EGROW
Foundation for Economic Growth and Welfare

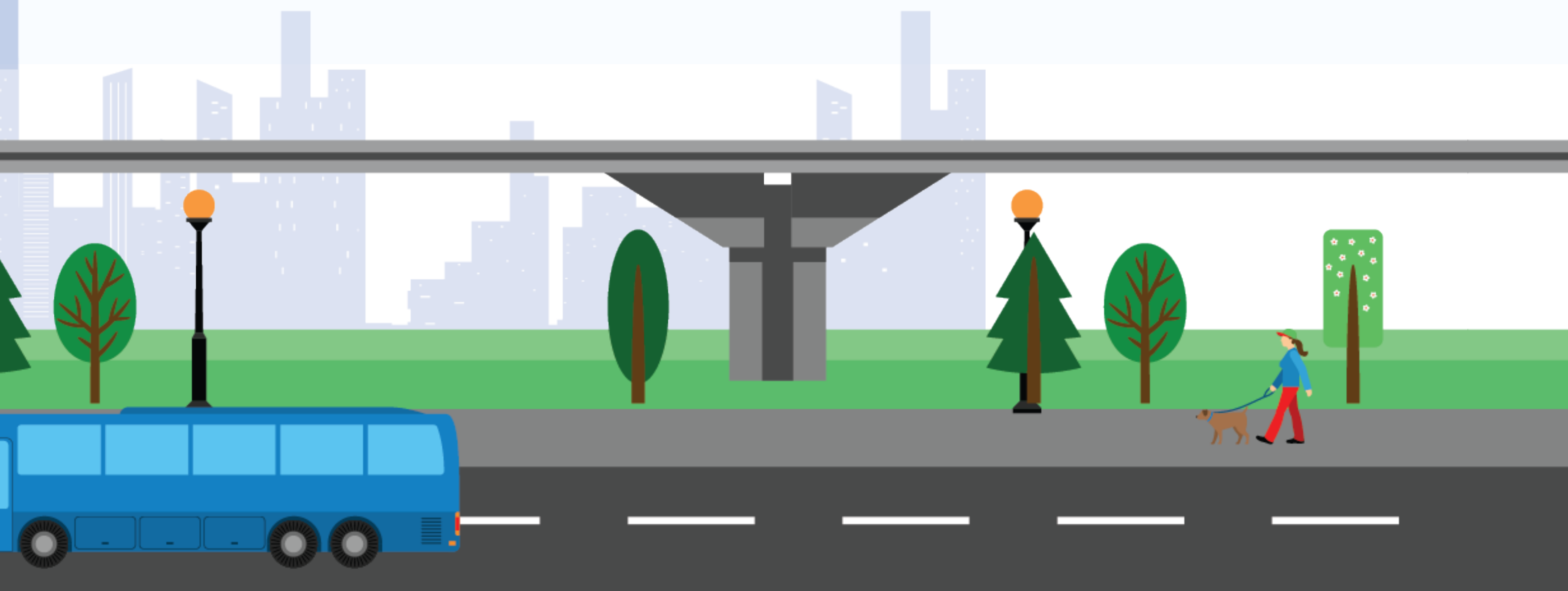
PRIMUS PARTNERS

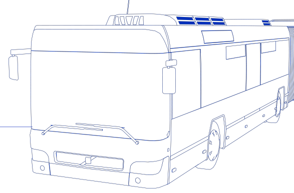
RETROFITTING OF INTER-CITY DIESEL PASSENGER BUSES

An Economic Analysis and Policy Prescriptions

June 2024

CONTENTS





FOREWORD

DR. CHARAN SINGH
Chief Executive Officer,
EGROW Foundation

MR. DAVINDER SANDHU
Chairperson & Co-Founder,
Primus Partners

Climate change has presented a major challenge to long term growth and prosperity across the world. It directly impacts economic well being of individuals and countries through macroeconomic developments and financial policy instruments. Climate change, is infact, the biggest elephant in the room. The policy makers are addressing this issue by various means like transition to green economy, low carbon transport, and emphasis on renewable energy, especially adopting solar power.

In India, the government has undertaken a strong initiative to address the issue of climate change. In 2021, in Glasgow, India presented a fivefold action plan and committed to achieve net zero emission by 2070. Since then, our monetary and fiscal policies are focused on this subject. In India, where road transport alone accounts for 90 percent of total energy consumption, the need for sustainable solutions is pressing, particularly in densely populated urban areas grappling with air pollution and congestion.

The report, "Retrofitting of Inter-city Diesel Passenger Buses: Economic Benefits Analysis and Policy Prescriptions," provides a comprehensive examination of how retrofitting diesel-operated buses to electric propulsion systems offers a viable and impactful strategy for India. It provides a detailed analysis, revealing that retrofitted buses significantly reduce operating and maintenance costs compared to both traditional and new electric buses. The economic benefits of this approach are profound, extending beyond mere financial savings to broader economic revitalization and environmental improvements. Retrofitting offers a pragmatic solution, leveraging existing infrastructure while transitioning towards cleaner mobility. It represents a critical step towards sustainable urban transport, demonstrating how innovation and policy alignment can drive tangible progress.

The report also outlines policy recommendations aimed at catalyzing widespread adoption of retrofitting across India. The select recommendations are: pilot programs to revising the vehicle scrappage policy, providing subsidies for retrofitting, introducing exclusive finance schemes, and encouraging R&D in retrofitting technologies and electric batteries. Further, the Report recommends integrating retrofitting incentives into the Faster Adoption and Manufacturing of Electric Vehicles (FAME III) policy could significantly accelerate the adoption of electric vehicles, particularly for State Transport Undertakings which are pivotal in this transition.

In addition to the economic and environmental benefits outlined in the Report, nationwide workshops and service centres dedicated to retrofitting operations can be strategically placed near urban centres with high demand for bus conversions. This localized approach will not only reduce logistical costs but also increase the efficiency of the transition to electric buses, making sustainable transportation more accessible and feasible. The decentralizing of the retrofitting process through nationwide workshops, could serve as a catalyst for employment creation, directly supporting the workforce engaged in retrofitting tasks. It will also benefit related MSMEs engaged in supporting industries engaged in manufacturing components and providing maintenance services. This localized industrial activity will also foster regional economic growth.

As our country embarks on this journey towards a cleaner, more sustainable future, collaboration and innovation will be the key. By embracing the opportunities presented by retrofitting, India will not only reduce its carbon footprint but also stimulate economic growth, foster technological innovation, and improve public health .We trust that the insights and recommendations presented herein will serve as a guiding force for meaningful actions, helping India move decisively towards a sustainable, prosperous, and environmentally responsible future.

EXECUTIVE SUMMARY

The escalating concerns surrounding climate change have prompted a global shift toward adopting greener technologies, particularly in pollution-intensive sectors like transportation. This report delves into the economic and environmental incentives of retrofitting diesel-operated passenger buses in India, a significant contributor to the sector's carbon emissions.

Through a comprehensive analysis spanning economic, technical, and policy dimensions, this study identifies retrofitting as a feasible transitional strategy to accelerate the adoption of electric vehicles (EVs).

Retrofitting involves replacing the internal combustion engine of buses with electric counterparts, a measure that not only curtails emissions but also extends the vehicle's operational life, thereby enhancing economic returns and contributing to environmental sustainability. The detailed analysis reveals that retrofit buses significantly reduce operating and maintenance costs compared to traditional and new electric buses. Particularly, when considering the lifespan and daily operational parameters, the cost per kilometre for retro-fitted buses emerges substantially lower, reinforcing the economic argument for retro-fitting. The financial analysis reveals that retrofitting can achieve a faster return on investment (ROI), making it an attractive option for bus fleet operators and government authorities alike.

Transitioning to a circular economy approach in the transportation sector, retrofitting significantly impacts the economic landscape. Research shows that such shifts in policy and operational frameworks can decrease greenhouse gas emissions and boost employment. In the context of India, where there is a targeted goal to generate upwards of three crore green jobs by 2047, retrofitting supports this vision by creating direct and indirect employment opportunities in the retrofitting process itself as well as in the growing sectors of battery and charger production, and other EV-related accessories.

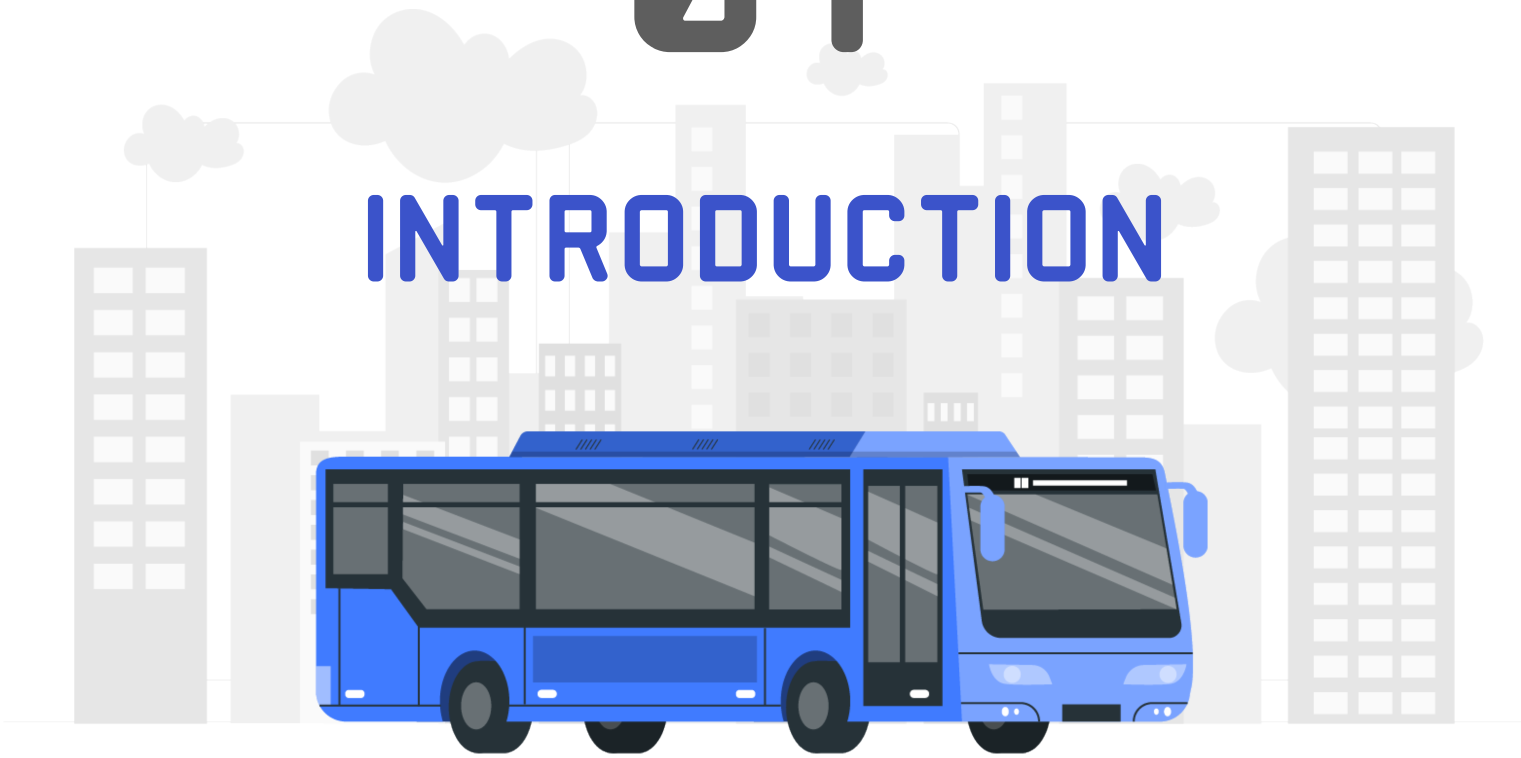
Policy initiatives play a crucial role in encouraging the shift towards retrofit buses. Recommendations include revising vehicle scrappage policies to extend the life of retrofitted buses, providing subsidies for retrofitting, and introducing financing schemes targeted at older buses. Additionally, fostering research and development in retrofitting technologies and electric batteries can further reduce costs and improve the efficiency of retrofitted buses. Incorporating incentives from the Faster Adoption and Manufacturing of Electric Vehicles (FAME) Phase III policy can also expedite this transition, providing crucial financial support.

To effectively gauge the viability and optimize the process of retrofitting diesel buses, implementing scaled pilot projects across varied geographic and operational environments within India is recommended. These projects will help assess performance improvements, cost-effectiveness, and environmental benefits, offering benchmarks and data crucial for scaling up this initiative nationally.

This report advocates for an integrated approach involving policy revision, financial support, and technology advancement to overcome barriers and realize the extensive benefits of retrofitting diesel buses. By doing so, India can make significant strides toward achieving its climate goals and enhancing urban mobility sustainably, catalysing economic growth and environmental conservation while promoting substantial employment generation in the green economy sector.


ELECTRIC
BUS

01 INTRODUCTION



The concern over climate change is steadily increasing thereby forcing global economies to adopt environment-friendly technologies in pollution-intensive sectors, among others (Pamidimukkala, et al, 2023). With economic development, more and more developing economies are facing these challenges (Ali and Oliveira, 2018).

Globally, the transportation sector is the second largest carbon-emitting industry (Pamidi-mukkala, et al, 2023), which is responsible for approximately 25% of the total Green House Gas (GHG) emissions from energy utilization (CSE, 2021).

The transportation sector is the third most GHG emitting sector in India accounting for 13% of the total GHG emissions (PIB, 2020). Within the transport sector, road transport accounted for 90% of total energy consumption (Hagemann, et al, 2020).

These emissions have more than tripled since 1990 due to increasing motor-ization and demand for mobility thereby causing air pollution, and congestion as well as increasing GHG emissions in urban areas (PIB, 2020). This calls for urgent and immediate measures for pollution abatement through the adoption of environment-friendly technologies.

Decarbonization of the road transport sector must assume priority. One of the pathways for decarbonization is moving away from diesel and petrol vehicles towards more eco-friendly options such as Electric Vehicles (EVs) (The Energy and Resources Institute, 2021). But this can be done on a gradual basis as the adoption of EVs and the development of electricity charging infrastructure would take time and call for heavy investments. In the road transport sector, diesel-operated passenger buses account for a major share of all intra-city and inter-city transport.

The manufacturing sector is presently undergoing two significant changes: the introduction of technology-driven manufacturing through Industry-4.0 (I-4.0) and the substitution of environmentally friendly electric vehicles (EVs) for fossil fuel-powered mobility vehicles. One of the industries with the quickest rate of growth now is e-mobility. According to the report by the International Energy Agency, the e-mobility market is one of the fastest-growing sectors and has increased by 30 percent, which means it has reached 7.2 million in 2019 from 2 million in 2016 (IEA, 2024).

The globe is seeing a rapid shift from fossil fuel-powered automobiles to more environmentally friendly electric vehicles (EVs). It is anticipated that the tremendous increase in EV sales will put a strain on the use of material resources for batteries made of earthly metals. On the other hand, resource management may be solved sustainably in the electric vehicle battery ecosystem through the application of a circular economy (Ojha and Agarwal, 2023).

It is expected that the number of buses will grow in the coming years, though at present the share of electric buses is just 0.2% (International Energy Agency (IEA) and NITI Aayog, 2023). It is expected that given the strong push for electrification under the FAME scheme, the share of electric buses will increase to 8% in 2030 and further to 25% in 2050. To accomplish the target, nearly 20000 buses need to be deployed annually, which will be difficult given the financial and environmental constraints.

For diesel-operated passenger buses, moving from internal combustion engine (ICE) to EV retrofitting can be a potential transitional solution to improve the shift towards the adoption of EVs. It can be a via media for decarbonization. Given the financial and environmental challenges, retrofitting can be an economical and smarter alternative. This can add to the pace of EV adoption and boost the speed of EV infrastructure development (Hoeft, 2021).

However, before developing a strategy for retrofitting diesel-operated buses, it is imperative to understand the concept of retrofitting, retrofitted buses as an alternative to diesel-operated and new EV buses, the possible costs, and benefits as discussed in the empirical literature.

This will help us to derive appropriate policy recommendations. Accordingly, a literature backup is provided to appreciate the issues relating to retrofitting.

02

WHY RETROFITTING?

A LITERATURE BACKDROP

Transport is a major source of air pollution and therefore a steady growth of the transport sector poses severe challenges for environmental sustainability globally. Particularly, in non-OECD countries, transport emissions have grown at a much faster rate than in OECD countries since 2000 (World Economic Forum, 2022). The transportation sector accounts for the second largest carbon emissions globally (Pamidimukkala, et al, 2023), and the third largest in India (IEA and NITI Aayog, 2023). It is one of the fastest emission-generating sectors in the country, along with industry (IEA, 2024).

Within India's transport sector, road transport accounted for 90% of total energy consumption (Kumar, et al, 2022). Air pollution from road transport has detrimental effects on both air quality and human beings' health (Singh, et al, 2021). At present, road transport primarily utilizes petroleum, the majority of which is imported, causing a huge burden on India's foreign exchange reserves as well.

Petroleum, Oil and Lubricants (POL) imports accounted for more than 30% of the total import bill in 2022/23 (Ministry of Finance, 2023).

Further, in its Nationally Determined Contribution (NDC) under the Paris Agreement, India has committed to bring down the CO_2 emissions intensity of its GDP by 33% to 35% below 2005 levels by 2030, which is a huge responsibility (Hagemann, et al, 2020).

India aims to achieve net zero carbon emissions by 2070 (IEA and NITI Aayog, 2023). Decarbonization of the transport sector would create a cleaner, healthier, and more affordable future (PIB, 2020).

Therefore, as part of the decarbonization strategy to achieve a net zero-emission environment, there has been an increasing emphasis on the adoption of electric transport.

Among the various modes of road transport, bus transport assumes significance as it accounts for a considerable share of CO_2 emissions from the overall transport sector (The Energy Resources Institute (TERI), 2021).

The transport sector poses a huge challenge for emission reductions as reducing emissions in the transport sector is more costly than in any other sector and the reason is that transport still heavily relies on fossil fuels (Santos, 2017). Another dimension of challenge for reducing the CO_2 emissions from the road transport sector is the high cost of clean technologies (Santos, 2017).

However, the steadily growing concern over climate change and the need to achieve environmental sustainability force global economies including India to employ alternative fuel technology to combat the vehicular emissions of GHGs (Pamidimukkala, et al, 2023).

Conventional gasoline and diesel automobiles, also known as internal combustion engines (ICE) produce greenhouse gas emissions such as carbon dioxide (CO_2), sulphur hexafluoride (SF6), carbon monoxide (CO), hydrocarbons, nitrogen oxides (N_2O), soot, and particulate matter. The main benefit of an electric vehicle is that its tailpipe emits no pollutants. Electrification of vehicles is considered a key component in the shift to environmentally friendly urban transportation. [1]

The most recommended path for decarbonization is to shift from internal combustion engines (ICE) to electric vehicles (EVs) (JMK Research & Analytics, 2022; CSE, 2022). EVs are considered energy efficient, generating less GHG emissions and reduced noise (Khurana, et al, 2020). But this calls for huge investments, because clean technologies are more expensive than carbon-intensive technologies, especially in the transport sector (Hepburn, 2015). Further, there are technological, environmental, financial, and infrastructure barriers to the adoption of EV vehicles (Pamidimukkala, et al, 2023).

[1] https://jmkresearch.com/how-electric-vehicle-retrofitting-can-be-a-viable-solution-to-limiting-vehicular-emissions-in-india/

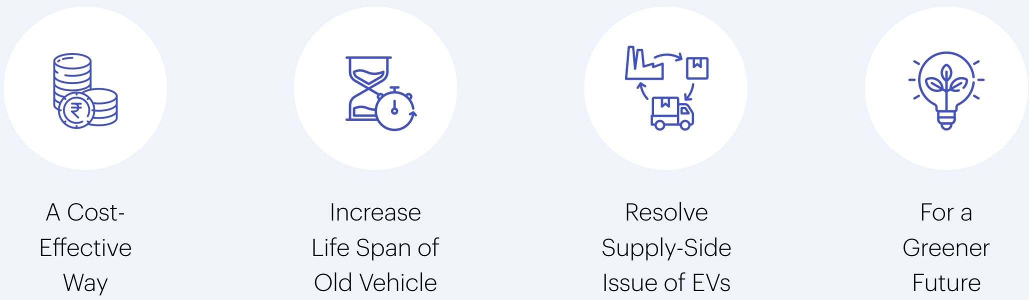
Despite technological advancement in the emission efficiency of vehicles, aggregate pollution levels continue to rise due to the ever-increasing number of vehicles on the road. Given this context, retrofitting to EVs emerges as a cost-efficient, fast, and adaptable solution that opens the possibility of replacing conventional internal combustion engines with cleaner and more efficient electricity battery-powered units. Retrofitting stands out as a viable option that strikes the balance in the ongoing shift towards electrification of the transportation ecosystem (Ravi et al., 2023).

Retrofitting refers to converting current gasoline or diesel-powered vehicles to run on electricity. The procedure entails swapping out the original engine and any associated parts for a new alternative energy source that will be installed inside the current vehicle body.

Not only would the retrofitting help the environment, but it will also enable individuals to keep using their expensive vehicles rather than having them demolished.[2] India's adoption of EV retrofitting is driven by policy initiatives like those in Delhi, where older diesel and petrol vehicles are legally transitioning to electric through retrofitting (Karthik & Giriyapur, 2019).

The number of buses on Indian roads is expected to hit three million by 2030. Similarly, the amount of other public transit will increase at the same rate. If we continue to add electric public vehicles to the existing fleet in the guise of reducing carbon footprint, our country streets will grow clogged. Thus, retrofitting the existing buses is one of the best solutions. This will not only keep the number of autos in check, but it will also reduce vehicle emissions (Figure 1).

FIG 1 **BENEFITS OF RETROFITTING**



Source: Primus Partners' and EGROW's creation

[2] https://ev.delhi.gov.in/retro-fitment#:~:text=Electric%20Vehicle%20Retro%2Dfitment%20means,into%20the%20existing%20vehicle%20body

Bus transportation is crucial for mitigating city traffic congestion and reducing emissions. In Shenzhen, diesel-powered buses accounted for 20% of vehicle emissions but accounted for 0.5% of the city's vehicle fleet. E-buses, powered by electricity and with zero emissions, are advocated to replace traditional buses. The Chinese government has introduced policies with massive financial subsidies to support bus electrification, with an estimated 5 million EVs by the end of 2020. The Chinese government has prioritized the construction of charging infrastructure for public service vehicles, such as buses, taxis, and sanitation vehicles (Lu et al., 2018).

Electrification of mobility has been considered an option to accommodate the decarbonization demand while maintaining accessible costs. However, the pace of this transition cannot be dramatic, and thus, to complement the addition of new EVs, retrofitting existing ICE vehicles is a given requirement.

Retrofitting increases the useful life span of existing vehicles by 8 to 10 years and allows them to be exempted from the scrappage policy. This is essential to note when dealing with vehicles owned by public entities that fall under the ambit of the scrappage policy. The market for EV retrofitting is still in its infancy and has several obstacles to overcome. But this may be addressed, and the industry can expand dramatically with rising demand for EVs and state government regulatory measures.

Given the massive number of EVs required to reach carbon emission targets, retrofitting must be taken into consideration as a viable option in addition to producing new Electric Vehicles. [3]

India's transition to electric vehicles (EVs) relies heavily on the evolution and standardization of the Electric Vehicle Ancillary Industry. This involves creating ancillary clusters in cities and bolstering local manufacturing of EV parts and components. The growing retrofitting industry presents opportunities for start-ups offering retro fitment kits and a structured pathway toward standardization. The need for skilled profess-ionals and expansive manufacturing networks could stimulate the educational sector and entrepreneurial opportunities. Retrofitting also provides a real-world testing platform for new technical improvements. [4]

3 https://jmkresearch.com/how-electric-vehicle-retrofitting-can-be-a-viable-solution-to-limiting-vehicular-emissions-in-india/
4 https://primuspartners.in/docs/documents/GhA4jW0pKiMjc4jyoEgv.pdf

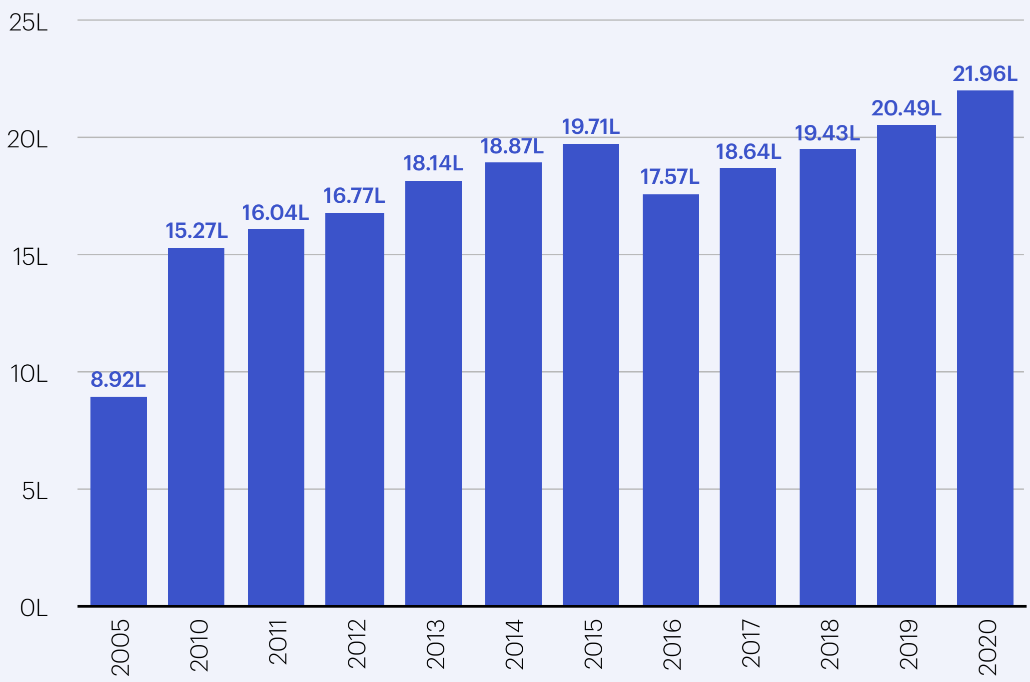
The number of vehicles on the road is rising rapidly due to urbanization and population expansion, especially in emerging economies like India where economic development is faster than the world average (PIB, 2020).

Figure 2 shows the growth of buses on Indian roads. According to Ali and Oliveira (2018), among other things, economic expansion has been identified as the primary cause of pollution and CO_2 emissions.

Even if millions of cars are produced each year, it is not a wise decision to discard existing cars, often even before their usable lives are up (Darekar et al., 2021).

Furthermore, not all of a vehicle's systems and parts will wear out as it matures and approaches the end of its useful life. Instead, if they are modified to fit into a different vehicle, some of their elements and components will still be functional (Darekar et al., 2021).

FIG 2 TOTAL NUMBER OF REGISTERED BUSES IN INDIA | 2005-2020



Source: Road Transport Year Book 2019-20

FIG 3 **RETROFIT PARTS**

Source: Darekar, et al (2021)

Building a brand-new electric bus from the ground up takes a lot of time and money. Retrofitting an existing bus, on the other hand, only entails swapping out the engine, gas tank, and catalytic converter for an electric motor, batteries, and controller in place of all the internal combustion engine components. Because the bus's body, frame, or structure aren't altered, this method is considerably quicker than building a new one and doesn't compromise safety. [5]

As a via media, ICE to EV retrofitting is recommended as a potential solution to improve the shift towards widespread adoption of EVs (Hoeft, 2021).

Retrofitting technology is an alteration process of an ICE vehicle by inducting batteries. It involves choosing the vehicle, sizing a motor, and the type of batteries. Therefore, it is considered a green mobility solution that comprises the conversion of a conventional engine-powered vehicle into an electric-powered vehicle (Darekar, et al, 2021).

The retrofitting of ICE vehicles to EVs can accelerate the transition to more sustainable transport in a resource-efficient way (Hoeft, 2021). Figure 3 represents the retrofit parts required for the conversion of an ICE vehicle to a retrofitted vehicle.

[5] https://ev.delhi.gov.in/retro-fitment#:~:text=Electric%20Vehicle%20Retro%2Dfitment%20means,into%20the%20existing%20vehicle%20body

For the entire country, there are several advantages to EV retrofitting. It may quicken the rate of EV adoption, improve EV acceptance among the public, raise the resource usage of ICE vehicles (which would otherwise be scrapped), and quicken the construction of EV infrastructure (Hoeft, 2021).

Increased retrofitting can result in cheaper operating costs for consumers, quieter operations, and a cleaner environment - that is if they are more widely implemented in public transportation systems (Hoeft, 2021). In comparison to scrappage rules, the conversion and refurbishing of existing and about-to-be scrapped vehicles will prolong their lifespan and reduce vehicle emissions more effectively (Singh, et al, 2021; Singh, et al, 2017).

Retrofitting ICE buses to make EV buses, while bringing out all the benefits of new EV buses such as reduced CO_2 emissions, and reduced petroleum imports, is assumed to be more economical and, therefore, accounts for higher ROI, lengthening the life of buses (which would have otherwise got scrapped after 10 years), and a contribution to the circular flow of the economy. However, retrofitting would require a lot of redesigning of vehicles, and if older vehicles are considered for retrofitting, refurbishment would add to the cost. This would call for a more critical technical, and economic analysis (Darekar, et al, 2021).

The Delhi Government has initiated retrofitting technology for 10-year-old diesel and 15-year-old petrol vehicles, promoting the transition to electric mobility, supported by EV Policy 2.0. The Delhi Government has allowed old diesel vehicles to continue using electric vehicles, bypassing the National Green Tribunal ban. In June 2022, the government launched a portal for retrofitting petrol and diesel vehicles, allowing customers and agencies to participate. The Vahan Portal now offers a module for retrofitting EV kits in diesel vehicles, allowing citizens to visit authorized Retro Fitment Centres for installation. [6]

Retrofitting of diesel vehicles can be a cost-effective way to reduce air pollution (JMK Research & Analytics, 2022; USEPA, 2006). Retrofitting is increasingly adopted in public transport systems to convert diesel trucks and buses into zero-emission EVs in developed countries such as Germany, France, the UK, and Norway, among others (JMK Research & Analytics, 2022). Cities in these countries are trying to get rid of diesel vehicles by going for retrofitting which would allow operators to turn quickly conventional diesel buses into electric buses. [7] Retrofitted existing buses are cheaper and faster (Green Alliance, 2022). However, retrofitting ICE buses into electric buses is an untapped opportunity in India. A retrofitted EV is considered 1.5 times cheaper than an original EV (Clean Mobility Shift, 2022).

6 https://economictimes.indiatimes.com/industry/renewables/ev-policy-2-0-here-is-delhi-governments-new-plan-to-boost-electric-vehicles/articleshow/103603640.cms

7 https://www.route-one.net/features/bus-retrofitting-looking-to-the-past-for-a-zero-emissions-future/

A diesel bus remains in the system even after purchasing a new electric bus. It is frequently moved to another fleet where it continues to release dangerous chemicals and consume diesel.

Recycling the existing resources is what retrofitting a school bus entails. The bus that burns diesel is fully removed from service and replaced with an electric vehicle that emits no exhaust. To quickly cut greenhouse gas emissions and enhance the health of school children, this nation must electrify its school buses. Refitting the current fleet of buses can assist in accomplishing this aim more quickly, with less money spent, and with waste.

Long charging time, limited driving range, limited battery life, low reliability of charging power grid, etc. are some of the technological barriers, whereas environmental barriers refer to problems with battery life and the environmental impact of battery production.

Financial barriers consist of the high purchase price of EV vehicles, adaptation cost of the electrical system, high electricity price for charging, lower resale value, etc. Infrastructure barriers include insufficient public charging stations, and insufficient maintenance and repair services, among others (Pamidimukkala, et al, 2023). Thus, there are significant adoption barriers for EVs. Perhaps that is why, EVs account for less than one percent of road vehicles in most countries (Hoeft, 2021).

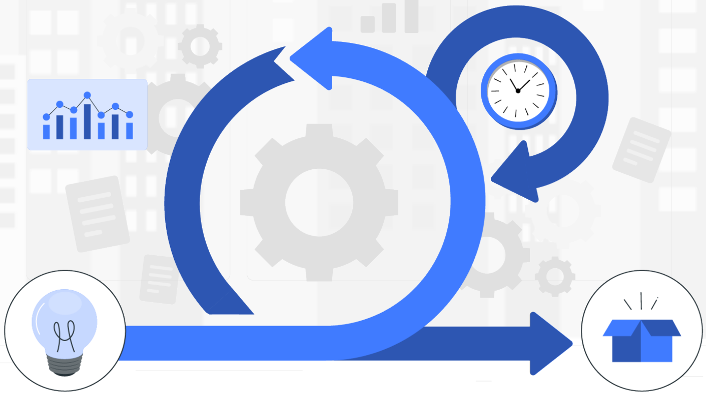
EV retrofitting can have multiple benefits for a nation at large. It can potentially increase the adoption pace of EVs, enhance public acceptance of EVs, lift resource utilization of ICE vehicles (which would otherwise be discarded), and boost the speed of EV infrastructure development (Hoeft, 2021).

Assuming that they are more adopted into public transport systems, increased retrofitting can bring lower operating costs for customers, quieter operations, and a cleaner environment (Hoeft, 2021). The conversion and refurbishment of old and scrapped vehicles will increase their longevity and it will be more effective in reducing vehicular emissions than the scrappage policies (Singh, et al, 2021; Singh, et al, 2017). Retrofitting of diesel vehicles can be a cost-effective way to reduce air pollution (JMK Research & Analytics, 2022; USEPA, 2006).

Retrofitting ICE buses to make EV buses, while bringing out all the benefits of new EV buses such as reduced CO_2 emissions, and reduced petroleum imports, is assumed to be more economical and, therefore, account for higher ROI, lengthening the life of buses (which would have otherwise got scrapped after 10 years), and a contribution to the circular flow of the economy. However, retrofitting would require a lot of redesigning of vehicles, and if older vehicles are considered for retrofitting, refurbishment would add to the cost. This would call for a more critical technical, and economic analysis (Darekar, et al, 2021).

03

CONCEPTUAL FRAMEWORK



India faces the dual challenge of increasing access to mobility and reducing emissions. It cannot electrify public transportation in one go given its financial constraints. Therefore, India must adopt the policy of incentivizing those who will be purchasing their first-ever vehicle to opt for an electric vehicle, but simultaneously converting the existing diesel-operated vehicles, especially the buses into electric vehicles.

Alternatively, it can be said that retrofitting existing fleets into electric vehicles could be a less costly transition to pollution-free electrification of road transportation from the fossil-fuel-based polluting sector. This section analyses the cost-effectiveness of retrofitting diesel-operated buses vis-à-vis a new EV.

However, there is no empirical evidence to spell out the costs and benefits of retrofitting of buses. This assumes significance in a fast-growing emerging economy like India, which faces steadily worsening urban air pollution, on the one hand, and a widening trade gap, due to steadily rising POL imports, on the other. This calls for an empirical investigation.

It is against the literature backdrop that we proposed a conceptual framework for our study (Figure 4). The conceptual framework comprises (i) inducing factors for promoting retrofitting, (ii) retrofitting costs, and (iii) expected benefits. The inducing factors are primarily (a) Paris Agreement commitment, (b) steadily rising air pollution, and (c) the need to promote environmentally sustainable development. The retrofitting costs would include costs of (a) installation of electric motors, (b) batteries, (c) wiring and controller, (d) refurbishments, and (e) system dissembling of old buses.

The expected benefits would consist of macro and micro benefits. At the macro level, benefits would comprise (a) progressing towards meeting the Paris Agreement commitment, (b) curtailing air pollution, (c) contributing towards environmentally sustainable development, (d) reducing diesel imports, and (e) contributing to the circular flow of the economy. At the micro level, benefits would emerge in the form of higher ROI and longer life of buses (for bus operators), reduced air pollution and therefore cleaner air (for society at large), reduced noise, and more economical and more comfortable travel (for commuters).

FIG 4 **RETROFITTING OF DIESEL BUSES INTO EV: A CONCEPTUAL FRAMEWORK**

Source: Primus Partners' and EGROW's creation

04

RESEARCH OBJECTIVES, SCOPE & ASSUMPTIONS

OBJECTIVES

The study has the following three research objectives:

- A. To assess the costs and benefits of EV retrofitting of diesel-operated buses plying between Mumbai and Pune
- B. To understand the need for a scaled pilot implementation of EV retrofitting
- C. To make policy recommendations for promoting EV retrofitting of diesel buses

SCOPE AND ASSUMPTIONS

The scope and assumptions of the study are described below:

1. The study is confined to diesel buses plying between Mumbai and Pune covering an approximate distance of 150 km.
2. Only equal to or more than 8-year-old diesel-fuel-based passenger buses plying between Mumbai and Pune are considered for the study.
3. Apart from retrofitting, they must be refurbished for a longer life, after retrofitting.
4. Retrofitting and refurbishment will extend the bus life for another seven years to 10 years (with a maximum total life of 15 years or 18 years).
5. Buses run from both sides between Mumbai and Pune every day (24X7).
6. Each bus will run forat least, 28 days a month. There will be a buffer of 7% buses.
7. The study period would apply to all three seasons (Monsoon, Summer & Winter).
8. Financial calculations are made for 9-meter and 12-meter buses, for a single scenario: A bus will have two single trips between Mumbai and Pune.
9. A retrofitted e-bus once charged will be able to run for about 200 km. Therefore, there is no need for an electric charging station between Mumbai and Pune.
10. An electric charging station will be installed in Mumbai and Pune, respectively. These charging stations must be manned by two persons each.
11. It is anticipated that there will not be much of an impact on employment due to the introduction of retrofitted buses. Therefore, our analysis is bereft of employment and labour cost implications.
12. A retrofitted bus is proposed as an alternative to the ICE bus on the one hand and a new Electric bus on the other. Accordingly, the financial calculations are made for Capital Expenditure (CapEx) and Operational Expenditure (OpEx) for (i) a Retrofitted bus (9-meter bus and 12-meter bus, respectively), (ii) an ICE bus, and (iii) a new Electric bus.

05

DATA SOURCES

Secondary data sources have been used for our analysis. Apart from published journal articles and reports, we have primarily used the data generated from experiments conducted

Financial benefits include rate of Return on Investment (ROI), reduction in CO_2 emissions, reduction in diesel imports, reuse and recycling of parts and components of discarded buses (including used batteries), cost of retrofitting (including the cost of dissembling), cost of refurbishment of buses, battery replacement cost (for EV buses), cost of diesel and electricity, average run of diesel, retrofitted and new Electric buses, cost of installing electric charging stations, annual subsidy for electric vehicle operation, the useful life of retrofitted buses, battery replacement cost, etc. are calculated based on these data sources.

Based on the analysis done and results obtained, we have subsequently made policy recommendations for promoting retrofitting and conversion of diesel buses into Electric buses.

06

ANALYSIS AND RESULTS

Currently, there are two types of buses plying between Mumbai and Pune:

(i) Internal Combustion Engine (ICE) diesel buses
(ii) New Electric buses

There is a significant difference in the cost of these two versions of transport buses, in terms of Capex.

As an alternative, we propose retrofitted and refurbished electric buses, the capex cost of which would involve (i) retrofitting cost, (ii) refurbishment cost, and (iii) battery cost, but its scrap would be disposed of at a price.

Further, if a battery would last long up to six years, a battery replacement would be required during its life.

Considering these cost elements, a detailed Capital Expenditure (CapEx) comparison between a new ICE bus, a new Electric bus, and three kinds of retrofitted buses, namely, a 9-meter bus with two batteries, a 12-meter bus with two batteries, and a 12-meter bus with three batteries, is presented in Table 1.

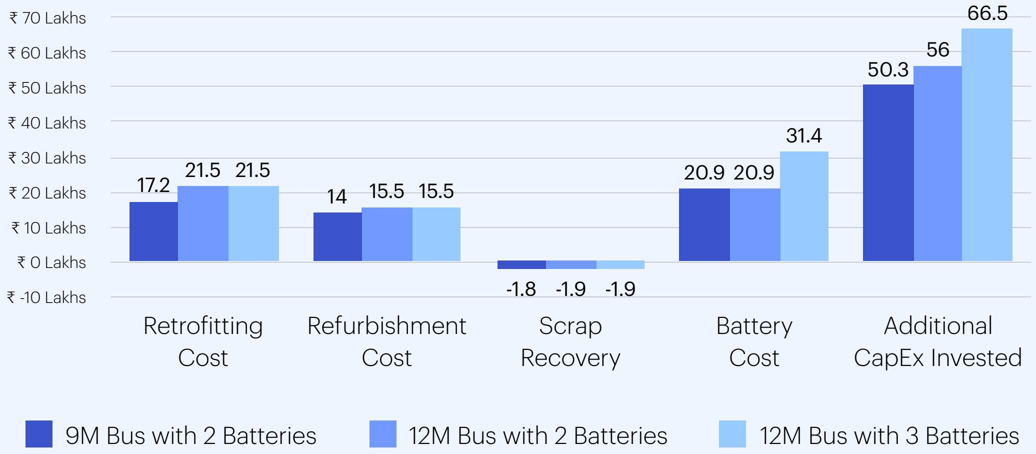
TABLE 1 CAPITAL EXPENDITURE (CAPEX) AND OPERATING EXPENDITURE (OPEX) OF BUSES

Parameters	New ICE Bus	New E Bus	Retrofitted Bus		
			9M Bus with 2 batteries	12 M Bus with 2 batteries	12 M Bus with 3 batteries
CapEx					
Vehicle cost	45,00,000	1,40,00,000	4,50,000	4,50,000	4,50,000
Additional CapEx Investment required		-	50,31,500	55,96,500	66,46,500
Battery Replacement Cost I		15,35,975	15,35,975	15,35,975	23,07,821
Battery Replacement Cost II		23,07,821			
OpEx					
Fuel cost per year	20,00,000	11,19,000	9,25,000	11,10,000	11,10,000
Annual maintenance cost	6,50,000	6,00,000	3,05,000	3,05,000	3,05,000
Annual subsidy for Electric vehicle operation			-1,00,000	-1,00,000	-1,00,000
Total OpEx Incurred	26,50,000	17,19,000	11,30,000	13,15,000	13,15,000
Opex Savings Fuel			10,75,000	8,90,000	8,90,000
Opex Savings Maintenance			3,45,000	3,45,000	3,45,000
Total OpEx Savings			15,20,000	13,35,000	13,35,000

Source: Primus Partners' and EGROW's creation

The broad cost components of retro-fitment and possible revenue are presented in Figure 5. While retrofitting cost, refurbishment cost, battery cost and additional CapEx investment together represent the total cost of retro-fitment, scrap recovery, and sale represent the revenue side. The CapEx recovery period for the three types of retrofitted buses is presented in Table 2 and Figure 6.

FIG 5 COMPONENTS OF RETRO-FITMENT COST



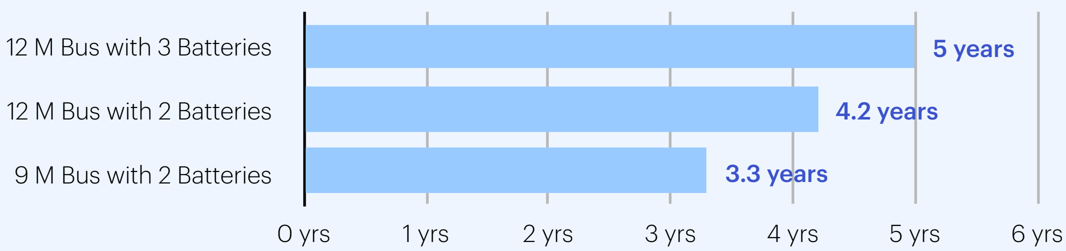
Source: Primus Partners' and EGROW's creation

TABLE 2 CAPEX RECOVERY PERIOD FOR THE RETROFITTED BUSES

CapEx Recovery Period	Retrofitted Bus		
	9M Bus with 2 batteries	12 M Bus with 2 batteries	12 M Bus with 3 batteries
In Years	3.3	4.2	5.0
In Months	40	50	60

Source: Primus Partners' and EGROW's creation

FIG 6 CAPEX RECOVERY PERIOD FOR THE RETROFITTED BUSES



Source: Primus Partners' and EGROW's creation

It is equally important to understand the economics of retrofitted bus operations in terms of per km cost, relative to an ICE bus and a new Electric bus. Table 3 presents the economics of bus operations for the different categories of buses for two kinds of scenarios: (i) a retrofitted bus will have an extended life of seven years, and (ii) a retrofitted bus will have an extended life of 10 years. The comparative economics is calculated based on the assumption that a bus will run 300 km per day, for 28 days per month, and 336 days per year. Accordingly, a bus, irrespective of its fuel, length, and number of batteries, would have run 100,800 km per year.

TABLE 3 ECONOMICS OF RETROFITTED BUSES VS. NEW ELECTRIC AND ICE BUSES

	New ICE Bus	New E Bus	Retrofitted Bus		
			9M Bus with 2 batteries	12 M Bus with 2 batteries	12 M Bus with 3 batteries
7 Years					
No. of Kilometres Run Per day	300	300	300	300	300
No. of days Vehicle Run Per month	28	28	28	28	28
No. of days Vehicle Run Per year	336	336	336	336	336
Vehicle Run Kilometres Per year	1,00,800	1,00,800	1,00,800	1,00,800	1,00,800
Useful Life of Retrofitted bus			7	7	7
Years of Operation	15	15			
Vehicle Run Kilometres over the years of operation	15,12,000	15,12,000	7,05,600	7,05,600	7,05,600
Cost Incurred over the years of Operation	4,42,50,000	4,20,92,821	1,33,91,500	1,52,51,500	1,63,01,500
Cost Per Kilometre	**29.3**	**27.8**	**19.0**	**21.6**	**23.1**
10 Years					
No. of Kilometres Run Per day	300	300	300	300	300
No. of days Vehicle Run Per month	28	28	28	28	28
No. of days Vehicle Run Per year	336	336	336	336	336
Vehicle Run Kilometres Per year	1,00,800	1,00,800	1,00,800	1,00,800	1,00,800
Useful Life of Retrofitted bus			10	10	10
Years of Operation	15	12			
Vehicle Run Kilometres over the years of operation	15,12,000	12,09,600	10,08,000	10,08,000	10,08,000
Cost Incurred over the years of Operation	4,42,50,000	4,36,28,795	1,49,27,475	1,67,87,475	1,86,09,321
Cost Per Kilometre	**29.3**	**36.1**	**14.8**	**16.7**	**18.5**

Source: Primus Partners' and EGROW's creation

Accordingly, we have calculated the total km run over its lifetime, for an ICE bus, a new Electric bus, and retrofitted buses. For the ICE bus and the new Electric bus, a uniform life of 15 years is assumed. In the first part of the table, we have calculated the total km run and cost per km for retrofitted buses, with an assumption of an extended life of seven years. The figures bring out the merits of retrofitting. While an ICE bus would cost more than Rs. 29/- per km, an Electric bus would cost almost Rs. 28/- per km, whereas a 9-meter retrofitted bus would cost Rs. 19/- per km, a 12-meter retrofitted bus (with two batteries) would cost nearly Rs. 22/- per km, and a 12-meter retrofitted bus (with three batteries) would cost slightly more than Rs. 23/- per km.

Retrofitting buses yields significant cost savings when compared to traditional internal combustion engine (ICE) buses. Here are the calculated benefits in percentage terms:

- For a standard retrofit on a 9-meter bus, the cost per kilometer is reduced by approximately 34.48% compared to an ICE bus.
- A 12-meter retrofitted bus with two batteries sees a cost reduction of about 24.14%.
- A 12-meter retrofitted bus equipped with three batteries offers a saving of around 20.69%.

When considering an extended operational life of 10 years for these retrofitted buses, the savings increase further:

- The 9-meter retrofitted bus shows a dramatic cost reduction of about 48.28% per kilometer.
- The 12-meter bus with two batteries exhibits a saving of 41.38%.
- The 12-meter bus with three batteries achieves a cost reduction of approximately 34.48%.

These figures underscore the economic advantage of retrofitting buses over continuing with traditional ICE buses, particularly when extended operational lifespans are factored in.

When comparing the cost benefits of retrofitting buses to new electric buses, the savings are also substantial:

- For the 9-meter retrofitted bus, the cost per kilometer is reduced by approximately 32.14% compared to a new electric bus.
- A 12-meter retrofitted bus with two batteries offers a reduction of about 21.43%.
- A 12-meter retrofitted bus with three batteries provides a saving of around 17.86%.

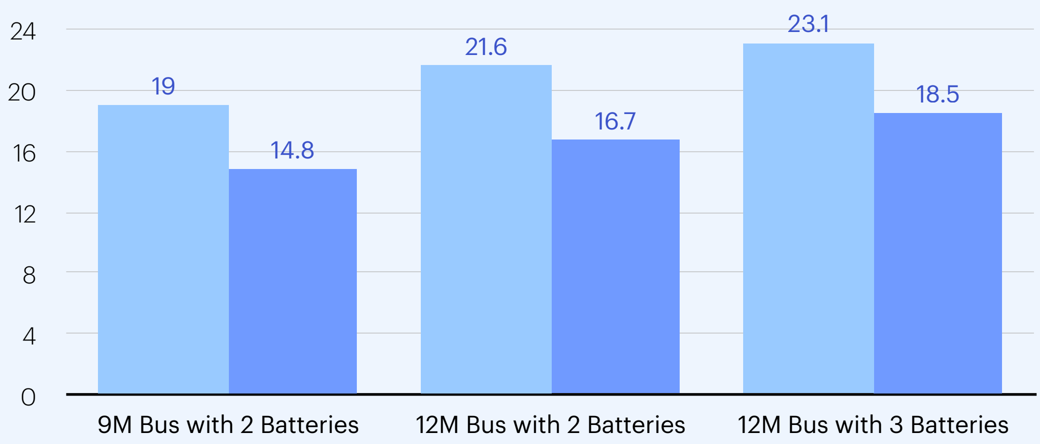
With an extended lifespan of 10 years, these savings are even more pronounced:

- For a 9-meter retrofitted bus, the cost per kilometer decreases by about 46.43%.
- For the 12-meter bus with two batteries, the savings increase to 39.29%.
- The 12-meter bus with three batteries shows a cost reduction of approximately 32.14%.

These comparisons highlight the significant cost-effectiveness of retrofitting buses over purchasing new electric buses, especially when a longer operational timeframe is considered. While all three versions of retrofitted buses turned out to be more economical, the 9-meter bus stands out as the most economical.

If we consider an extended life of 10 years for the retrofitted buses, the economics is still more favourable to retrofitted buses. The per km cost declines to less than Rs. 15/- for a 9-meter bus, less than Rs. 17/- for a 12-meter (with two batteries) bus, and less than Rs. 19/- for a 12-meter (with three batteries) bus. This brings out that the RoI is significantly in favour of retrofitted buses, irrespective of whether a retrofitted bus will have an extended life of 7 years or 10 years. But the advantages being more with a 10-year life, there is a strong need to legally permit the extension of the life of a retrofitted bus up to 10 additional years after retrofitting. The cost per km for the three versions of retrofitted buses is presented in Figure 7.

FIG 4 COST PER KILOMETRE FOR RETROFITTED BUSES



Source: Primus Partners' and EGROW's creation

Given the savings in fuel cost through the consumption of electricity as a clean fuel by retrofitted buses, there will be a significant reduction in CO_2 emissions. Thus, clearly, our analysis brings out that retrofitting is more economical via media for decarbonization in our country. Further, if retrofitted buses are promoted in a big way for both inter-city and intra-city transport, there will be a considerable reduction in diesel requirements and therefore diesel imports, thereby reducing our import bill. Finally, the sale of recovered scrap from the retrofitted buses can be considered a contribution to the 'circular flow of economy' as those scrapped parts and components will be used in automobile products appropriately.

07

ENVIRONMENTAL BENEFITS

Electrification is considered one of the major ways of decarbonizing the transport sector. EVs have zero tailpipe emissions and are equipped with batteries that are charged with grid electricity.

Electrification of the transport sector asks for more electricity generation which will increase the emissions from the electricity sector. Therefore, the electricity must come from renewable sources. Table 4 presents the emission factors of ICE and electric buses.

TABLE 3 **EMISSION FACTORS FOR ICE & ELECTRIC BUSES (Emissions/km in 2021)**

Pollutant	ICE Bus	Electric Bus
CO	3.026	0.47
HC	0.271	8.98E-05
NO_x	4.641	2.143
CO_2	611.48	1065.24
PM2.5	0.09	0.153

Source: Sharma and Chandel (2020)

Emission from the EV depends on the sources of electricity generation and electricity consumption by these vehicles. Table 4 shows that the quantity of emissions per kilometre travelled is less for the electric vehicles for the local pollutants such as CO, HC, and NO_x but it is more for CO_2 and $PM_{2.5}$ pollutants. In India, more than 75% of electricity comes from coal-based thermal power generation.

Therefore, it can be said that if India wants to decarbonize its transport sector, the electricity should come from renewable sources rather than fossil fuels.

Sharma and Chandel (2020) further show that if the share of renewables in electricity generation in the country increases to 50%, then the CO_2 emission factor (g/km) from the ICE and electric buses will be comparable. However, it should be noted that the local adverse effects of criteria pollutants in terms of health effects will be lesser due to the greening of the transport sector as the thermal power plants are generally located outside the cities, i.e., though, at the prevailing emissions factors, we will not be able to decarbonize the transport sector, but the benefits will be realized in terms of lower local adverse environmental effects.

08 ENERGY SECURITY

Retrofitting of ICE vehicles, as outlined above, is affordable and economically viable via media in the transitory period. The road transport sector is the largest consumer of Petroleum, Oil and Lubricants (POL) in India. To meet the growing demand for POL, the country fulfils more than 80% of its demand through imports. Electricity is mostly produced using domestically available coal resources. Thus, moving from ICE vehicles to ICE will reduce India's dependence on imported oil and enhance the country's energy security.

The above analysis reveals that a 12-meter AC ICE bus annually uses about 31250 litres and a 12-meter non-AC ICE bus consumes about 22222 litres of diesel. If the country plans to retrofit about 20000 buses annually, a mix of AC and non-AC buses we can save about five lakh tonnes of diesel, or we will be required to import crude oil less equal to 127 lakh barrels and on the prevailing crude oil prices, India's import bill come down more than a US$ 1 billion annually. [8]

8 The calculations are based on the assumption of Brent crude oil price of US$ 82 per barrel and one barrel of crude oil yields about 42 litres of diesel.

09

CIRCULAR ECONOMY AND EMPLOYMENT

The concept of circular economy fosters reuse and extends service life through repair, remanufacture, upgrade, and retrofit. The concept asks for turning old products into new, useful products. It replaces production with sufficiency: "reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired" (Stahel, 2016). The retrofitting of ICE buses into EVs effectively is based on the concept of circular economy. It extends the service life of buses by reusing and remanufacturing the existing materials and effectively reduces the demand for waste material disposal.

Retrofitting reduces costs and enhances the profits of the businesses through these processes. It also saves huge energy input for recycling, new part production, and new manufacturing. The government policies should be targeted to the technologies that encourage the reuse of waste by-products and design products that facilitate remanufacturing, retrofitting, and recycling so that waste disposal incineration and illicit dumping can be reduced (Fullerton, 2024). Future research should take care of the benefits arising from retrofitting using the concept of circular economy.

Stahle (2016) mentions that a shift to the circular economy, based on the study of 7 European countries, reduces GHG emissions by about 70% and increases employment by about 4%. India targets to create an additional 3 to 3.5 crores of new green jobs by 2047. [9]

Retrofitting will generate direct and indirect jobs in the country. Repairing and converting ICE buses into EV buses, and production of batteries, chargers, and other EV-related accessories would result in direct job creation.

A recent report of the Central Road Research Institute reveals that in March 2021, there were 132225 and in the year 2019-2020 11604 buses were scrapped. The number of scrapped buses was more than the number of new buses purchased in the year.

Retrofitting can be the best policy in this scenario, given the financial and environmental constraints facing the state transport undertakings, to meet the social obligation of the state governments in providing public transport to the public.

The state transport undertakings (STUs) employed 640690 persons for the operation of these undertakings in 2020-21, i.e., employing a total of 5.63 persons per bus. Out of this 4.46 was the traffic staff comparing drivers, conductors, and supervisory staff. The conversion of ICE buses to EV buses is not supposed to affect the traffic staff per se, but it will help in maintaining existing employment as the STUs are not in a position to purchase new EVs due to their financial constraints. STUs employed 84818 persons in various workshops for repair & maintenance work and these persons can be saved from displacement with reskilling and upskilling them. In a nutshell, it can be said that retrofitting will result in the generation of net new jobs. Retrofitting is projected to add 6000-7000 direct jobs and 36,000-42,000 indirect jobs over the next few years.

In the transitory period, the government should arrange for training programs for displaced workers to develop new skills so that they can work in the modernized sectors. Moreover, to reduce job-matching frictions, assistance programs in job search should be formulated.

9 https://sscgj.in/wp-content/uploads/2022/06/Green-Jobs-Hand-Book-PDF.pdf

10

POLICY RECOMMENDATIONS

Based on the findings and inferences of our study, we would like to make the following policy recommendations for promoting retrofitting and conversion of diesel buses into EV buses:

1. Implementation of a Scaled Pilot Project
2. Revise Vehicle Scrappage Policy
3. Provide Subsidy for Retrofitting
4. Introduce Retrofitting Finance Scheme
5. Encourage R&D in Retrofitting & Electric Batteries
6. FAME III Policy
7. GST Rebate for Retrofitted Vehicles
8. Nurture Tech Startups in the Retrofit Space
9. Need for Retrofit EV Policy at the State Level

10.1 IMPLEMENTATION OF A SCALED PILOT PROJECT

An EV retrofitting pilot project aimed at converting ICE buses into EV buses within urban environments must be implemented to augment the supply of EV buses in the short to medium run. The pilot projects can be carried out in different regions of the country – north, south, east, west and central India as well as in three different seasons – monsoon, winter, and summer months, in a time-bound manner at the earliest. This would enable the pilot project to capture the challenges in terms of regional and seasonal variations in the adoption of retrofitted buses.

Based on these pilot project findings an appropriate strategy can be worked out to give a fillip to the adoption of EV buses at the state level across the country. The implementation of these pilot projects can be overseen by NITI Aayog, and the Ministry of Road Transport and Highways (MORTH). In addition, the assistance of Indian Institutes of Technology (IITs) may be sought wherever necessary.

These pilot projects would call for a budget of about Rs. 5000 million for which financial support can be sought from international organizations such as International Finance Corporation (IFC), The World Bank, Asian Development Bank or New Development Bank.

The implementation agencies for the pilot projects must be chosen though an open tendering process. The pilot projects must aim at bringing out:

(i) Plan of action for scaling up the adoption of retrofitted EV buses

(ii) Associated costs and benefits, with an estimation of cost savings

(iii) Expected emission reductions

(iv) Probable impact on diesel imports

In addition, the feedback of bus staff for its larger application, and the feedback of bus commuters for its larger acceptance must be ascertained. That is, the views of both service providers and service users must be considered. These must be documented as per inter-national standards.

Subject to successful pilot project implement-ation, this initiative can be replicated on a larger scale to further support India's environmental goals and set a precedent for sustainable transportation initiatives.

10.2 REVISE VEHICLE SCRAPPAGE POLICY

There is a need to revise the present vehicle scrappage policy of the government. Currently, commercial vehicles over 15 years and passenger vehicles over 20 years of age are subjected to increased re-registration fees or scrapping under India's Vehicle Scrappage Policy.

Retrofitting can give a new and longer lease of life to otherwise discarded diesel vehicles. To encourage this trend, the government must modify the scrappage policy and substantially reduce the re-registration fees for the retrofitted EV buses. This can give a fillip to the sustainable development goals of a circular economy as well.

10.3 PROVIDE SUBSIDY FOR RETROFITTING

To promote the retrofitting of diesel buses, State Road Transport Public Sector Undertakings could be provided with a subsidy.

This can increase the Rate of return on Investment (ROI) significantly and thereby encourage them to reuse their old diesel buses through retrofitted conversion.

10.4 INTRODUCE RETROFITTING FINANCE SCHEME

By tapping climate funds of international organizations, the government can introduce exclusive finance schemes for retrofitting of diesel buses of state road transport undertakings. These schemes must be made available for diesel buses that are five years or older. This will ensure a longer life of retrofitted EV buses, thereby contributing to the reduction of emissions and aligning with the broader goals of sustainable development.

10.5 ENCOURAGE R&D IN RETROFITTING AND ELECTRIC BATTERIES

The EV retrofitting market is in its infancy. Bringing down the cost of retrofitting and the price of batteries can give a further boost to retrofitting. Accordingly, the Department of Science & Technology (DST) must encourage R&D and process innovations in retrofitting as well as in electric batteries towards cost reduction and longer life.

10.6 FAME III POLICY

Faster Adoption and Manufacturing of Electric Vehicles (FAME) policy III must include encouragement to retrofit vehicles to accelerate the momentum towards electric mobility. Outright purchase subsidies may be provided to retrofitted vehicles in this regard.

In the adoption of retrofitting of buses, the STUs are the critical actors and can lead by example demonstrating the financial, environmental, energy security, and employment benefits.

Including retrofitting incentives in FAME-III may prove transformative in the adoption of EVs in the country, especially for the STUs. Like the new EVs, the retrofitted buses should be subsidized along with provisions for favourabe loan rates and interest subversion schemes which remove the financial barriers in the adoption of retro-fitted buses. Since the purchase of new EV buses is given subsidies linked to the battery size per kilowatt, a similar framework may be adopted for the retrofitted buses as given in Table 5.

TABLE 5 PROPOSED SUBSIDIES FOR ACQUIRING RETROFITTED BUSES

Categories	Incentives / Subsidies (per kWh)	Approximate Battery Size	Ex-Factory Price Limit	Cap per Cost of Vehicle
E-Retrofitted Buses	INR 20,000	200 kWh	1,00,00,000	40%

Source: Primus Partners' and EGROW's creation

10.7 GST REBATE FOR RETROFITTED VEHICLES

To encourage the purchase of retrofitted vehicles, GST for retrofitted vehicles and their parts and components may be charged at a rate not more than 5%, like that of a newly built EV bus. Currently, spare batteries and essential components for EVs are levied a higher GST rate of 18%, which makes retrofitting more expensive and unattractive. Further, there is no provision for an EV retro-fitment kit in GST now. To make retrofitting more attractive, the cost of retrofitting EVs and components can be brought down through fiscal incentives.

10.8 NEED FOR RETROFIT EV POLICY AT THE STATE LEVEL

States must explicitly encourage retrofitting of vehicles through an exclusive policy. Interest rate subsidy, developing charging infrastructure, and revision of vehicle scrappage should form part of the state-level policies.

10.9 NURTURE TECH STARTUPS IN THE EV SPACE

Tech start-ups to promote the EV industry including retrofit EVs may be encouraged explicitly in the Higher Education Institution-based Technology Business Incubators (in engineering institutions, particularly IITs, and NITs). Initiatives to economize and lengthen the life of electric batteries should be the focus of such start-ups.

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ABOUT
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Founded with the vision to position the Foundation as a premier think tank globally, contributing to formation of sound public policies, especially in India and in the region, the EGROW Foundation aims to provide research-based support to policy making. Its objectives include providing a platform for socio-economic policy analysis to foster steady and sustainable growth, generating debate on existing and emerging issues with academia, area specialists and policy makers, and supporting India's leadership, impact and contribution to global development.

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EGROW
Foundation for Economic Growth and Welfare

egrowfoundation.org

EGROW Foundation

Foundation for Economic Growth & Welfare,
998, Sector 29, Noida, Uttar Pradesh 201301

E: admin@egrowfoundation.org

T: +91-120-3693-886

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1 to 7, Upper Ground Floor, Tolstoy House,
Tolstoy Road, Connaught Place, Delhi 110001

E: info@primuspartners.in

ACKNOWLEDGEMENTS

EGROW Foundation

Authors & Contributors

Dr. Charan Singh
Chief Executive Officer,
EGROW Foundation

Dr. M.H. Bala Subrahmanya
Senior Professor,
IISc Bangalore

Dr. Surender Kumar
Senior Professor,
Delhi School of Economics

Dr. Ganesaraman K.
Professor of Practice,
FMC, MSRUAS

Dr. Shalini Singh Sharma
Head Research & Training
EGROW Foundation

Supported by

Ms. Shivani Kushwaha
Research Associate (RA),
EGROW Foundation

Ms. Manvi Singh
Research Associate (RA),
EGROW Foundation

Mr. Beer Bahadur Rai
Research Associate (RA),
EGROW Foundation

Ms. Arshia Nag
Research Associate (RA),
EGROW Foundation

Primus Partners

Authors & Contributors

Mr. Davinder Sandhu
Chairperson & Co-Founder,
Primus Partners

Mr. Nikhil Dhaka
Vice President,
Primus Partners

Mr. Anshuman Singh
Senior Consultant,
Primus Partners

Ms. Mayuri Dutta
Senior Consultant,
Primus Partners

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