Sustainable Transportation Systems
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology, Roorkee
Lecture 46
Decarbonizing the Transport Sector

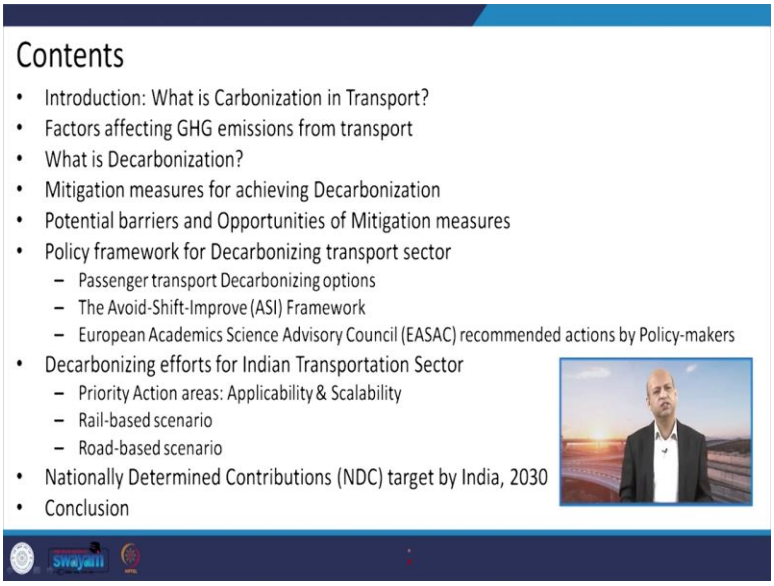
Hello, friends. Today we will discuss Decarbonizing the Transportation Sector. So, basically, the whole story, as you know, when we talk about sustainable transportation system, so basically the shift is going towards, instead of fossil fuel based or carbon economy-based development, we are going towards renewable energy-based development.

So, the trajectory is towards decarbonization of everything, whatever anthropogenic activities are there, which are based on this energy intensive fossil fuel-based activities, we are going towards, even if it is energy intensive, we are going to have the sources of energy which are less polluting, less emitting in terms of greenhouse gas emissions.

So, when we talk about carbonization or decarbonization, so the basic issue is that the CO 2 emissions or the greenhouse gas emissions, when we talk about greenhouse gas emissions, basically we are talking about not only the CO 2 emissions but other emissions which are having the greenhouse effect or global warming effect or the effects which are causing climate change all over the globe.

So, we will discuss in today's lecture like what is the carbonization, especially in transportation sector, we are focusing our, all lectures, as you know. So, without touching more on general nature aspects of carbonization or decarbonization, we will discuss about, like, carbonization of transport sector, and the factors which are affecting the GHG emissions or greenhouse gas emissions in the transport sector.

(Refer Slide Time: 02:21)



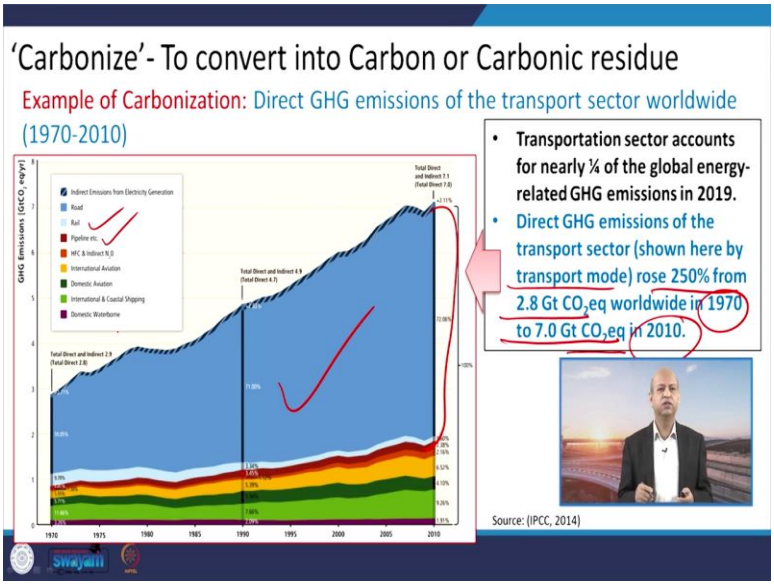
So, how can we reduce the greenhouse gas emissions, that is, how can we do decarbonization. Decarbonization means reducing greenhouse gas emissions. So, we will discuss that what is the decarbonization in definition, and then what are the mitigation measures for achieving decarbonization. So, reducing greenhouse gas emissions, different ways.

Then, the potential barriers and opportunities of mitigation measures. So, there may be different mitigation measures. So, there will be some challenges and some opportunities. And then the policy framework. Policy framework for decarbonization transport sector. Different kind of policies are there, different kind of practices are there.

So, we will discuss about them like, passenger transport decarbonization options, or Avoid, Shift, Improve, ASI related framework. Then, there are recommendations from European Academic Science Advisory Council. So, the recommendation-based actions are there for, by policy makers for the decisions makers. So, those kinds of recommendations we will discuss.

Then, we will also discuss like, decarbonization efforts in the Indian transportation sector. So, especially, focus on Indian transportation sector, we will have these discussions on like, priority action areas and their scalability and applicability, then rail-based scenarios, or road-based scenarios, which are better and why they are better? Then, Nationally Determined Contributions, NDC targets which established by India, and which are to be achieved before or up to 2030. So, those targets we will discuss and later, we will conclude the lecture.

(Refer Slide Time: 03:58)

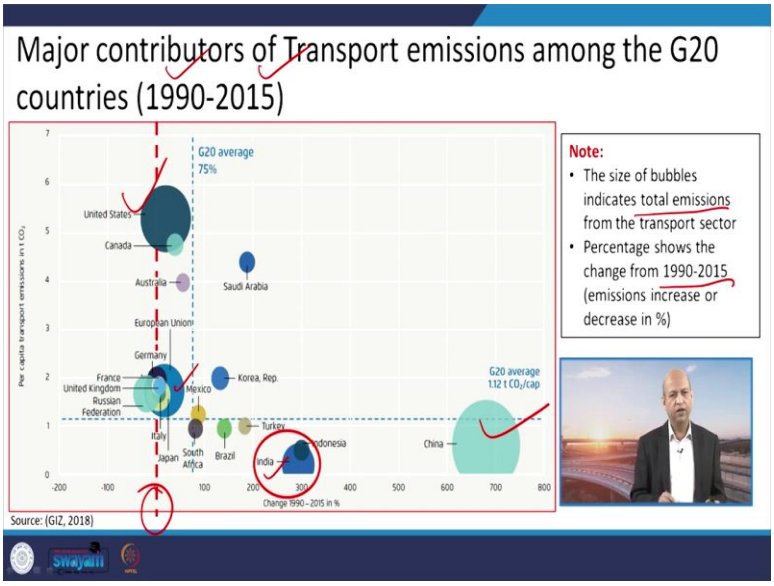


So, when we focus on carbonization, or what is the carbonize?, how do we carbonize? Basically, that is like converting something into carbon related products, carbon dioxide, carbon emissions, carbonic residues, all those organic related things. So, direct greenhouse gas emissions are basically the example of carbonization.

So, you can see in this figure like, if you compare from 2010 to 1970, so in comparison to 1970 if we see the data of 2010, the CO 2 equivalent emissions of the greenhouse gas emissions, so from 2.8 giga ton CO 2 equivalent, because the greenhouse gasses are not only the CO 2 emissions but other emissions or different gases which are having the similar effects like Methane also.

And it has been like 7 giga tons of CO 2 equivalent emissions in 2010. So, how much? 250 % increase by this particular transport mode. Only transport mode. You can see this much. So, the biggest culprit in that sense is this road transport, you can see, in comparison to rail, and then pipeline, or other kind of transportation modes may be there. But the road transportation is the biggest contributor in the carbonization. So, this is the focused area, basically. We will see.

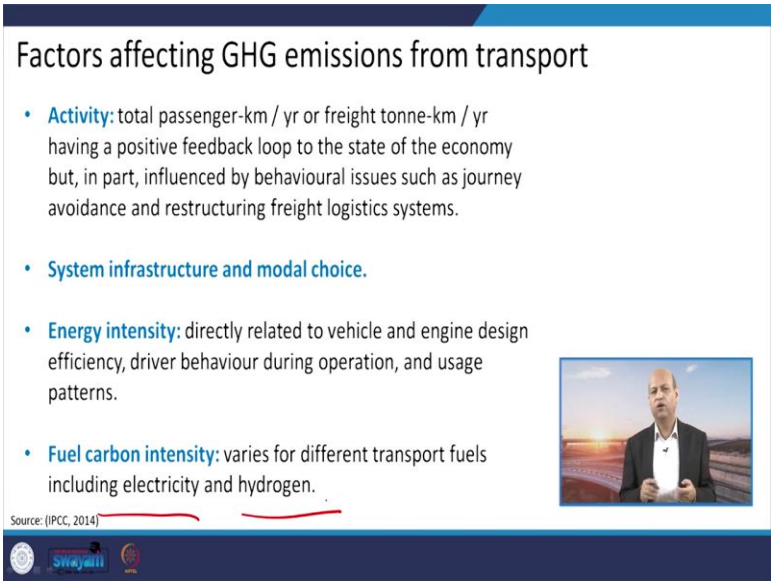
(Refer Slide Time: 05:30)



Now, if we want to compare like, major contributors for, of transport emissions among G 20 countries, group of 20 countries, so between 1990 to 2015, if we compare the data, so this is the graph which is showing like, the size of these bubbles are basically the total emissions. So, you can see, like United States, China and then this Mexico, all these are big contributors. Even India is rapidly going towards, joining this club of major contributors.

But also, we can see like, percentage changes from 1990 to 2015. So, how much increase? If we compare with this line, which is the base line of 1990, so the biggest change is in China. So, that means more and more activities of the transport related infrastructure, transport related activities have been very intensive in, in, in those, in that particular area. And India is also increasing in that sense. Although, in developed countries the increment is little lower but already they are emitting lot of emissions of greenhouse gas emissions from the transport sector.

(Refer Slide Time: 06:46)

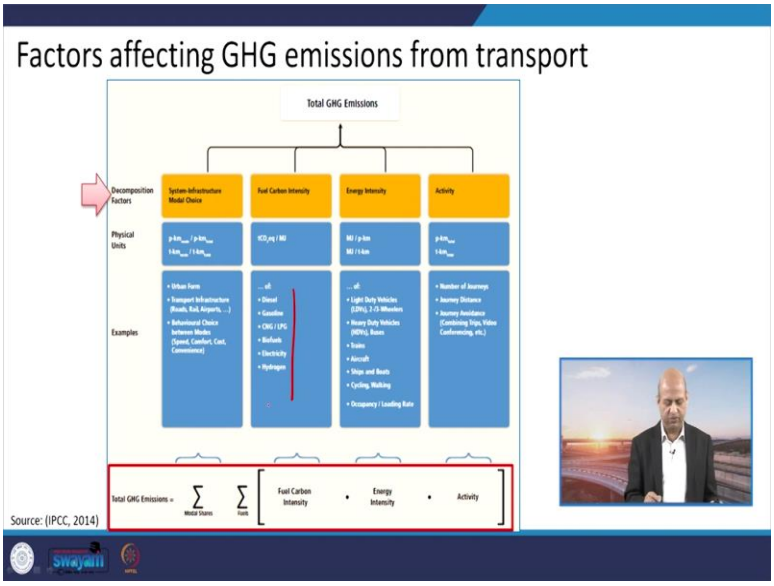


Now, if we see the factors which are responsible for these GHG emissions from the transportation sector, then there are several factors like activity, for example, total passengers kilometer per year, or freight ton, means the total volume and the weight of the freight which has been transported per kilometer, per year. So, those kinds of activities, they give the positive feedback loop, you can see in this economic sector, because they are drivers of the economy.

Then, the infrastructure and model choice. If we are having more on road transportation, our whole transport related activities are more dominated by road transportation, then as you have seen the transport emission from the road sector is much more than other sectors.

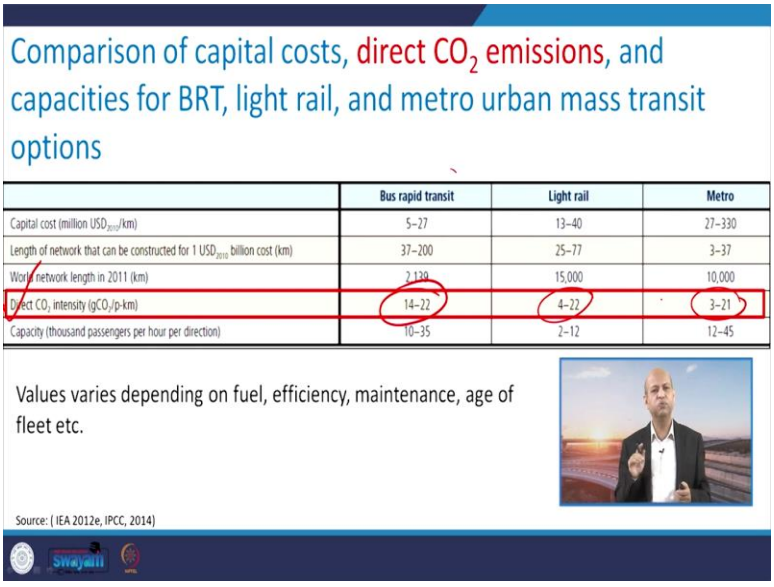
Energy intensity like, what kind of engine design is there, and efficiency or driver behavior, all those influence this energy intensity. Then, fuel carbon intensity. For example, different kind of transport fuels give different kind of emissions and their like, per kilometer driven by certain fuel may be different value of the greenhouse gas emissions or even air pollutants. So, like, electricity or hydrogen fuel cell or gasoline or diesel, all, they have different emission rates or emissions volumes.

(Refer Slide Time: 08:15)



Well, so you can see like, these factors affecting greenhouse gas emissions. So, these categories have been explained properly here, depending like, the fuel category, the intensity of diesel, gasoline, they will be different. So, these kind of examples are there.

(Refer Slide Time: 08:31)

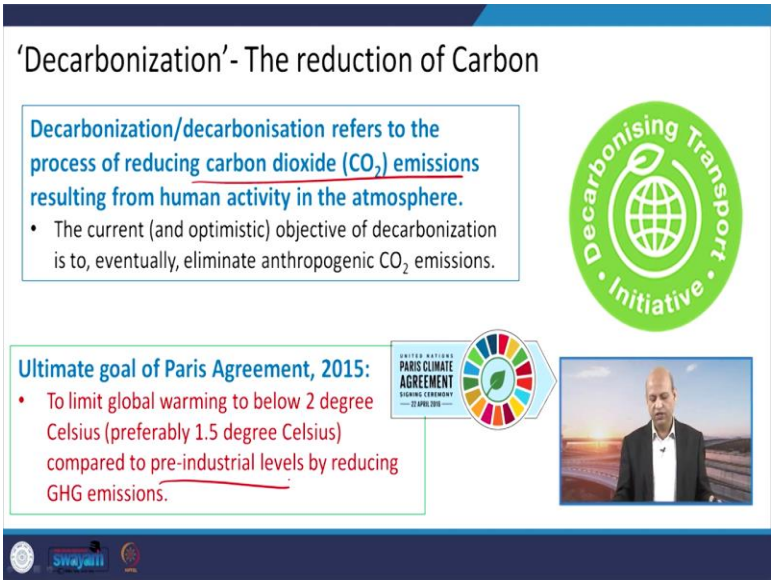


Well, when we compare the capital cost and direct CO 2 emissions, direct CO 2 emissions, not only the indirect ones, but the direct ones and the capacities for this Bus Rapid Transit system and light rail or metro urban mass transit options, then you can see, if we see this direct CO 2 emissions. If we for a, for a moment if we forget other factors, if we focus only on this CO 2

equivalent emissions, the greenhouse gas emissions, so the bus rapid transit is responsible for highest emissions, 14 to 22, these grams CO 2 per passenger per kilometer.

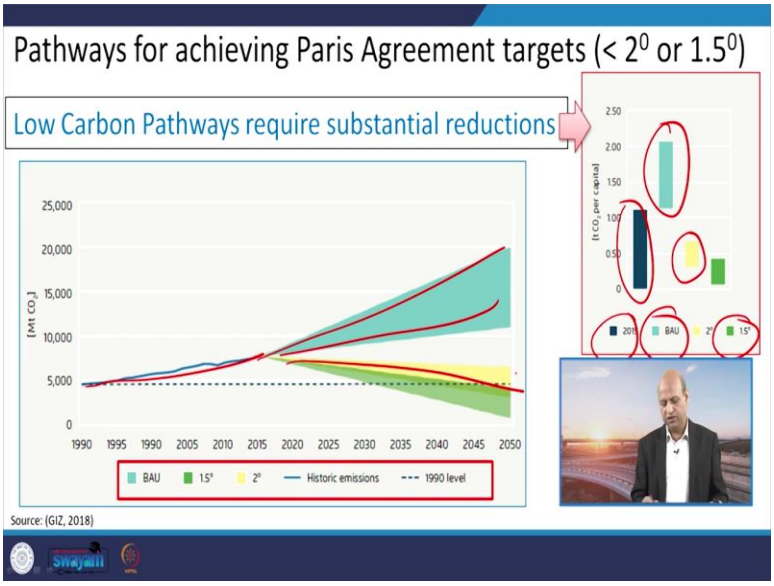
So, that rate is quite high in comparison to like light rail, which is only 4 to 22 or metro, this is 3 to 21. So, they are more or less the same. But this bus rapid transit is more. So, that way road transportation sector is responsible for more emissions of greenhouse gasses in comparison to the rail transportation sector.

(Refer Slide Time: 09:35)



Well, so when we focus upon decarbonization, so that means reduction of the carbon emissions, reduction of the CO 2 emissions basically. So, that refers to the reducing the carbon dioxide emissions. Then, when we see about like, what is the ultimate goal, so ultimate goal in context of Paris Agreement of 2015, they want to reduce the level of greenhouse gas emissions in comparison to this, those pre-industrial levels. So, around 2 degree to 1.5-degree Celsius temperature should be reduced in that comparison. So, that is the goal, basically. And we want to achieve that goal by reducing the emissions of greenhouse gasses.

(Refer Slide Time: 10:15)



So, different pathways have been suggested to achieve this Paris Agreement. And scenarios may be like, how much emission reduction should be there for achieving 2 degree Celsius reduction or 1.5 degree Celsius reduction. So, you can see like, 2015, this is the base emissions, tons CO 2 per capita. And this BAU means this business as usual. So, if we go without changing any technology, without having any intervention to reduce the emissions, then it will increase like this. But if we adopt this policy of reducing up to 2 degree Celsius, then we will come here. Reduction will be there. Major reduction will be there, of course, for 1.5-degree Celsius reduction.

So, these are the different pathways. You can see the historic emissions are there. This is going like that. So, this business as usual scenario will go in that way, increase. But these 2 degrees Celsius and 1.5 degree Celsius reduction scenario will reduce the emissions or CO 2.

(Refer Slide Time: 11:25)

Well, when we talk about like, what are the ways, what are the means, what are the policies and programs to reduce these carbon dioxide emissions or greenhouse gas emissions or to achieve the decarbonization, then, in overall sense, or in totality, 4 pillars are very much discussed, which are like decarbonization of electricity generation because as you know, we use lot of coal based thermal power plants for energy production. So, that is responsible for lot of emissions or the CO 2.

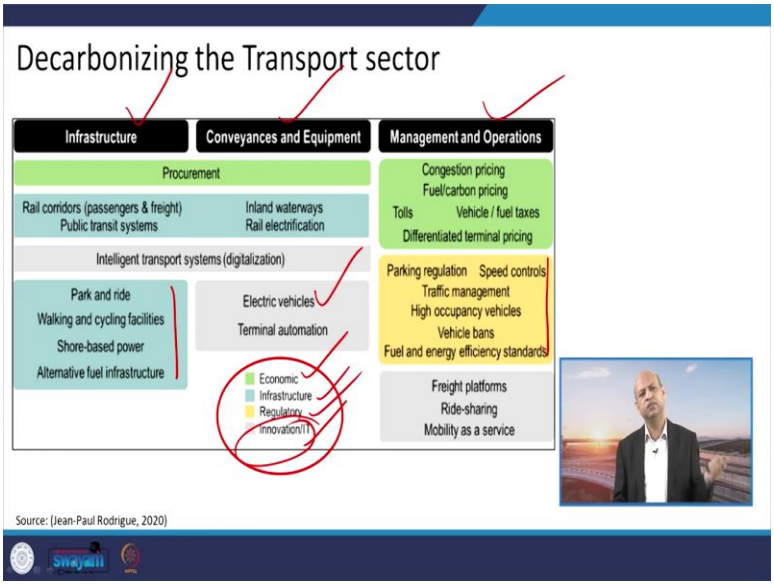
So, if we go for decarbonization of these plants, maybe like renewable, nuclear which are emitting like, they are neutral in the sense, they are not emitting much CO 2, except when they are, we are building those plants, then of course, we are using those raw material et cetera which are extracted and emissions are there. But later on, very, only operational related activities are there, very less amount of emission is there in comparison to the thermal power plants.

Then, the fuel shifting in transportation sector. So, like, for heating, or for industrial emissions also, if we shift towards electricity generated from renewable resources, rather than fossil fuel-based systems, the shift can be very much important for achieving decarbonization.

Similarly, like this, in buildings or transport, efficiency matters, in all sectors. So, like, even domestic areas, in buildings if we are having these light bulbs, if we are going for, like, efficient technologies, like LEDs rather than the normal bulbs et cetera, so that way, we can achieve good efficiency in all sectors including building transport and agriculture.

Then, we can also go for eco-centric development and preservation of these natural carbon sinks like forest areas, agriculture practices, agriculture practices without using much more of these fossil fuels. Rather, better practices which are responsible for every less amount of emissions of greenhouse gasses.

(Refer Slide Time: 13:42)

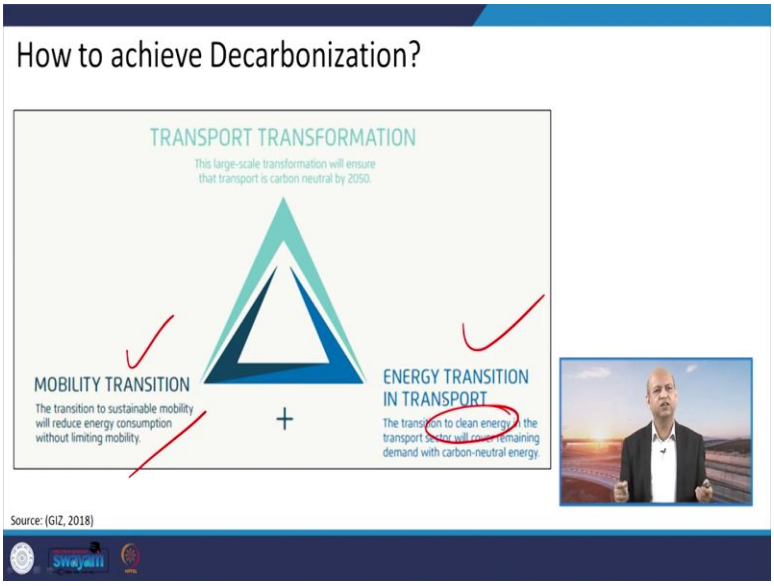


So, rather increasing greenery and increasing the sink because plants absorb the CO2, they are acting like the sink. So, if we go for these kinds of natural habitats, we are increasing the sink for carbon dioxide. So, that is also helping because it is reducing the CO 2 content in the atmosphere.

Then, if you talk about, like transportation sector, decarbonization of the transportation sector, then we focus on infrastructure of the transportation sector, conveyance and equipment, and the management and operations. So, all these, three important activities are there which include economic, infrastructure, regulatory and innovation.

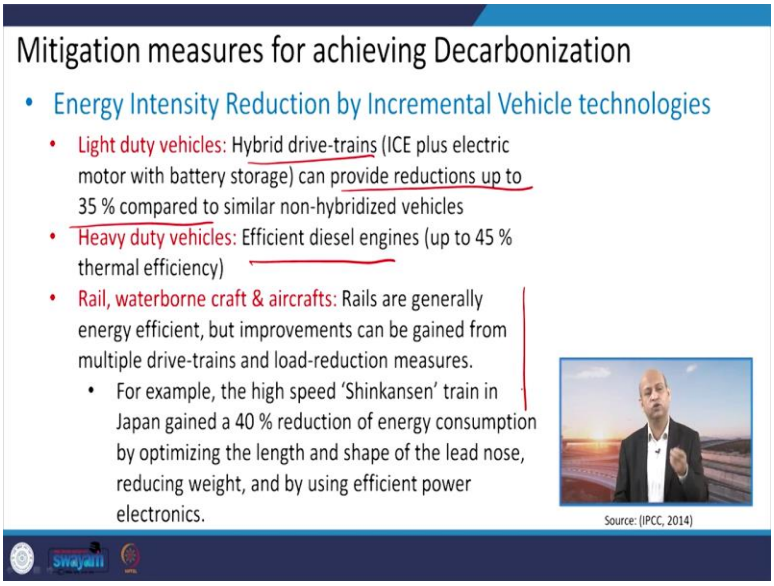
So, in different color scheme you can see these different activities are there. Like, for infrastructure, you can focus on parking or sharing rides, or having some tracks for cycle, walking, those kind of things. And if you go for innovations or IT, then electric vehicles or intelligent transportation system, something like that. Regulatory areas like parking regulations may be there. You can charge some fees so that you can discourage people to bring their privately owned vehicles such that they can shift towards public transportation system.

(Refer Slide Time: 14:58)



So, to achieve the decarbonization, basically, when we go for mobility transition or energy transition in transport, so in mobility, without sacrificing the mobility related needs, we can go for sustainable mobility like reducing energy consumptions. So, more public transportation system, more non-motorized system, those kind of things. Similarly, the clean energy. So, whatever energy which are, we are using in the transportation sector, if you are deriving it from cleaner sources like renewable ones, then we are really going to achieve the decarbonization in that way.

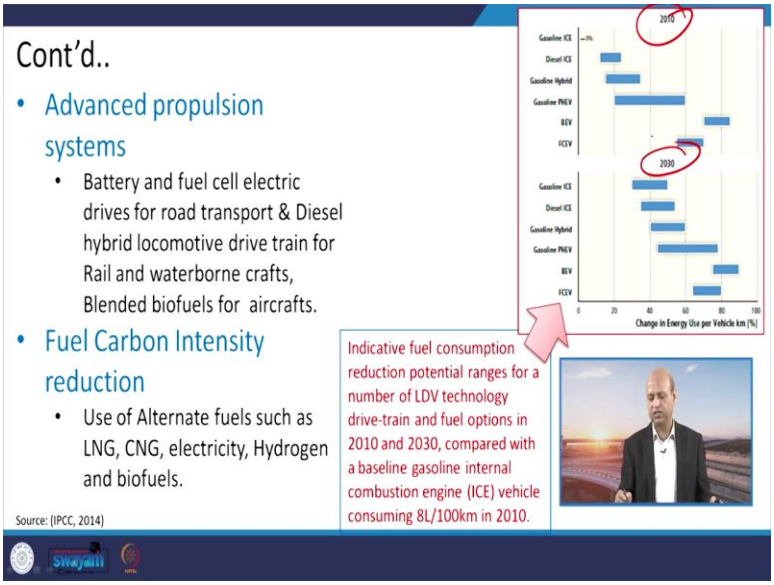
(Refer Slide Time: 15:35)



Well, when we talk about mitigation measures for achieving decarbonization, then there are certain ways. Like, we can go for light duty vehicles which are of hybrid nature, IC plus electric motor, battery operated vehicle. We have seen in other presentations also. So, that can really help us to reduce up to 35 % compared to the non-hybridized vehicles. So, that is a good achievement if we go for hybrid vehicles.

Then, heavy duty vehicles can be of efficient diesel engines. So, that can go for 45 % thermal efficiency to achieve, basically. And then rail, water-borne crafts or aircrafts, those kind of transportation modes can really help us to reduce significantly, the GHG emissions. We have seen in other presentations also, like, inland water ways and rail transportation sector, they have like, per ton per kilometer or per passenger, per kilometer, emission is very less when compared to the road transportation.

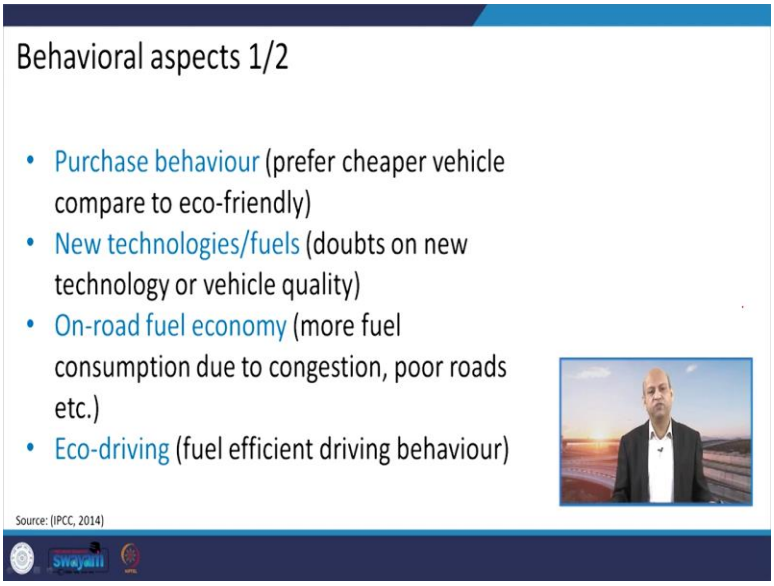
(Refer Slide Time: 16:41)



Well, then we can also talk about like, advanced propulsion systems. So, battery, fuel cell electric drives for road transportation, and the diesel hybrid rather than purely diesel locomotives for driving the trains. And then the water-borne crafts or inland water ways you can say.

Fuel carbon intensity reduction through, like, using the alternate fuels such as this LNG, that is Liquid Natural Gas and the CNG Compressed Natural Gas, electricity, hydrogen and bio-fuels, all those things. So, that way, if you compare 2010 to 2030, so those policies can really help us to reduce these, this energy use per vehicle. Percentage reduction can be seen properly here.

(Refer Slide Time: 17:33)

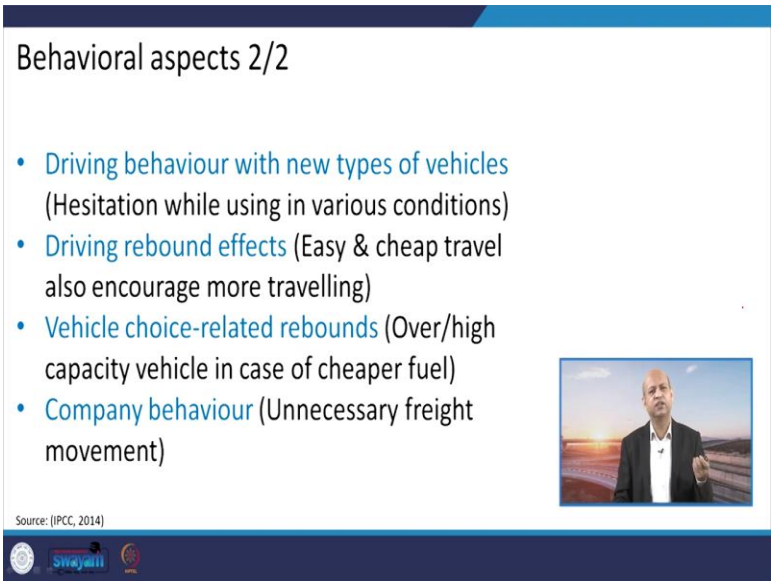


Well, behavioral aspects are also very important. So, like, purchase behavior. If you go for cheaper vehicles, then their technology may not be very good. So, they are not very eco-friendly. So, if we can invest little bit more, but that is eco-friendly, then in longer term, the benefit, health benefit we have, because the emissions of the pollution and greenhouse gasses are less, so the benefits are quite several-fold. Although, those are indirect effects and we do not visualize them very quickly. That is why our tendency is to go for cheaper things.

But if we go for the eco-friendly things which have invested in better technology, then, little bit more costly but it is better for overall quality of life. Then, the new technologies and fuels are there. So, sometimes people have some inertia, they have some doubts. We do not know what kind of, whether it is reliable or not.

Those kinds of doubts are there. So, people wait, okay, other people will buy, only then I will also buy that battery operated vehicle. Those kinds of tendency is there. Then, on-road fuel economy. So, the consumption due to congestion is more. When speed is more, the congestion is more, then consumption of fuel is more as we have discussed it several times. So, the poor road should not be there. The quality of road should be very good so that smooth flow of traffic must be achieved. The, eco-driving. Like, fuel efficient driving behavior. So, the driving behavior also play important role in emissions, the total emissions.

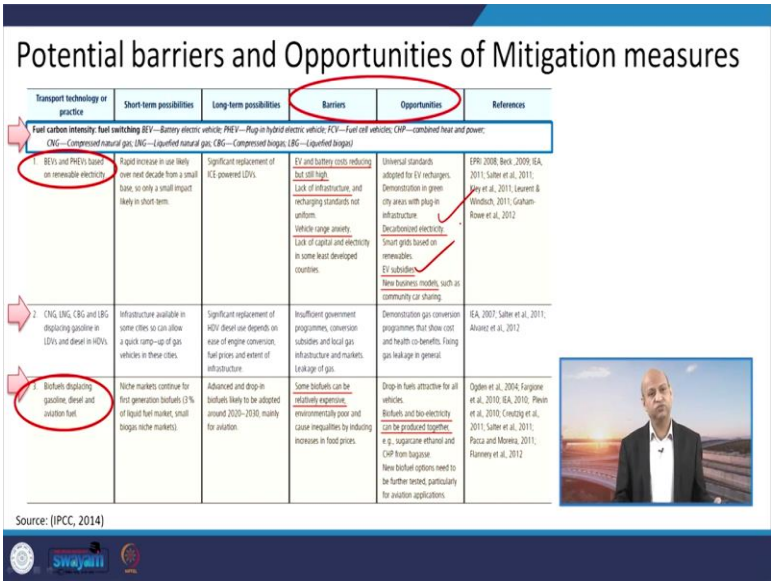
(Refer Slide Time: 19:11)



Then the hesitation using the new types of vehicles. Every time this happens. So, slowly people change the behavior. Then, the driving rebound effects like easy and cheap travel also encourage more travel. So, if more travel, then again, for example, road network if you are increasing, so more cars are there. Then again, emissions increase.

In Delhi, this has happened in way. Like, even if CNG was implemented later on, after some dip, again, emissions increased because the sheer number of vehicles increased. Then, vehicle choice related rebounds like over or high capacity vehicles in case of cheaper fuel. So, those indirectly, they can really contribute to the emissions. Then company behavior like, unnecessary freight movement may be there. So, if logistic related planning is not better then again emissions may be more.

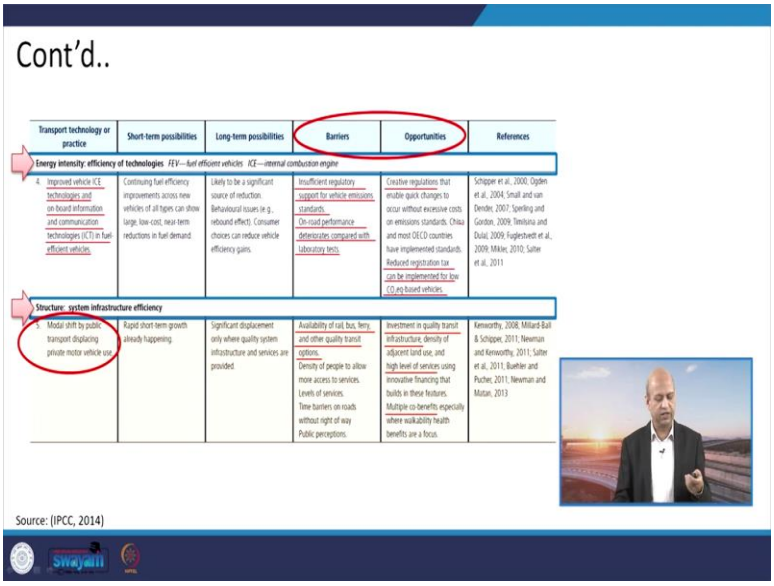
(Refer Slide Time: 20:15)



Well, there are then several barriers and opportunities of mitigation measures. So, they are discussed in these tables. And you can see in detail, related to like, battery operated vehicles, what are the barriers like, if charging infrastructure is not there then again people hesitate to buy. So, if infrastructure is created, then people will be having more motivation to buy those kind of vehicles.

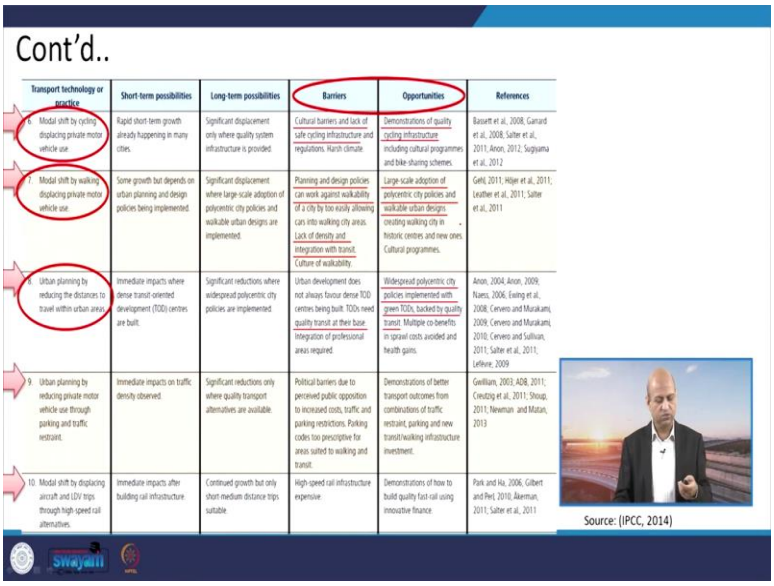
So, opportunities are there. Decarbonized electricity, then subsidies may be there. On, I think recently there are many advertisements from different state governments. They are promoting these electric vehicles. So, they are not charging road tax or registration tax. They are giving even subsidies for two wheelers, like, 20,000, for four wheelers, 1.5 lakhs. So, those kind of promotional policies are there. So, opportunities are there for this sector. Lot of opportunities are there.

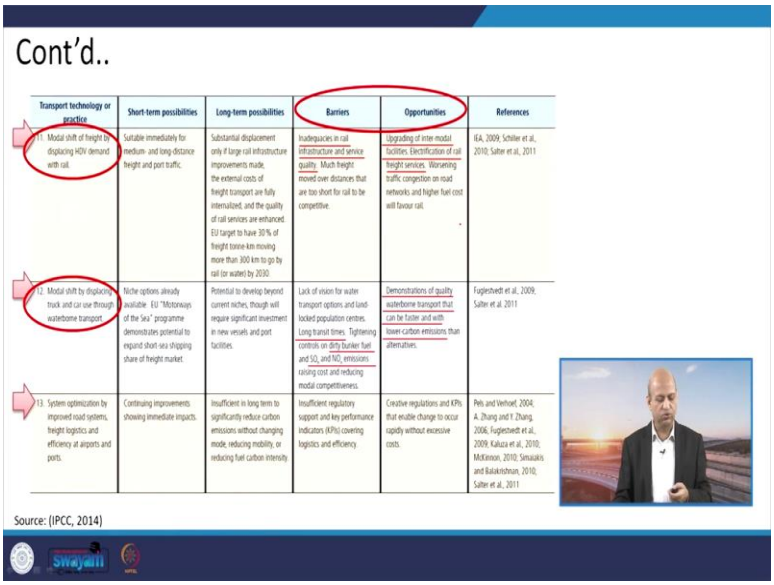
(Refer Slide Time: 21:13)

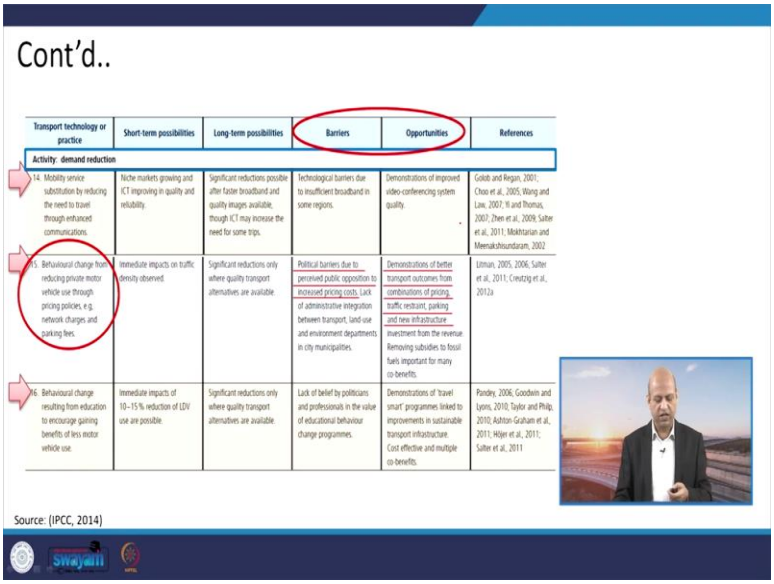


So, we have discussed these kind of barriers and opportunities in comparison to like energy intensity of efficiency technologies.

(Refer Slide Time: 21:19)

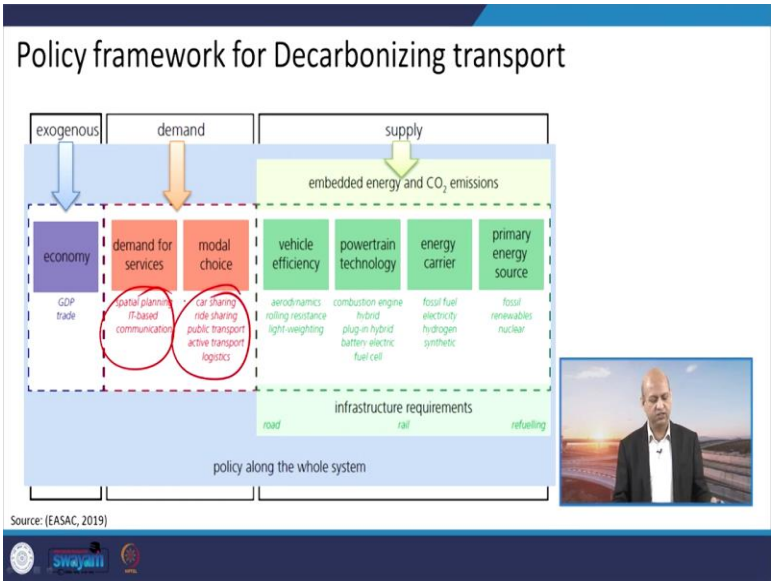






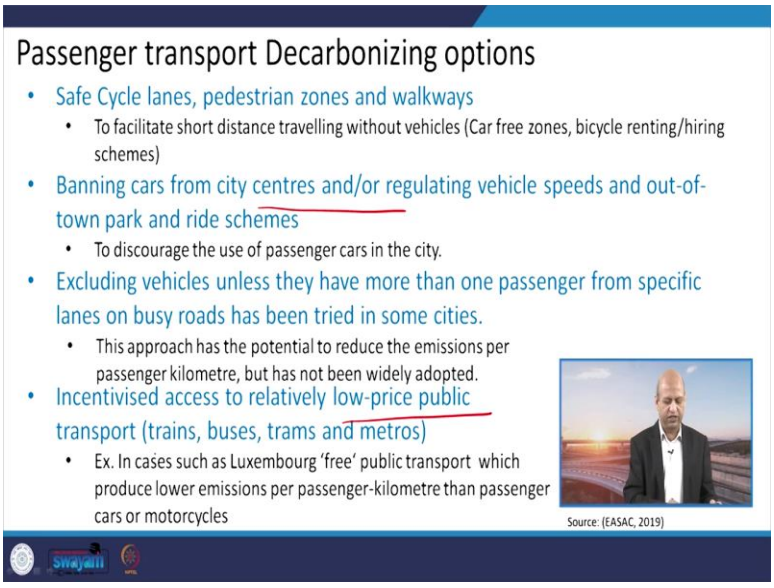
So, these are tabulated in this. You can go through in detail. I will just skip them because this is all those kind of things which we have discussed several times.

(Refer Slide Time: 21:25)



Then, there are like, policy frameworks for decarbonization of the transport. So, you see like, special planning, IT based communications, or car sharing, all those things we have already discussed. So, these are the policy frameworks we should focus upon.

(Refer Slide Time: 21:45)

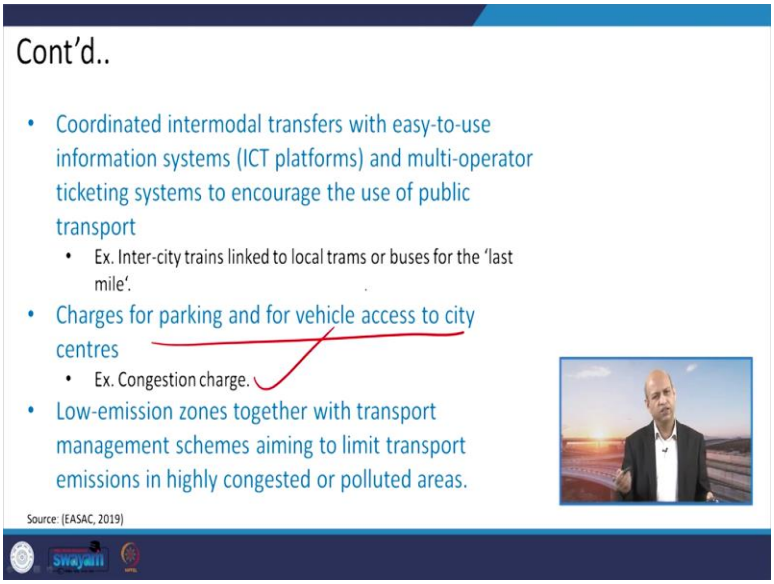


Then, if you talk about passenger transport decarbonization options, so like safe cycle lanes, again, we have discussed this several times when we were focusing on non-motorized kind of things. So, the cycle lanes, pedestrian zones, walk ways, all those help people to decarbonizing

because they are not using these two wheelers or four wheelers, then emissions are automatically less.

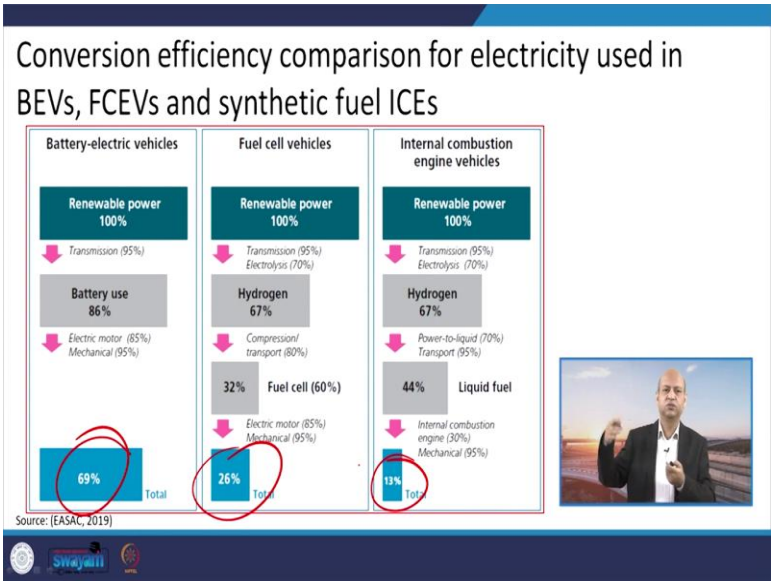
So, similarly, like banning cars from the city centers. Again, we have seen these examples like, London, there is congestion tax city center kind of policies are there. So, you can see these low price public transport trains. We have discussed this again and again. So, I will not like to give more time on those things.

(Refer Slide Time: 22:25)



Charges for parking and vehicle access to city centres, congestion charges. We have discussed all those things so these are the repetition but because these are the important part of decarbonization, that is why they have been included in this particular thing.

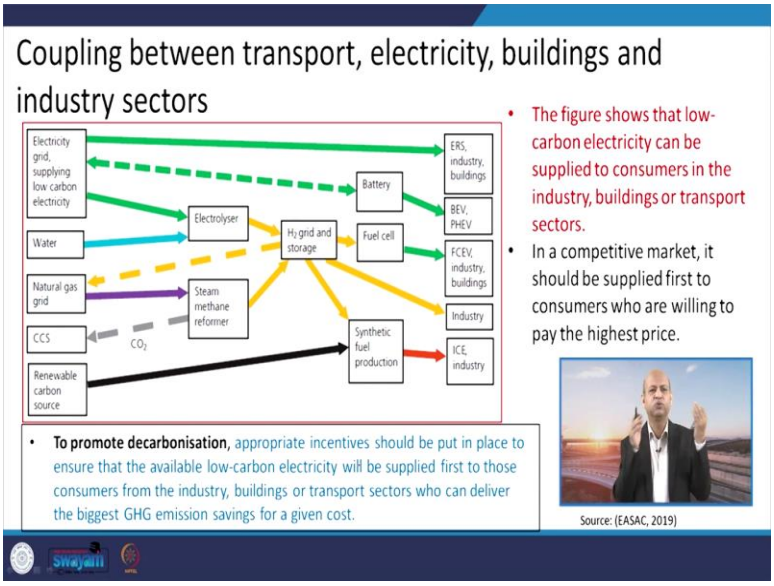
(Refer Slide Time: 22:36)



Now, if we compare, like conversion efficiency of electricity used in battery or electric vehicles or these fuel cell vehicles or synthetic fuel ICEs, internal combustion engines, so you can see like overall conversion of the power transmission is 69 %, maximum in battery operated electric vehicles. Whereas in fuel cells it is only 26 % and in internal combustion, IC engines, it is only 13 %.

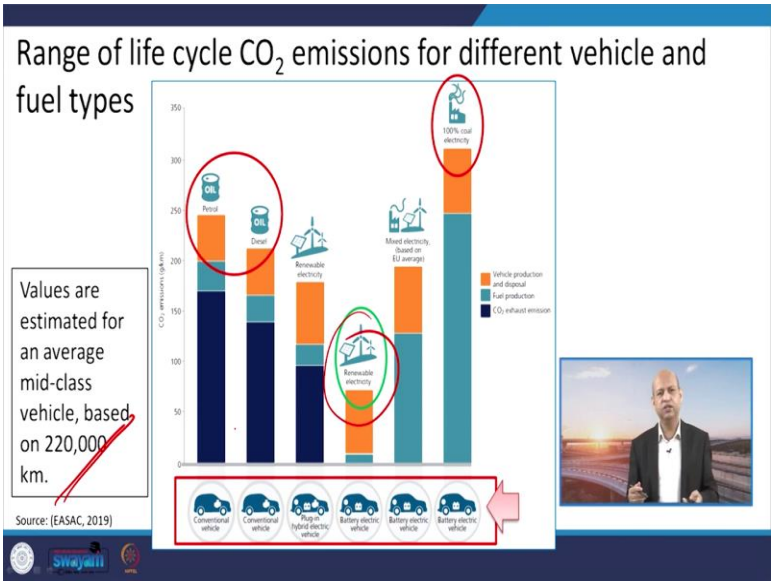
So, it makes lot of sense if we go for electric, battery operated electric vehicles. So, these transmission power efficiency, we are achieving very high. So, that means with the same energy, we will have the, the mobility much more than, in comparison to other transportation modes.

(Refer Slide Time: 23:37)



Well, when we couple this transportation electricity in buildings and industry sector, then lot of decarbonization related things can be really achieved. So, when we like, solar pans using, in the buildings as well as renewable sources, so whether you are using in buildings, lighting et cetera, or in the transportation sector, that really helps in decarbonization.

(Refer Slide Time: 24:06)

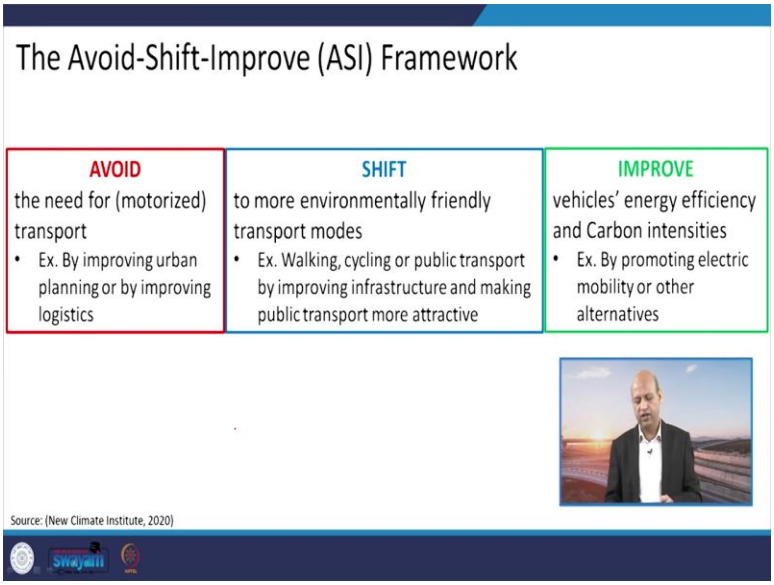


So, comparison is very, you can see, very visible. Like, range of the life cycle CO 2 emissions for different vehicles, and the fuel types, when you see, this petrol and the diesel, so this much is

there. The values are like, average for a particular, this total, 220, 000-kilometer travel or life cycle, you can see.

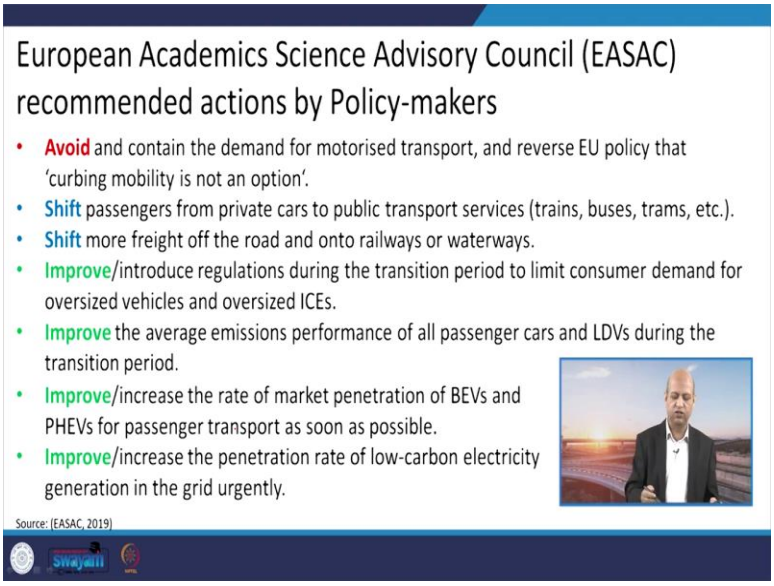
So, the diesel and petrol, they are having around 250 CO 2 emissions grams per kilometer, when we talk about life cycle. Renewable electricity is very less. Around, between 50 to 100. So, again, this is also visualization of benefits of, in terms of decarbonization.

(Refer Slide Time: 24:48)



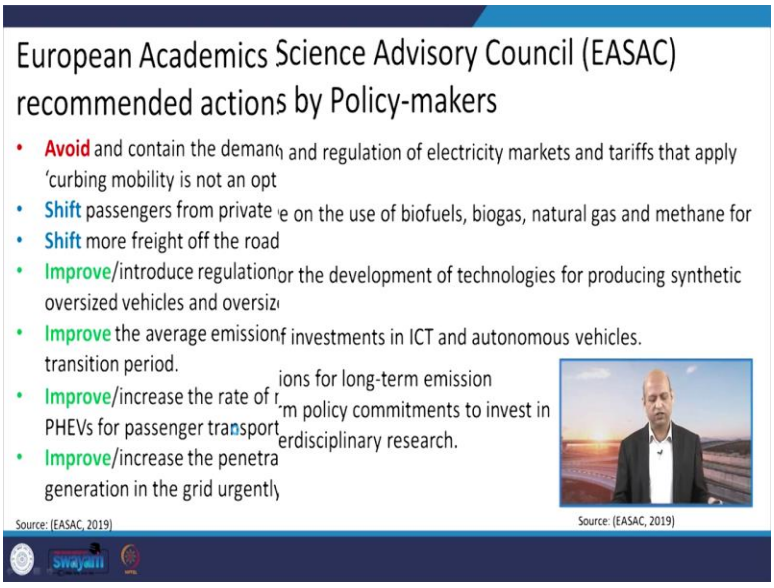
Then we talk about like Avoid-Shift-Improve framework. So, avoiding like those kind of logistics, which are more of nature, motorized, shifting towards working non-motorized ways. And improving like, mobility of electric based kind of things.

(Refer Slide Time: 25:06)



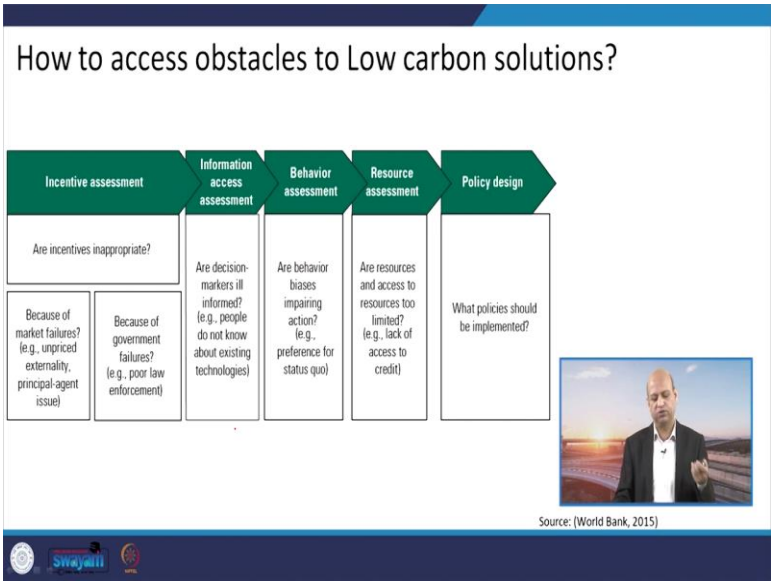
So, these are the ways we can do, recommendations, based on the recommendations by European Academic Science Advisory Council. So, they have given these kind of suggestions, which can be easily implemented in transportation sector.

(Refer Slide Time: 25:22)



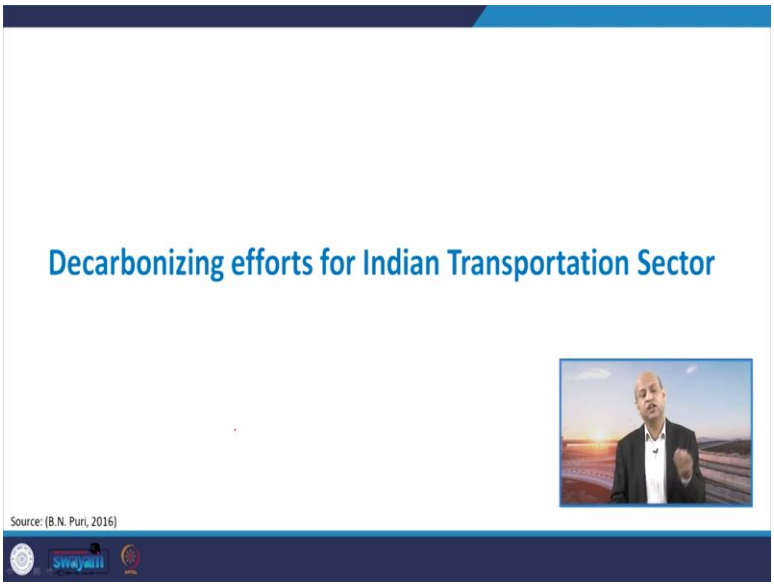
So, that way, we can improve the efficiency of transportation.

(Refer Slide Time: 25:25)



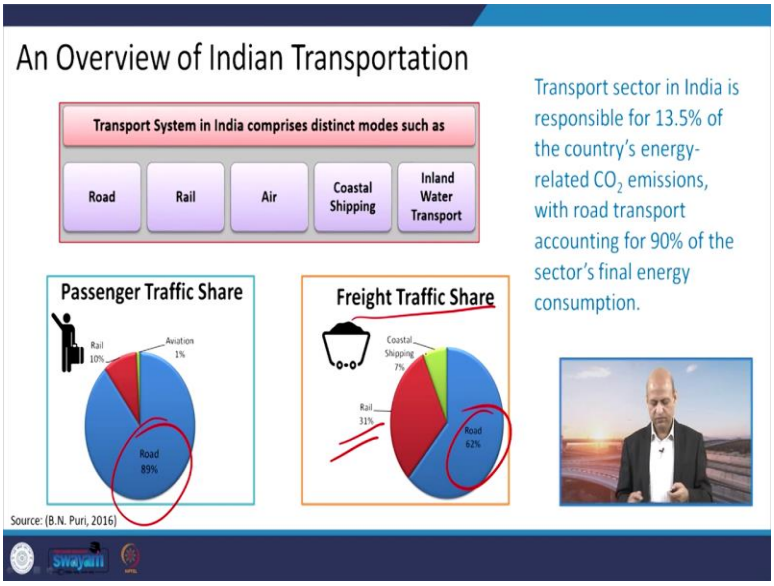
Then, how to access obstacles to low carbon solutions? So, these are again, ways which can be implemented in behavioral assessment or resource assessment or policy designs. So, that can help again for decarbonization.

(Refer Slide Time: 25:40)



Now, if we talk about the case study, like Indian transportation sector, how do we, going towards decarbonizing efforts, what are the efforts which are, we are making for decarbonizing the Indian transportation sector.

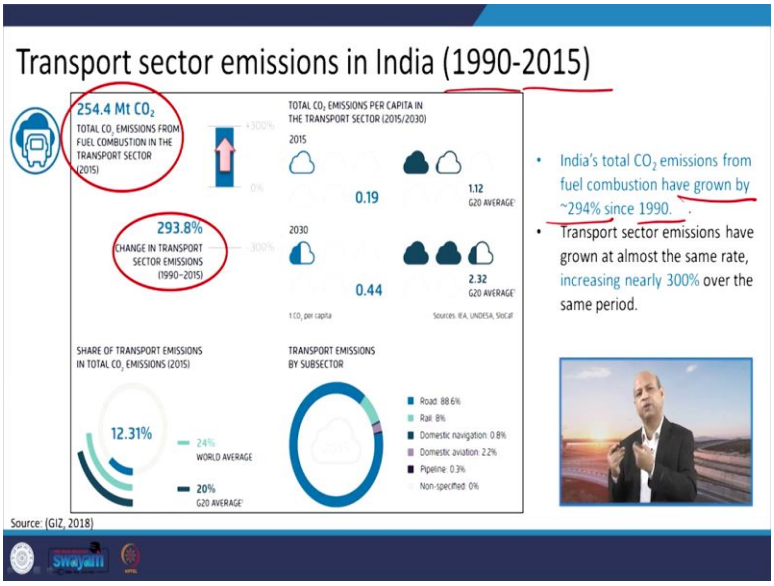
(Refer Slide Time: 26:32)



So, you can see like, passenger traffic here, on road it is 89 %, rail it is only 10 %. You can see. So, the huge scope is there for decarbonizing the road transportation sector. Similarly, in freight traffic also, only rail has 31 %. Road still has 63 %. So, again, huge scope is there.

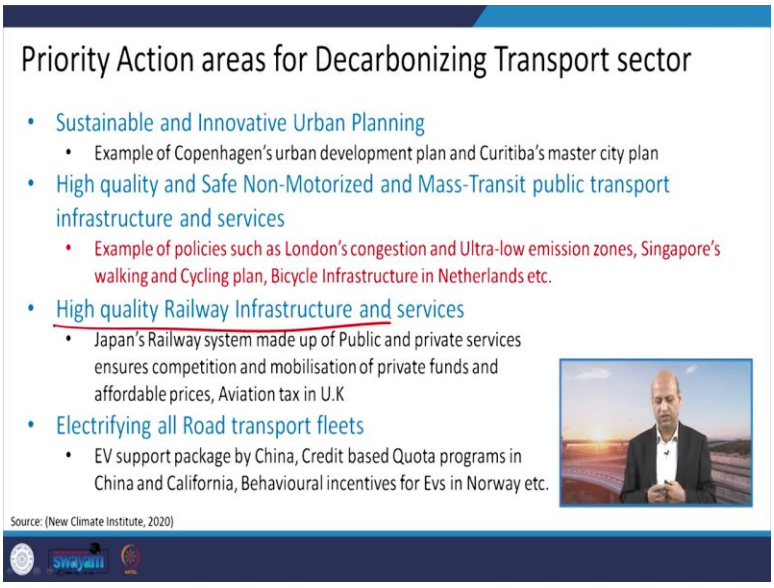
If we can shift freight from road to the rail or inland water ways etc., like, these coastal shipping is there, 7 %, but huge scope is there in inland water ways, in the rivers, etc. If we can have those kind of infrastructure, lot of scope is there for shifting this freight from the road to rail, as well as, if we can have integrated approach, then we can go for inland water ways also. So, there is a huge scope for reduction of transport related emissions from the road sector.

(Refer Slide Time: 26:42)



So, 1990 to 2015 comparison is given here. So, the total emissions like, 294 %. This has grown since 1990. So, this, this kind of path is there. If we can reduce this path of carbonization towards decarbonization, so benefits are much more.

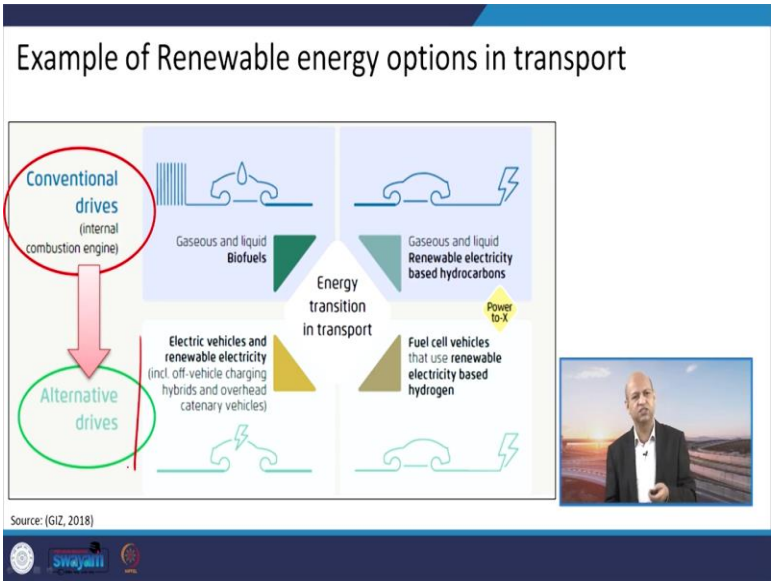
(Refer Slide Time: 27:05)



If we talk about like priority actions which are related to decarbonizing the transportation sector in India. So, the highway must be of good nature, urban planning should be of good nature, then high quality railway infrastructure can be there for services and we are having collaborations

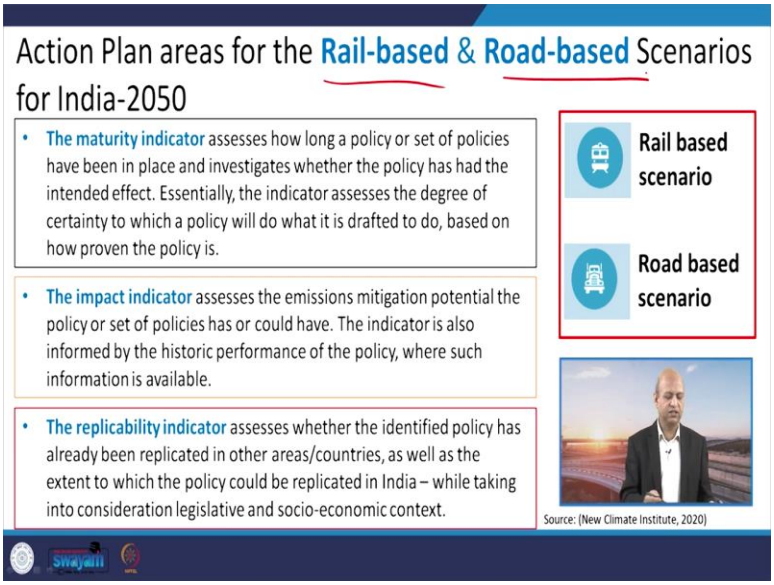
with the Japanese technology and other mast transit related public transportation system, metros etc., are there.

(Refer Slide Time: 27:33)



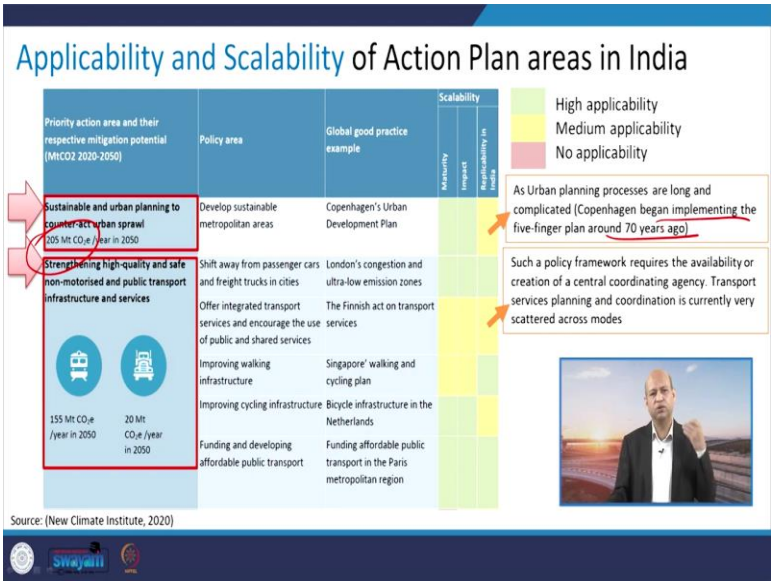
So, we can see the examples for renewable energy options in transportation sector. So, conventional drives, internal combustions engines to alternatives drives, electricity vehicles, et cetera. So, this representation is there, how can we go for transformation from IC engine to battery operated vehicles.

(Refer Slide Time: 27:53)



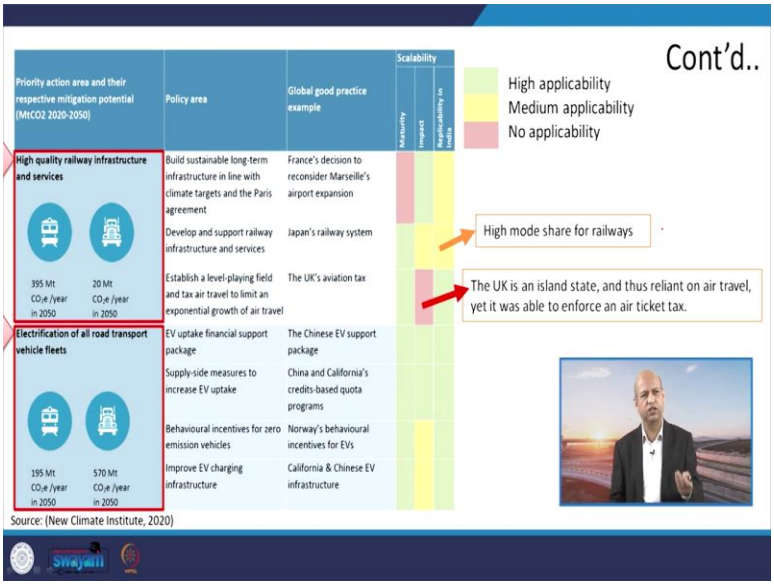
Then, if we talk about action plans up to 2050, so the rail-based and road-based scenarios you can see. So, there are certain indicators which can be used for shifting towards that road-based or railway-based.

(Refer Slide Time: 28:04)



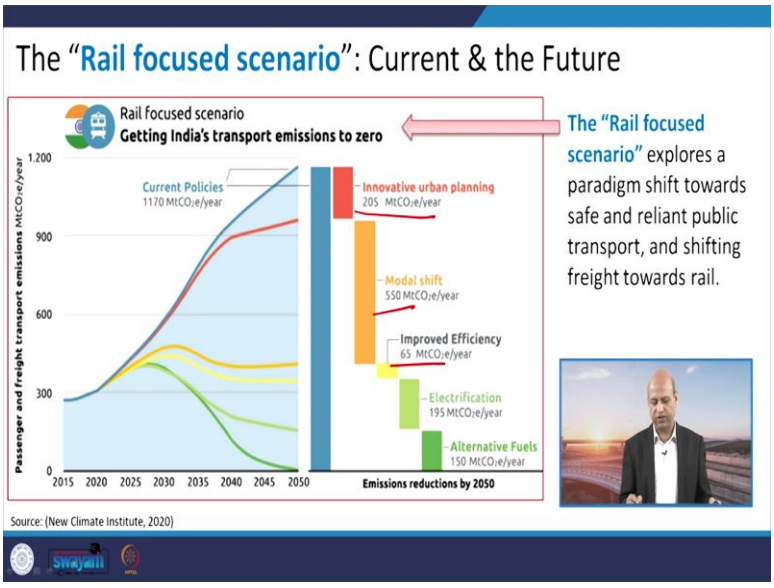
So, you can see like, sustainable and urban planning to counter-act urban sprawl. So, these kind of values are there, which can be seen. So, in urban planning, which are long and complicated, like in Copenhagen, this implemented for 70 years ago. So, it is a very long, long kind of planning but we have to do, consistent efforts are to be made and we have to be patient to achieve those goals.

(Refer Slide Time: 28:35)



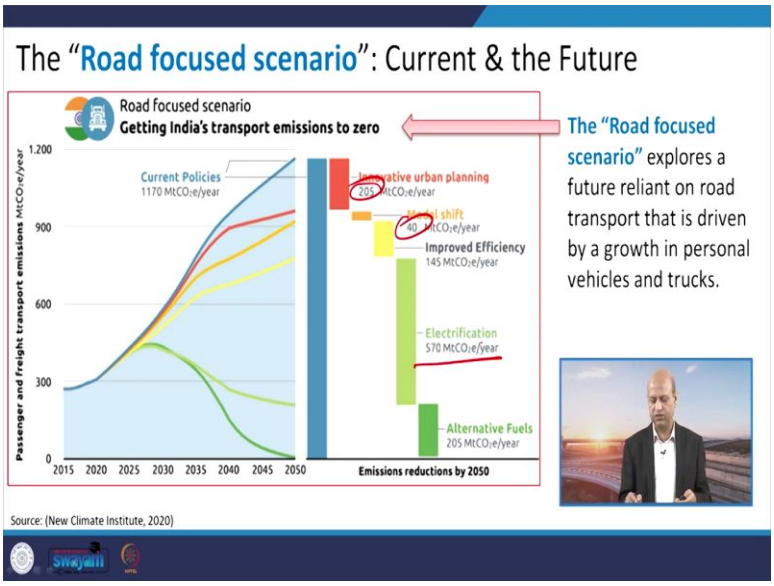
And then, if we talk about like Railways, et cetera, so, again, which kind of mobility or modes we are giving emphasis, that can be seen from best practices around the world, and how can we achieve those reductions in GHG emissions.

(Refer Slide Time: 28:48)



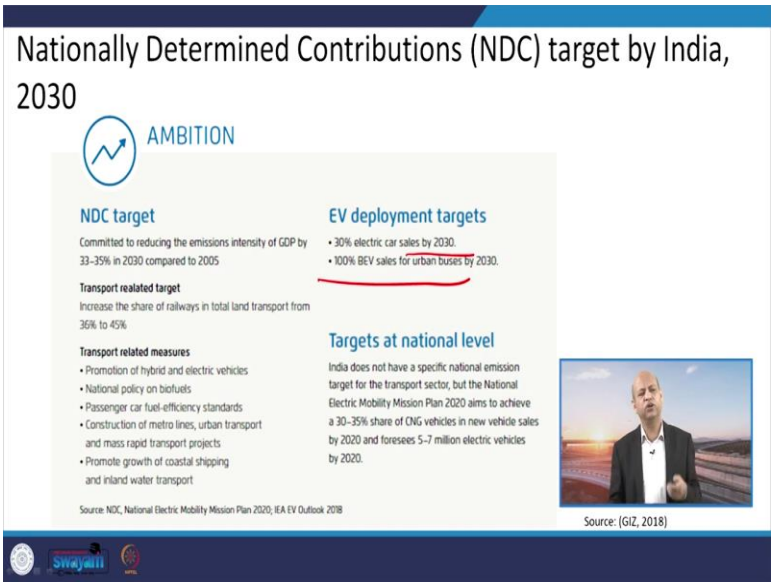
Like, rail focused scenarios you can see. Innovative urban planning 205 metric ton of carbon dioxide equivalent per year. And model shift 550, improved efficiency 65.

(Refer Slide Time: 29:07)



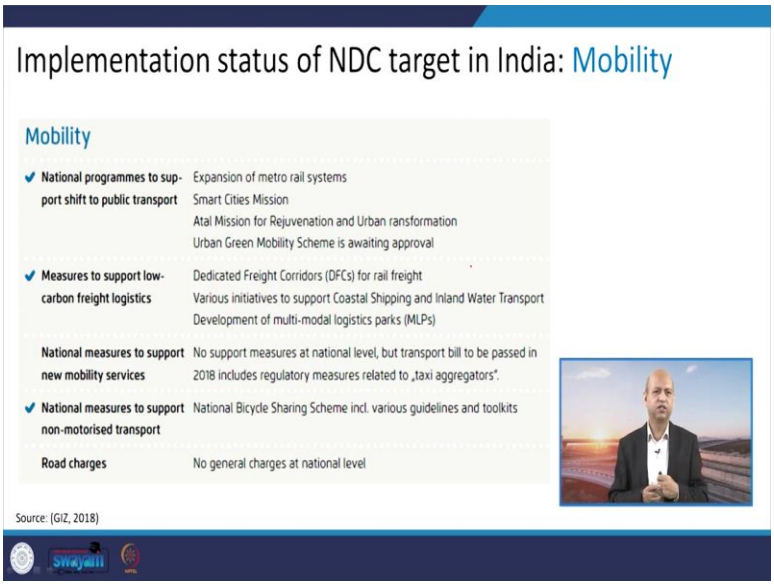
Whereas road focused, you know, this is values 205, 40 and 570, electrification. So, lot of advantage is there, lot of scope is there for reduction in road transportation.

(Refer Slide Time: 29:20)



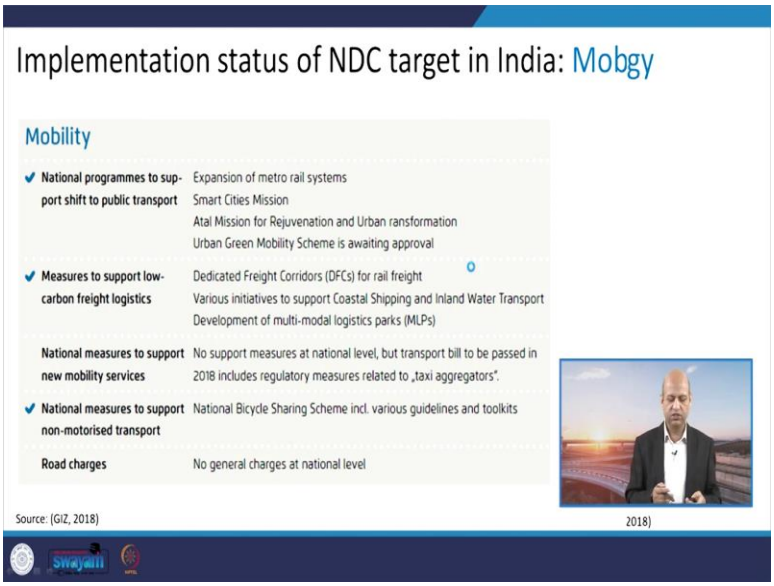
So, that we have seen in other values also. Now, nationally determined contributions target by India, so these are the target. Like, 30 % electric car sales by 2030 should be achieved, 100 % battery electric vehicles sales for urban buses by 2030. So, lot of efforts are being made at the national level.

(Refer Slide Time: 29:47)



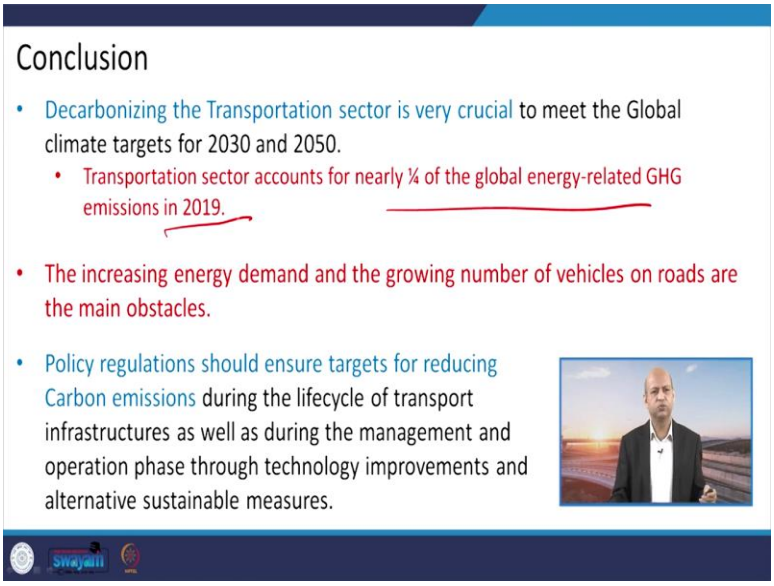
And all states are also coming with new policies, new majors, new programs, which can help the people shift towards less polluting vehicles or these kind of renewably energy charged kind of infrastructure and mobility.

(Refer Slide Time: 30:03)



So, these are the implementation status, which can be seen in these tables.

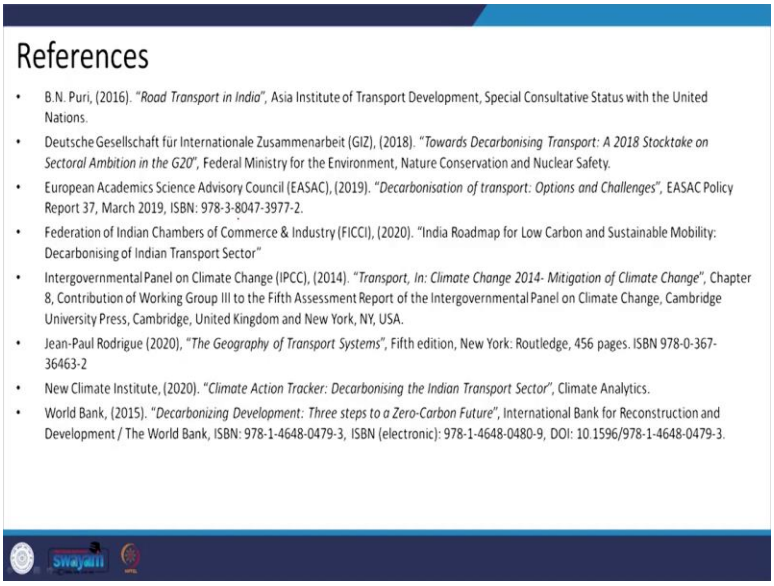
(Refer Slide Time: 30:07)



And ultimately, we can see that this transportation sector accounts for around one fourth of the total global energy related greenhouse gas emissions. So, huge scope is there, if you see this 2019 data. And the increasing energy demand and the growing number of vehicles on roads are the main obstacles.

So, we can go for better policies which can promote the public transportation system, non-motorized, so urban planning has to be that way, like, people feel to work whatever activities they want to do. They do not need any kind of vehicles in that way. So, those kind of planning majors are to be there. So, decarbonization effort is basically an integrated way should be adopted so that we can achieve decarbonization in all sectors including the transportation sector. So, accordingly policy and programs have to be adopted by each country.

(Refer Slide Time: 31:01)



So, this is all for today, and these are the references which you can go through for additional information. So, thank you for your kind attention. See you again. Thanks a lot.