Alliance for an™ Energy Efficient Economy

ELECTRIFYING TRIPURA

Roadmap for Retrofitting ICE 3-Wheelers to EVs

ELECTRIFYING TRIPURA

Roadmap for Retrofitting ICE 3-Wheelers to EVs

Prepared by: Alliance for an Energy Efficient Economy (AEEE).

AEEE PROJECT TEAM

Dr. Md Saddam Hussain, Senior Research Associate, AEEE
Dr. Vikas Nimesh, Principal Research Associate, AEEE
Anmol Jain, Research Associate, AEEE
Divyansh Khare, Intern, AEEE
Pramod Kumar Singh, Senior Director - Research & Programs, AEEE

Suggested citation:

Hussain, M.S., Nimesh, V., Jain, A.; Khare, D., & Singh, P.K. (2024). Electrifying Tripura: Roadmap for Retrofitting ICE 3-Wheelers To EVs. New Delhi: Alliance for an Energy Efficient Economy

Disclaimer:

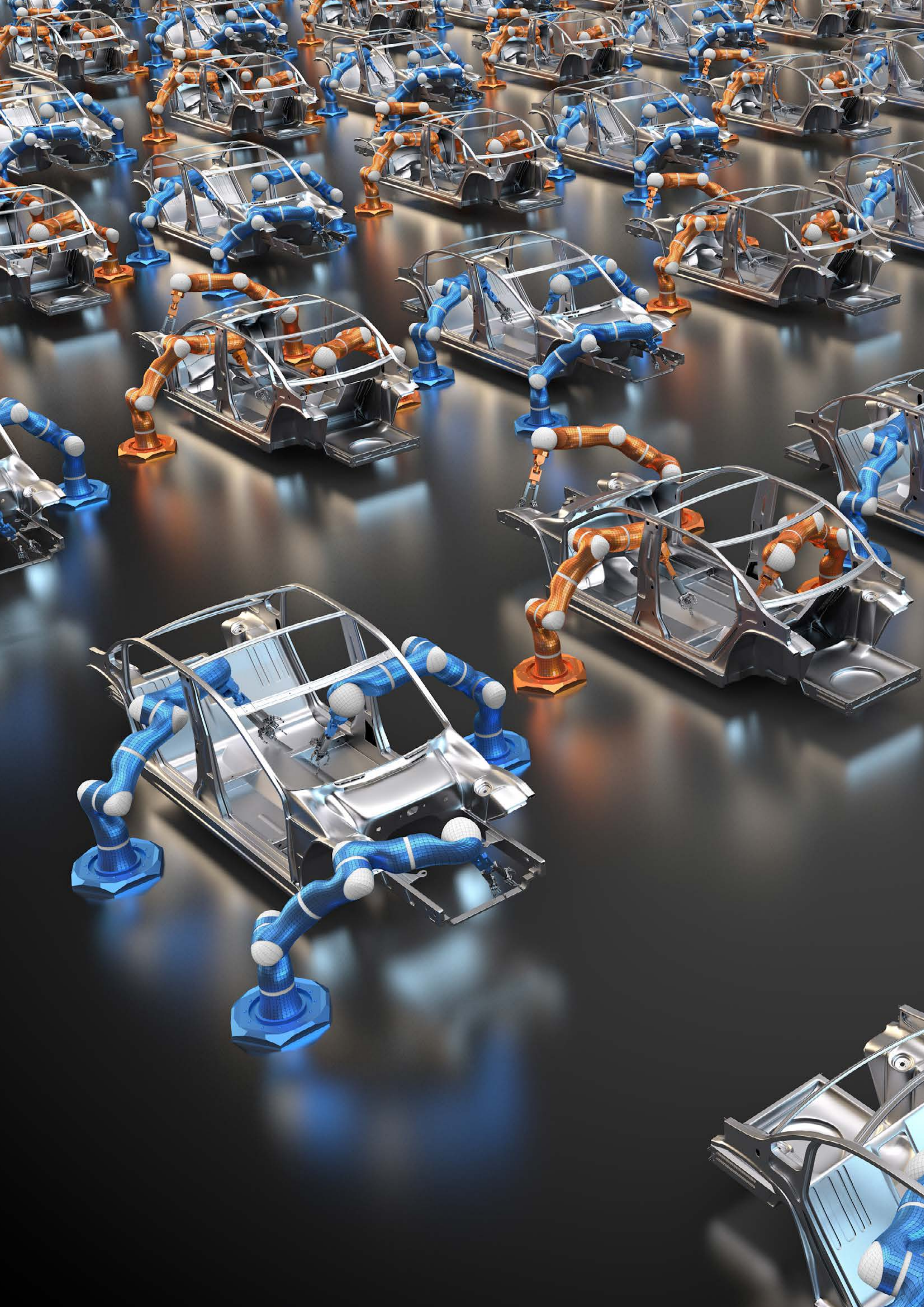
This report is based on the best available information in the public domain. Every attempt has been made to ensure the correctness of the data. However, AEEE does not accept responsibility for the consequences of the use of such data.

Acknowledgments

The authors would like to express their profound appreciation to Dr. Satish Kumar, President and Executive Director, AEEE, for providing invaluable guidance and feedback throughout the project. The authors extend their heartfelt gratitude to Ashwini Tiwary, Autobot, for his expert technical support and insightful feedback, which significantly contributed to the enhancement of this report.

Furthermore, the authors would like to extend their sincere thanks to the Tripura Transport Department for their unwavering support and invaluable contributions that have been instrumental in shaping this comprehensive and well-researched report. Throughout the project, their guidance and insights have provided us with the necessary foundation to address key issues in the field of energy efficiency. Additionally, our sincere appreciation goes to Don Bosco Technical School (DBTS), Shillong, for their collaboration in co-organizing the training program, which played a pivotal role in shaping this report. The feedback gathered during this event has been crucial in refining our findings and recommendations.

We also extend our appreciation to our local partner, Mr. Bibhudatta Sahu, for his pivotal role in connecting with the local community, rallying support for our cause, and facilitating participation in workshops and stakeholder consultations. His efforts have been crucial in the successful completion of this report.



Executive Summary

This report aims to address transportation challenges in Tripura, such as pollution and congestion, by leveraging electric vehicles (EVs) as a cleaner, more sustainable mode of transport. Retrofitting, which involves modifying conventional vehicles to electric, is presented as a cost-effective method to utilize the existing vehicle fleet while advancing towards greener mobility.

The report identifies retrofitting as a viable path to enhance the environmental performance of the existing transportation infrastructure and align with global climate change mitigation efforts. The analysis includes a Total Cost of Ownership (TCO) for retrofitting, comparing it against maintaining existing internal combustion engine vehicles or purchasing new EVs. Findings indicate that retrofitting, especially with leased batteries, offers significant cost advantages over long-term ownership, underscoring its economic viability alongside environmental benefits.

Furthermore, consumer perceptions and potential adoption rates are explored, highlighting the importance of addressing skepticism and educating potential adopters about retrofitting benefits. The report emphasizes the role of policy and stakeholder engagement in creating a conducive environment for retrofitting, with specific recommendations for government incentives, technical standards, and public-private collaboration.

Strategic recommendations include promoting battery leasing, implementing scrappage policies, and developing infrastructure to support EVs. The roadmap advocates for awareness campaigns, subsidies, and the development of a regulatory framework to facilitate retrofitting. Additionally, the importance of training for technicians and collaboration with original equipment manufacturers (OEMs) is highlighted to ensure the successful scaling of retrofitting initiatives.

In conclusion, the report posits retrofitting as a cornerstone for Tripura's transition to sustainable transportation. It calls for concerted efforts across government, industry, and the public to realize the full potential of EV retrofitting, positioning it as a critical step towards achieving environmental sustainability and economic growth.


VIN
VIN
VIN
VIN
VIN
VIN

Acronyms

2W	-	2-Wheeler
3W	-	3-Wheeler
4W	-	4-Wheeler
ARAI	-	Automotive Research Association of India
CAGR	-	Compound Annual Growth Rate
CMVR	-	Central Motor Vehicle Rules
EV	-	Electric Vehicles
E3W	-	Electric 3-Wheeler
FAME	-	Faster Adoption and Manufacturing of Hybrid & Electric Vehicles
GVW	-	Gross Vehicle Weight
ICE	-	Internal Combustion Engine
KM	-	Kilometer
KWh	-	Kilowatt-Hour
LCV	-	Light Commercial Vehicle
MoRTH	-	Ministry of Road Transport and Highway
NEMMP	-	National Electric Mobility Mission Plan
NH	-	National Highway
OEM	-	Original Equipment Manufacturer
R&D	-	Research and Development
RVSF	-	Registered Vehicle Scrapping Facilities
TCO	-	Total Cost of Ownership

Contents

Acknowledgments **5**

Executive Summary **7**

Acronyms **9**

1. Introduction **13**

1.1 Public Transportation Landscape in Tripura 14

1.2 Importance of Retrofitting in the Transition to Electric Vehicles 15

1.3 Vision-Missions 15

2. Understanding Retrofitting **17**

2.1 Concept and Mechanism of ICE to EV Retrofitting 17

2.2 Total Cost of Ownership (TCO) Analysis for Retrofitting 19

3. Consumer Insights **23**

3.1 Perceptions and Attitudes Towards Retrofitting 24

3.2 Demand Analysis and Potential Adoption Rates 25

4. Policy and Stakeholder Engagement **27**

4.1 Government Policies Supporting EV Retrofitting 27

4.2 Roles and Responsibilities of Key Stakeholders 29

4.3 Current Regulatory Framework for EVs and Retrofitted EVs in India 30

4.4 Impact of Financial Incentives and Subsidies 30

5. Technical Considerations and Challenges **31**

5.1 Technical Consideration and Challenges 31

5.2 Safety Standards and Certification Processes 32

6. Way Forward **33**

7. Conclusion **37**

7.1 Summary of Findings 37

7.2 Final Thoughts and Future Outlook 38

References **39**

01

Introduction

The northeastern state of Tripura, nestled amidst lush greenery and cultural richness, grapples with the challenges typical of rapid urbanization, including transportation woes. As the state's population grows and economic activities flourish, so do concerns related to pollution and congestion on its roadways. With inadequate infrastructure and a burgeoning number of vehicles, Tripura faces an urgent need for sustainable solutions to mitigate these issues and ensure a smooth traffic flow.

Transportation in Tripura forms the lifeblood of its economy, connecting urban centers, rural communities, and industrial hubs. However, the reliance on conventional fossil fuel-powered vehicles has exacerbated pollution levels and contributed to traffic congestion, particularly in urban areas. The harmful emissions from vehicles not only degrade air quality but also pose significant health risks to the residents, necessitating immediate action to transition towards cleaner alternatives.

In this context, integrating electric vehicles (EVs) into public transportation emerges as a promising solution to address Tripura's transportation challenges. Electric vehicles offer several advantages, including lower emissions, reduced dependence on fossil fuels, and quieter operation, making them an environmentally friendly and sustainable mode of transport. Moreover, adopting EVs aligns with global efforts to combat climate change and reduce greenhouse gas emissions, positioning Tripura as a frontrunner in embracing clean energy solutions. [1]

Retrofitting existing vehicles with electric propulsion systems presents a viable approach to leverage the state's existing transportation infrastructure while transitioning towards greener mobility. Retrofitting involves modifying conventional vehicles to incorporate electric drivetrains, batteries, and associated components, extending their lifespan and enhancing their environmental performance. Tripura can significantly reduce emissions and create a sustainable transportation ecosystem by retrofitting buses, taxis, and other public transportation vehicles with electric propulsion systems.

This report comprehensively outlines the roadmap for retrofitting existing vehicles in Tripura with electric propulsion systems, encompassing the technical, economic, and policy aspects of the retrofitting process. The report aims to provide stakeholders with actionable insights to facilitate the widespread adoption of electric vehicles in the state's public transportation sector through detailed analysis and strategic recommendations. By embracing retrofitting as a transformative solution, Tripura can chart a path toward cleaner, greener, and more efficient transportation, ensuring a sustainable future for generations to come.

1.1 Public Transportation Landscape in Tripura

Tripura relies heavily on the National Highway 8 (NH-8) as its primary connection to the rest of India, starting from Sabroom in southern Tripura, traversing north to Agartala, then veering east and northeast to enter Assam. Locally referred to as the "Assam Road," NH-8 is vital for Tripura's connectivity but suffers from drawbacks such as being single-lane and of substandard quality, often prone to disruptions like landslides and heavy rains, isolating the state from neighboring regions. Another route, National Highway 108 (NH-108), links Panisagar in North Tripura District to Aizawl, Mizoram. The Tripura Road Transport Corporation oversees public road transport in the state, which is crucial given Tripura's hilly terrain and lack of direct access to sea routes. The state boasts a road network spanning 16,931 km, with national highways covering 88 km and state highways 689 km as of 2009–10, though rural residents often rely on waterways for commuting. Tripura shares an 856 km international border with Bangladesh, with 777.4 km fenced as of 2012. Various border points facilitate bilateral trade between India and Bangladesh, including Akhaura near Agartala, Raghna, Srimantpur, Belonia, Khowai, and Kailasahar. A bus service operates between Agartala and Dhaka, Bangladesh's capital. In 2013, both nations agreed to establish a 15 km (9.3 mi) railway link between Agartala and Bangladesh's Akhaura junction. Citizens of both countries require visas for legal entry into the respective nations.[2]

Agartala, a captivating and pivotal city within Tripura, is experiencing rapid growth and development. This progression is evident in the government's significant emphasis on enhancing the city's transportation infrastructure. Serving as a crucial hub, Agartala connects Tripura with other towns and cities in the Northeast region through a well-established air, rail, and road network, ensuring seamless travel for tourists visiting this picturesque destination.

National Highway 44 (NH-44) links Agartala to Assam and other parts of India, facilitating smooth connectivity. Highways like NH-44 and NH-44A further extend Agartala's reach to Dharmanagar, Silchar, Guwahati, Shillong, and Aizawl. Bus services from Guwahati, Shillong, and Silchar to Agartala contribute to accessible transportation options. Within the city, buses, auto-rickshaws, jeeps, and trekkers are popular modes of travel for locals and tourists alike. Tourists exploring Agartala can also avail themselves of car and van rental services. Notably, a bus service connects Agartala to Dhaka, offering another convenient travel option for visitors.[3]

Table 1: Category wise registered 3W

S.no	Mode	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011
1	E-Rickshaw (Passenger)	2481	2701	2061	3138	1371	1	1	0	0	0	0	0	0
2	3W (Goods)	410	359	260	284	447	338	245	299	126	93	101	211	215
3	3W (Passenger)	6852	4968	3504	3529	1224	1938	2757	2620	3272	1943	1874	2668	2060

Source: Vahan Sewa Dashboard

1.2 Importance of Retrofitting in the Transition to Electric Vehicles

1 Significance of retrofitting

Retrofitting holds more significance for commercial vehicles than passenger cars due to the substantial reduction in carbon emissions and significant operational cost benefits for end-users. Commercial vehicle conversions, particularly in the 15-50 GVW range, can yield over 60% in operating cost savings per kilometer, along with considerable reductions in maintenance costs due to fewer moving parts.

2 Urgency and Benefits of Retrofitting

The urgency for electric vehicle retrofitting in India stems from projections indicating a considerable increase in the number of buses and other public transport on the roads by 2030. Simply, adding more electric public vehicles to the existing fleet risks congestion on city roads. Hence, a more practical approach involves incorporating a limited number of electric vehicles while retrofitting existing ones to electric variants, effectively managing vehicle counts and reducing vehicular emissions.

Retrofitting is particularly crucial in India due to a lack of indigenous technology for developing EV components suitable for the country's tropical climate. Additionally, EVs remain economically uncompetitive in India, and there's a reluctance among customers to fully transition to electric fleets.

The advantages of retrofitting are manifold. From the customer's perspective, it reduces vehicle running costs, extends vehicle life, and fosters a sense of pride in contributing to sustainability. Societally, electric/hybrid vehicles promote public health and mitigate harm to the global climate. From the government's standpoint, retrofitting decreases crude oil consumption, vehicular emissions, and expenditure on oil imports.

In India's nascent electrification market, where charging infrastructure poses a significant barrier to EV adoption, retrofitted EVs can serve as pioneers by stimulating demand for charging infrastructure, localized components and batteries, service infrastructure, and understanding usage patterns, among other factors. [4]

1.3 Vision-Missions

The Government of India has set an ambitious target for electric vehicles (EV), alongside plans to significantly reduce carbon emissions via diesel and petrol engines by 2030. Because of this, the country is taking steps towards switching to electric vehicles. However, the pace of this transition can't be dramatic, and thus, to realize its dream of reducing its carbon footprint, the country must focus on converting the existing ICE vehicles into electric ones. Retrofitting increases the useful life span of existing vehicles by 5-7 years and would also not fall into the new scrappage policy.

The Government of India initiated the National Electric Mobility Mission Plan (NEMMP) 2020 in 2013 to bolster national fuel security by promoting hybrid and electric vehicles (EVs). The plan set an ambitious target of achieving 6-7 million annual sales of hybrid and electric vehicles starting from 2020 onwards. To incentivize adoption, fiscal and monetary incentives were planned, aiming to kickstart this emerging technology. With government support, cumulative sales were projected to reach 15-16 million by 2020, resulting in an estimated savings of 9500 million liters of crude oil, equivalent to Rs. 62000 crores. The Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME India) scheme, launched under NEMMP 2020 with an initial outlay of Rs. 75 crores in the Union Budget for 2015-16, aimed to accelerate the adoption and market creation of hybrid and electric vehicles. The scheme sought to position hybrid and electric vehicles as the preferred choice for consumers, thereby reducing liquid fuel consumption in the automobile sector. It was anticipated that early market creation through demand incentives, technology development, and domestic production would lead to self-sufficient economies of scale by 2020. By 2012-13, approximately 42,000 electric vehicles were sold, predominantly electric low-speed scooters, with nearly 20,000 hybrid and electric vehicles sold in 2013-14. The introduction of the FAME scheme was expected to stimulate the market for hybrid and electric vehicles across all vehicle segments, including 2W, 3W, 4W, LCVs, and buses. The scheme aimed to incentivize buyers through monetary support, with the Department of Heavy Industry finalizing details such as the incentive amount per vehicle-technology segment. The incentive would be administered through an electronic mechanism/portal, with manufacturers reducing the purchase price of hybrid and electric vehicles for buyers, reimbursed by the government. [5]

02

Understanding Retrofitting

2.1 Concept and Mechanism of ICE to EV Retrofitting

Retrofitting refers to a mechanical process involving the removal of the petrol/diesel engine and fuel tank from an Internal Combustion Engine (ICE) vehicle, which are then substituted with an electric motor and battery, effectively transforming the vehicle into an electric one. The electric motor utilized in this process has the capability to operate either directly from a battery or indirectly through a fuel cell, such as hydrogen, providing flexibility in power sources for the electric vehicle. [6]

Steps Involved in Vehicle Retrofitting

a Vehicle Assessment

Before commencing retrofitting, it is crucial to evaluate your vehicle to determine its suitability for conversion. Key factors to consider include the vehicle's age, condition, weight, and the availability of replacement parts.

b Retrofitting Planning

Once the vehicle assessment confirms its viability for conversion, the next step involves meticulous planning for the retrofit. This includes selecting the suitable electric motor and battery pack and determining the optimal placement of these components.

c Removing the Conventional Engine

Subsequently, the conventional engine and associated parts, such as the fuel tank and exhaust system, must be carefully removed. This step can be intricate and may necessitate the expertise of a professional mechanic.

d Installing the Electric Components for Electric Vehicle Retrofitting Conversion Process

With the conventional engine removed, the electric motor, controller, and other essential components are installed. This phase also demands precision and may require the assistance of a skilled electric vehicle technician.

d Wiring and Control Systems

After installing electric components, the wiring and control systems must be configured. This entails connecting the battery pack, motor, and controller while ensuring the system is optimized for performance.

f Battery Installation for Electric Vehicle Retrofitting Conversion Process

The battery pack plays a pivotal role in the conversion of electric vehicles. It is imperative to select a high-quality battery pack that matches the vehicle's size and weight. The battery should be securely installed in an easily accessible location for maintenance purposes.

g Testing and Fine-tuning

Upon completion of the retrofit, thorough testing and fine-tuning are essential to ensure optimal performance. This involves evaluating acceleration, braking, and handling and monitoring battery life and range.

h Certification and Registration

Finally, certifying and registering the electric vehicle retrofit with the relevant government agencies is imperative. This may entail obtaining specialized licensing or certification to ensure compliance with regulations. [4,7]

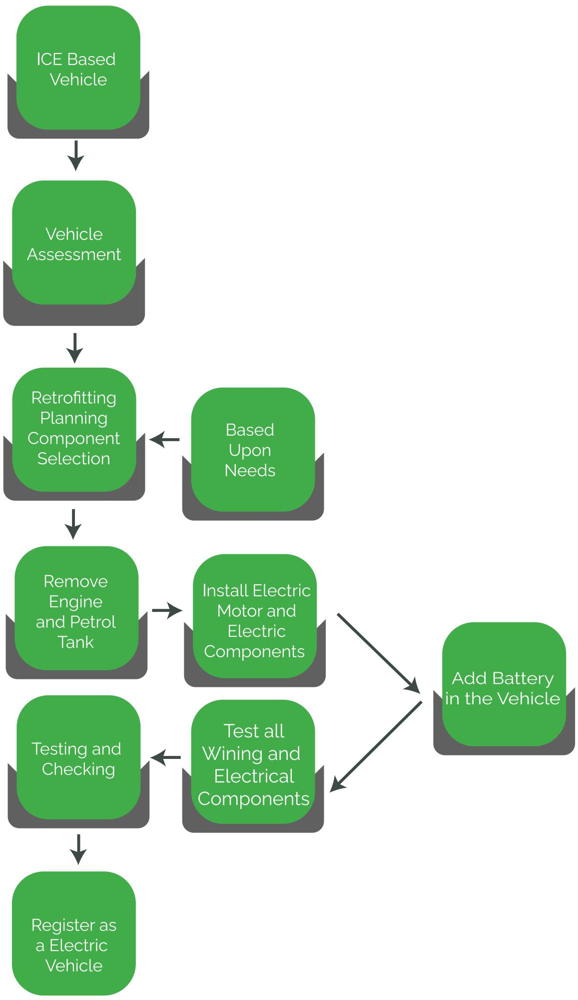


Figure 1: Retrofitting Process

Source: Author Generated

2.2 Total Cost of Ownership (TCO) Analysis for Retrofitting

Converting traditional internal combustion engine (ICE) vehicles into electric vehicles (EVs) is being viewed as a viable solution to meet the demand for decarbonization without imposing excessive costs on the public. However, the transition process must be gradual. Therefore, retrofitting current ICE vehicles is deemed necessary alongside integrating new EVs. [8]

The Total Cost of Ownership (TCO) offers a method for accurately assessing and comparing the expenses associated with owning and operating a vehicle throughout its lifespan. It encompasses various factors, including initial purchase price, ongoing expenses like fueling/charging and maintenance, and financing costs. Given that these costs vary depending on the technologies involved, TCO analysis aims to assist users in comprehending the trade-offs involved and making well-informed decisions when selecting a vehicle to purchase.

2.2.1 Scenario-01

Here, a detailed Total Cost of Ownership (TCO) analysis was conducted for three different options. In the first option, operators continued to use their existing ICE vehicle after the 10th year. Operators retrofit their 3W into an E3W and purchase the battery in the second option. In the third and final option, operators install a retrofitment kit into their 3W but do not purchase the battery. Instead, they opt to lease the battery and utilize battery swapping stations.

Table 2: Considered Values for the calculation of TCO

S.No	Factors	ICE	Retrofitted (Owned Battery)	Retrofitted (Leased Battery)
1.	Battery Cost	0	110000	0
2	Retrofitting Kit Cost	0	100000	100000
3	Tax	0	0	0
4	Insurance Cost/Yr	4000	5500	5500
5	Financial Incentives	0	20000	5000
6	Annual Maintenance	4000	3000	2500
7	Battery Capacity	0	8KWh	8KWh
8	Mileage	20 KMPL	15 KM/KWh	15 KM/KWh
9	Fuel/Electricity Cost	98.66/Litre	10/KWh	20/Kwh

Source: Author Generated

In analyzing the Total Cost of Ownership (TCO) for the aforementioned three cases, various factors were considered. Fixed components included the cost of the battery, retrofitment kit, and government incentives. Operational cost components encompassed annual maintenance, battery capacity, insurance per year, mileage (measured in kilometers per liter or kilometers per kilowatt-hour), and the cost of refueling, recharging, or battery swapping. A discount and resale rate of 10% were factored in the CAPEX cost, while 5% growth rate is considered for Fuel, electricity and maintenance cost.

It is observed that if the operator drives the vehicle 120 KM per day for 5 years, the TCO for the ICE 3W stands at Rs.5.65/KM, indicating its higher cost over the specified period. In contrast, the Retrofitted (Owned Battery) E3W demonstrates a slightly lower TCO of Rs.3.16/KM, suggesting less cost expenses compared to the ICE variant. Moreover, the Retrofitted (Leased Battery) E3W exhibits the lowest TCO of Rs.2.73/KM, indicating a moderate decrease in cost compared to the owned battery electric version.

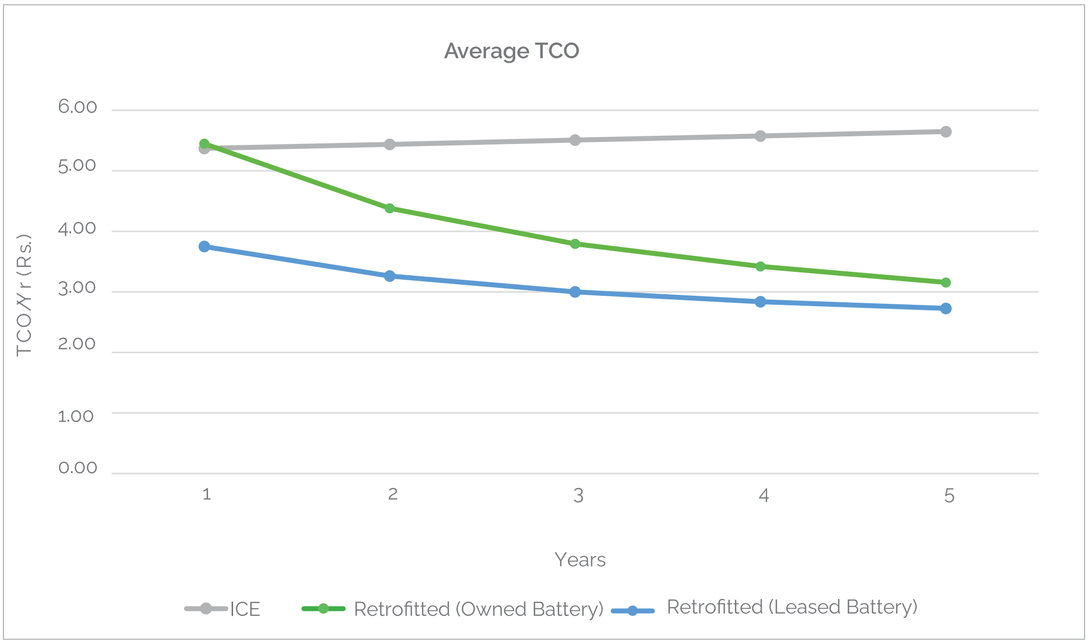


Figure 2: Average TCO value

Source: Author Generated

At the end of the 5th year, the TCO further emphasizes the economic advantage of electric vehicles, with the Retrofitted (Owned) E3W showing the lowest TCO of Rs.2.10/KM, followed by the Retrofitted (Leased Battery) E3W with a TCO of Rs. 2.73/KM, and for ICE vehicles, it is Rs.5.65/KM. This data underscores the potential financial benefits of transitioning to electric vehicles, especially considering long-term ownership costs.

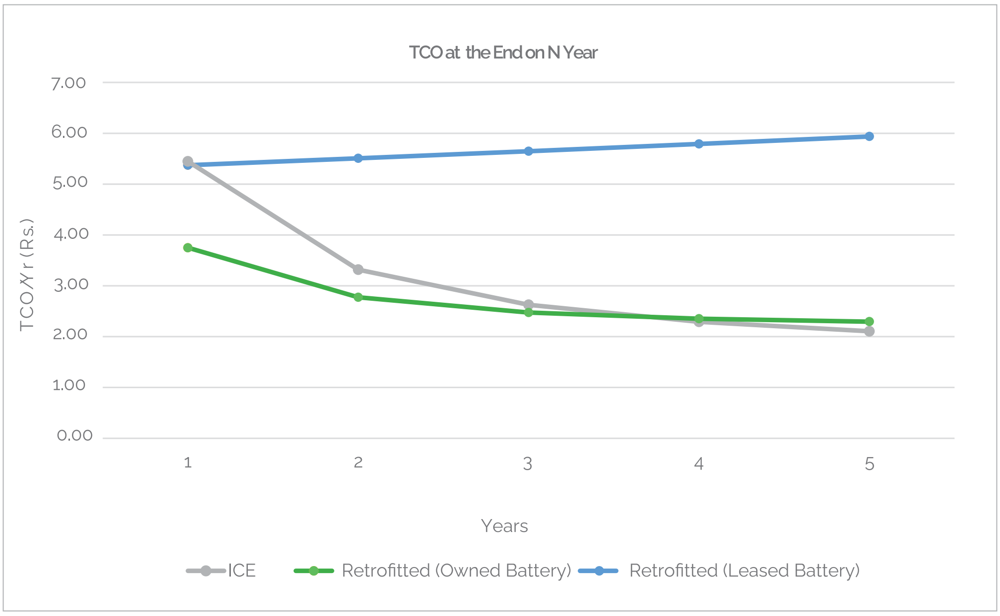


Figure 3: TCO value at the end of each year

Source: Author Generated

2.2.2 Scenario-02

Here, a detailed Total Cost of Ownership (TCO) analysis was conducted for four different options. The first option is for operators to buy a new ICE vehicle after the 10th year. Operators retrofit their 3W into an E3W and purchase the battery in the second option. In the third option, the operator switches to a new E3W, and in the fourth and last option, operators install a retrofitment kit into their 3W but do not purchase the battery. Instead, they opt to lease the battery and utilize battery swapping stations.

Various factors were considered in analyzing the Total Cost of Ownership (TCO) for the abovementioned cases. Fixed components included the battery cost, retrofitment kit, and government incentives. Operational cost components encompassed annual maintenance, battery capacity, insurance per year, mileage (measured in kilometers per liter or kilometers per kilowatt-hour), and the cost of refueling, recharging, or battery swapping and battery change as well (After the first 5 years). A discount and resale rate of 10% was factored in the CAPEX cost, while a 5% growth rate is considered for Fuel, electricity, and maintenance costs.

Table 3: Considered Values for the calculation of TCO

S.No	Factors	ICE	Retrofitted (Owned Battery)	New EV 3W	Retrofitted (Leased Battery)
1.	Battery Cost	0	110000	0	0
2	Retrofitting Kit Cost/ Vehicle Cost	210000	100000	310000 (Includes Battery)	100000
3	Tax	10500	0	0	0
4	Insurance Cost/Yr	5000	5000	7500	5000
5	Financial Incentives	0	20000	50000	5000
6	Annual Maintenance	11000	5000	5000	4000
7	Battery Capacity	0	8KWh	9KWh	8KWh
8	Mileage	20 KMPL	15 KM/KWh	15 KM/KWh	15 KM/KWh
9	Fuel/Electricity Cost	98.66/Litre	10/KWh	10/KWh	20/Kwh
10	New Battery Cost	0	115000	115000	0

Source: Author Generated

It is observed that if the operator drives the vehicle 120 KM per day for 10 years, the TCO for the New ICE 3W stands at Rs.9.31/KM, indicating its higher cost over the specified period. In contrast, the Retrofitted (Owned Battery) E3W demonstrates a significantly lower TCO of Rs.4.31/KM, suggesting cost expenses compared to the ICE variant. At the same time, the average TCO for New E3W stands at Rs.5.21/KM. Moreover, the Retrofitted (Leased Battery) E3W exhibits the lowest TCO of Rs.2.54/KM, indicating a moderate decrease in cost compared to the owned battery electric version.

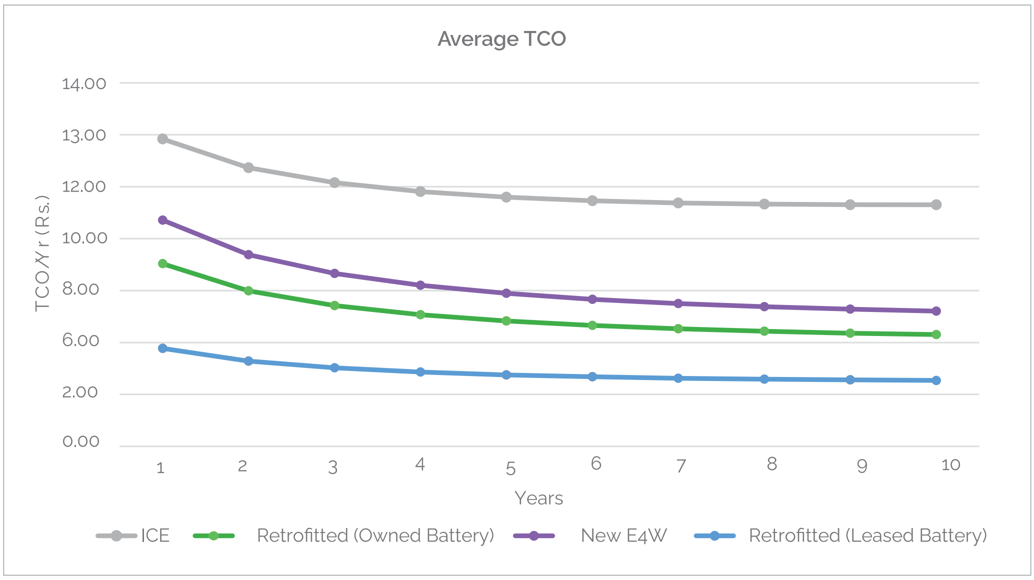


Figure 4: Average TCO value

Source: Author Generated

At the end of the 10th year, the TCO further emphasizes the economic advantage of electric vehicles, with the Retrofitted (Leased Battery) E3W showing the lowest TCO of Rs.2.37/KM, followed by the Retrofitted (Owned Battery) E3W with a TCO of Rs.3.82/KM, and for new ICE vehicle it is Rs.9.31/KM. In contrast, the TCO value for New E3W at the end of the tenth year stands at Rs.4.55/KM. This data underscores the potential financial benefits of transitioning to electric vehicles, especially considering long-term ownership costs.

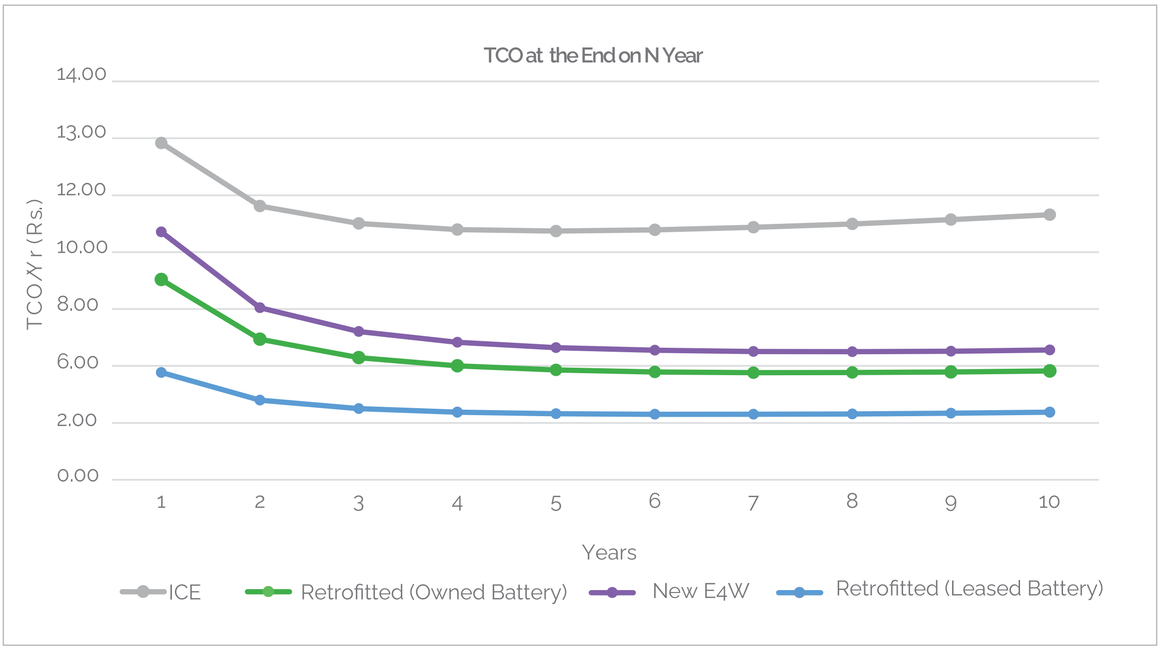


Figure 5: TCO value at the end of each year.

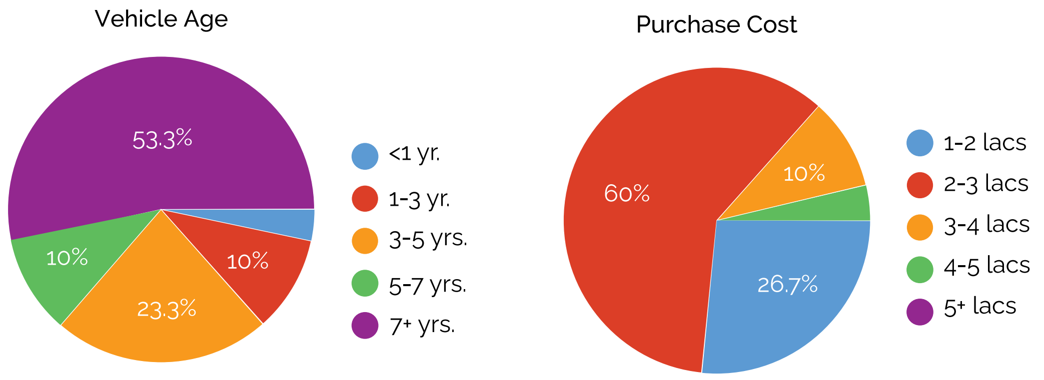
Source: Author Generated

03

Consumer Insights

Attracting skeptical consumers and fostering their acceptance of retrofitted electric vehicles (EVs) is essential for increasing market adoption. Educating consumers about the benefits of retrofitting, addressing their concerns, and building confidence in the available solutions are key strategies in this process.

We surveyed approximately 50 3-W auto rickshaw drivers in Agartala to understand the target audience's perspective better. These drivers primarily operate Bajaj Auto-Model-C, which runs on Petrol and Compressed Natural Gas (CNG). These autos, which typically have a passenger capacity of three to four per trip, are mostly owned individually and were acquired through upfront payments. This information is crucial in tailoring strategies that resonate with drivers' specific needs and concerns, facilitating a smoother transition to retrofitted EVs.



(a) (b)

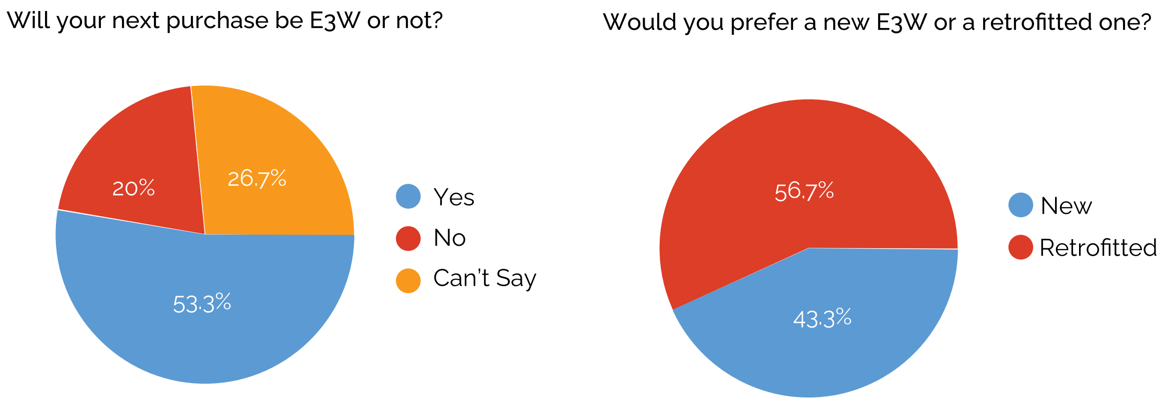
Figure 6: Descriptive Analysis for (a) Vehicle Age (b) Purchase Cost (c) Ownership type (d) On an average, how many kms do you drive in a day?

Ownership type

(c) (d)

3.1 Perceptions and Attitudes Towards Retrofitting

Understanding consumer attitudes towards converting ICE three-wheelers to EVs in Tripura is pivotal for fostering positive perceptions of E-mobility. Initial apprehensions typically include concerns about EVs' limited range and their suitability primarily for urban settings. Additionally, the concept of retrofitting is often met with skepticism, primarily due to the perceived high costs and a lack of comprehensive knowledge about the process.



(a) (b)

Figure 7: Descriptive Analysis for (a) Will your next purchase be E3W or not? (b) Would you prefer a new E3W or a retrofitted one?

Drivers' primary concerns include the high initial purchase price, range limitations, inadequate charging infrastructure, and difficulties in obtaining permits for EVs. Nevertheless, most drivers are open to purchasing new or retrofitted EVs if these come with the necessary permits and subsidies. Notably, 56.7% of drivers prefer retrofitting their existing 3Ws over buying new ones, viewing it as a cost-effective way to extend vehicle lifespan and enhance performance.

The decision to switch to EVs is motivated by several factors. Drivers recognize the environmental advantages, such as significantly lower emissions. They are also attracted by the potential for better acceleration, reduced operating and maintenance costs, and the opportunity to prolong the life of their vehicles. This growing interest in EV technology is a key factor driving the exploration of retrofitting options among 3W drivers in Tripura, suggesting a readiness to embrace these innovations if adequately supported by policy and incentives.

3.2 Demand Analysis and Potential Adoption Rates

The retro-fitting sector, though still in its infancy according to market analysis, displays significant potential for expansion owing to its technological simplicity and accessibility. As of 2023, the global retrofit vehicle market is estimated to be valued at USD 65.94 billion, with projections indicating a growth to USD 125.37 billion by 2032 at a notable CAGR of 7.40%. Notably, the Asia-Pacific region commands a dominant share of 62.5%, driven by substantial investments in clean transportation and robust R&D efforts primarily led by countries such as India, China, Japan, and South Korea.

Moreover, the sector presents promising opportunities for continuous expansion fueled by increasing consumer demand and stricter emission regulations. Anticipated transitions from commercial to passenger vehicles and 2W in the next decade further bolster prospects. Retrofitted vehicles reportedly boast longer lifespans and superior power delivery. EV retrofitting also emerges as a vital asset in the decarbonization of transportation systems, underscoring its role in sustaining high-cost vehicles that might otherwise face scrappage. [9]

In India, this concept has gained substantial traction, backed not only by legal frameworks but also regarded as an upgrade to the existing vehicular system.

Integrating EV conversion into national legislative frameworks is essential to advance EV retrofitting and solidify its position in the transportation sector. Policies should explicitly acknowledge retrofitted vehicles within existing EV incentives, enhancing their appeal and adoption. This inclusive approach facilitates comprehensive monitoring and regulation, transitioning retrofitting from a niche alternative to a mainstream solution in the electrification agenda.

04

Policy and Stakeholder Engagement

4.1 Government Policies Supporting EV Retrofitting

Government subsidies and incentives can play a pivotal role in enhancing the economic viability of retrofitting. In a significant move, the 2021 Delhi Government policy allowed vehicles over ten years old, which would usually violate the National Green Tribunal's ban, to keep running if they're retrofitted with an Electric Vehicle (EV) kit. This proactive decision has led to the growth of an industry focused on converting older Internal Combustion Engine (ICE) vehicles into cleaner EVs, creating a path for older vehicles to contribute to the vision of 'Cities of Tomorrow'.

Additionally, various states are introducing EV policies, some of which offer incentives for retrofitting. These actions show a commitment to promoting sustainable transportation and speeding up the shift to electric mobility.

Table 4: State EV Policies and Vehicle Retrofitting Initiatives

S. No.	State / UT	Policy and Year	Retrofitting Policy
1	Rajasthan	Rajasthan EV Policy 2022	Eligible retrofit kits will be incentivized by 15% of the retrofit kit cost.
2	Karnataka	Karnataka EV Policy 2017	Existing auto rickshaws will be encouraged for retrofitting and move towards the EV segment.
3	Andhra Pradesh	Electric Mobility Policy 2018	Registration will be allowed for 3W retrofitted with an electric motor and an electric powertrain using advanced battery technologies and certified by the Automotive Research Association of India (ARAI) or other Government recognized agencies.
4	Tripura	Tripura EV Policy 2022	During the policy period, 25% of the on-road vehicles will be targeted for conversion by retrofitting into EV vehicles from ICE vehicles.
5	Chhattisgarh	Chhattisgarh State EV Policy 2022	To promote replacing existing ICE installations with electric kits in the vehicles. This may also be taken up at AVSF centers setup in the State. This shall also include the conversion of existing ICE vehicles to hybrid vehicles with both ICE and electric kit provisions.
6	Haryana	Haryana Electric Vehicle Policy 2022	Registration will be allowed for 2W and 3W retrofitted with an electric motor and an electric power train using advanced battery technologies and certified by the Automotive Research Association of India (ARAI), Pune, or other government recognized agencies.
7	Assam	Electric Vehicle Policy Assam 2021	Retrofitment subsidy of 15000 for 3Ws
8	Telangana	Telangana Electric Vehicle Policy 2020	Retro-fitment incentive at 15% of the retro-fitment cost capped at Rs. 15,000 per vehicle for first 5,000 retrofit 3seater auto rickshaws in Telangana

Source: Author Generated

To further enhance the transition from traditional internal combustion engine (ICE) vehicles to electric vehicles (EVs), it is imperative to establish a comprehensive and incentivizing policy scheme. Central to this framework is the introduction of robust incentives designed to support retrofitting existing vehicles into EVs. This policy should treat newly manufactured and retrofitted EVs equally within the commercial sector, promoting a seamless integration into the market.

4.2 Roles and Responsibilities of Key Stakeholders

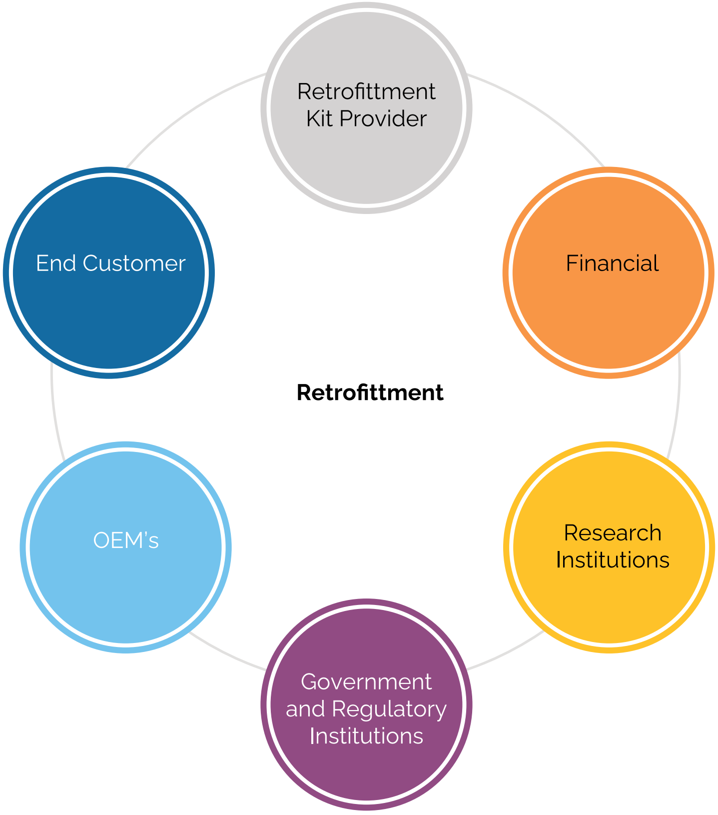


Figure 8: Involved Stakeholders

Source: Author Generated

In the retrofitting industry for converting 3Ws to E-wheelers, several key stakeholders are involved, each with their specific roles and responsibilities:

- Conversion Kit Providers and Service Delivery Companies: These entities provide core elements necessary for the conversion process. They secure business operations, coordinate activities, and ensure the supply of certified conversion kits and trained specialists for installation. Additionally, they provide service points to end customers. They provide infrastructure for vehicle conversions, carry out installations, and offer servicing.
- Financial Institutions (Venture Capital Partners/ Banks): Venture capital partners and banks play a crucial role by providing financial resources required to implement conversion processes. They invest in retrofitting ventures, enabling them to scale their operations and reach a larger market.
- Research Institutions: These institutions support the technical development of electrification solutions for 3Ws. Their involvement fosters innovation and drives advancements in E-wheeler technology. Depending on their contribution, they may receive financial remuneration.
- Government and Regulatory Institutions: Governments provide grants, subsidies, and regulatory support to incentivize the adoption of electric vehicles, including 3Ws. They offer subsidies for both end customers to promote purchases and for research and development in the electrification sector. Regulatory bodies oversee registrations, fitness tests, and compliance with safety standards.

- OEMs: These entities supply components required for converting 3Ws to E-wheelers.
- End Customers: End customers are the ultimate stakeholders in the conversion process. They pay for the conversion service and receive their 3Ws converted into E-wheelers in return. Their feedback and satisfaction are essential for the success and growth of the retrofitting industry.

4.3 Current Regulatory Framework for EVs and Retrofitted EVs in India

A collaborative partnership between the government and industry stakeholders is essential to mitigate the potential risks linked with retrofitting. Establishing a robust regulatory framework becomes imperative to uphold strict quality standards for both retrofitting kits and processes. [10]

Table 5: Regulatory Frameworks

Regulatory Sections Reference	Sections 41(7), 41(10), 56, and 59 of the Motor Vehicle Act, alongside Rule 62 and Rule 189 of the CMVR, constitute the regulatory backbone for EVs and retrofitted EVs under the oversight of MoRTH.
Registered Vehicle Scrapping Facilities (RVSFs)	Section 8 of the RVSFs guidelines is pivotal in the context of EVs and Retrofitted EVs, contributing to the comprehensive governance of these vehicle categories in India.
Governing Bodies	Ministry of Road Transport and Highways (MoRTH) oversees the implementation and interpretation of the Central Motor Vehicles Rules (CMVR) and Motor Vehicle Act, which provide the legal framework for registration, fitness, and lifespan of transport vehicles, including EVs and retrofitted EVs in India.
Registration Renewal	As per Rule 62 of the CMVR and Sections 41(7) and 41(10) of the Motor Vehicle Act, the current regulations permit the renewal of registration for retrofitted EVs akin to other conventional vehicles. This provision applies to both private and commercial entities.
Fitness Tests	Rule 189 of the CMVR delineates three additional fitness tests specifically for EVs pertinent to retrofitted EVs. Upon passing these tests, the initial registration of 15 years can be renewed.
Scrappage Policy	The existing laws do not mandate a scrappage requirement for EVs and retrofitted EVs. Any scrapping activity by private players is conducted voluntarily.
Vehicle Lifespan	The prescribed lifespan for these categories of vehicles is set at 15 years. However, a provision for 5-year extensions exists, subject to the vehicle passing requisite fitness tests and provided the chassis remains in a fit condition.

Source: Author Generated

4.4 Impact of Financial Incentives and Subsidies

The primary hurdle lies in the economic feasibility of retrofitting, particularly considering the significant expenses associated with procuring and installing retrofit kits. With the decreasing costs of new EVs, there's growing skepticism regarding the financial prudence of opting for retrofitting. This doubt intensifies as battery expenses are anticipated to reduce in the future, prompting questions about the long-term viability of retrofitting as a sound investment decision. [1]

However, financial incentives and subsidies present a crucial opportunity for overcoming these economic challenges and encouraging a shift towards retrofitting. By offering financial support and incentives, governments can help offset the upfront costs associated with retrofitting, making it a more attractive option for vehicle owners.

05

Technical Considerations and Challenges

While retrofitting offers various benefits, it also poses specific challenges and risks that require careful consideration. This chapter aims to explore the detailed landscape of risks linked with Electric Vehicle (EV) retrofitting, recognizing the complexities involved in such endeavors.

5.1 Technical Consideration and Challenges

A major concern revolves around the technical and performance limitations. Retrofitting might not consistently achieve the same efficiency and performance as vehicles originally designed as EVs. The conversion process can be complex, requiring specialized knowledge and expertise. This disparity can lead to differing performance levels, potential technical malfunctions, and challenges with weight distribution.

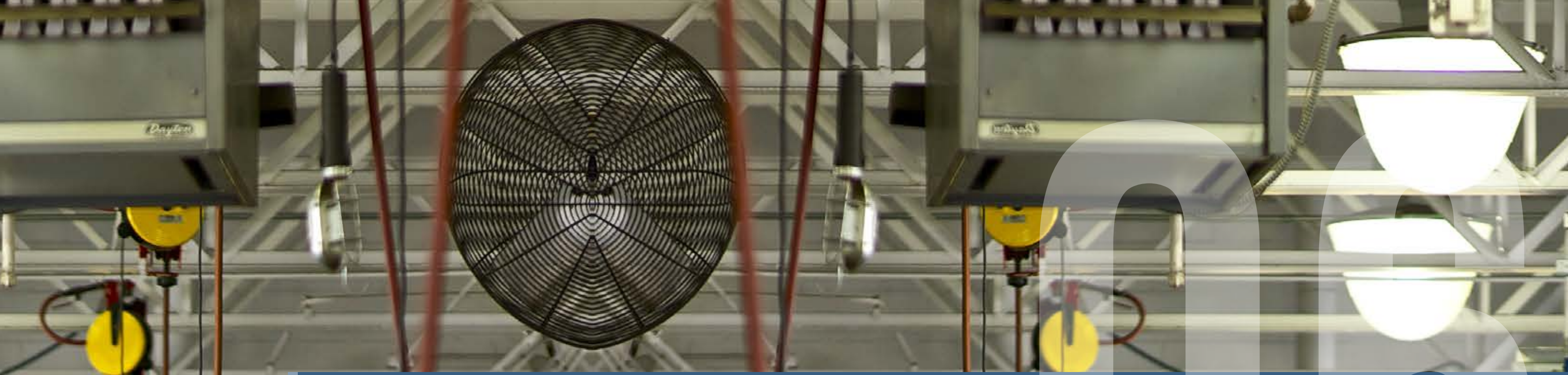
Depending on a wide range of suppliers for specialized components introduces inherent vulnerabilities within the supply chain. Disruptions in the procurement process or inconsistencies in component quality can slow down project timelines and increase costs, posing operational risks to retrofitting initiatives.

Furthermore, swift advancements in EV technology may make retrofitted vehicles vulnerable to early obsolescence. Balancing the integration of state-of-the-art innovations with long-term sustainability is essential to reduce the risk of technological redundancy. [9]

5.2 Safety Standards and Certification Processes

Thorough testing and calibration are imperative when retrofitting vehicles for electric propulsion, ensuring seamless integration and functionality of all system components. This involves meticulous motor controller calibration, charging functionality validation, and rigorous safety checks to identify and address potential hazards. Safety considerations are paramount throughout the retrofit process, necessitating compliance with established safety standards and regulations. It is essential to guarantee that high-voltage components are adequately insulated, properly grounded, and equipped with critical safety features such as cutoff switches and emergency shutdown procedures.

Moreover, legal and regulatory compliance is non-negotiable, mandating adherence to local, regional, and national regulations governing vehicle modifications, emissions, and safety standards, along with obtaining requisite permits and approvals. Thus, documentation plays a crucial role in maintaining comprehensive records detailing component specifications, wiring diagrams, and implemented safety measures. Certification may also be required for certain aspects of the retrofit to ensure adherence to industry standards. Finally, an essential step before integrating the retrofitted electric vehicle (EV) into daily operations is a thorough final examination by a skilled technician, ensuring adherence to safety and performance benchmarks and assuring the dependability and security of the converted vehicle. [9]



06

Way Forward

6.1 Strategic Recommendations for Policy, Infrastructure, and Consumer Engagement

Public-private partnerships have the potential to cultivate collaboration between government bodies and private companies specializing in EV technologies. These partnerships support joint ventures aimed at developing and distributing retrofitting kits, thereby advancing the adoption of retrofitting solutions.

After analyzing the total cost of ownership (TCO) across various scenarios, it becomes evident that there is an immediate need to introduce multiple innovative business models to foster the growth of the battery leasing sector in the region. This move would not only yield significant profits for operators but would also incentivize them to retrofit their vehicles after 10 years. Additionally, implementing a scrappage policy initially in urban areas and gradually extending it statewide would foster the adoption of electric vehicles and retrofitting of the current fleet.

Anticipating advancements in battery technology, which would lower battery costs and enhance energy density, is vital to extending vehicle range. Providing financial support to early adopters is a critical step toward establishing a self-sustainable model within the state. Furthermore, offering fiscal and non-fiscal incentives for charging stations and battery swapping facilities will encourage investors to develop the required infrastructure in the region. [11]

6.2 Scheme for Scaling Retrofitting Initiatives in Tripura

To develop a scheme for retrofitting 3-wheeler internal combustion engine (ICE) vehicles to electric vehicles (EVs) in Tripura, it's essential to address several policy, infrastructure, and financial aspects. Here's a comprehensive approach to such a scheme:

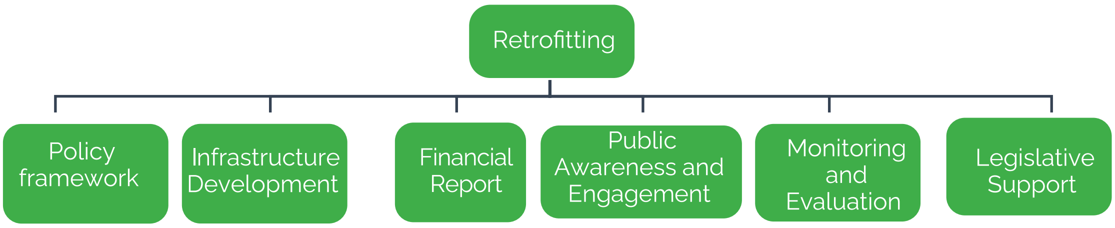


Figure 9: Retrofitting Scheme

a Policy Framework

Incentivization and Regulatory Support

- **RTO Fee Exemption:** Eliminate Regional Transport Office (RTO) fees for EV retrofitting, including charges for Registration Certificate renewal, retrofitting permissions, vehicle evaluation, and fitness certification.
- **Road Tax Exemption:** Introduce a road tax exemption for retrofitted EVs to lower operational costs and enhance the economic appeal of EVs.
- **Equal Treatment:** Ensure that retrofitted EVs receive the same benefits and are subject to the same regulations as newly manufactured EVs, especially in commercial applications.
- **Extended Vehicle Life:** Amend scrapping policies to extend the operational life of vehicles by 10 years post-retrofit, contingent on receiving a new EV fitness certificate.

b Infrastructure Development

Retrofitting Facilities

- **Capital Subsidies:** Offer financial support to existing garages to upgrade their EV retrofitting facilities or establish new authorized retrofitting centers.
- **Technical Training:** Provide training programs for technicians on EV technologies and retrofitting procedures to ensure high-quality conversions.

Inspection and Certification Centers

- **Single-Window Compliance:** Develop a streamlined API for all RTO-related activities to facilitate faster processing and minimize bureaucratic hurdles.
- **Inspection and Certification Infrastructure:** Establish dedicated Inspection and Certification (I&C) centers that can handle the specific needs of retrofitted EVs, ensuring compliance with safety and performance standards.

c Financial Support

Subsidies and Grants

- **Direct Subsidies:** Offer direct financial incentives to both vehicle owners and retrofitting companies to cover a portion of the retrofitting costs.
- **Tax Incentives:** Provide tax breaks or credits to retrofitting service providers and vehicle owners who convert their vehicles to electric.

Low-Cost Financing

- **Green Loans:** Collaborate with financial institutions to offer low-interest loans for retrofitting projects for both individual vehicle owners and businesses engaged in retrofitting services.

f Public Awareness and Engagement

Education and Outreach

- **Awareness Campaigns:** Launch state-wide awareness campaigns to educate the public about the advantages of EVs' and the available retrofitting incentives.
- **Stakeholder Workshops:** Organize workshops targeting vehicle owners, service providers, and local government units to discuss the retrofitting process, its benefits, and regulatory changes.

Demonstrations and Pilot Projects

- **Pilot Retrofitting Project:** Implement a pilot project in select cities within Tripura to demonstrate the feasibility and advantages of vehicle retrofitting, adjusting the program based on feedback and results.

g `Monitoring and Evaluation

Data Collection and Analysis

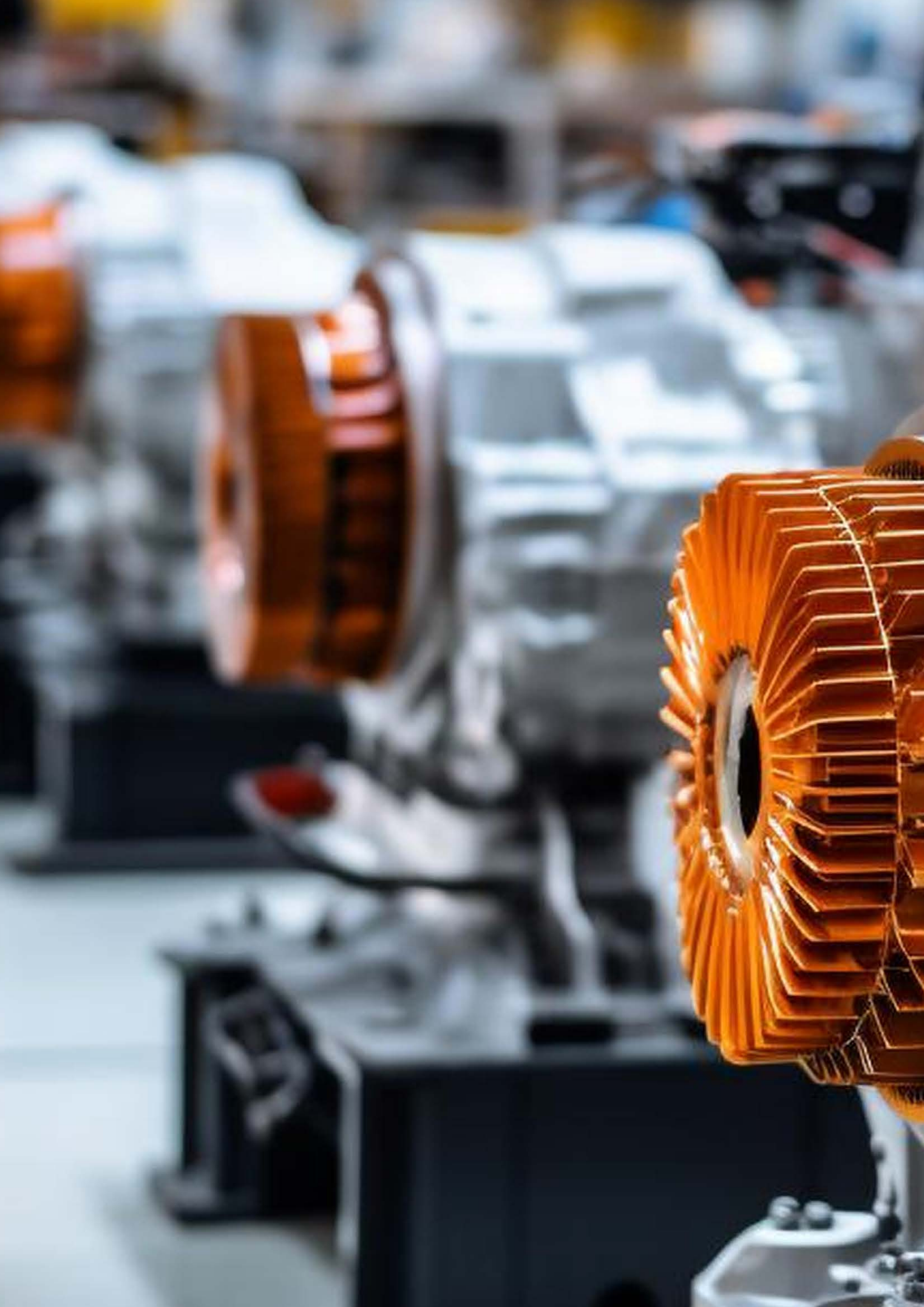
- **Performance Tracking:** Establish a system to monitor the performance of retrofitted vehicles and the utilization of retrofitting centers, gathering data to improve the scheme continuously.
- **Feedback Mechanism:** Set up channels for participants to provide feedback on the retrofitting process and the effectiveness of the incentives and support provided.

h Legislative Support

Legal Framework

- **Modify Existing Laws:** Amend transportation and environmental regulations to support the integration of retrofitted EVs into the transportation system and ensure compliance with environmental standards.
- **Protection Policies:** Implement policies to protect consumers and ensure that retrofitting services meet strict quality and safety standards.

By implementing these strategic steps, Tripura can effectively scale its retrofitting initiatives, paving the way for a more sustainable transportation system while contributing to the broader goals of environmental conservation and economic development.



07

Conclusion

7.1 Summary of Findings

The retrofitting of internal combustion engine (ICE) vehicles to electric vehicles (EVs) represents a significant step forward in accelerating the transition to more sustainable transportation practices. This approach offers a viable and environmentally friendly solution capable of transforming a multitude of ICE vehicles into EVs, thereby mitigating emissions. A comprehensive examination of the significance, market potential, and policy landscape surrounding EV retrofitting underscores its crucial role in reducing emissions and optimizing resource utilization within the automotive sector. By facilitating this transition, EV retrofitting becomes instrumental in addressing pressing environmental concerns.

While EV retrofitting holds immense promise, it confronts various challenges, ranging from technical intricacies to safety considerations, financial constraints, and regulatory complexities. Addressing these challenges necessitates strategic solutions to ensure the effective implementation and scalability of retrofitting initiatives. Collaborative efforts between governments and industry stakeholders are paramount in devising and executing strategies that foster widespread acceptance of EV retrofitting as a viable alternative to vehicle replacement or scrappage. This entails the implementation of tailored awareness campaigns, vocational training programs, and robust research and development endeavors.

Furthermore, innovative business models are pivotal in making retrofitting economically feasible and accessible. By exploring creative approaches to financing, such as leasing or subscription-based models, and incentivizing aftermarket retrofitting services, businesses can expand the reach of retrofitting solutions to a broader market. Additionally, strategic partnerships between automotive manufacturers, technology providers, and service providers can drive innovation and efficiency in the retrofitting process. These collaborative ventures can leverage policy incentives, such as tax reliefs and economic subsidies, to streamline retrofitting and stimulate growth in related industries. Ultimately, a balanced regulatory framework is essential to ensure that technological advancements in retrofitting align with consumer safety, environmental sustainability, and economic viability, thereby paving the way for a more sustainable transportation landscape.

7.2 Final Thoughts and Future Outlook

The potential of retrofitting to drive the widespread adoption of electric vehicles (EVs) is not only undeniable but also pivotal in shaping the future of transportation toward sustainability. By prioritizing this approach, we have the opportunity to propel advancements in EV technologies, resulting in transformative changes that align with global efforts to reduce carbon emissions and achieve ecological sustainability. Retrofitting, rather than being a temporary solution, stands as a significant step towards sustainable mobility, offering a pathway to mitigate the environmental impact of transportation.

The potential impact of effective retrofitting extends beyond individual vehicles; it has the power to reshape entire transportation systems and patterns. By enabling the conversion of a significant portion of the existing vehicle fleet to electric power, retrofitting can potentially revolutionize how people commute, travel, and transport goods. This shift towards electric mobility not only reduces emissions but also opens doors to new modes of transportation and innovative business models centered around sustainable mobility solutions.

However, achieving effective retrofitting requires more than just technological advancements; it necessitates informed decision-making, strategic planning, and collaborative efforts across various sectors. Policymakers, industry players, and the public must work together to develop and execute clear action plans promoting the widespread adoption of EV retrofitting. This report serves as a comprehensive guide, offering insights and recommendations to navigate the complexities of retrofitting and steer towards a sustainable future. It emphasizes the urgency of turning the concept of EV retrofitting into a widespread reality, highlighting its critical role in shaping the future of transportation and safeguarding the planet for future generations.

References

1. Garje, R. R. (2022). Hybrid conversion kit need to be promoted along with pure electric vehicles in India. In Peer Reviewed and Refereed Journal (Issue 5). http://ijmer.in.doi./2022/11.05.92

2. Unknown. (n.d.). Transportation in Tripura. In Unknown. https://slbctripura.pnbindia.in/pdf/Transportation_Tripura.pdf

3. Transport Services in Agartala, Public Transport in Agartala. (n.d.). https://www.agartalaonline.in/city-guide/transport-in-agartala

4. Singh, K. (2023, April 20). Electric vehicle retrofitting conversion process. DIYguru. https://diyguru.org/automotive/electric-vehicle retrofitting-conversion-process/

5. National Electric Mobility Mission Plan. (n.d.). https://pib.gov.in/newsite/printrelease.aspx?relid=116719

6. Going from combustion to electric through retrofitting - Renault Group. (n.d.). Renault Groupe. Going from combustion to electric through retrofitting - Renault Group

7. Raghvendra Singh Patel, A., & Ajeet Mishra, A. (2023). Scope of Retrofitting ICE Vehicle into E Vehicle in India. 11, 5.

8. What is electric vehicle retro-fitment?. Switch Delhi - Find a charging station near you. (n.d.). https://ev.delhi.gov.in/retro-fitment

9. Hoeft, F. (2021). Internal combustion engine to electric vehicle retrofitting: Potential customer's needs, public perception and business model implications. Transportation Research Interdisciplinary Perspectives, 9. https://doi.org/10.1016/j.trip.2021.100330

10. Research, J. (2023, March 28). How electric vehicle retrofitting can be a viable solution to limiting vehicular emissions in India. JMK Research & Analytics. https://jmkresearch.com/how-electric-vehicle-retrofitting-can-be-a-viable-solution-to-limiting-vehicular-emissions-in-india/

11. Shandilya, N., Saini, V., & Ghorpade, A. R. (2019). Supporting Sustainable Mobility under Smart City Mission Title: E-Rickshaw Deployment in Indian Cities-Handbook (Supporting Sustainable Mobility under Smart City Mission) Publisher: ICLEI-Local Governments for Sustainability, South Asia (ICLEI South Asia). http://southasia.iclei.org/

Alliance for an Energy-Efficient Economy
37, Link Road, Ground Floor, Lajpat Nagar III,
New Delhi 110024

+91-11-4123 5600 info@aeee.in www.aeee.in