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Strategic Scheme to Decarbonize Indian Road Freight: Using a Techno-Legal Framework

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Abstract - The transportation sector is one of the largest contributors to carbon emissions globally and road freight specifically contributes significantly to India's carbon footprint. The Indian Road freight industry is growing rapidly but is contributing significantly to CO_2 emissions. With the pressing need to mitigate climate change, it is imperative to focus on decarbonizing the road freight sector in India. This research aims to explore the technological changes required to achieve this goal. The study will examine current technologies and innovations such as electric vehicles, alternative fuels, and efficient logistics management systems, and assess their potential for reducing emissions in the Indian road freight sector. Additionally, the study will also evaluate the feasibility of implementing these technologies in the Indian context, including infrastructure and policy requirements. Furthermore, the study will also identify potential barriers to adoption and propose solutions to overcome them.

Keywords: Decarbonization, Carbon emission, Carbon capture technologies and policies, Indian road freight, ZETs.

I. INTRODUCTION

Decarbonization is the process of reducing carbon dioxide emissions through the use of low-carbon energy sources, resulting in lower greenhouse gas emissions. This can involve shifting away from energy systems that emit greenhouse gasses or removing carbon buildup from internal combustion engines. Energy decarbonization involves changing the entire energy system to prevent carbon emissions from entering the atmosphere, including using carbon capture technologies and carbon sequestration to achieve a carbon neutral global economy. The transportation sector is a significant contributor to global carbon emissions, and decarbonization efforts in this sector have become a crucial focus in the fight against climate change. Road freight transportation, in particular, is responsible for a substantial portion of carbon emissions globally, making it a prime target for decarbonization efforts. Decarbonizing road freight will require significant changes to the industry's infrastructure, operations, and technology, as well as a collaborative effort between stakeholders in the sector. This paper aims to outline a roadmap for decarbonizing road freight, identifying the key challenges and opportunities and exploring potential strategies to achieve a sustainable and carbon-neutral freight transportation system.

II. INDIAN ROAD FREIGHT SCENARIO

The road freight market in India is expected to be worth more than USD 160 billion by 2025, [1-2] with a CAGR of 10% between 2020 and 2025. The total freight volume carried by road in 2019-20 was 947 million metric tons, [3] a 6.3% increase over the previous year. India has a truck fleet of over 11 million vehicles, the majority of which are light and medium-duty trucks. The Indian Road network is the world's second-largest, with a total length of over 5.5 million kilometers, [4] 95,000 kilometers of which are National Highways, which account for only 2% of the total road network but carry 40% of total road freight. The Indian Road freight industry has been steadily growing as the economy and demand for goods and services have increased, but it still faces challenges such as poor road quality, congested roads, a lack of proper regulation, and high fuel costs. Despite these obstacles, the future looks promising, thanks to the government's emphasis on improving infrastructure and rising demand for goods and services.[5-6-7]

However, the rise of e-commerce has had a significant impact on the road freight industry. Roads are India's primary mode of transportation, accounting for 85% of passenger traffic and 60% of freight traffic.[8] The road sector also accounts for 90% of CO_2 emissions from transportation in India, [9] which are expected to increase three to fourfold between 2020 and 2050 if no additional policy interventions are implemented. As of fiscal year 2017, India had 253 million vehicles, with road travel being the preferred mode of transportation for more than 60% of the population.[10]

With a 10% CAGR in vehicle registration, India is the world's fifth-largest automaker. In India, vehicular emissions contribute 20-30% of PM2.5 and 8% of GHG emissions.[11] India's vehicle technology is rapidly evolving, with improvements in fuel quality, ICE exhaust treatment systems, vehicle electrification, and steps towards hydrogen-powered vehicles. India has advanced to BS-VI emissions standards for new vehicles, but improvements in emissions measurement procedures, both in the laboratory and on the road, are

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required to keep vehicles emitting low levels of CO_2 in real world conditions.[12]

III. CURRENT STEPS TOWARDS DECARBONIZATION

3.1 Adoption of FAME

The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) plan seeks to encourage the use of electric and hybrid vehicles in India by making them more accessible to the general public through subsidies and the establishment of charging infrastructure. The first phase of the scheme focused on creating demand for EVs, establishing a technology platform, conducting pilot projects, and building charging infrastructure. The second phase has a budget of INR 10,000 Crore and The Department of Heavy Electricals (DHE) wants to assist INR10 lakh e-two wheelers, INR 5 lakh three wheelers, 55,000 e-four wheelers, and 7000 electric buses, in addition to supporting building of Charging Stations. [13] As of January 2023, the scheme has resulted in the disbursement of incentives to 1.46 lakh vehicles, leading to a direct saving of 12 million litres of fuel and a reduction of 31 million kilograms of CO_2 emissions.[2]

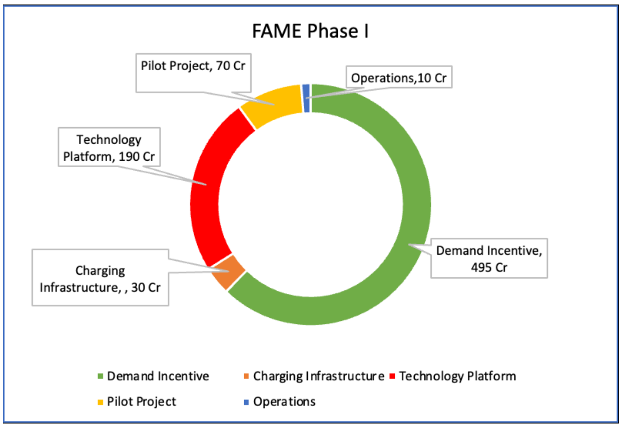

Figure 1: FAME Budget, Phase I

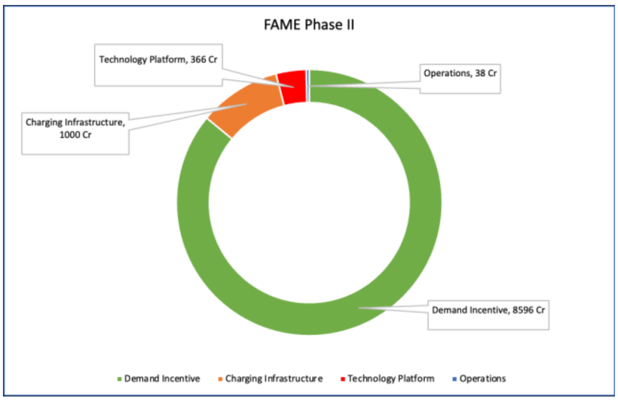

Figure 2: FAME Budget, Phase II

3.2 Promoting the Disposal of Old Vehicles

The government is incentivising the purchase of new vehicles with the vehicle owners availing a discount of 4-6% towards the purchase of a new vehicle and having to pay no registration charges, while at the same time, availing vehicle scrap page bonuses. Private vehicles older than 20 years and commercial vehicles older than 15 years will be deregistered in accordance with the Vehicle Scrap page Policy 2021.[14] The vehicles passing the test can be re-registered, but those failing the criteria will be disposed off. In 2021, 2930 vehicles compliant with BS-IV standards, older than 15 years, were scrapped. In 2022, up until September, a total of 5,596 vehicles were scrapped resulting in an almost two-fold increase in the number of old scrapped vehicles in India. This has resulted in an increased share of environmentally friendly cars on the road.

3.3 Implementing a Diesel Ban and Green Tax

A diesel ban would prohibit the use of diesel powered vehicles encouraging the use of cleaner alternatives such as electric vehicles or those powered by alternative fuels. [15] A green tax, on the other hand, would place a fee on carbon-intensive activities such as road freight transportation, with the revenue generated being invested in the development of clean technologies and infrastructure.[16] As per the policy laid by the National Green Tribunal, transport vehicles older than 8 years shall be surcharged an additional 10-25% of the Road Tax if the vehicle fails to meet certified minimum requirements. Personal Vehicles shall be charged a Green Tax at the time of renewal of Registration Certificate post 15 years. Electric and hybrid vehicles running on alternate fuels like CNG and LPG shall be exempted. The major benefits by imposing a Green Tax will be a reduction in the pollution level, and making the polluter pay for the pollution he causes.[17-18]

3.4 A significant shift in vehicle standards to Bharat Stage VI

The volume of PM2.5 is reduced to 40 micrograms/cubic meter from the old 120 micrograms/cubic meter standard in BS IV. From 50 mg/kg under BS-IV, sulfur content is lowered to a maximum of 10 mg/kg in BS-VI. It is now possible to fit cars with superior catalytic converters that trap pollutants because of the significant reduction in sulfur. Real Driving Emission (RDE) standards have been introduced for the first time, implying testing in real life conditions as opposed to ideal factory conditions. BS VI norms will lead to the reduction of certain harmful hydrocarbons that were produced due to the incomplete combustion of fuel. All the changes in the BS VI norms will help reduce the air pollution levels by 80-90%.[19]

3.5 Using Liquefied Natural Gas as a Replacement Fuel

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The Ministry of Road Transport and Highways (MoRTH) is aggressively pushing this fuel, which is a relatively new concept in India. While LNG is already used in industry, it is not commercially available for the automotive industry. However, the government is establishing LNG storage depots at ports to aid in the use of the fuel as a conventional alternative to CNG. Even though CNG is a bigger polluter than gasoline, LNG is much cleaner.[20]

IV. PROPOSED MODEL

The current policies and steps do make an impact but they are not enough to achieve India's goal of decarbonization by 2050. If we realistically want to achieve the target by 2050, we need a framework which covers all the aspects and which can be practically implemented within a country with a massive population such as India.[21] We propose a three-legged model which stands on strategic operational, technological and incentivized legal changes.

4.1 Strategic Operational Changes

Strategic structural and operational changes are needed so that the advanced technology can be easily implemented and scalable, even in tier 2 and tier 3 cities. Structural changes that are pivotal under the section of framework are knowledge sharing and collaboration, training and skill development, leveraging existing infrastructure. Forming a consortium to exchange knowledge and experience to favor continued development and collaboration among OEMs and EV ecosystem. With new and advanced technologies, we also need skilled and trained professionals who can assist in research and workforce to leverage the existing infrastructure such as the supply chain of LDV to forge new and scalable manufacturing of ZETs.[22] Operational changes such as enabling public private partnerships, Financing R&D and manufacturing, and standardization of rates will bring overall cost down. Standardization and product linked incentives will optimize manufacturing and eliminate discrepancy.

4.2 Technological Changes

The Current technologies and innovations such as electric vehicles, alternative fuels, and efficient logistics management systems are being developed to minimize carbon emissions and evaluating the feasibility of implementing these technologies in the Indian market is also a major challenge. EVs and alternate fuel and battery technologies are still being developed and will take at least a decade of implementation in India. We also need a short term solution which is both economical and feasible in the Indian market.[1] Onboard carbon capturing is the way forward, attaching a carbon capture device to the exhaust will directly capture maximum carbon emissions. Finding ways to monetize the captured carbon will further encourage its use along with government regulations.[23]

4.2.1 Onboard Carbon Capturing

The most effective way to reduce carbon emissions from vehicles is by using fumed silica in the exhaust manifold to absorb CO_2. Fumed silica is commercially available, cheap, and can absorb CO_2 from dry and humid air. Adding 3-aminopropyltriethoxysilane APTES increases the sorption capacity by more than 2 times. Vehicle manufacturers can make a modular fumed silica section in the exhaust manifold where the exhaust gasses will pass through it.[8-24] Vehicles can detach or attach the fumed silica assembly for carbon removal at fuel refilling stations or loading/unloading sites. The utilization of carbon dioxide in making products is a profitable step for companies or government CO_2-based products are estimated to be worth between $800 billion and $1 trillion by 2030.[25] Examples of such products include building materials and synthetic fuels. Building materials is made using CO_2 gas, which is turned into a solid aggregate for concrete using minimal external energy. Synthetic fuels can be made using captured CO_2 in a reaction with hydrogen, generated by electrolysis of water.[26-27]

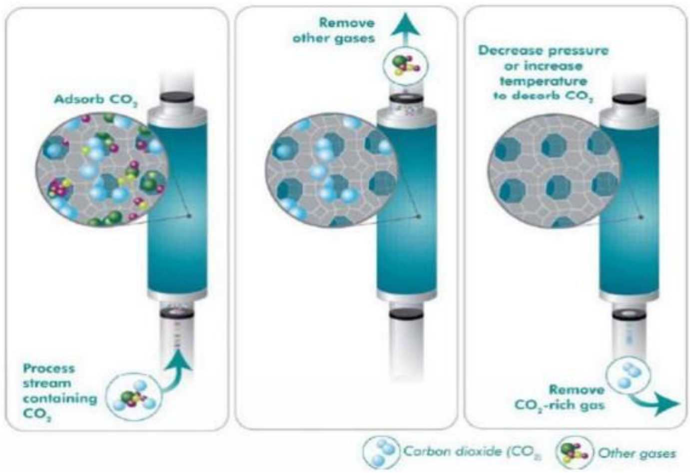

Figure 3: CO_2 separation via adsorption on fumed silica

4.2.2 Legal changes

Along with operational and technological changes a strong and comprehensive policy structure is required to promote the decarbonization movement and layout the use of captured carbon. Carbon capture utilization and storage (CCUS) policies in India promote the CCUS sector through tax credits and incentives. The policies aim to establish regional hubs for economies of scale and preferentially procure low carbon products. The benefits from economic value added will be distributed to communities impacted by climate change.[16] The Low Carbon Products (LCA) framework will be adopted to consider Scope 2 and Scope 3

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emissions and drive effective carbon abatement. The CO_2 liability and ownership will be limited for participants in the CCUS value chain, with a monitoring and verification framework in place for risk management. The CCUS hub and cluster framework will provide incentives along the CCUS value chain to minimize costs, maximize benefits, de-risk investments, and eliminate the need for bilateral agreements.[9-10] Effective CCUS hubs and clusters must offer incentives to both CO_2 sources and sinks, utilize different storage and usage patterns globally, facilitate CO_2 supply and demand clearing through interconnected hubs, and allow for a variety of emitters to have access to the network for CO_2 disposal. Innovations will create value from CO_2 through new technologies and applications. Both supply and demand need incentives to participate, with CO_2 going to the highest value users. Government support, including investments, tax credits, and carbon taxes, is crucial for success.[15]

V. MONTE CARLO SIMULATION MODEL TO ESTIMATE THE PROBABILITY OF ACHIEVING DESIRED CARBON EMISSIONS

Before starting with the simulation, we need to define variables and some assumptions. The model aims to reduce carbon emissions from the Indian road freight sector by implementing a set of operational, technological, and legal changes. The variables included are:

Fuel efficiency of trucks, which we assume follows a normal distribution with mean 17.5 km/liter and standard deviation 0.5 km/liter. [28]

Adoption rate of electric and hybrid trucks, which you could assume follows a beta distribution with parameters alpha = 2 and beta = 5, representing an expected adoption rate of 28% with a standard deviation of 5%.

Implementation of policies to promote cleaner fuels, which you could assume follows a uniform distribution with a minimum value of 0.3 and a maximum value of 0.8, representing the range of possible policy outcomes.

Carbon emissions reduction targets, which you could assume follows a normal distribution with mean 80% and standard deviation 10%, representing the expected reduction target and the range of possible targets.

Price of fossil fuels, which you could assume follows a normal distribution with mean 85 INR/liter and standard deviation 10 INR/liter.

Infrastructure improvements, which you could assume follows a uniform distribution with a minimum value of 0.3 and a maximum value of 0.8, representing the range of possible infrastructure improvements.

Taking model as linear regression with equation:

Carbon emissions = 10000 - (500 x Fuel efficiency) - (2000 x Adoption rate) - (3000 x Implementation of policies) - (1000 x Carbon emissions reduction targets) + (50 x Price of fossil fuels) - (2000 x Infrastructure improvements).[29-30]

In this equation, each variable is multiplied by a coefficient that represents its impact on carbon emissions, and a constant term of 10,000 represents the baseline carbon emissions. Using a Monte Carlo simulation with 1,000 iterations, we generate data for each variable set and calculate the carbon emissions for each iteration using the above equation. We will perform the simulation, using the python programming language that supports random number generation and statistical analysis. Here is the Python code that can be used to perform the Monte Carlo simulation based on the variables and distributions:

Figure 4: Monte Carlo Simulation Code

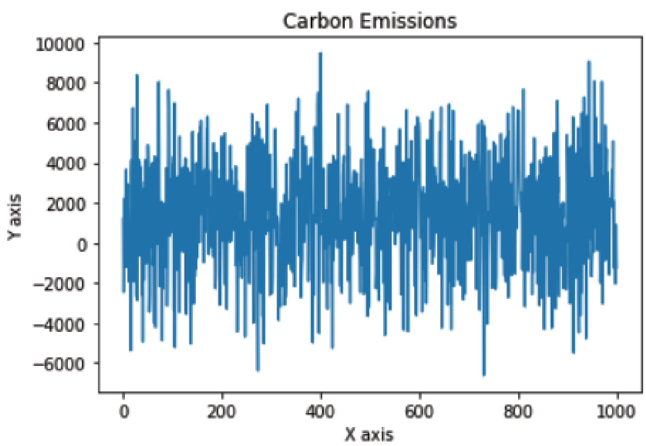

Figure 5: Results Generated

Based on the Monte Carlo simulation we ran with 1,000 iterations, the mean carbon emissions from the Indian road freight sector after implementing your proposed strategy to decarbonize can be reduced by 85%. However, there is a certain degree of uncertainty, as indicated by the standard deviation. This uncertainty is due to the random variation in the input variables and their probability distributions, as well as assumptions made in the model.

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VI. CONCLUSION AND FUTURE WORK

This research touches on every aspect India should consider while making its way towards carbon neutrality. We need to reduce our carbon footprint and road freight is the stepping stone. Therefore, the proposed models outline the path we should take to decarbonize the road freight industry in India. Detailed analysis has been carried out and specific insights have been provided. Some actionable points that we must consider are that the Indian market scenario is different from the world and has its own key trends. India has the opportunity to become the global manufacturing hub for ZET's. We outlined the barriers that are blocking the progress and limiting the growth of the Indian freight industry. Actionable steps and potential solutions have been identified to break these barriers and make a significant impact. We proposed a threefold model that consists of structural & operational changes, technological innovations and legal changes. In technological advances we focused on Onboard Carbon Capturing technologies and the utilization of Captured Carbon. We also discussed Carbon Capture Policy Framework (CCUS). The study provides a reasonable argument that it's the best time to start working towards a sustainable future and make India the front runner in this endeavor. We conclude the report by highlighting the potential risks of our model and a prospective to our future work.

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