

Sustainable Transportation Systems
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Lecture 46
Decarbonizing the Transport Sector

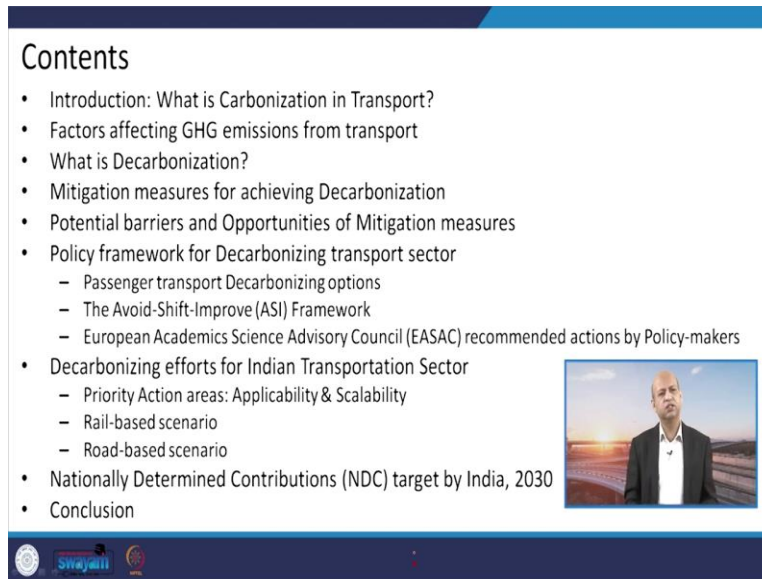
Hello, friends. Today we will discuss Decarbonizing the Transportation Sector. So, basically, the whole story, as you know, when we talk about sustainable transportation system, so basically the shift is going towards, instead of fossil fuel based or carbon economy-based development, we are going towards 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 CO₂ emissions or the greenhouse gas emissions, when we talk about greenhouse gas emissions, basically we are talking about not only the CO₂ 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.

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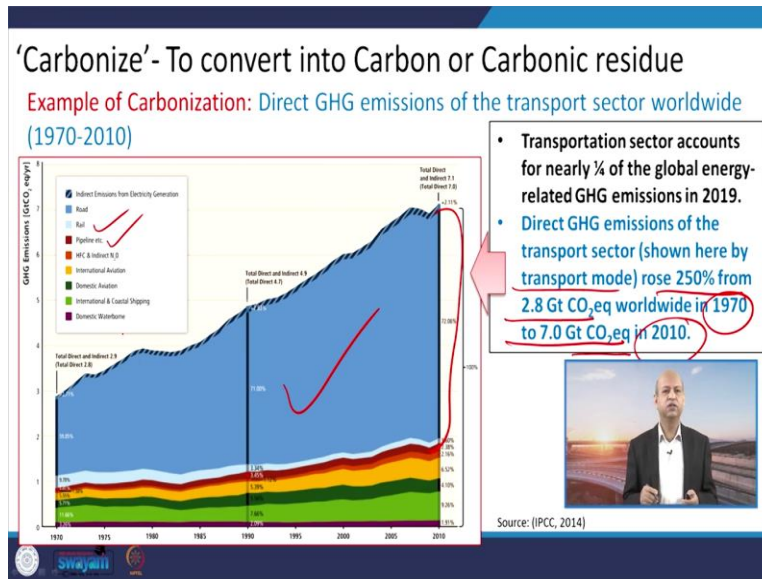
So, how can we reduce the greenhouse gas emissions, that is, how can we do decarbonization. Decarbonization means reducing greenhouse gas emissions. So, we will discuss that what is the decarbonization in definition, and then what are the mitigation measures for achieving decarbonization. So, reducing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

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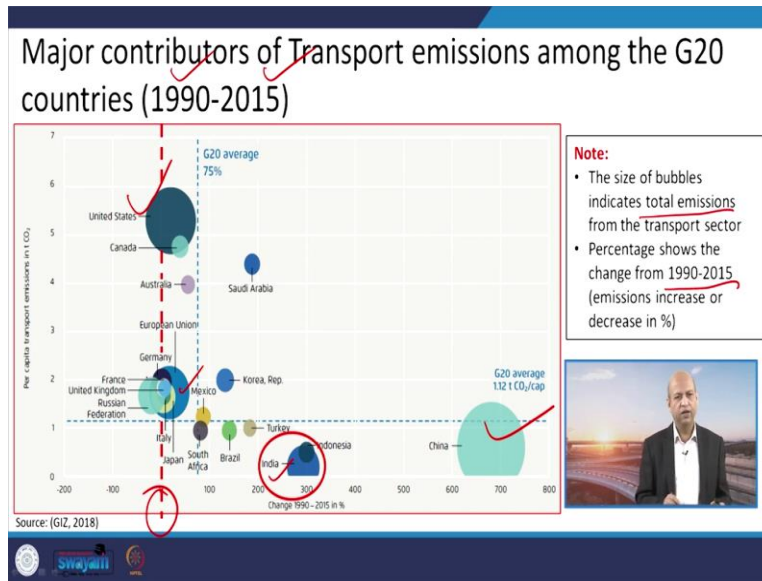


So, when we focus on carbonization, or what is the carbonize?, how do we carbonize? Basically, that is like converting something into carbon related products, carbon dioxide, carbon emissions, carbonic residues, all those organic related things. So, direct greenhouse gas emissions are basically the example 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 CO₂ equivalent emissions of the greenhouse gas emissions, so from 2.8 giga ton CO₂ equivalent, because the greenhouse gasses are not only the CO₂ 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 CO₂ 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.

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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.

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Factors affecting GHG emissions from transport

- **Activity:** total passenger-km / yr or freight tonne-km / yr having a positive feedback loop to the state of the economy but, in part, influenced by behavioural issues such as journey avoidance and restructuring freight logistics systems.
- **System infrastructure and modal choice.**
- **Energy intensity:** directly related to vehicle and engine design efficiency, driver behaviour during operation, and usage patterns.
- **Fuel carbon intensity:** varies for different transport fuels including electricity and hydrogen.

Source: (IPCC, 2014)

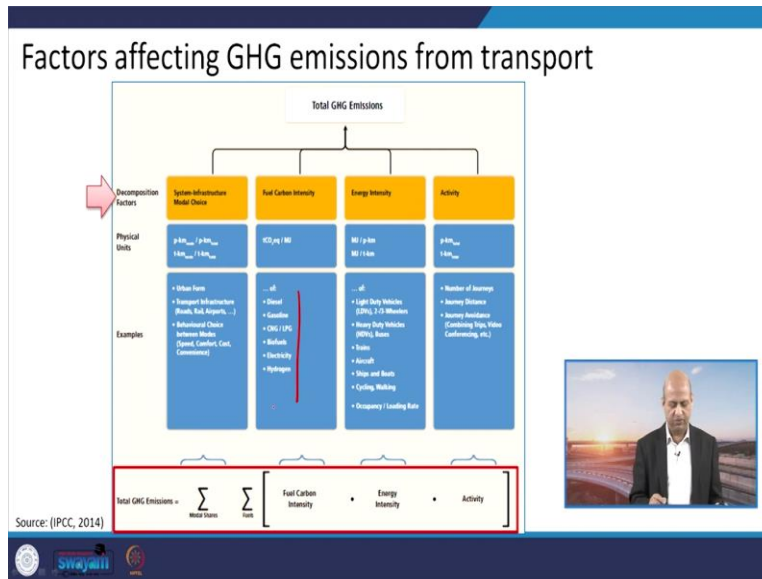


Now, if we see the factors which are responsible for these GHG emissions from the transportation sector, then there are several factors like activity, for example, total passengers kilometer per year, or freight ton, means the total volume and the weight of the freight which has been transported per 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.

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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.

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Comparison of capital costs, direct CO₂ emissions, and capacities for BRT, light rail, and metro urban mass transit options

	Bus rapid transit	Light rail	Metro
Capital cost (million USD ₂₀₁₁ /km)	5–27	13–40	27–330
Length of network that can be constructed for 1 USD ₂₀₁₁ billion cost (km)	37–200	25–77	3–37
World network length in 2011 (km)	2,120	15,000	10,000
Direct CO ₂ intensity (gCO ₂ /p-km)	14–22	4–22	3–21
Capacity (thousand passengers per hour per direction)	10–35	2–12	12–45

Values varies depending on fuel, efficiency, maintenance, age of fleet etc.

Source: (IEA 2012e, IPCC, 2014)

Well, when we compare the capital cost and direct CO₂ emissions, direct CO₂ 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 CO₂ emissions. If we for a, for a moment if we forget other factors, if we focus only on this CO₂

equivalent emissions, the greenhouse gas emissions, so the bus rapid transit is responsible for highest emissions, 14 to 22, these grams CO₂ 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.

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'Decarbonization' - The reduction of Carbon

Decarbonization/decarbonisation refers to the process of reducing carbon dioxide (CO₂) emissions resulting from human activity in the atmosphere.

- The current (and optimistic) objective of decarbonization is to, eventually, eliminate anthropogenic CO₂ emissions.

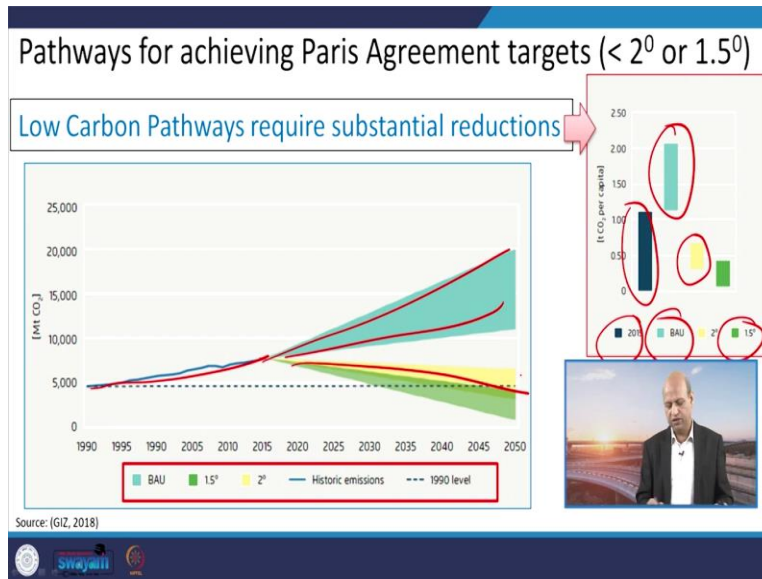
Ultimate goal of Paris Agreement, 2015:

- To limit global warming to below 2 degree Celsius (preferably 1.5 degree Celsius) compared to pre-industrial levels by reducing GHG emissions.

Logos: Decarbonising Transport Initiative, Paris Climate Agreement, Swayamiti.

Well, so when we focus upon decarbonization, so that means reduction of the carbon emissions, reduction of the CO₂ 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.

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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 CO₂ 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 CO₂.

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The Four Pillars of Decarbonization

- Decarbonization of electricity generation, i.e., renewable, nuclear, and/or CCS
- Fuel shifting (especially to electricity) in transport, heating, and industries
- Efficiency in all sectors, including building, transport, and agriculture
- Preservation and increase of natural carbon sinks

Source: (World Bank, 2015)

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 CO₂.

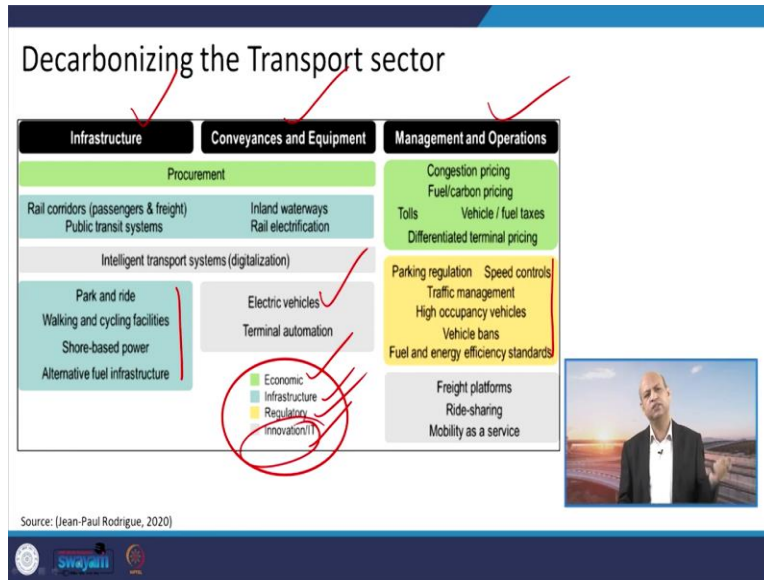
So, if we go for decarbonization of these plants, maybe like renewable, nuclear which are emitting like, they are neutral in the sense, they are not emitting much CO₂, except when they are, we are building those plants, then of course, we are using those raw material et cetera which are extracted and 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.

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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 CO₂ 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.

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How to achieve Decarbonization?

TRANSPORT TRANSFORMATION
This large-scale transformation will ensure that transport is carbon neutral by 2050.

MOBILITY TRANSITION
The transition to sustainable mobility will reduce energy consumption without limiting mobility.

ENERGY TRANSITION IN TRANSPORT
The transition to clean energy of the transport sector will cover remaining demand with carbon-neutral energy.

Source: (GIZ, 2018)


The diagram features a central blue triangle with a plus sign below it. To the left is the 'MOBILITY TRANSITION' box, and to the right is the 'ENERGY TRANSITION IN TRANSPORT' box. A small video inset on the right shows a man speaking. Red checkmarks and a red circle are drawn on the slide.

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.

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Mitigation measures for achieving Decarbonization

- **Energy Intensity Reduction by Incremental Vehicle technologies**
 - **Light duty vehicles:** Hybrid drive-trains (ICE plus electric motor with battery storage) can provide reductions up to 35 % compared to similar non-hybridized vehicles
 - **Heavy duty vehicles:** Efficient diesel engines (up to 45 % thermal efficiency)
 - **Rail, waterborne craft & aircrafts:** Rails are generally energy efficient, but improvements can be gained from multiple drive-trains and load-reduction measures.
 - For example, the high speed 'Shinkansen' train in Japan gained a 40 % reduction of energy consumption by optimizing the length and shape of the lead nose, reducing weight, and by using efficient power electronics.



Source: (IPCC, 2014)

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.

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- **Advanced propulsion systems**
 - Battery and fuel cell electric drives for road transport & Diesel hybrid locomotive drive train for Rail and waterborne crafts, Blended biofuels for aircrafts.
- **Fuel Carbon Intensity reduction**
 - Use of Alternate fuels such as LNG, CNG, electricity, Hydrogen and biofuels.

Source: (IPCC, 2014)

Indicative fuel consumption reduction potential ranges for a number of LDV technology drive-train and fuel options in 2010 and 2030, compared with a baseline gasoline internal combustion engine (ICE) vehicle consuming 8L/100km in 2010.


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.


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Behavioral aspects 1/2

- **Purchase behaviour** (prefer cheaper vehicle compare to eco-friendly)
- **New technologies/fuels** (doubts on new technology or vehicle quality)
- **On-road fuel economy** (more fuel consumption due to congestion, poor roads etc.)
- **Eco-driving** (fuel efficient driving behaviour)



Source: (PCC, 2014)



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.

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Behavioral aspects 2/2

- **Driving behaviour with new types of vehicles** (Hesitation while using in various conditions)
- **Driving rebound effects** (Easy & cheap travel also encourage more travelling)
- **Vehicle choice-related rebounds** (Over/high capacity vehicle in case of cheaper fuel)
- **Company behaviour** (Unnecessary freight movement)



Source: (IPCC, 2014)



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.

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Potential barriers and Opportunities of Mitigation measures

Transport technology or practice	Short term possibilities	Long-term possibilities	Barriers	Opportunities	References
<p>Fuel carbon intensity: fuel switching BEV—Battery electric vehicle; PHEV—Plug-in hybrid electric vehicle; FCV—Fuel cell vehicles; CHP—combined heat and power; CNG—Compressed natural gas; LNG—Liquefied natural gas; CBG—Compressed biogas; LBG—Liquefied biogas</p>					
BEVs and PHEVs based on renewable electricity	Rapid increase in use likely over next decade from a small base, so only a small impact likely in short-term.	Significant replacement of ICE powered LDVs.	EV and battery costs reducing but still high Lack of infrastructure, and recharging standards not uniform. Vehicle range anxiety Lack of capital and electricity in some least developed countries.	Universal standards adopted for EV rechargers Demonstration in green city areas with plug-in infrastructure Decarbonized electricity Smart grids based on renewables EV subsidies New business models, such as community car sharing	EPRI, 2008; Berts, 2009; EA, 2011; Satter et al., 2011; Kim et al., 2011; Lourent & Windisch, 2011; Graham-Romer et al., 2012
CNG, LNG, CBG and EBG displacing gasoline in LDVs and diesel in HDVs	Infrastructure available in some cities so can allow a quick ramp-up of gas vehicles in these cities.	Significant replacement of HDV diesel use depends on ease of engine conversion, fuel prices and extent of infrastructure	Inefficient government programmes, conversion subsidies and local gas infrastructure and markets Leakage of gas	Demonstration gas conversion programmes that show cost and health co-benefits. Fixing gas leakage in general.	EA, 2007; Satter et al., 2011; Alonazi et al., 2012
Biobutanol displacing gasoline, diesel and aviation fuel.	Niche markets continue for first generation biofuels (1 st gen) of liquid fuel market, small biogas niche markets.	Advanced and drop-in biofuels likely to be adopted around 2020–2030, mainly for aviation.	Some biofuels can be readily expanded; environmentally poor and cause inequalities by inducing increases in food prices.	Drop-in fuels attractive for all vehicles Biofuels and bio-electricity can be produced together, e.g., sugarcane ethanol and CHP from bagasse. New biofuel options need to be further tested, particularly for aviation applications.	Ogden et al., 2004; Kargone et al., 2010; EA, 2010; Pears et al., 2010; Cmelig et al., 2011; Satter et al., 2011; Patra and Moreira, 2011; Ramey et al., 2012

Source: (IPCC, 2014)

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.

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Transport technology or practice	Short-term possibilities	Long-term possibilities	Barriers	Opportunities	References
Energy intensity efficiency of technologies: FEV—fuel efficient vehicles ICE—internal combustion engine					
4. Improved vehicle ICE technologies and on board information and communication technologies (ICT) in fuel efficient vehicles	Continuing fuel efficiency improvements across new vehicles of all types can drive large, low-cost, near-term reductions in fuel demand	Likely to be a significant source of reduction. Behavioural issues (e.g. reduced effects). Consumer choices can reduce vehicle efficiency gains	Insufficient regulatory support for vehicle emissions standards. On-road performance deteriorate compared with laboratory tests	Clearer regulations that enable quick changes to occur without excessive costs for emissions standards. China and most OECD countries have implemented standards. Reduced registration tax can be implemented for low CO ₂ and fuel efficient vehicles.	Schopper et al., 2000; Oudin et al., 2004; Small and van Dender, 2007; Springling and Gordon, 2009; Timboua and Dial, 2009; Faghihnezhad et al., 2009; Malik, 2010; Satter et al., 2011
Structure: system infrastructure efficiency					
5. Modal shift by public transport displacing private motor vehicle use	Rapid short-term growth already happening	Significant displacement only where quality system infrastructure and services are provided	Availability of rail, bus, ferry and other quality transit options. Scarcity of people to allow more access to services. Levels of services. Time barriers on roads without right of way. Public perceptions	Investment in quality transit infrastructure, density of independent land use, and high level of services using innovative financing that builds in these features. Multiple co-benefits especially where walkability health benefits are a focus.	Kennworthy, 2008; Milard-Ball & Schipper, 2011; Newman and Kenworthy, 2011; Satter et al., 2011; Banister and Pucher, 2011; Newman and Mazan, 2013

Source: (IPCC, 2014)




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

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Transport technology or practice	Short-term possibilities	Long-term possibilities	Barriers	Opportunities	References
6. Modal shift by cycling displacing private motor vehicle use	Rapid short-term growth already happening in many cities	Significant displacement only where quality system infrastructure is provided	Cultural barriers and lack of safe cycling infrastructure and regulations. Harsh climate	Demonstrations of quality cycling infrastructure including cultural programmes and bike-sharing schemes	Basore et al., 2008; Garand et al., 2008; Satter et al., 2011; Anon, 2012; Sugiyama et al., 2012
7. Modal shift by walking displacing private motor vehicle use	Some growth but depends on urban planning and design policies being implemented	Significant displacement where large-scale adoption of polycentric city policies and walkable urban designs are implemented	Planning and design policies can work against walkability of a city by too easily allowing cars into walking city areas. Lack of density and integration with transit. Culture of walkability	Large-scale adoption of polycentric city policies and walkable urban designs including walking city in historic centres and new cities. Cultural programmes	Geli, 2011; Hilger et al., 2011; Leithner et al., 2011; Satter et al., 2011
8. Urban planning by reducing the distances to travel within urban area	Immediate impacts where dense transit-oriented development (TOD) centres are built	Significant reductions where widespread polycentric city policies are implemented	Urban development does not always favour dense TOD centres being built. TODs need quality transit at their base. Integration of professional areas required	High-density polycentric city policies implemented with green TODs, backed by quality transit. Multiple co-benefits in sprawl costs avoided and health gains	Anon, 2004; Anon, 2009; Nunes, 2006; Ewing et al., 2008; Cervero and Murakami, 2009; Cervero and Sullivan, 2010; Satter et al., 2011; Lafrance, 2009
9. Urban planning by reducing private motor vehicle use through parking and traffic restraint	Immediate impacts on traffic density observed	Significant reductions only where quality transport alternatives are available	Political barriers due to perceived public opposition to increased costs, traffic and parking restrictions. Parking codes too prescriptive for areas suited to walking and transit	Demonstrations of better transport outcomes from combinations of traffic restraint, parking and new transit/walking infrastructure investment	Guilliam, 2003; AQB, 2011; Coatsworth et al., 2011; Shoup, 2011; Newman and Mazan, 2013
10. Modal shift by displacing aircraft and UAV trips through high-speed rail alternatives	Immediate impacts after building rail infrastructure	Continued growth but only short-medium distance trips suitable	High-speed rail infrastructure expensive	Demonstrations of how to build quality fast rail using innovative finance	Park and Ku, 2006; Gilbert and Piel, 2010; Altemann, 2011; Satter et al., 2011

Source: (IPCC, 2014)



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Transport technology or practice	Short-term possibilities	Long-term possibilities	Barriers	Opportunities	References
11. Modal shift of freight by displacing HGV demand with rail.	Suitable immediately for medium- and long-distance freight and port traffic.	Substantial displacement only if large rail infrastructure improvements made: the external costs of freight transport are fully internalized, and the quality of rail services are enhanced. EU target to have 20% of freight tonne-km moving more than 300 km to go by rail for water by 2030.	Inadequacies in rail infrastructure and service quality. Short freight moved over distances that are too short for rail to be competitive.	Upgrading of inter-modal facilities. Electrification of rail freight services. Alleviating traffic congestion on road networks and higher fuel cost will favour rail.	EA, 2009; Schiller et al., 2010; Satter et al., 2011
12. Modal shift by displacing truck and car use through waterborne transport.	Niche options already available. EU "Motorways of the Sea" programme demonstrates potential to expand short-sea shipping share of freight market.	Potential to develop beyond current niches, though will require significant investment in new vessels and port facilities.	Lack of vision for water transport options and land-locked population centres. Long transit times. Tightening controls on GHG (bunker fuel and CO ₂) emissions, splitting cost and reducing modal competitiveness.	Demonstrations of quality waterborne transport that can be faster and with lower carbon emissions than alternatives.	Fugère et al., 2009; Satter et al., 2011
13. System optimization by improved road systems, freight logistics and efficiency at airports and ports.	Continuing improvements showing immediate impacts.	Insufficient in long term to significantly reduce carbon emissions without changing mode, reducing mobility, or reducing fuel carbon intensity.	Insufficient regulatory support and key performance indicators (KPIs) covering logistics and efficiency.	Creative regulations and KPIs that enable change to occur rapidly without excessive costs.	Pis and Verhoef, 2004; A. Zhang and Y. Zhang, 2006; Fugère et al., 2009; Kaku et al., 2010; McKinney, 2010; Semaoka and Balakrishnan, 2010; Satter et al., 2011

Source: (IPCC, 2014)



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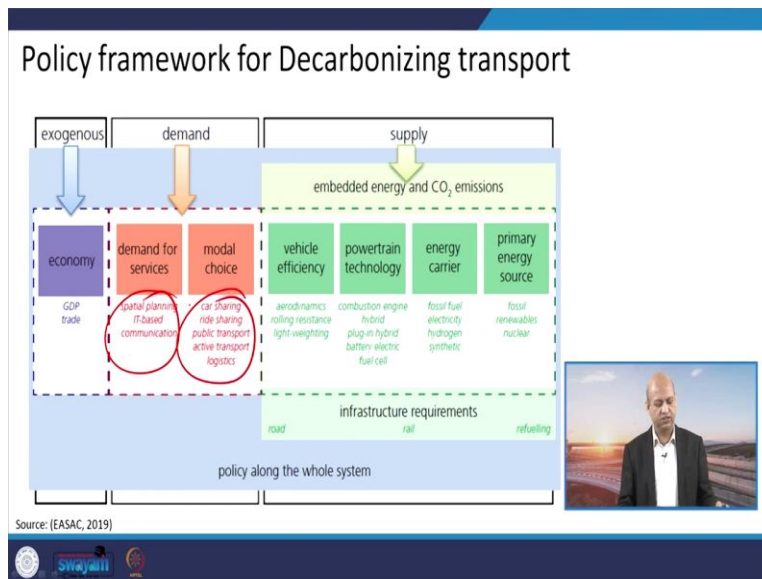
Transport technology or practice	Short-term possibilities	Long-term possibilities	Barriers	Opportunities	References
Activity: demand reduction					
14. Mobility service substitution by reducing the need to travel through enhanced communications.	Niche markets growing and ICT improving in quality and reliability.	Significant reductions possible after faster broadband and quality images available, though ICT may increase the need for some trips.	Technological barriers due to insufficient broadband in some regions.	Demonstrations of improved video-conferencing systems quality.	Celik and Rogan, 2001; Choo et al., 2005; Wang and Lau, 2007; Yi and Thomas, 2007; Zhen et al., 2009; Satter et al., 2011; Maktarian and Maenakshundaram, 2002
15. Behavioural change from reducing private motor vehicle use through pricing policies, e.g. network charges and parking fees.	Immediate impacts on traffic density observed.	Significant reductions only where quality transport alternatives are available.	Political barriers due to perceived public opposition to increased pricing costs, lack of administrative integration between transport, land-use and environment departments in city municipalities.	Demonstrations of better transport outcomes from combinations of pricing, staff, reduced parking and new infrastructure investment from the revenue. Removing subsidies to fossil fuels important for many co-benefits.	Linnus, 2005, 2006; Satter et al., 2011; Christy et al., 2012a
16. Behavioural change resulting from education to encourage gaining benefits of less motor vehicle use.	Immediate impacts of 10-15% reduction of LDV use are possible.	Significant reductions only where quality transport alternatives are available.	Lack of belief by politicians and professionals in the value of educational behaviour change programmes.	Demonstrations of travel smart programmes linked to improvements in sustainable transport infrastructure. Cost effective and multiple co-benefits.	Pandey, 2006; Goodwin and Lyons, 2010; Taylor and Philp, 2010; Ashton-Gustan et al., 2011; Hajar et al., 2011; Satter et al., 2011

Source: (IPCC, 2014)



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.

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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.

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Passenger transport Decarbonizing options

- **Safe Cycle lanes, pedestrian zones and walkways**
 - To facilitate short distance travelling without vehicles (Car free zones, bicycle renting/hiring schemes)
- **Banning cars from city centres and/or regulating vehicle speeds and out-of-town park and ride schemes**
 - To discourage the use of passenger cars in the city.
- **Excluding vehicles unless they have more than one passenger from specific lanes on busy roads has been tried in some cities.**
 - This approach has the potential to reduce the emissions per passenger kilometre, but has not been widely adopted.
- **Incentivised access to relatively low-price public transport (trains, buses, trams and metros)**
 - Ex. In cases such as Luxembourg 'free' public transport which produce lower emissions per passenger-kilometre than passenger cars or motorcycles

Source: (EASAC, 2019)

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.

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- Coordinated intermodal transfers with easy-to-use information systems (ICT platforms) and multi-operator ticketing systems to encourage the use of public transport
 - Ex. Inter-city trains linked to local trams or buses for the 'last mile'.
- Charges for parking and for vehicle access to city centres
 - Ex. Congestion charge.
- Low-emission zones together with transport management schemes aiming to limit transport emissions in highly congested or polluted areas.

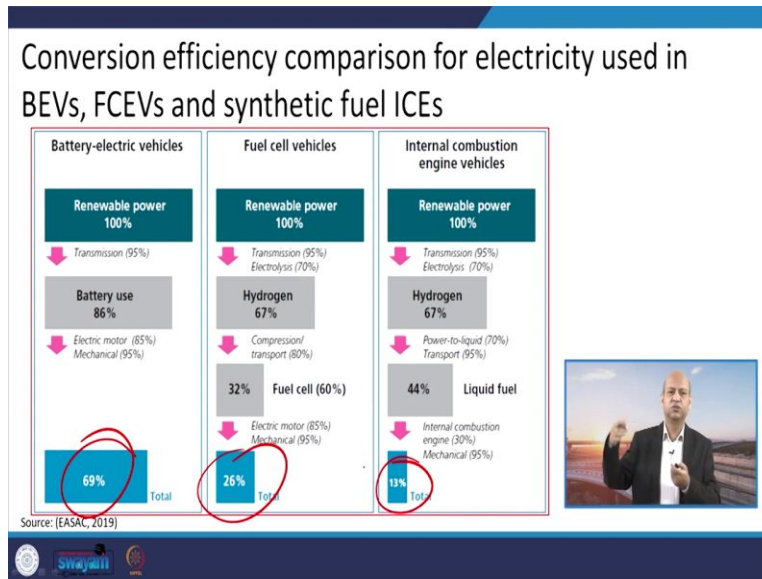


Source: (EASAC, 2019)

Swayam

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.

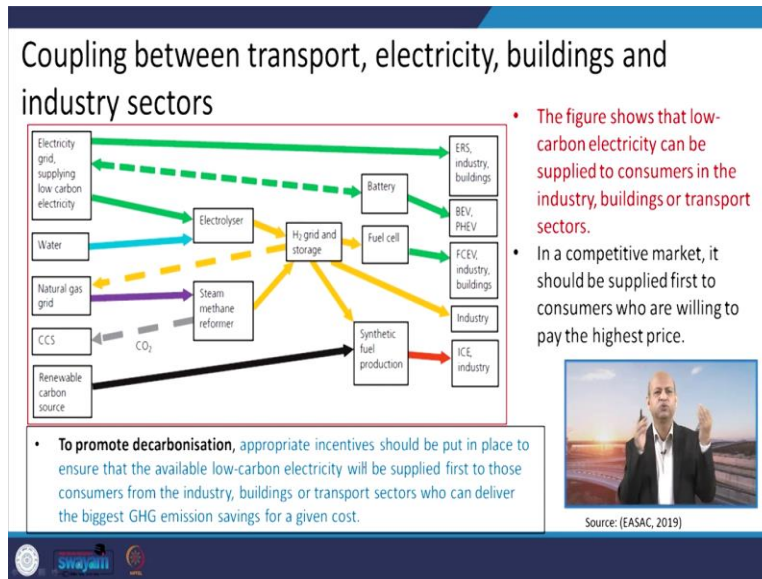
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Now, if we compare, like conversion efficiency of electricity used in battery or electric vehicles or these fuel cell vehicles or synthetic fuel ICEs, internal combustion engines, so you can see like overall conversion of the power transmission is 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 %.

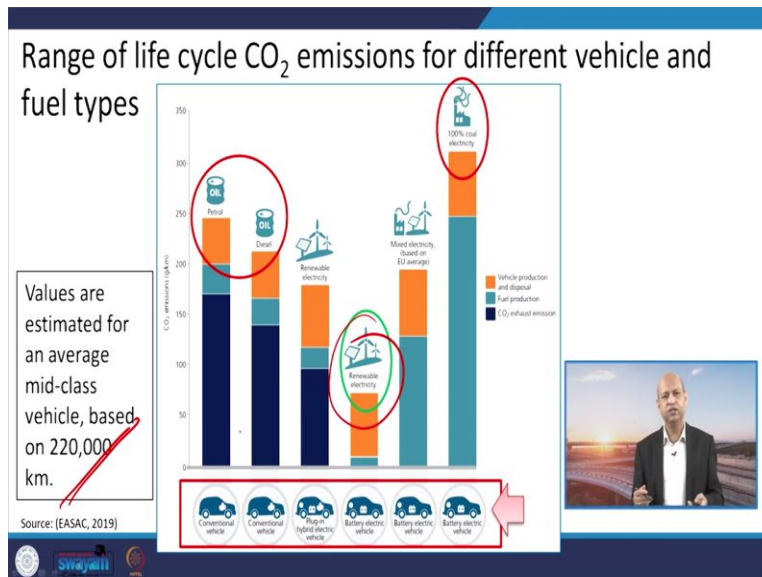
So, it makes lot of sense if we go for electric, battery operated electric vehicles. So, these transmission power efficiency, we are achieving very high. So, that means with the same energy, we will have the, the mobility much more than, in comparison to other transportation modes.

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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.

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So, comparison is very, you can see, very visible. Like, range of the life cycle CO₂ 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 CO₂ 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.

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The Avoid-Shift-Improve (ASI) Framework

AVOID	SHIFT	IMPROVE
the need for (motorized) transport • Ex. By improving urban planning or by improving logistics	to more environmentally friendly transport modes • Ex. Walking, cycling or public transport by improving infrastructure and making public transport more attractive	vehicles' energy efficiency and Carbon intensities • Ex. By promoting electric mobility or other alternatives

Source: (New Climate Institute, 2020)




The slide features a blue header with the title 'The Avoid-Shift-Improve (ASI) Framework'. Below the title is a table with three columns: 'AVOID' (red border), 'SHIFT' (blue border), and 'IMPROVE' (green border). Each column contains a brief description and an example. At the bottom right, there is a small video inset of a man in a dark suit and white shirt speaking. The footer includes the source 'Source: (New Climate Institute, 2020)' and logos for 'Swayam' and other organizations.

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.


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European Academics Science Advisory Council (EASAC) recommended actions by Policy-makers

- **Avoid** and contain the demand for motorised transport, and reverse EU policy that 'curbing mobility is not an option'.
- **Shift** passengers from private cars to public transport services (trains, buses, trams, etc.).
- **Shift** more freight off the road and onto railways or waterways.
- **Improve**/introduce regulations during the transition period to limit consumer demand for oversized vehicles and oversized ICEs.
- **Improve** the average emissions performance of all passenger cars and LDVs during the transition period.
- **Improve**/increase the rate of market penetration of BEVs and PHEVs for passenger transport as soon as possible.
- **Improve**/increase the penetration rate of low-carbon electricity generation in the grid urgently.



Source: [EASAC, 2019]




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.


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European Academics Science Advisory Council (EASAC) recommended actions by Policy-makers

- **Avoid** and contain the demand and regulation of electricity markets and tariffs that apply 'curbing mobility is not an option'.
- **Shift** passengers from private cars to public transport services (trains, buses, trams, etc.).
- **Shift** more freight off the road and onto railways or waterways.
- **Improve**/introduce regulations during the transition period to limit consumer demand for oversized vehicles and oversized ICEs.
- **Improve** the average emissions performance of all passenger cars and LDVs during the transition period.
- **Improve**/increase the rate of market penetration of BEVs and PHEVs for passenger transport as soon as possible.
- **Improve**/increase the penetration rate of low-carbon electricity generation in the grid urgently.

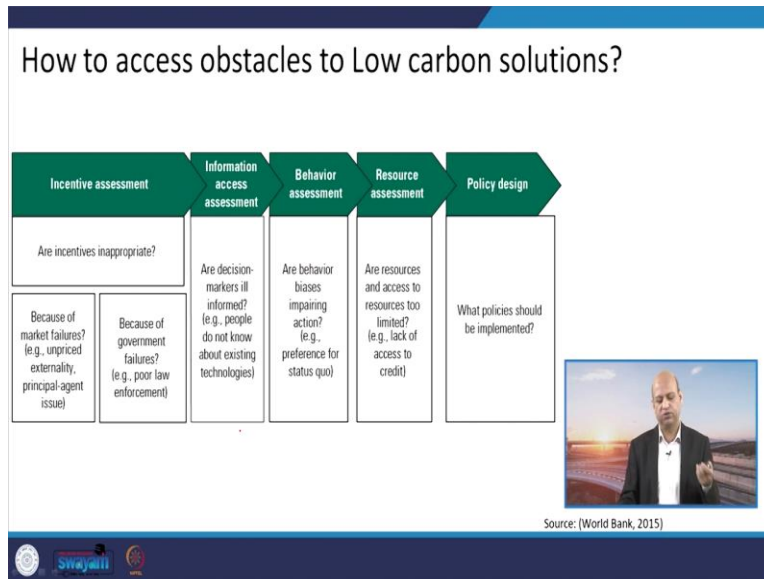


Source: [EASAC, 2019]



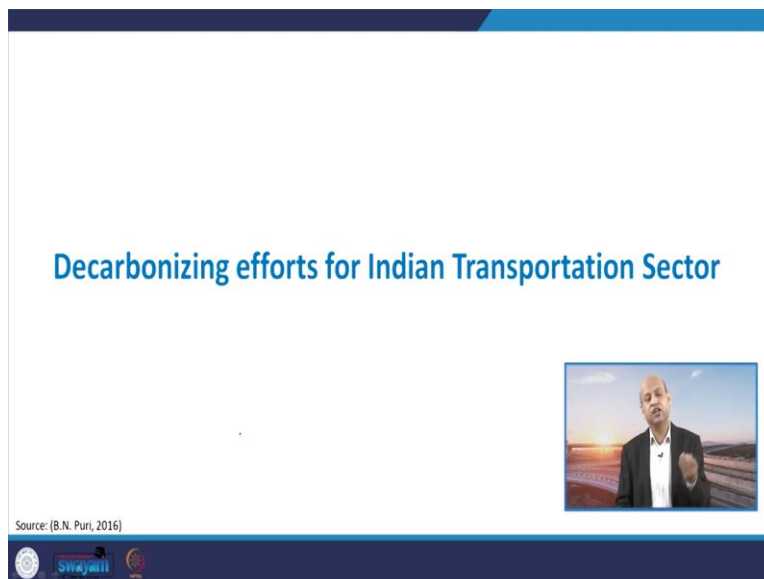
So, that way, we can improve the efficiency of transportation.

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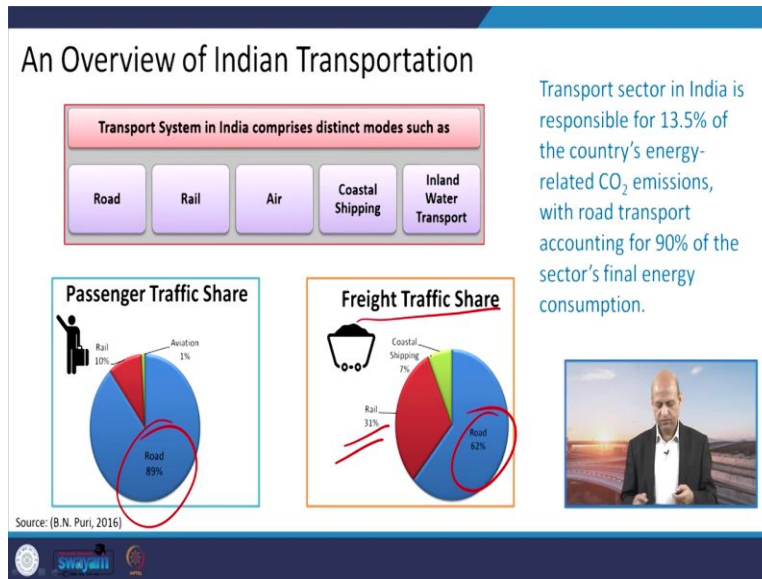
Then, how to access obstacles to low carbon solutions? So, these are again, ways which can be implemented in behavioral assessment or resource assessment or policy designs. So, that can help again for decarbonization.

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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.

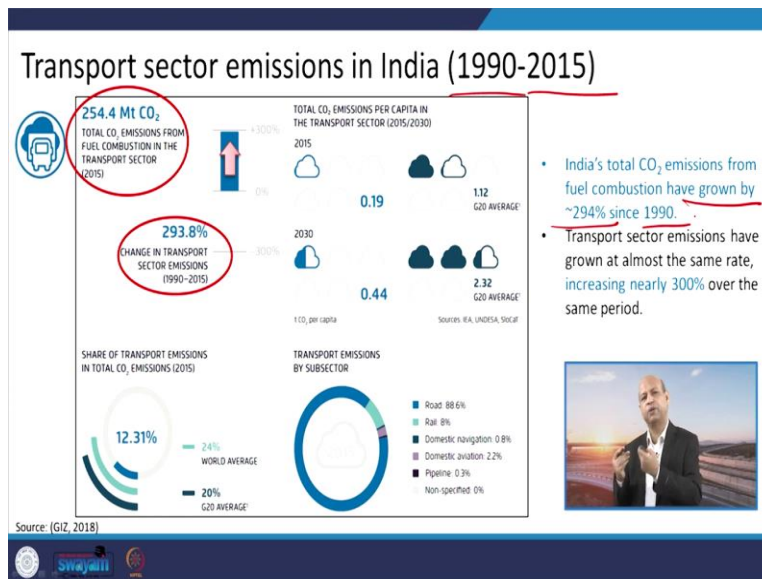
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So, you can see like, passenger traffic here, on road it is 89 %, rail it is only 10 %. You can see. So, the huge scope is there for decarbonizing the road transportation sector. Similarly, in freight traffic also, only rail has 31 %. Road still has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

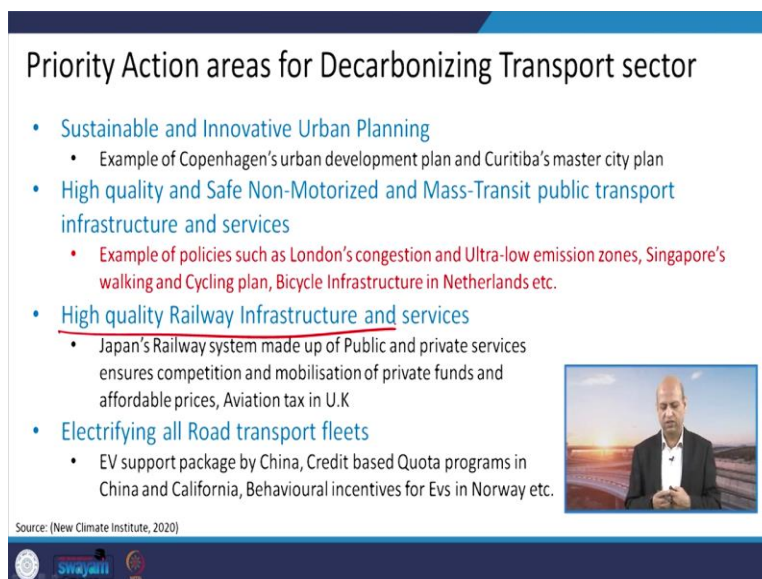
If we can shift freight from road to the rail or inland water ways etc., like, these coastal shipping is there, 7 %, but huge scope is there in inland water ways, in the rivers, etc. If we can have those kind of infrastructure, lot of scope is there for shifting this freight from the road to rail, as 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.

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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.

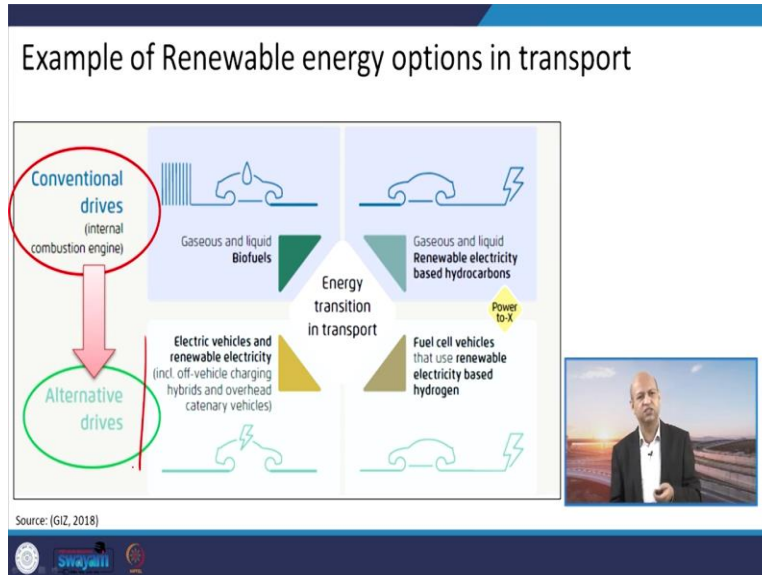
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If we talk about like priority actions which are related to decarbonizing the transportation sector in India. So, the highway must be of good nature, urban planning should be of good nature, then high quality railway infrastructure can be there for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

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

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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.

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Action Plan areas for the Rail-based & Road-based Scenarios for India-2050

- **The maturity indicator** assesses how long a policy or set of policies have been in place and investigates whether the policy has had the intended effect. Essentially, the indicator assesses the degree of certainty to which a policy will do what it is drafted to do, based on how proven the policy is.
- **The impact indicator** assesses the emissions mitigation potential the policy or set of policies has or could have. The indicator is also informed by the historic performance of the policy, where such information is available.
- **The replicability indicator** assesses whether the identified policy has already been replicated in other areas/countries, as well as the extent to which the policy could be replicated in India – while taking into consideration legislative and socio-economic context.

Rail based scenario

Road based scenario

Source: (New Climate Institute, 2020)

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.

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Applicability and Scalability of Action Plan areas in India

Priority action area and their respective mitigation potential (MtCO ₂ e 2020-2050)	Policy area	Global good practice example	Scalability		
			Maturity	Impact	Reproducibility in India
Sustainable and urban planning to counter-act urban sprawl 205 Mt CO ₂ e /year in 2050 Strengthening high-quality and safe non-motorised and public transport infrastructure and services 155 Mt CO ₂ e /year in 2050 20 Mt CO ₂ e /year in 2050	Develop sustainable metropolitan areas Shift away from passenger cars and freight trucks in cities Offer integrated transport services and encourage the use of public and shared services Improving walking infrastructure Improving cycling infrastructure Funding and developing affordable public transport	Copenhagen's Urban Development Plan	High	High	High
		London's congestion and ultra-low emission zones The Finnish act on transport services Singapore' walking and cycling plan Bicycle infrastructure in the Netherlands Funding affordable public transport in the Paris metropolitan region	High	High	High

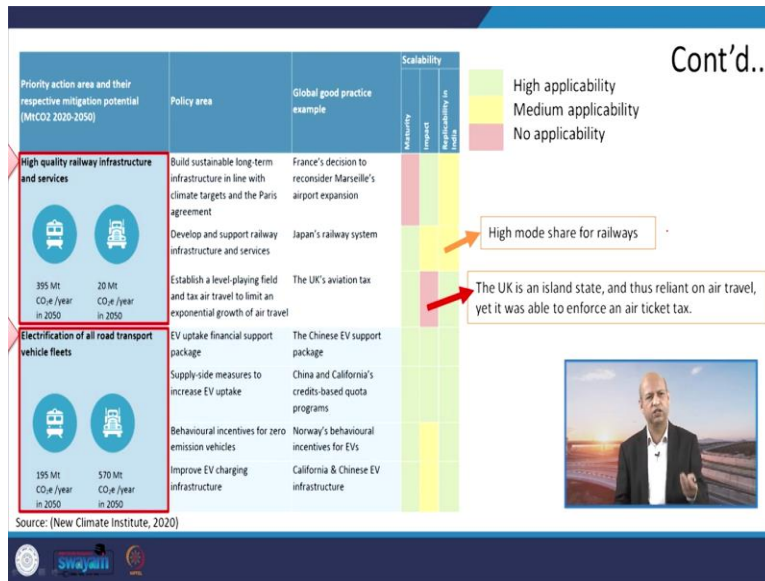
Legend:
■ High applicability
■ Medium applicability
■ No applicability

Annotations:
 - As Urban planning processes are long and complicated (Copenhagen began implementing the five-finger plan around 70 years ago)
 - Such a policy framework requires the availability or creation of a central coordinating agency. Transport services planning and coordination is currently very scattered across modes

Source: (New Climate Institute, 2020)

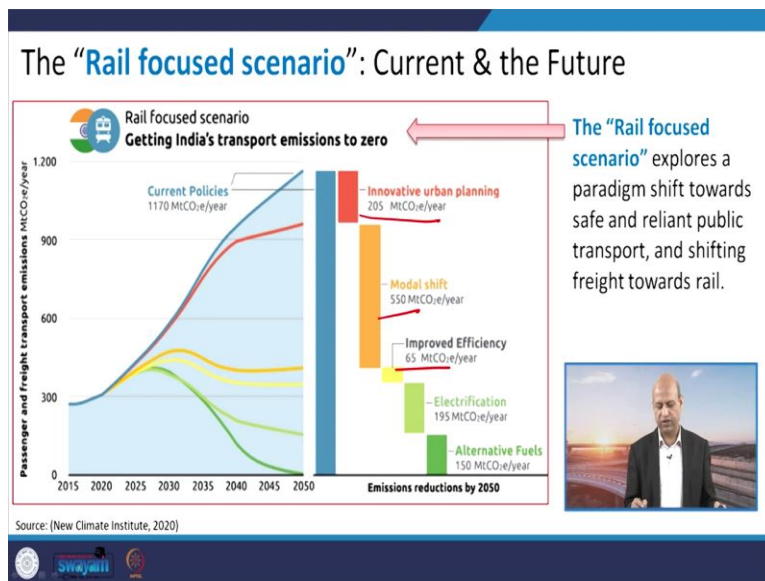
So, you can see like, sustainable and urban planning to counter-act urban sprawl. So, these kind of values are there, which can be seen. So, in urban planning, which are long and complicated, like in Copenhagen, this implemented for 70 years ago. So, it is a very long, long kind of planning but we have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

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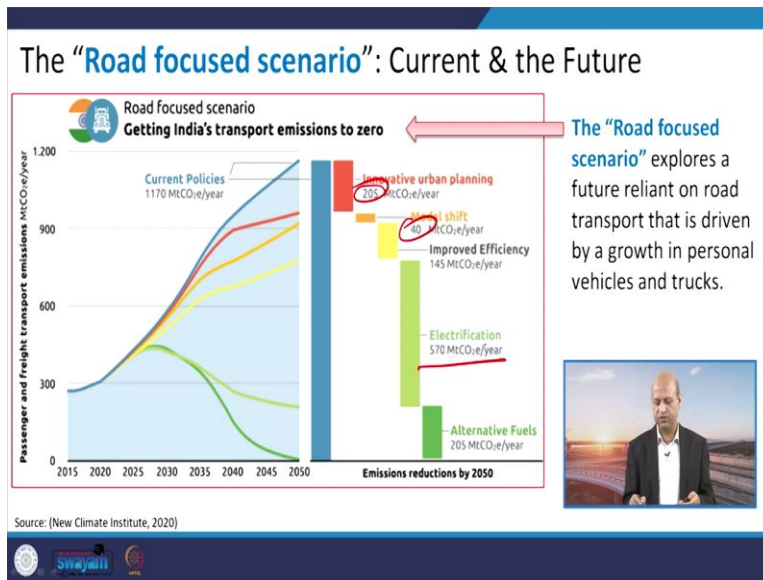
And then, if we talk about like Railways, et cetera, so, again, which kind of mobility or modes we are giving emphasis, that can be seen from best practices around the world, and how can we achieve those reductions in GHG emissions.

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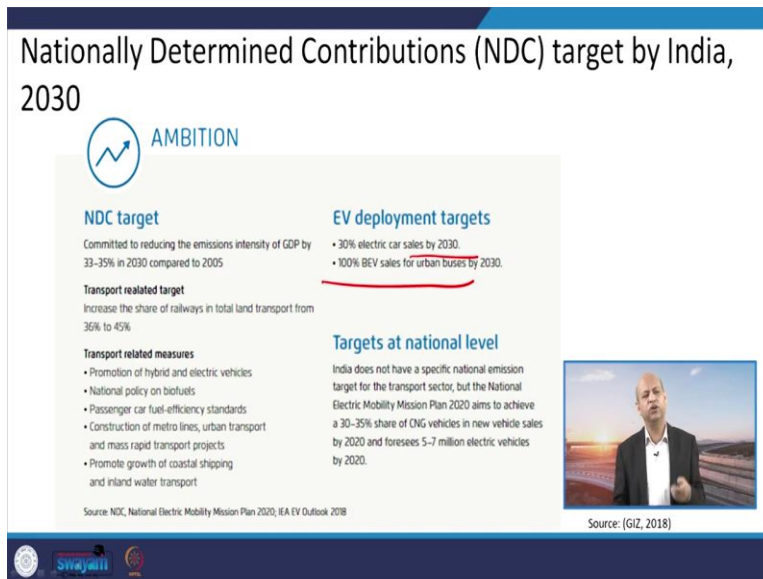
Like, rail focused scenarios you can see. Innovative urban planning 205 metric ton of carbon dioxide equivalent per year. And model shift 550, improved efficiency 65.

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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.

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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.

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Implementation status of NDC target in India: **Mobility**

Mobility

- ✓ **National programmes to support shift to public transport**
 - Expansion of metro rail systems
 - Smart Cities Mission
 - Atal Mission for Rejuvenation and Urban transformation
 - Urban Green Mobility Scheme is awaiting approval
- ✓ **Measures to support low-carbon freight logistics**
 - Dedicated Freight Corridors (DFCs) for rail freight
 - Various initiatives to support Coastal Shipping and Inland Water Transport
 - Development of multi-modal logistics parks (MLPs)
- National measures to support new mobility services**
 - No support measures at national level, but transport bill to be passed in 2018 includes regulatory measures related to „taxi aggregators“.
- ✓ **National measures to support non-motorised transport**
 - National Bicycle Sharing Scheme incl. various guidelines and toolkits
- Road charges**
 - No general charges at national level



Source: (GIZ, 2018)




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.

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Implementation status of NDC target in India: **Mobgy**

Mobility

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Source: (GIZ, 2018)




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

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Conclusion

- Decarbonizing the Transportation sector is very crucial to meet the Global climate targets for 2030 and 2050.
 - Transportation sector accounts for nearly $\frac{1}{4}$ of the global energy-related GHG emissions in 2019.
- The increasing energy demand and the growing number of vehicles on roads are the main obstacles.
- Policy regulations should ensure targets for reducing Carbon emissions during the lifecycle of transport infrastructures as well as during the management and operation phase through technology improvements and alternative sustainable measures.



The slide features a blue header with the word 'Conclusion' in white. The main content is a list of three bullet points. The first bullet point is blue, and the second and third are red. The first bullet point has a sub-bullet point in red. A red underline is drawn under the text 'nearly 1/4 of the global energy-related GHG emissions in 2019.' in the first bullet point. A small inset video frame is located on the right side of the slide, showing a man in a dark suit and white shirt speaking. The background of the slide is white with a blue header and footer. The footer contains several logos, including the Swachh Bharat Mission logo.


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)

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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.