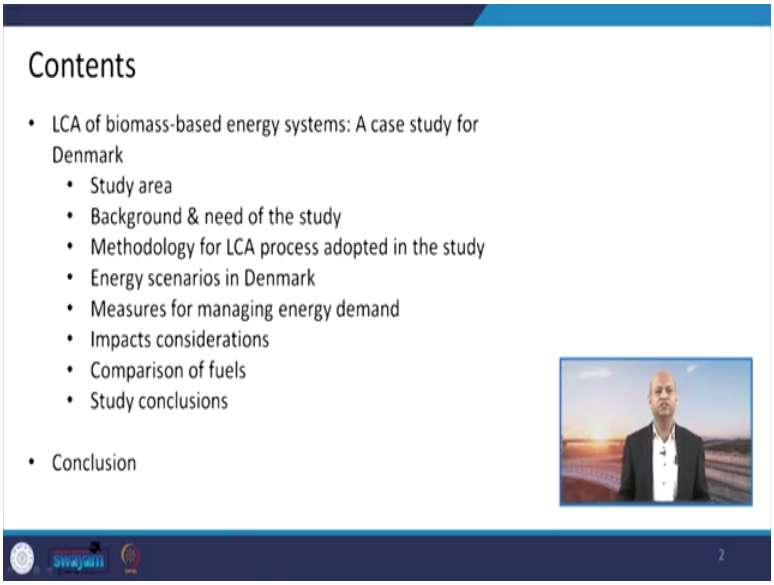
Sustainable Transportation Systems
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology Roorkee
Lecture 35
LCA - Case Study

Hello friends, so after the theory and practice of life cycle assessment, today we will discuss about a case study that will illustrate the concepts of the life cycle assessment in real world application you can say. How to implement LCA or how to use the LCA tool for carrying out some exercise which can help us to decide whether we have to go this way or that way, depending upon what alternates are there in terms of energy or in terms of any system related to transportation.

(Refer Slide Time: 01:05)



So today we will have a case study based on Denmark, and that is LCA, that is the life cycle assessment of biomass based energy system, which Denmark has targeted to, for going from fossil fuel based energy systems to this renewable energy resources.

So they conducted one particular study to learn whether if we shift from fossil fuel based economy or transportation system or energy sector, to the biomass based energy system, then whether there will be real advantage or not. So the LCA will give us this particular insight, whether in some way it is good or it is not going to give us much benefits in comparison to the fossil fuel based energy system.

So first of all we will discuss like study area, and then the background and scope of the study and the methodology of the LCA processes, which are adopted in the study and then we will discuss about the energy scenarios, which Denmark has considered for this particular study to shifting towards renewable energy resources.

So various kind of scenarios they have discussed besides this conservative scenario based on fossil fuel studies. Then we will see the measures for managing energy demand, because if we can reduce energy demand by some way of innovation, changing some processes, then also we are basically reducing fossil fuel emissions, those greenhouse gas emissions or air pollution emissions, those kind of things.

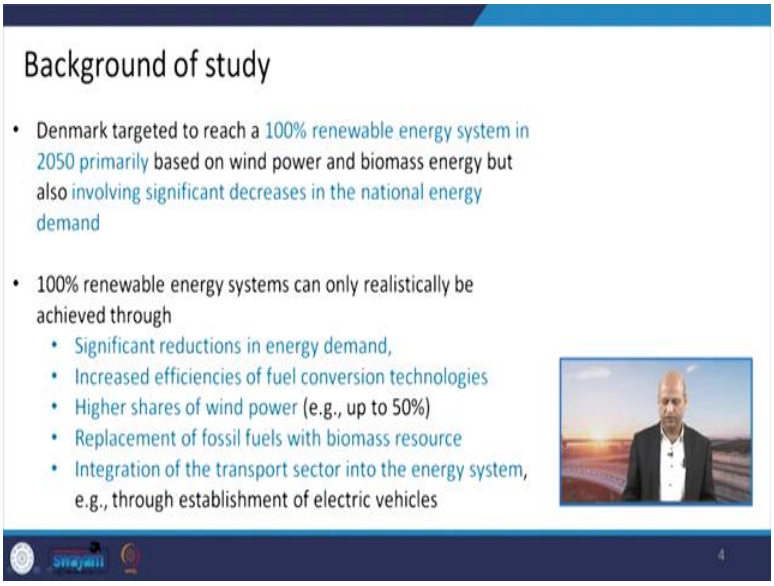
Then we will see the impacts related consideration, this fossil fuel based, plus the biomass based, energy system based, so that we can compare and the comparison of different fuels will be carried out and based on that we will conclude what is take away lesson or take away kind of strategy from this particular study.

(Refer Slide Time: 03:11)

This study area is basically based in Denmark, this country, which is nearer to this Germany and Sweden. So north part of the Europe, and the capital city is Copenhagen which is already quite famous for cycle friend infrastructure. If you recall there are various case studies and this Denmark related case study for non-motorized vehicle is also quite famous and it is also high

income economy, developed country you can say. A lot of activities are there which are contributing to this GDP.

(Refer Slide Time: 03:58)



So the background of the study is that, because Denmark is shifting its energy demand related systems and the resources towards 100 % renewable energy system, so that is a target for 2050. So step by step they want to change the infrastructure system as well as the energy production systems. So that from fossil fuel based energy system they can shift towards these renewable energy resources.

Renewable energy resources as you know, this may come from various sources like biomass or bio-fuels and then these wind or solar and so many renewable resources are there for energy. So also at the same time, like energy demand reduction, because as you know when we shifted from ordinary bulb to CFL and LCD bulbs so energy demand automatically got reduced, with same requirement fulfilling the same needs of the illumination, right?

So those kind of technological innovations also reduced the total demand of the energy at the national level. So not only the fuel related shifting but also the innovation related things have to be carried out to reduce the total energy demand. Plus we have to see like 100 % renewable energy systems which can realistically achieve.

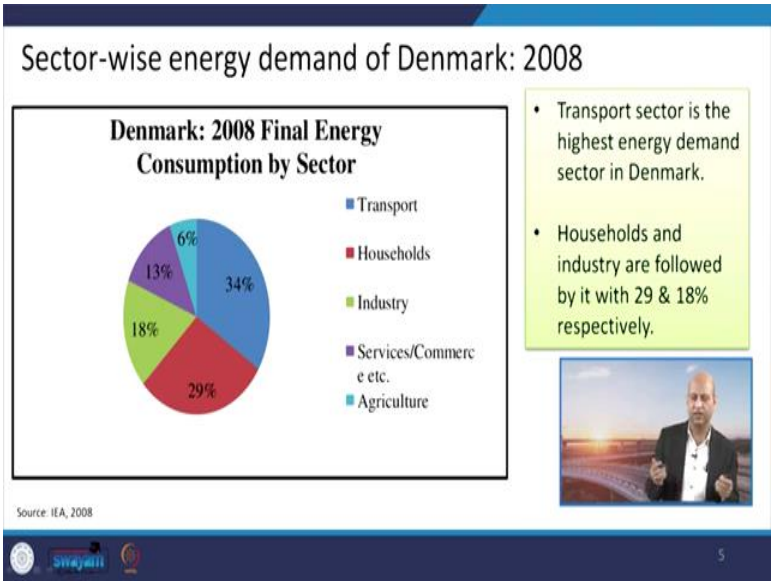
This is the baseline or the bottom line of this Denmark study that it should result in significant reductions in energy demand. It should also increase the efficiency of the fuel conversion technologies because every kind of fuel has its own positive or negative aspects and some system which are designed for a particular energy source then the work which we take or the work done by the energy input becomes very less, a lot of losses are there from conversion, from one state of energy to another one and then really taking it into action.

So higher shares of wind power it is also one aspect that not only other resources which are of renewable nature have to be increased like bio-fuel or solar, et cetera but in northern countries there are issues like they have a lot of long nights for several months because of their latitude and their positions or geographical location. So solar may not be so much, like in tropical countries as India, etc., but they can harness like bio-fuel related energy or bio-gas, bio-diesel, those kind of things they can go for and they have experimented in that direction.

Plus wind related, off shore wind farms, they can have a lot of wind energy resources, they can generate and that is why the target is like 50 % up to the share of this wind energy must be there and they have achieved, those data are not included in this study but there are data that they have, like in 2016 their share of wind energy was around more than 40 % or so.

Replacement of fossil fuels with biomass resources, this is one target of this study and then the integration of transportation sector into several energy systems including the electric vehicle so that if you have electric production, power production from renewable resources then again it gives advantage that you can use electricity for driving these vehicles, electric driven vehicles, battery based vehicles.

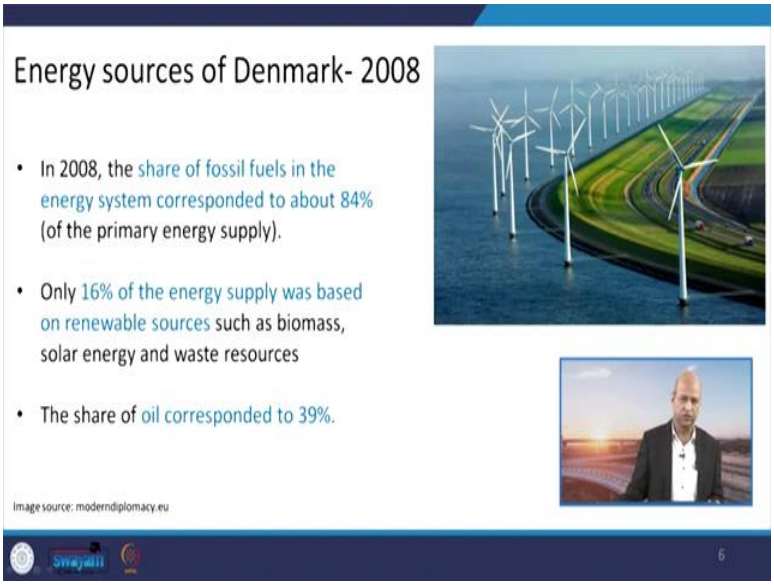
(Refer Slide Time: 07:59)



If we see this scenario of 2008 because that is the baseline information available in that study; so this is 2008 study data; so in that if consumption by sector, energy consumption by sector if we see; so the transportation sector has the maximum share, this is around 34 %, after that this household related energy usage are there.

So this is 29 %, followed by industry, that is 18 % and then service sector or commerce activity is 13 % and agriculture related energy consumption is only 6 %. So that is the kind of share. So a lot of scope is there in transportation sector or household sector if we can meet the demand of these two big sectors from renewable energy resources then big achievement can be there towards shifting to renewable energy sources and reducing the environmental impacts of greenhouse gas emissions, etc.

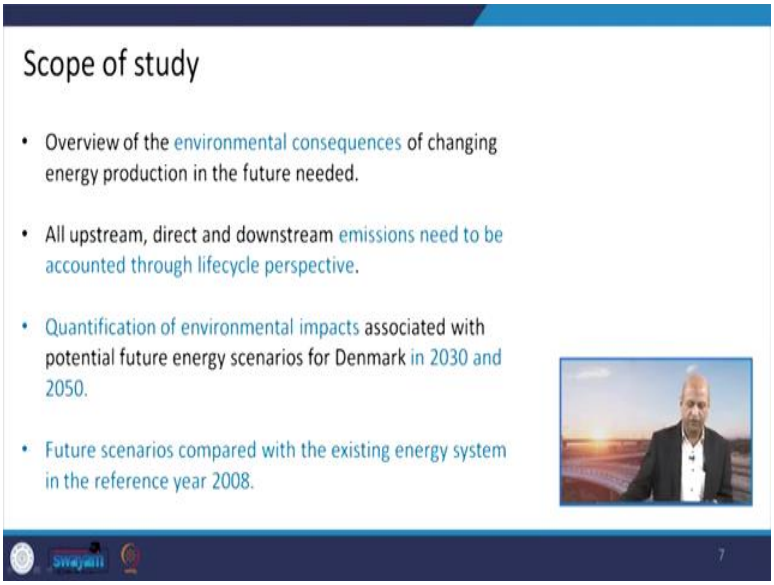
(Refer Slide Time: 09:01)



Well you can see these energy sources are of different nature and here this wind farm is shown. So the 16 % of this energy was based on renewable resources like biomass, solar, waste, etc., in 2008, and 84 % was primary from fossil fuel based. So a lot of scope is there for reduction of usage of the fossil fuel and increasing the share of renewable resources, whether biomass or solar or wind.

And in wind they have made a significant progress. Later on we can see those kind of things. The share of oil correspondence is around 39 % otherwise other fossil fuels are like gasses coal, etc., there are the share of that.

(Refer Slide Time: 09:50)

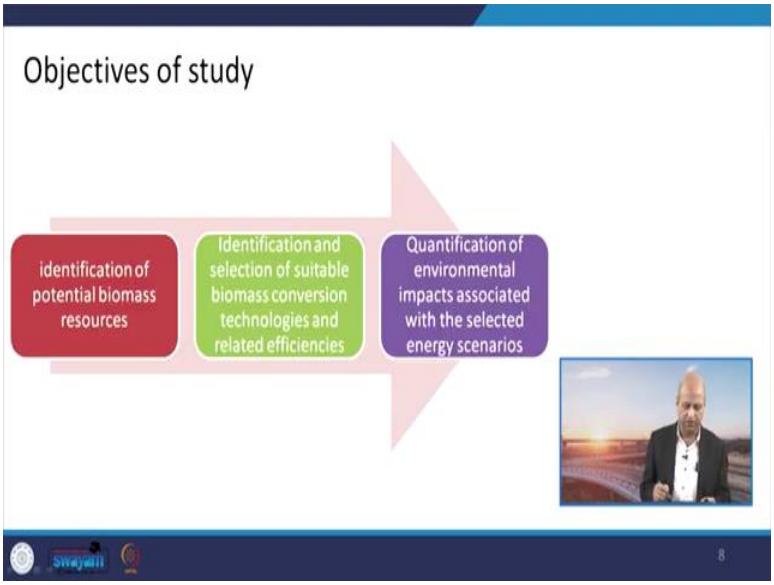


Well the scope of study is basically like overview of environmental consequences of changing energy production. So when we shift towards renewable energy resources so they will also have some environmental impacts. For example if we are going towards bio-diesel crop then land will be required. Then when we are growing crops then fertilizers will be used, so the fluent, this storm water may have nitrogen, etc.

So there are issues. It is not that renewable resources are very good in every aspects. There are issues and we have to tackle them properly. Then all upstream, direct and downstream emissions need to be accounted through life cycle perspective only then total picture will emerge, from beginning to the end, of every kind of energy system.

Then the quantification of environmental impacts, associated with these future energy scenarios which Denmark wants to achieve in 2030 or 2050 so those energy scenarios we have to discuss and the future scenario compared with the existing energy systems with reference to 2008, have to be seen to see whether how much advantage is there in terms of reduction of some pollutants or how much negative things are there due to release of some additional pollutants. So in totality we have to see.

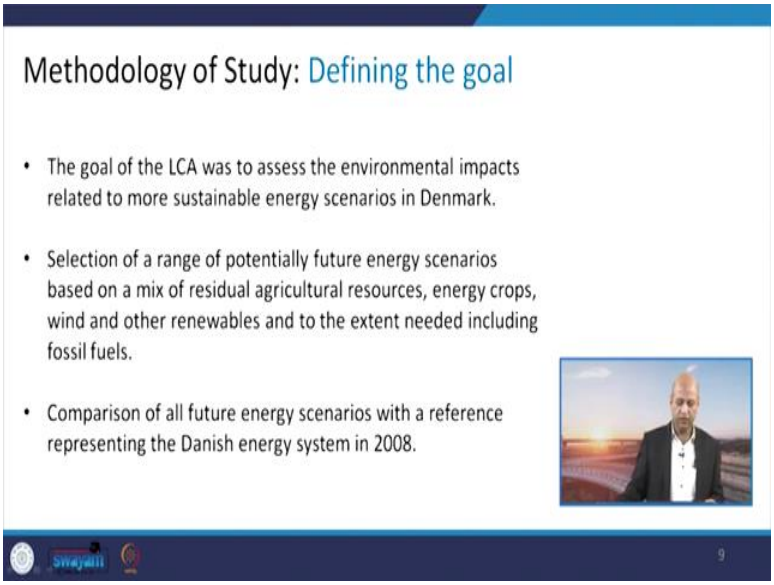
(Refer Slide Time: 11:21)



The objective of the study, so it is basically the identification of these potential biomass resources because this particular study is focused on biomass otherwise renewable resources are many, but to illustrate how to use this tool of LCA, life cycle assessment, we are just taking this study of Denmark, focused on biomass, please notice this thing.

Then identification and selection of suitable biomass, conservation, conversion technologies, means biomass conversion into energy, and then efficiencies also, how much efficiency we can achieve, then quantification of environmental impact that is the point which is basic the deciding criteria or benchmark, so the impacts on the environment associate with those selected energy scenarios, whether fossil fuel that is conservative scenario or this biomass related scenarios, so we have to see.

(Refer Slide Time: 12:20)

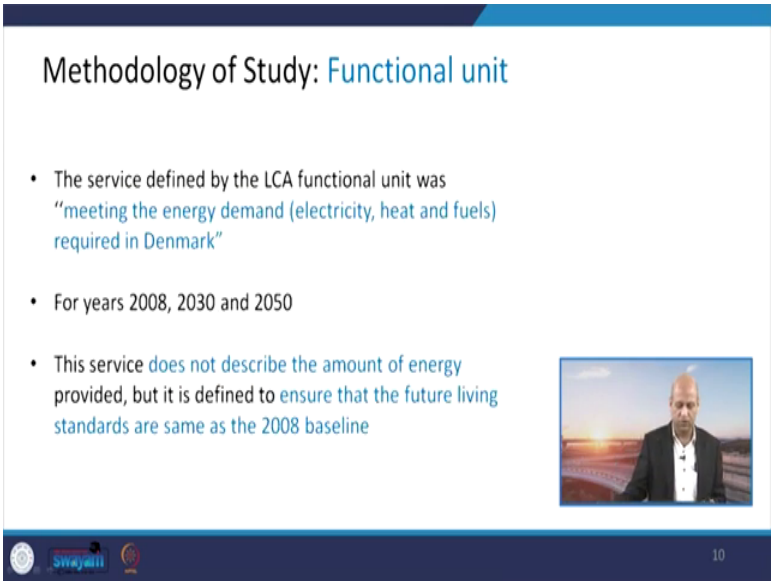


The methodology is basically like you have seen those steps when we discussed the theory of LCA or life cycle assessment that first we have to define the goal. Goal definition is very important, because it will help us to adopt the methodologies in different steps. So the goal of LCA is basically the environmental impacts related to different energy scenarios so assessment of those environmental impacts.

And then we have also to see the range of these potential future energy scenarios, whether based on agriculture residue, waste products or energy crops, means biomass, bio-fuel related some crops and then the wind and other renewables and to the extend some fossil fuel, of course we cannot go for zero fossil fuel just like that. Step by step we have to go in the direction of renewable resources.

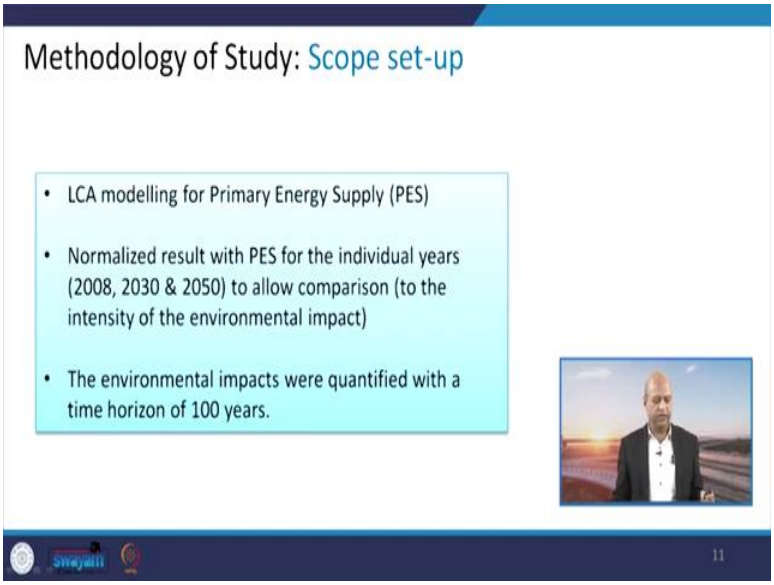
So for different scenarios some mix may be there, some quantity of fossil fuel can also be there, and then comparison of those future energy scenarios with the reference and the reference is energy scenario or energy system of 2008, and that is dominated by fossil fuel, you can recall we discussed that 84 % energy system is driven by fossil fuel based energy sources.

(Refer Slide Time: 13:42)



And the methodology, that functional unit we have to define again, so what is that? Whether this energy demand is to be taken from electricity or heat, fuel, those kind of requirements are there, so that has to be incorporated and what are the years? The boundary line you can say, so 2008, then 2030, and 2050, so three scenarios we can create in terms of timeline. And then the baseline data is related to 2008 only.

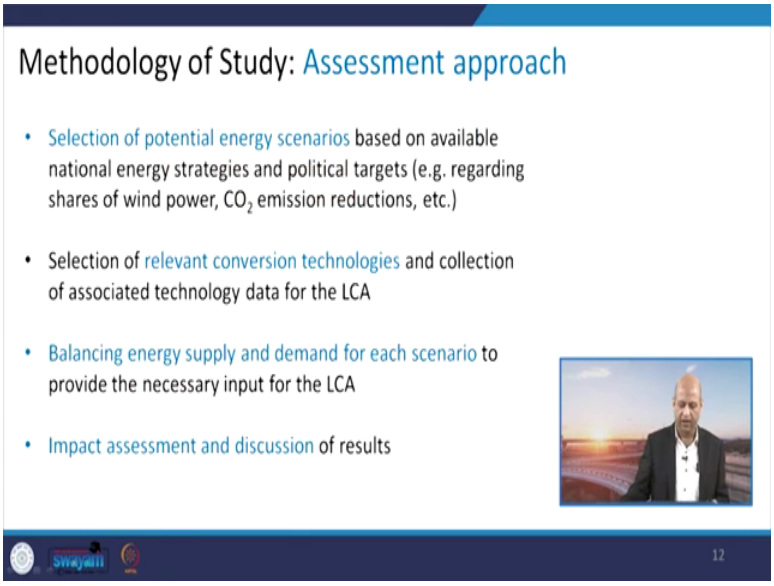
(Refer Slide Time: 14:16)



Scope is to be set up like modeling of LCA and then the primary energy supply related relationship and normalizing all those values in terms of the intensity whether CO2 emissions or

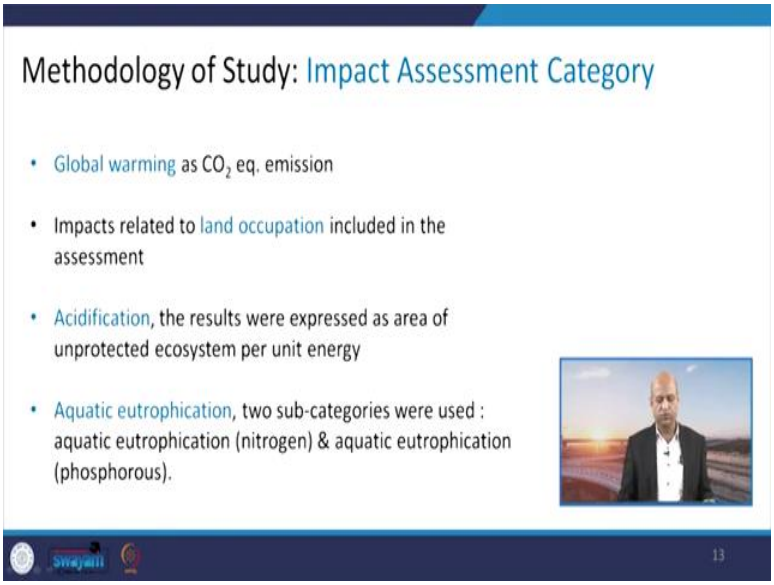
acidification related emissions or those, and then quantification for 100 years are also carried out by this study, but our focus is only for these scenarios like 2008, 2030 and 2050.

(Refer Slide Time: 14:42)



The assessment approach is basically, means what kind of parameters are there, which can give us idea about whether some advantage or disadvantage are there, so we have to compare, what are those parameters. Those parameters are like how much CO2 emission is there, whether it is increasing or reducing, or some acidification related potential is there, whether it is increasing or decreasing. So those kind of things. Then impact assessment and discussion in that particular integrated way we have to see.

(Refer Slide Time: 15:18)

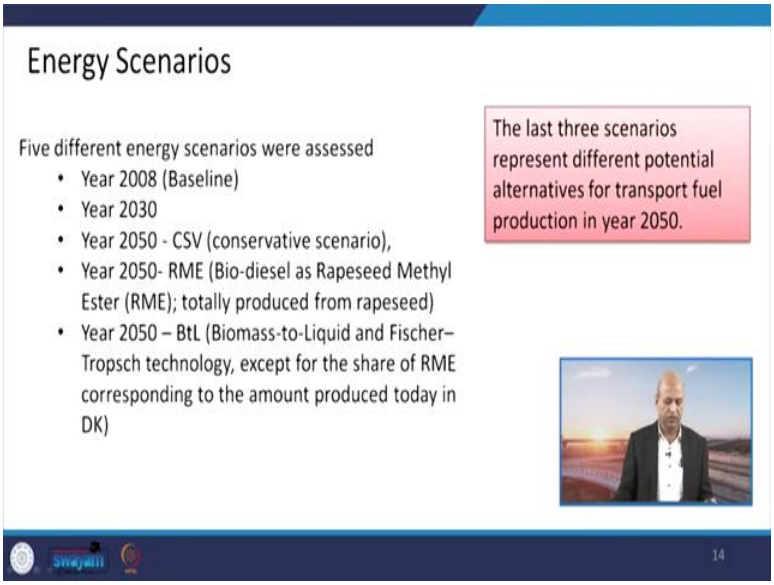


So you can see like global warming related potential we have to determine, in terms of CO2 emissions, so CO2 equivalent we can convert and see and then land occupation because if you are growing energy crops then you have to grow in agricultural fields so the land occupation is also one issue. Like fossil fuel, you do not occupy land except like refineries or some pipeline, etc.

But as such land use changes are not so significant, which can be there because of energy crops, because then you will need a lot of hectares of agricultural land for growing those crops, so those kind of things we have to see then acidification potential means those acidic gases like SO2, NO2, how much emission is there, whether emissions are reducing in this case or increasing.

Then aquatic eutrophication because when we are growing crops then issues are there with the fertilizers, so nitrogen phosphorous and these are the nutrients which boost or which go for eutrophication related problems, because algae production and all those kind of things may happen in water bodies because of these run offs.

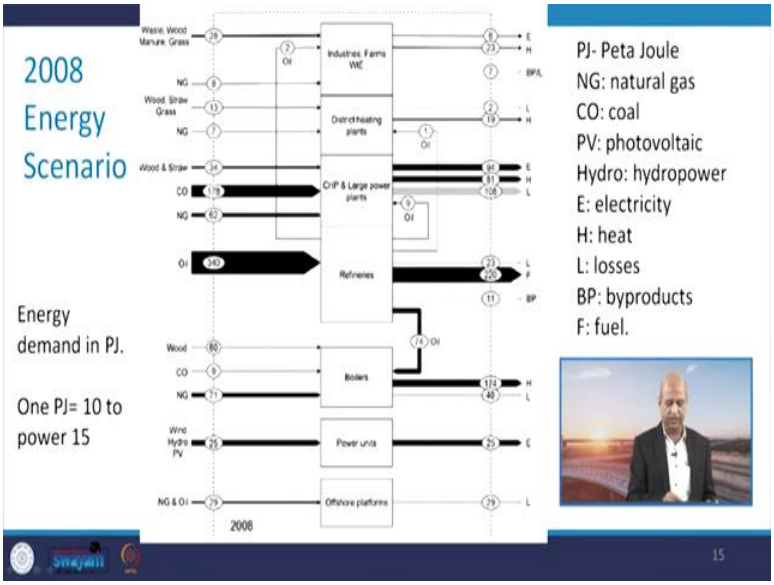
(Refer Slide Time: 16:37)



So the energy scenarios as we discussed like 2008 is the baseline, 2030 we have to see, 2050 conservative scenario means fossil fuel, we are not changing any, we are just using this kind of business as usual you can say.

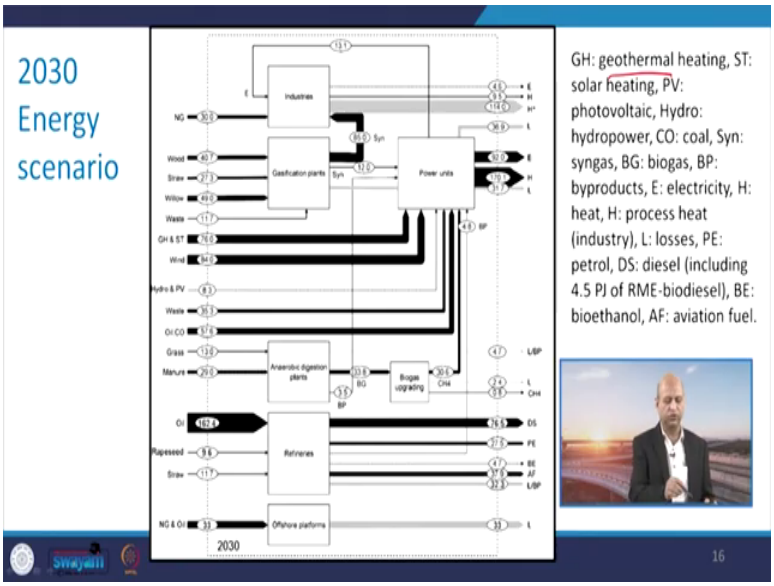
So that scenario, then other scenarios are based on bio-diesel produced by this Rapeseed Methyl Easter or then from biomass to liquid conversion, this technology, Fischer-Tropsch technology and then comparison of these scenarios so 2050 are kind of three scenarios conservation, conservative, and this RME related and then BtL related.

(Refer Slide Time: 17:28)

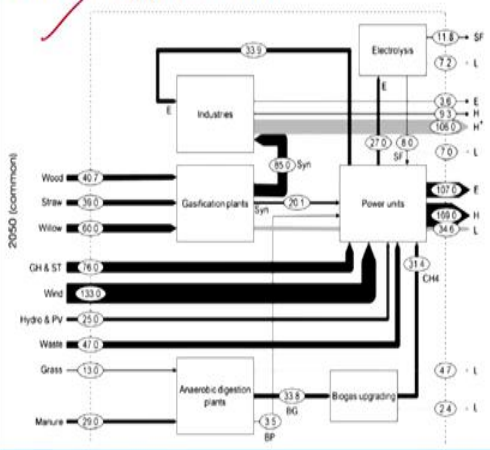


So you can see different kind of energy scenarios are there, like 2008. So the energy demand related calculations are there which are shown in this flow chart.

(Refer Slide Time: 17:33)

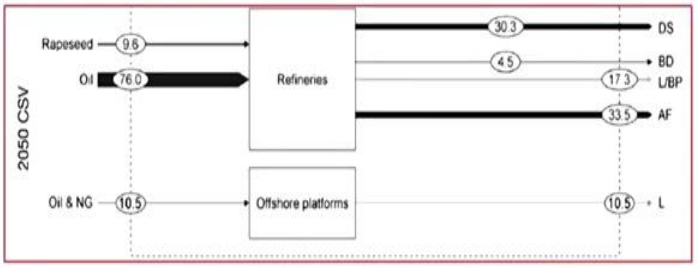


2050 Energy Demand : Common for all 3-alternative scenario

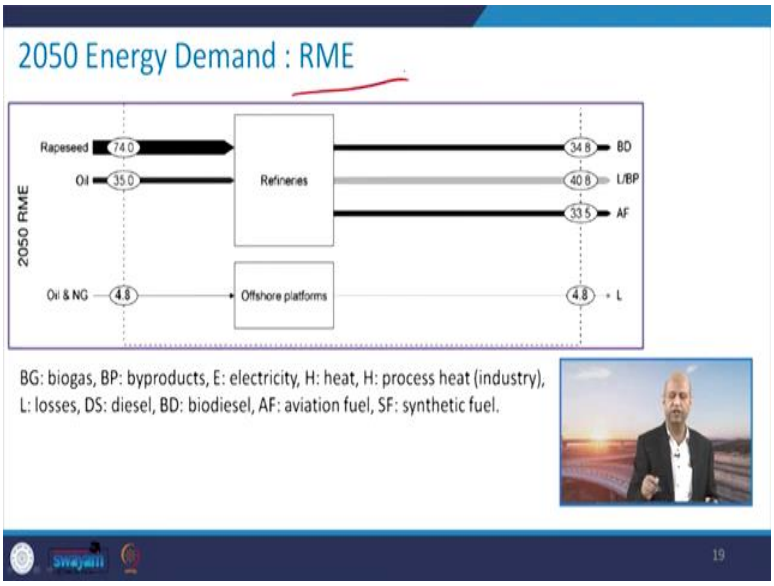


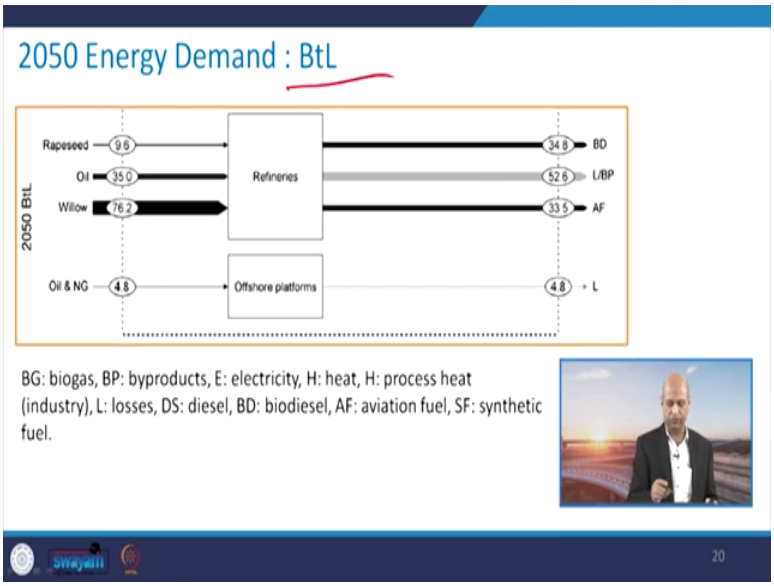
GH: geothermal heating, ST: solar heating, PV: photovoltaic, Hydro: hydropower, NG: natural gas, Syn: syngas, BG: biogas, BP: byproducts, E: electricity, H: heat, H: process heat (industry), L: losses, DS: diesel, BD: biodiesel, AF: aviation fuel, SF: synthetic fuel.

2050 Energy Demand : CSV



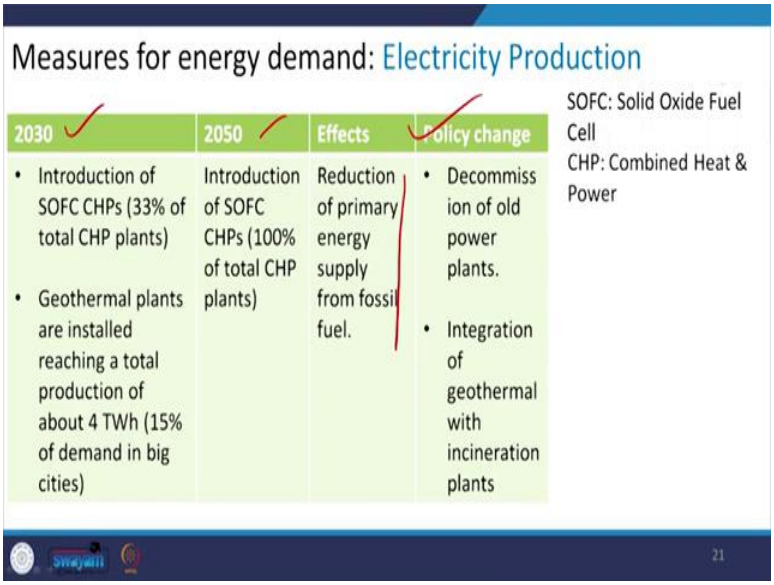
NG: natural gas, BG: biogas, BP: byproducts, E: electricity, H: heat, H: process heat (industry), L: losses, DS: diesel, BD: biodiesel, AF: aviation fuel, SF: synthetic fuel.





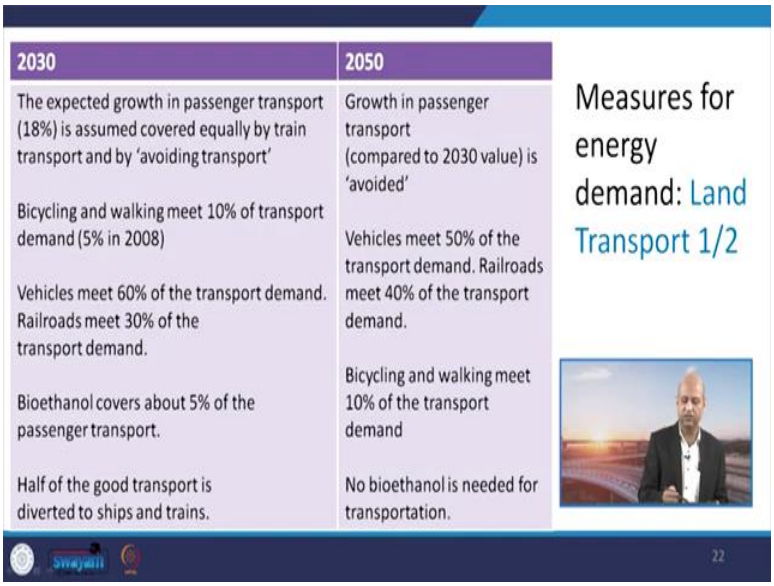
Similarly for 2030 and 2050, so those kind of values are there which can easily be compared with each other, 2050 for this conservative scenario. And then this RME related scenario and this BtL which we just discussed.

(Refer Slide Time: 17:50)



So measures of energy demand means how to see the energy demand in different years 2030, 2050, and what is there, effect like reduction in primary energy supply from fossil fuel when we are shifting to better fuel. So those kind of things and the policy change is required for those shifting.

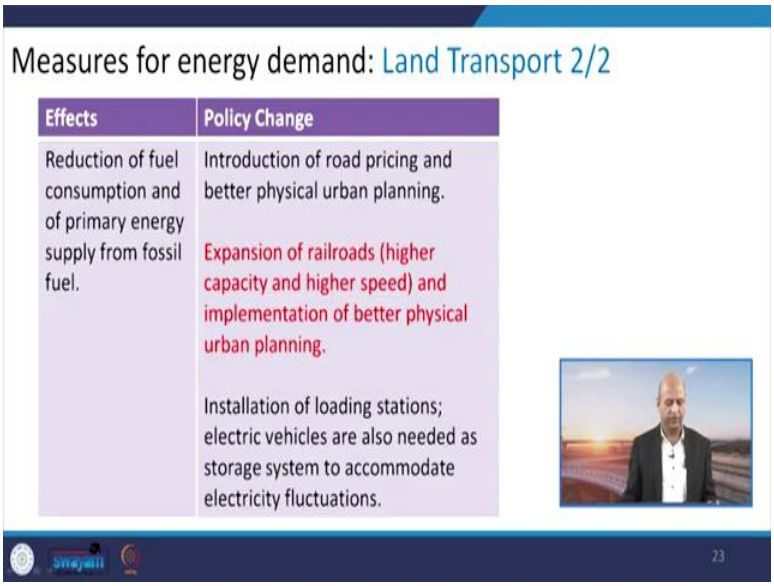
(Refer Slide Time: 18:08)



So you can see these are the listed from this study, that how much percentage is there, like bicycling, why this 10 % of the transportation demand in comparison to 2008 where it was only 5 %. So in 2030 they have assumed 10 %.

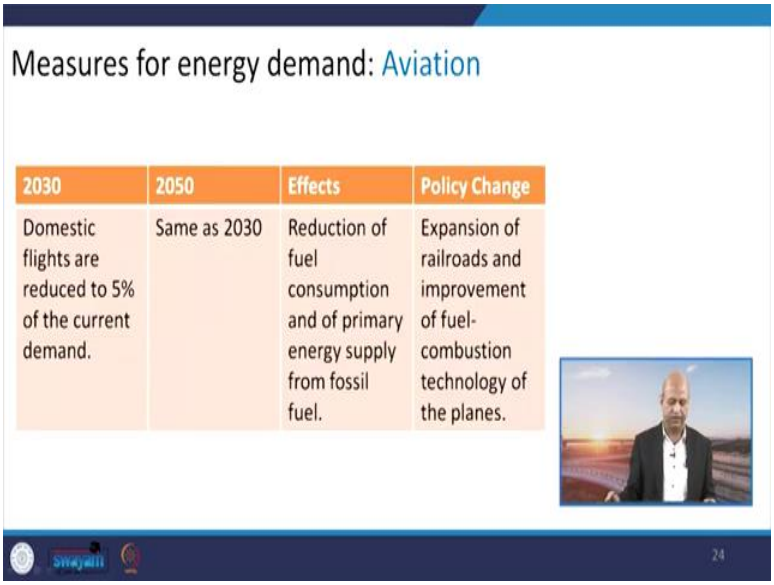
So similarly vehicles like in 2050, 50 % of the transport demand from public transportation like railroads, and 40 % of the transport demand is met by those. Similarly bio-ethenol covers 5 % of the passenger transport bicycling here 10 % remains, so those kind of different modes of the transport are there and their share is given.

(Refer Slide Time: 18:52)



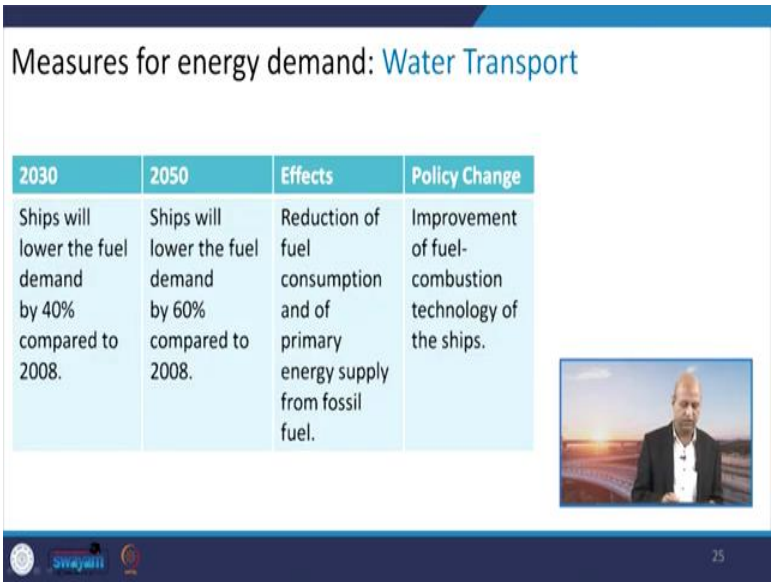
And land transport if you want to see then effects like reduction of fuel consumption in primary energy sources and then expansion of those as I said, railroads and capacity of higher speed, their increasing the higher capacity and then physical urban planning has to be implemented in that way so that more and more public related, those transportation can be used, because then per kilometer emissions becomes quite less.

(Refer Slide Time: 19:21)



Aviation is you see like domestic 5 percent of the current demand in 2030, it was assumed, in 2050 it was same, it was considered, so the reduction of the fuel consumption in primary energy, fossil fuel because aviation related share will be reduced and it will be catered by other land transportation kind of things and accordingly policy changes are to be there.

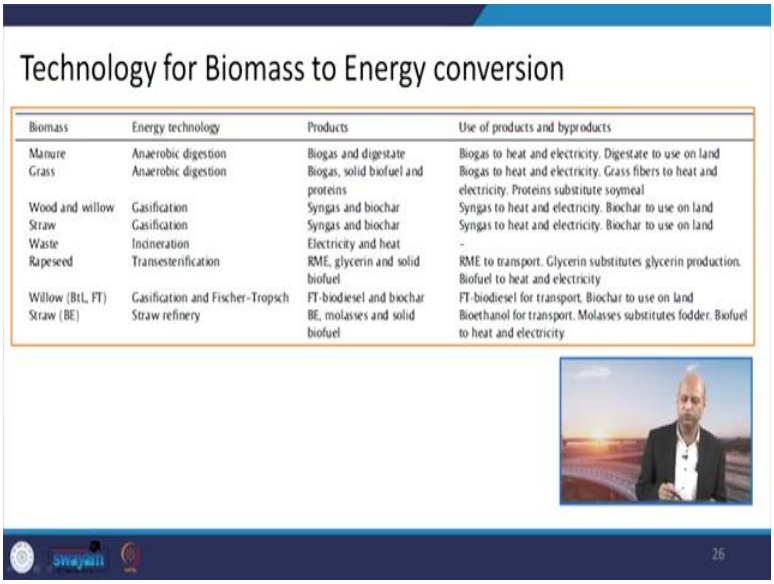
(Refer Slide Time: 19:48)



Then water transport like in 2030, ships will lower the fuel demand by 40 % compared to 2008, so because a lot of goods will be transported by that water transport and 2050 it will further

increase to 60 %. So fuel demand will further reduce from 40 % to 60 % so more advantage is there. So naturally the effect is reduction in fuel consumption of the fossil fuel and the improvement of some technologies, those kind of policies are also will be there for ships particularly.

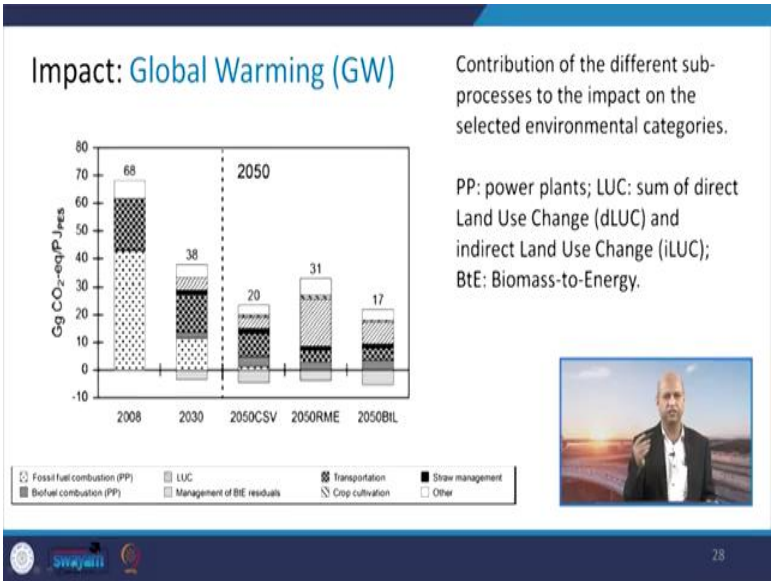
(Refer Slide Time: 20:23)



Then technology for biomass to energy conversion, we have to see, so like this biomass if it is manure or grass type, then through anaerobic digestion you can convert this into bio-gas, bio-gas can be produced. And this can be used for heating purpose, production of electricity also, so those kind of changes may be there for this system.

Then if you are going to use the wood and this straw, et cetera or waste, then you can convert them into gas, gasification can be there. Similarly other issue are there which can be linked with similar technology and ultimately whether you convert it into gas so accordingly the engine technology changes. If you convert it into the electricity by producing steam and running turbine, etc., then you can go for battery operated vehicles.

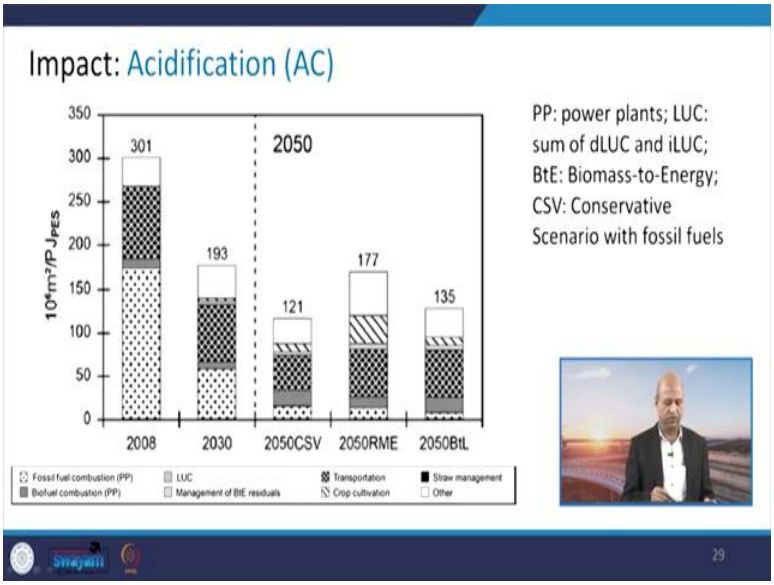
(Refer Slide Time: 21:20)



So when see in terms of the impact, so this pictorial representation gives very good illustration like in terms of global warming potential when we see this 2008, so it is quite gigagram CO2 equivalent, it is around 70, that is 68, the total value and which is from this fossil fuel and the bio-fuel combustion, etc.

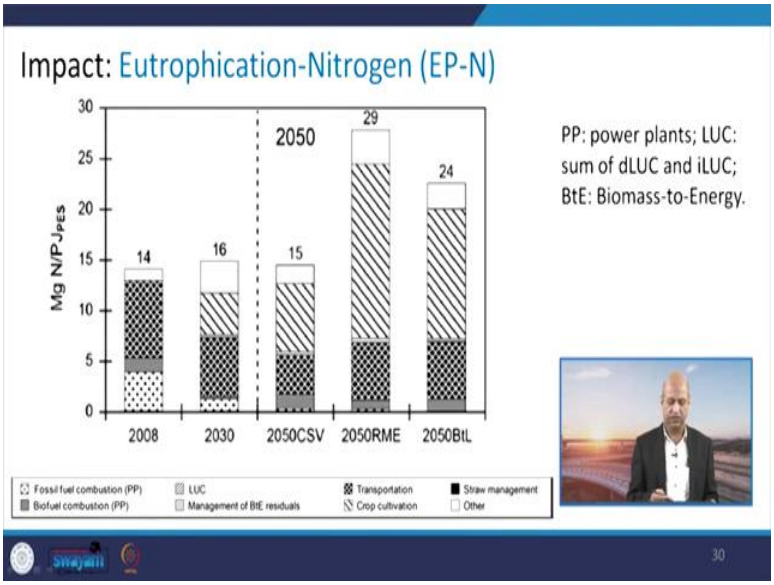
But when we are shifting that scenario of renewable resources 2030, then it is reducing to 38, great reduction. Similarly in 2050, further you can have these kind of values which are further reducing because of this share of renewable resources.

(Refer Slide Time: 22:06)



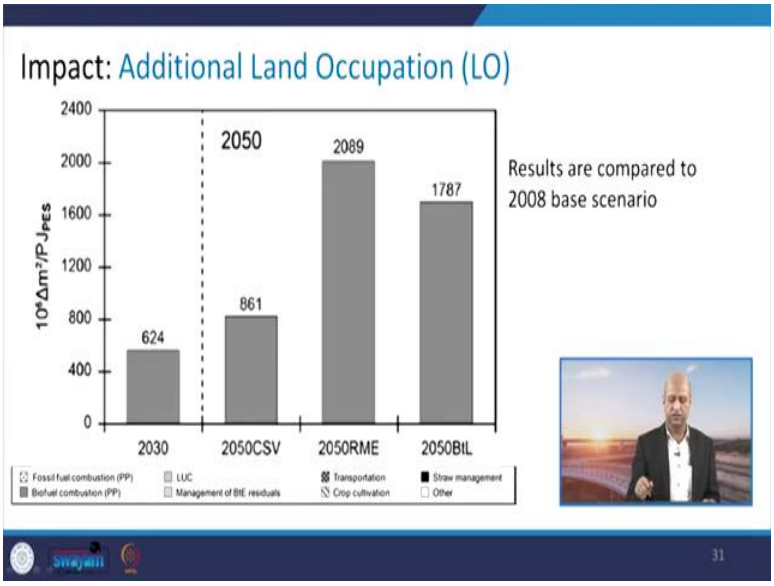
Similarly in acidification if you see, this 2008, in comparison to the other, like 2030 or 2050 related issues there. So of course you can see that this conservative related scenario is also giving less value because of technology improvement and acidification is increasing in terms of bio-fuel related emissions because these crops related issues are there and nitrogen emissions related issues are there.

(Refer Slide Time: 22:38)



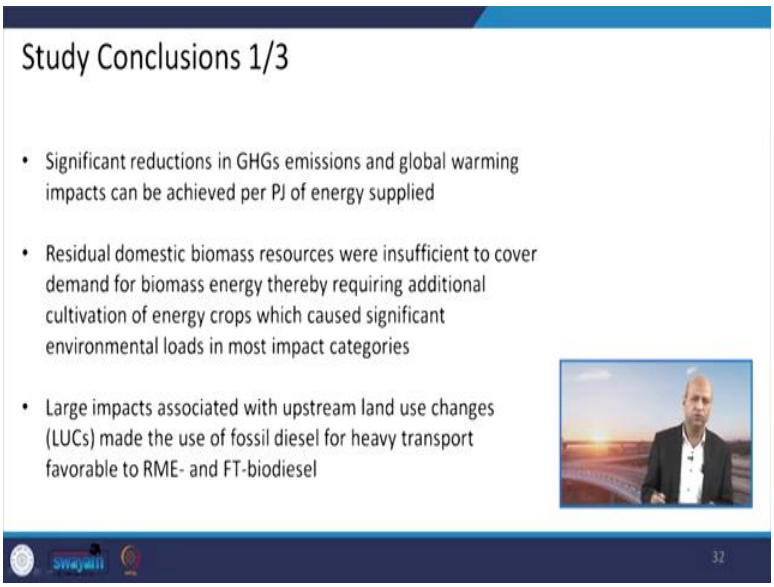
Similarly eutrophication is basically increasing, because when crop based bio-fuel energy system we are developing then the emissions of these nitrogen and phosphorous in the run-off is more in comparison to this 2008 and so, so that is the negative point you can say.

(Refer Slide Time: 22:59)



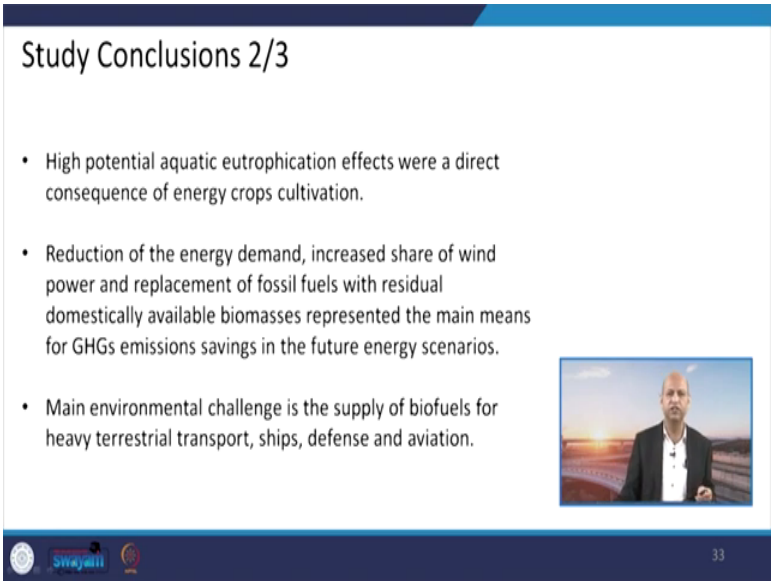
Similarly the land occupation as I said earlier also, that because you will need a lot of agricultural farms, so the land utilization will also increase in case of, we are shifting this bio crops related system.

(Refer Slide Time: 23:12)



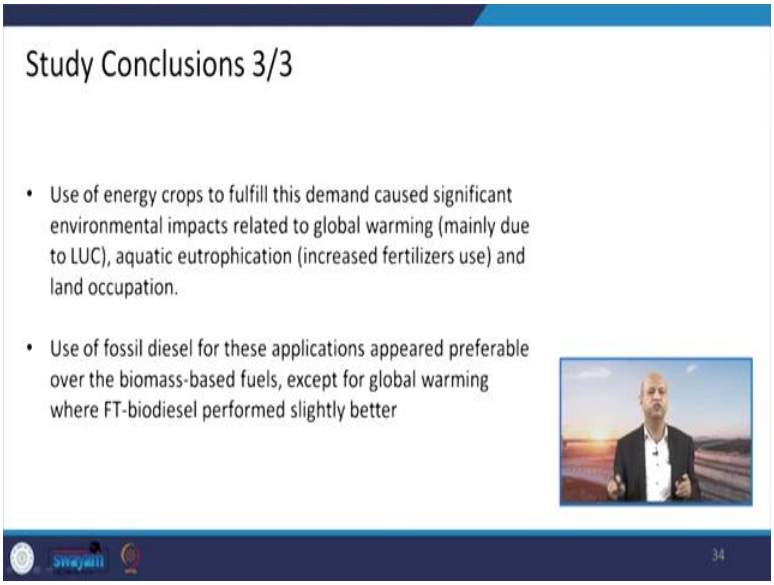
So in conclusion we can say that of course there are significant reduction in greenhouse gas emission. That is one advantage.

(Refer Slide Time: 23:25)



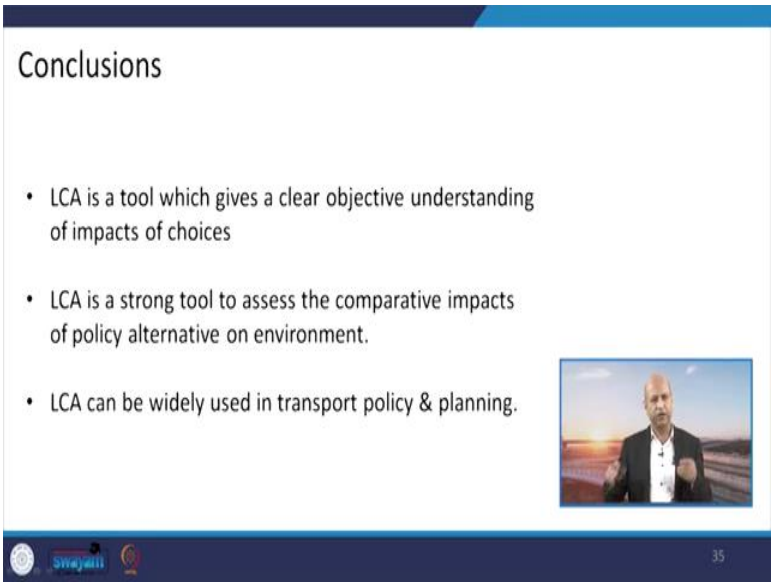
But at the same time a lot of land resources we need, because we need to have these energy crops to grow and also there are challenges, if we do not use fertilizers, et cetera, judicially, if we do not have better technology to retain these effluents of nitrogen and phosphorous then another problem can be there of eutrophication. Whether nitrogen driven or phosphorous driven, depending upon those water bodies, but that is also one very negative impact.

(Refer Slide Time: 23:54)



So in totality we have to see whether, what kind of advantage are there.

(Refer Slide Time: 23:59)



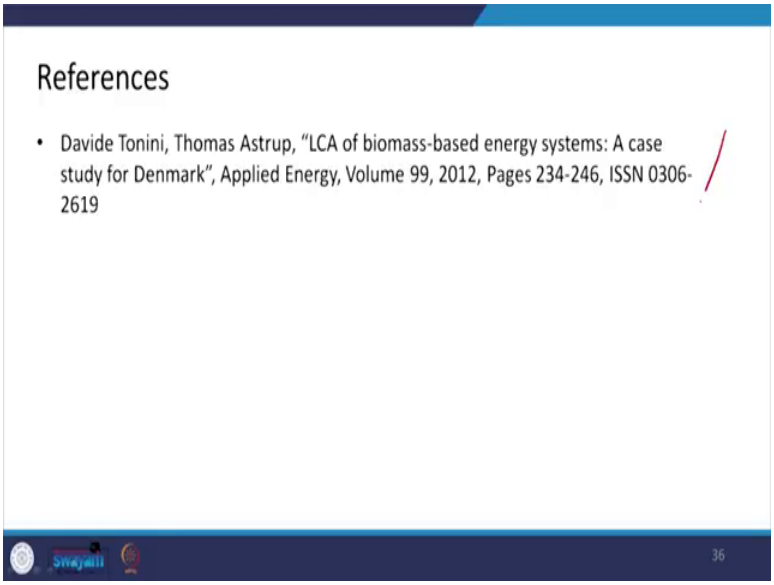
But LCA gives us this kind of total picture, because sometimes counter intuitive things happen, we feel that of course renewable resources is there so it is good, we are having all the time, these kind of impression but when you calculate, when you quantify only then you would be able that may be in certain aspect it is good, but in other aspects it may be challenging. You have to change some technologies otherwise you will not be able to remove the problems altogether.

Because one problem removal may be there or overcoming is there, but another problem may emerge, that is not good, like a side effect kind of a thing. So, negative side effects may be there. So in conclusion we can say that this is a tool which gives us clear objective understanding, means not subjective of imaginary based of, perception based of decision making but objective, quantification based kind of understanding it gives.

So we can choose better options, because we have values and we have the non-challenging values because we have quantified in certain way and following those equations and we have those values and values can be easily compared rather than judgment based on the perception. So this is a tool which can give us a good comparison between impacts of different policies, which are alternative policies in terms of technology or fuel types, etc.

So what would be the impact on the environment and it is also widely used basically for transportation policy and the planning, because it gives in totality from, we have discussed many times that from the cradle to grave kind of situation is there so every step, what kind of energy consumption is there, what kind of emissions, series or streams are there and whether they are reducing or increasing. So all in total we can compare.

(Refer Slide Time: 26:01)



This is the reference of this particular study on which it is based. So thank you for your kind attention and see you again for another kind of tool or application, thanks a lot.