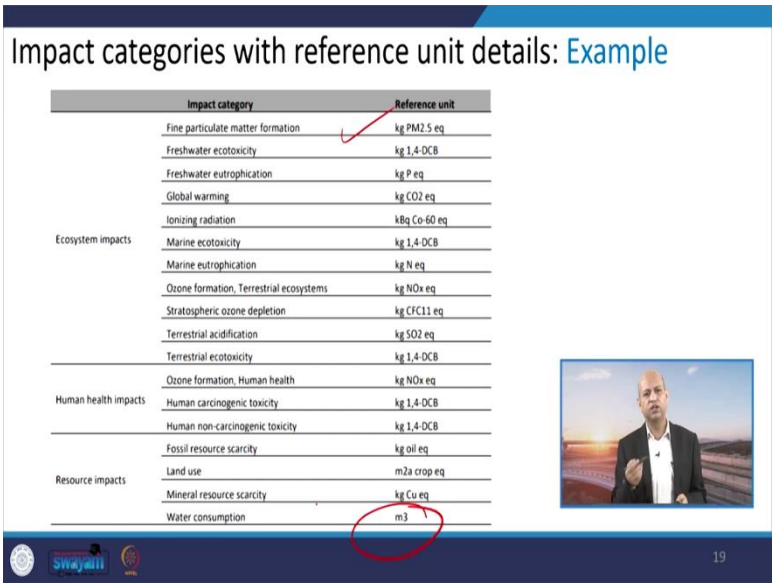
(Refer Slide Time: 15:44)



Then, we also have seen if you remember in the theoretical lecture related LCIA method and impact categories, this is related to this particular module of the ReCiPe. So, this midpoint impact categories are many like particulate matter or ozone formation or ozone depletion then human toxicity, water usage, global warming. There are so, many things.

Similarly, the drainage pathways are in terms of like increase in respiratory diseases or damage to the freshwater species, damage to terrestrial species those kinds of categories we have considered and the endpoint area of the protection is like damage to human health or damage to ecosystem damage to resource availability in those terms we have to see the things. So, this LCIA particular module is used for this particular study.

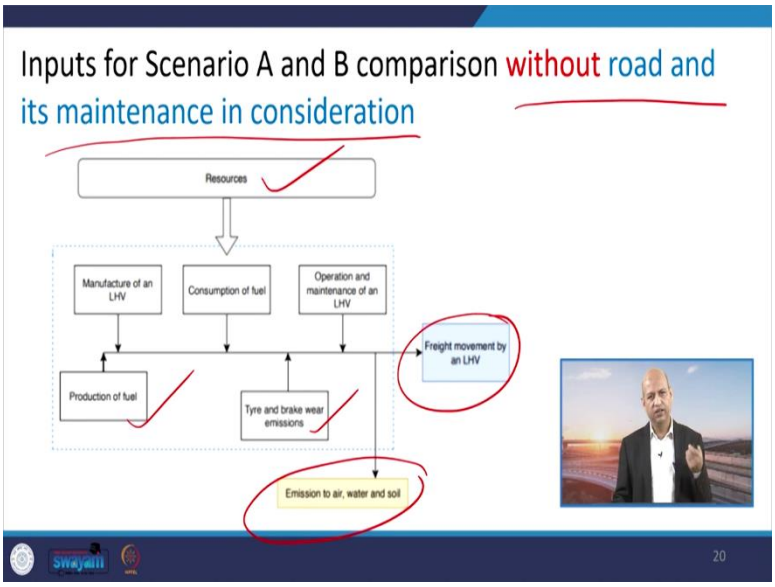
(Refer Slide Time: 16:35)



And then the impact categories with reference to unit details you can see what kind of units are being used because whenever in objective sense you want to study then you have certain values, those values have certain units if you mix up those then your calculations will be wrong. So, we have to be very careful about those values like in particulate matter, they are using this kilo gram, KPM 2.5 equivalent.

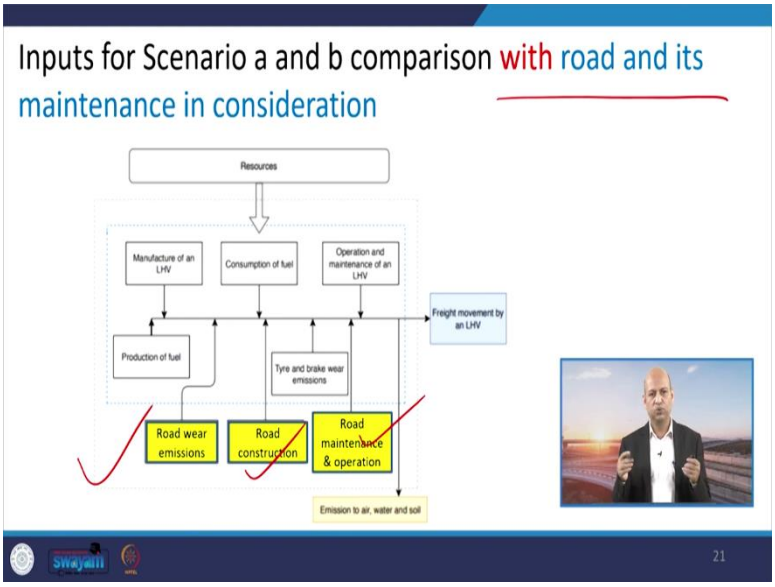
So, you do not please confuse with PM 10 or SPM like that. Similarly, you can see water consumption using volume cubic meter. So, keep an eye on the unit which have been used for the different values.

(Refer Slide Time: 17:13)



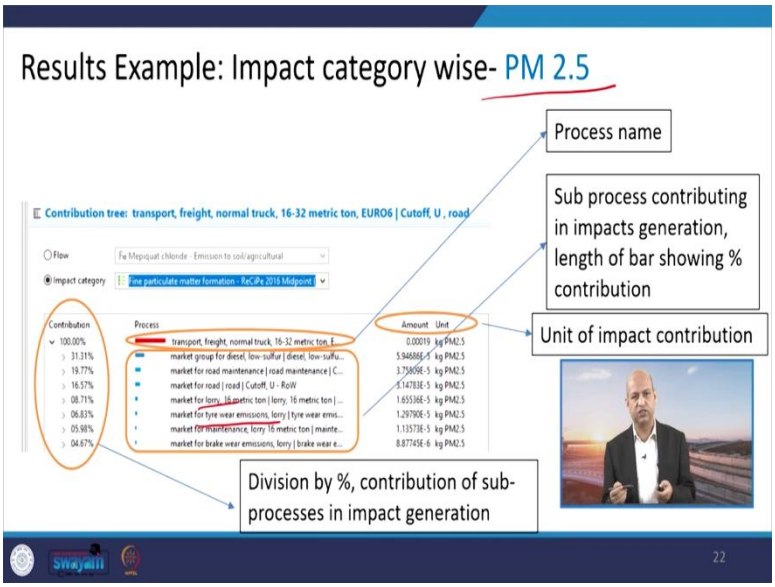
Then the input for these scenarios A and B the without road, and its maintenance in consideration that means only the trucks have been considered. So, the resources, manufacturing of LHV and the consumption of the fuel then operation and maintenance of an LHV that is the longer and heavier vehicles. Production of fuel and then the tire and the brake wear emissions, freight moment by an LHV and then emissions to air, water and soil. So, this is the without road and maintenance consideration, both scenario A and B have been run and compared.

(Refer Slide Time: 17:57)



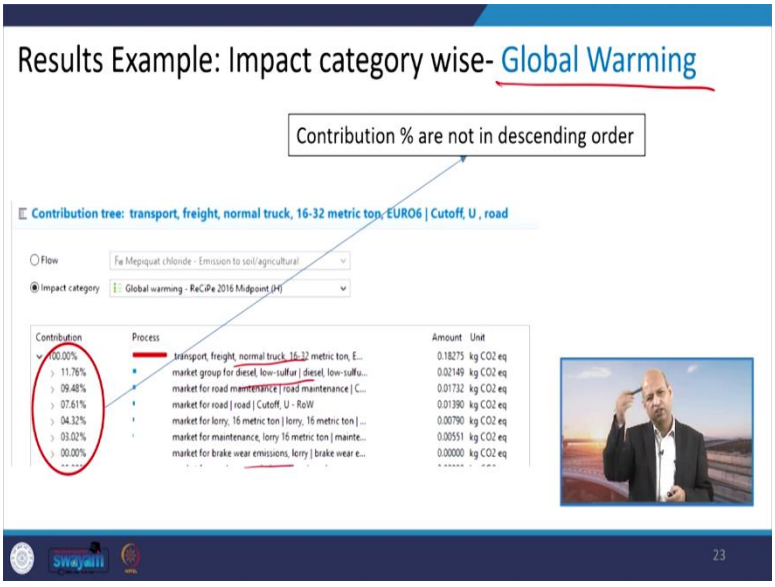
Then the next one is both scenarios have been considered with road and its maintenance that means these three things have been added road wear emissions, road construction related emissions, road maintenance and operation related emissions. So, these have been added when with road and its maintenance has been considered. So, this is the two different kind of data set which have been used.

(Refer Slide Time: 18:19)



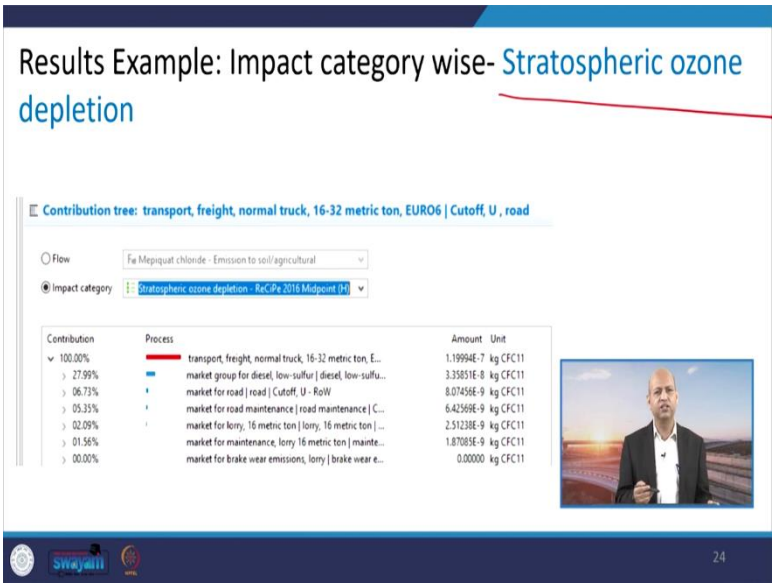
Now results when we see in terms of like different categories for PM 2.5 you can see different activities like road cut-off lorry related tire wear emissions. All these emissions in some percentage some values are there, but these are this model is giving in a particular sequence these are not in descending order. So, please do not get confused, but we have to see means which kind of activities producing how much emissions of PM 2.5.

(Refer Slide Time: 18:53)



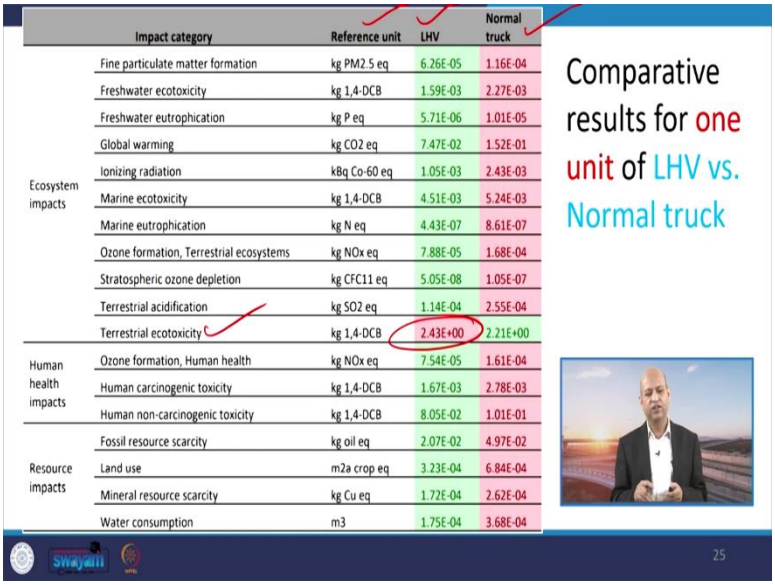
Similarly, from global warming perspective, we have to see how much contribution is coming from different activities like this normal truck, low sulphur diesel, then the break wear emissions all these there are a number of categories of these activities.

(Refer Slide Time: 19:07)



Similarly, stratospheric ozone depletion. So, all these activities are there you can go through those values.

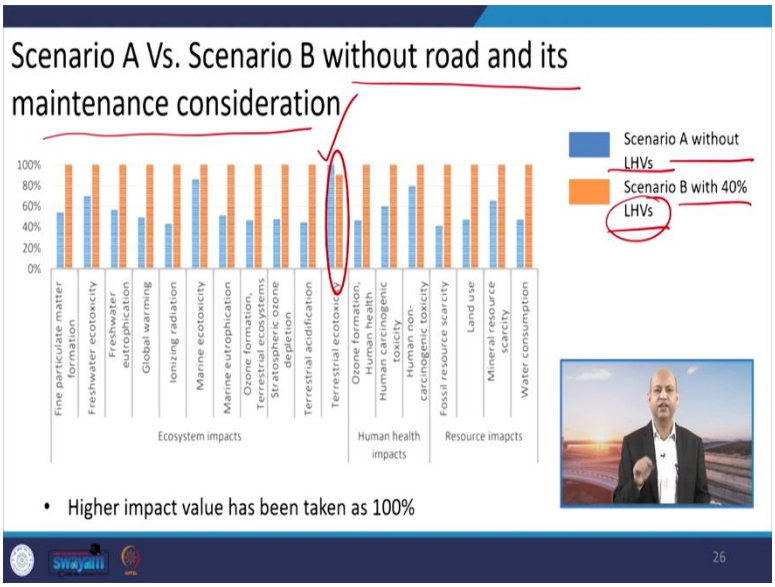
(Refer Slide Time: 19:15)



	Impact category	Reference unit	LHV	Normal truck
Ecosystem impacts	Fine particulate matter formation	kg PM2.5 eq	6.26E-05	1.16E-04
	Freshwater ecotoxicity	kg 1,4-DCB	1.59E-03	2.27E-03
	Freshwater eutrophication	kg P eq	5.71E-06	1.01E-05
	Global warming	kg CO2 eq	7.47E-02	1.52E-01
	Ionizing radiation	kBq Co-60 eq	1.05E-03	2.43E-03
	Marine ecotoxicity	kg 1,4-DCB	4.51E-03	5.24E-03
	Marine eutrophication	kg N eq	4.43E-07	8.61E-07
	Ozone formation, Terrestrial ecosystems	kg NOx eq	7.88E-05	1.68E-04
	Stratospheric ozone depletion	kg CFC11 eq	5.05E-08	1.05E-07
	Terrestrial acidification	kg SO2 eq	1.14E-04	2.55E-04
	Terrestrial ecotoxicity	kg 1,4-DCB	2.43E+00	2.21E+00
Human health impacts	Ozone formation, Human health	kg NOx eq	7.54E-05	1.61E-04
	Human carcinogenic toxicity	kg 1,4-DCB	1.67E-03	2.78E-03
	Human non-carcinogenic toxicity	kg 1,4-DCB	8.05E-02	1.01E-01
Resource impacts	Fossil resource scarcity	kg oil eq	2.07E-02	4.97E-02
	Land use	m2a crop eq	3.23E-04	6.84E-04
	Mineral resource scarcity	kg Cu eq	1.72E-04	2.62E-04
	Water consumption	m3	1.75E-04	3.68E-04

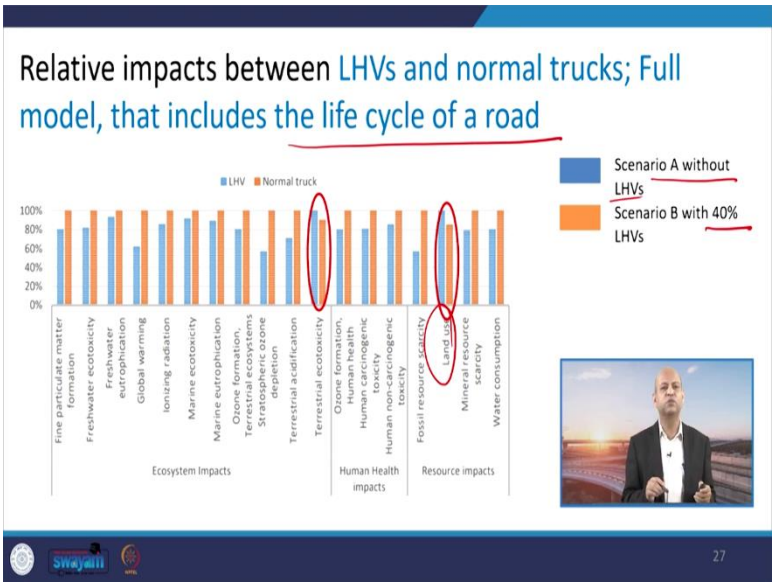
And these impact categories, reference units are there, then the comparison of values are of LHVs and normal truck. So, you can see LHV emissions are less in comparison to normal truck. But in case of this toxicity, ecotoxicity this is giving more value but in other categories or other, those kind of impact categories, and LHV is better in trans.

(Refer Slide Time: 19:41)



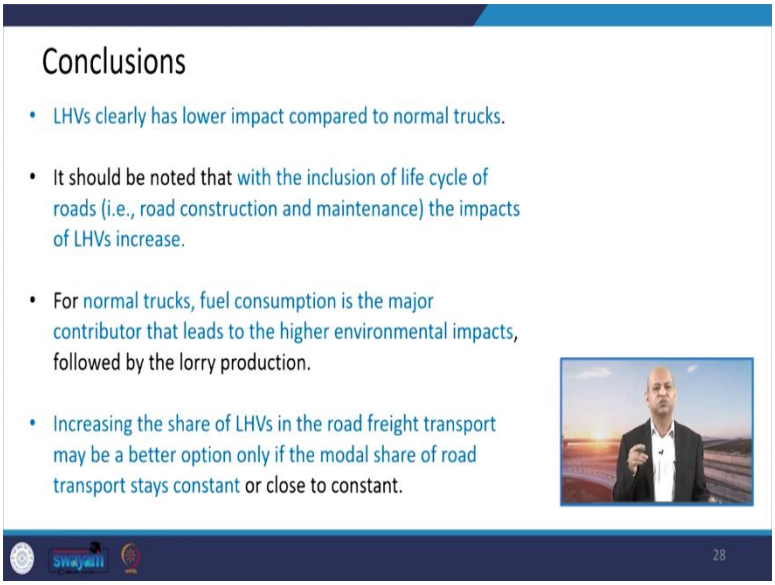
So here you can see like scenario A versus scenario B without road and its maintenance consideration. But in scenario A is without LHVs and scenario B is with LHVs. This is the difference between A and B. But this whole calculation is without road and its maintenance related considerations. So, you can see here toxicity related emissions in case of when we are considering LHVs is only in case of ecotoxicity the emissions are more otherwise this LHVs related the scenario gives the less emissions in all kinds of impact categories.

(Refer Slide Time: 20:17)



The same thing happens here also, but now, when we are including this road related emissions activities, then another land use related emissions also increase in case of scenario B. So, that means, if we are including these road and construction activities then LHV is further giving little bit negative impact, but overall, you can see the LHV's contribution is less in terms of emissions of various kinds.

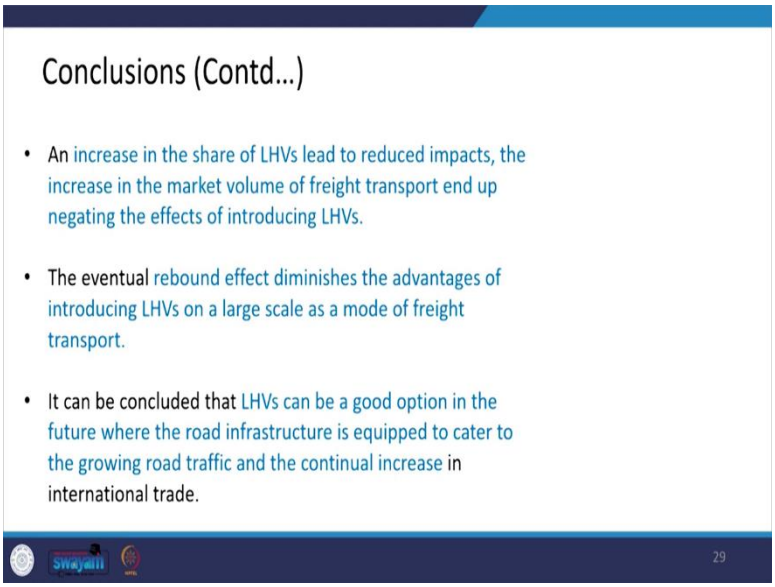
(Refer Slide Time: 20:47)



Well in conclusion, we can say that LHVs are clearly having a lower impact in comparison to the normal trucks that is clear with those values with the charts and those graphs. And it should be noted that with the inclusion of life cycle of the roads that the road construction and maintenance, the impacts of LHVs increased slightly. So, that is one thing we have to keep in mind.

Then the normal trucks and the fuel consumption is the major contributor that leads to the higher environmental impacts followed by the lorry production or production of the trucks and increasing the share of these longer and heavier vehicles in the road freight transport may be a better option only if the modal share of road transport stays constant or close to the constant.

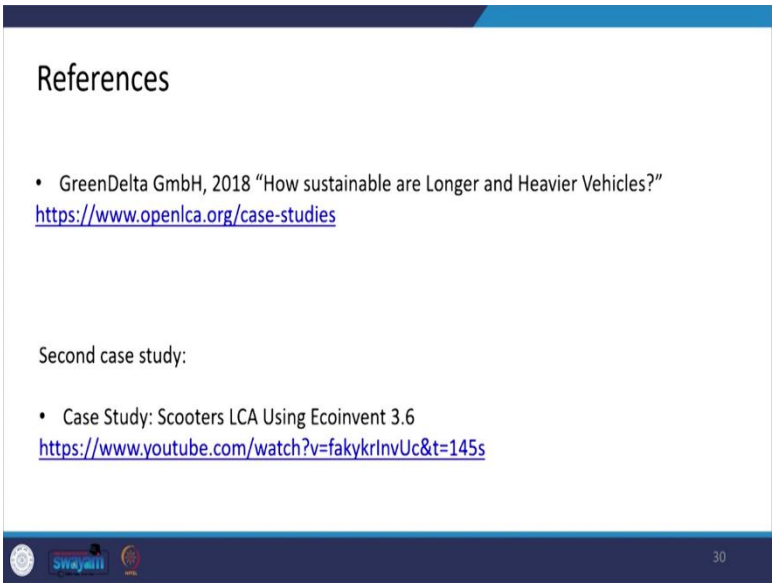
(Refer Slide Time: 21:35)



And then we also conclude that an increase in the share of these LHVs lead to the reduced impacts the increase in the market volume of the freight transport and up negative or negating the effects of the introducing LHVs. So, when the larger volumes then of course impact the total impact may increase. The eventual rebound effect of like diminishes the advantages of the introducing LHVs on a larger scale of a mode freight transport that means we have to explore other freight transport modes in parallel to the road transportation. Relying on road transportation may not help in that terms even if you go LHVs.

So, it can be concluded that LHVs can be a good option in the future where the road infrastructure is equipped to cater to the growing road traffic and the continual increase in international trade. But that we have to keep in mind that the other transport freight modes we have to also include like inland waterways, etc. Because a lot of emission reduction may be achieved in those sectors. So, this is all for today. Thank you for your attention.

(Refer Slide Time: 22:46)



These are the reference list where we have taken these data and information. So, if you want to have additional information, you can go through these references. Thank you.