POLICY FACTSHEET

E-RETROFITTING INTERNAL COMBUSTION ENGINES

Lessons and Next Steps

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Authors: Anumita Roychowdhury, Moushumi Mohanty, Rohit Garg and Mrinal Tripathi

Editor: Rituparna Sengupta

Cover and design: Ajit Bajaj

Layout: Surender Singh

Production: Rakesh Shrivastava and Gundhar Das

Citation: Anumita Roychowdhury, Moushumi Mohanty, Rohit Garg and Mrinal Tripathi 2024, *E-retrofitting internal combustion engines: Lessons and next steps*, Centre for Science and Environment, New Delhi

Published by
Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phone: 91-11-40616000
Fax: 91-11-29955879
E-mail: cse@cseinida.org
Website: www.cseindia.org

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About the study

India is advancing its efforts to accelerate the electrification of new vehicles, aiming for a target of 30 per cent electric vehicle adoption in the fleet by 2030.[1] This has sparked increasing interest among states to explore the option of retrofitting older internal combustion engines (ICE) with electric propulsion kits for full electric operations.

This interest is largely driven by concerns around the pollution impacts of ageing ICE fleet and the need for rapid fleet renewal. Currently, there is no incentive support for electric retrofitment (e-retrofitment) under the Faster Adoption and Manufacturing of Electric Vehicles (FAME) programme that had started in 2015. But several state governments who have framed their respective electric vehicle (EV) policies have begun to incorporate the provision on e-retrofitment of older ICE vehicles as an option for upscaled transition.

The primary reason for this interest is the high upfront cost of the new EVs and the challenges in motivating a large consumer base to move quickly towards them and bear the cost of this transition.

Additionally, under the National Clean Air Programme and directives from the Supreme Court, High Courts, and the National Green Tribunal (NGT), several cities and states are required to phase out old internal combustion engine (ICE) vehicles.[2]

In fact, following the NGT order that was upheld by the Supreme Court, diesel vehicles that are more than 10 years old and petrol vehicles that are 15 years old are not permitted in Delhi. Similarly, vehicles that are more than 15 years old are not allowed in the larger National Capital Region and other states including West Bengal. Similarly, for several other cities like Kochi, policy mandates that autorickshaws older than 15 years and running on diesel, should not be allowed to operate unless retrofitted with LPG/LNG/CNG/electric.[3]

The enforcement of these measures has intensified the pressure to phase out older vehicles.To mitigate the high upfront costs associated with replacing these vehicles with new Bharat Stage VI compliant ICE vehicles or electric vehicles, state governments and consumers are increasingly exploring the more economical option of retrofitting older ICE vehicles with electric propulsion technologies. This involves the installation of a battery- and motor-based propulsion system

after removing ICE components from a petrol/diesel-based system and making batteries the prime movers of vehicles.

As state EV policies have begun to permit this option and a retrofitment industry is beginning to take shape in the country, vehicle testing and certification bodies like the Automotive Research Association of India (ARAI) and International Centre for Automotive Technology (ICAT) have also stepped in to frame the regulations and technical standards for e-retrofitting ICE vehicles.This will provide a legal framework for the certification and testing of retrofitment kits for converting internal combustion engine (ICE) vehicles to electric vehicles.

This development has elicited mixed reactions within the market as well as in the policy community. On one hand, e-retrofitment is considered technically feasible and cost-effective, with tested, certified, and verifiable technology. However, there are concerns about potential safety risks arising from a weak compliance and implementation framework.

Several stakeholders have expressed the need for on-ground quality control and the prevention of inappropriate selection of older technologies that are not suitable for retrofitment, among others. There is also a concern that such a transitory and intermediate solutions could potentially divert attention from the new EV market and delay the mainstreaming of electric propulsion.

In view of its potential and also the challenges, the Centre for Science and Environment (CSE) has carried out a rapid review to understand the status of the e-retrofitment market, the emerging issues related to retrofitment and what is needed. It is not only important to inform the initiative in Indian states but also share experience with the initiatives that are emerging in the Gobal South, including Africa. Several developing countries, and especially countries that import vehicles, are showing interest in retrofitment strategies. A robust system in India can create a learning curve for experience sharing.

Key highlights

State EV policies support retrofitment, but lack comprehensive guidelines: Currently, there is no separate incentive programme for e-retrofitment at the central government level. However, nearly eight states including, Delhi, Assam, Chandigarh, Rajasthan, Telangana, Tamil Nadu, Uttar Pradesh and Kerala have provided for e-retrofitment in their respective electric vehicle policies.Some of them have included fiscal incentives largely targeting smaller vehicles like three-wheelers.

In most states,e-retrofitment has been permitted without adopting proper guidance framework for quality control of the programme. Only the Government of NCT of Delhi has a defined policy on e-retro-fitment that defines the type of diesel and petrol vehicles that can be retrofitted. The Delhi Transport Department has also empanelled retrofitment kits for different vehicle categories and models, and agencies or conversion centres.[4] Detailed procedures for prior approval for retrofitment and registration of retrofitted vehicles have been laid down.

Scope of implementation is still very limited: Despite some state governments offering financial incentives for retrofitment, this market is yet to scale. In most states the market is still very limited and largely confined to small vehicles like three-wheelers. Retrofitment is also being carried out for some niche use cases like the safari vehicles of the forest department in Madhya Pradesh. Retrofitment is also possible in bigger vehicles like buses and trucks. There are instances of medium-duty truck fleets being retrofitted for specific uses. But this is still very niche and small. Robust backing for new electric bus programmess, particularly under FAME and the PM e-Bus Sewa, along with state government commitments to base future expansion solely on new electric buses, has invigorated the electric bus market and contributed to achieving price parity with diesel buses. However, there is barely any data and evidence from systematic assessment of on-road performance of retrofitted vehicles. Most of the understanding is anecdotal.

Nascent growth of the e-retrofitment industry: This industry largely includes small companies and start-ups. Retrofitment centres have been set up in metropolitan cities and industrial hubs such as Delhi NCR, Bangalore, Hyderabad and Pune. Retrofitters usually offer services for selected vehicle models, as the retrofitment kits are designed and certified for specific models and cannot be applied generically across all models. But separate homologation procedures add to costs significantly. In the two and three-wheeler segments, few retrofitters have also attempted a battery subscription/swapping model to reduce the upfront cost of the retrofitted vehicle. Challenges such as expensive certifications and low consumer awareness/confidence are some of the impediments to achieving scale.

Evolving regulatory framework for retrofitment: There is already a regulatory mechanism in place for the certification of retrofitted vehicles. Specified regulatory requirements and conditions need to be fulfilled for quality control and safety. To address the concerns around safety, integrity, on-road performance and durability of the e-retrofitment technology and kits, regulatory framework and technical standards have been framed to ensure quality control, and safety, stability and

on-road performance. The Automotive Research Association of India (ARAI) has framed these technical norms and along with other testing and certification bodies like International Centre for Automotive Technology (ICAT), testing, homologation and certification of the retrofitment systems are being conducted.

Need to align the technical standards for retrofitment with the newly amended safety standards: Safety and on-road performance of e-retrofitment are concerns that several market observers and industry representatives have expressed. The retrofitting standard AIS-123 and AIS-048 standard for battery testing and certification are in place, but these have not incorporated the newly amended EV safety standards AIS- 038(Rev 2) and newly amended AIS-156 that are more stringent and apply to new vehicles. AIS-123 also does not cover safety and integrity of the battery in the retrofitted system. There are no tests for ensuring lower vibration levels with secure installation of the battery in the old vehicle chassis. This needs to be mandated. If the amended and more stringent safety norms under AIS156 are not applied, this may compromise safety performance. Therefore, it should be made mandatory to align the amended AIS 156 and AIS 038 (Rev 2) with AIS123.

Testing and certification capacity is limited and causes delay: For a retrofitted vehicle to be certified roadworthy, it needs to be homologated by a competent authority such as ARAI and ICAT. This includes fitness tests, emission and safety and road-worthiness tests as per the Central Motor Vehicle Rules (CMVR). But there are only two testing authorities to service large numbers of certification requests. The homologation process is also time consuming and involves high costs. Often the certifying body has to begin by buying the equipment required to test technology-rich vehicles. The high cost of certification affects the profit margin. Moreover, certification of one kit for a particular vehicle model cannot be used for another variant of the same model. If the kit fails the certification process, retrofitters have to re-apply and pay again.

Cost of e-retrofitment: The cost of e-retrofitment of older ICE vehicles is much cheaper than the upfront cost of new EVs. The cost components of a new EV include the upfront costs of purchase and for the battery replacement after five to eight years. The total cost of ownership of new vehicles includes the entire useful life of the vehicles. Retrofitted vehicles have a much smaller lifespan depending on the age at the time of retrofitment. With retrofitment, a vehicle may get an additional life of another four to five years depending on the age of the vehicle. Therefore, the total cost of ownership in this case is different.

However, simply put, if a new electric two-wheeler costs between Rs 80,000 to Rs 1.65 lakh, a retrofitted unit will be priced between Rs 25,000 to Rs 65,000 including registration fees. Similarly, three-wheelers used for commercial purposes can be retrofitted in the range of Rs 50,000 to Rs 1.25 lakh, compared to Rs 2.5 lakh to Rs 4 lakh for a new one. While there is a huge difference in the capital cost of a new EV and the retrofitment cost of an older vehicle, the common costs include registration costs, purchase taxes, maintenance, insurance, home charger installation cost, electricity charges and residual value. The GST on a new EV is five per cent while on spare parts (other than batteries), it is 28 per cent. The retrofitters also usually include registration fees in their overall retrofitment cost. However, overall, the lower cost of retrofitment (the range may vary across models and vehicle segment) makes this an attractive option for addressing the problem of old ICE vehicles.

Demand for adequate and effective safeguard while implementing retrofitment programme: While technically, retrofitment is possible and feasible, there are concerns that, if not done with adequate quality control, it may compromise on-road performance and safety. The Clean Air Policy 2022 of the Air Commission of Delhi-NCR states that 'while technically and principally e-retrofitment is possible and feasible, several safeguards and preparedness are needed for its conditional implementation for safe and reliable conversion.'[5] This policy recommends that retrofitment be permitted under certain conditions, including the certification of retrofitment kits for specified makes and models according to established standards. Additionally, based on the central government rules, the state governments need to further define and notify the implementation mechanism for retrofitment. In fact, the Delhi government, in its EV policy, has outlined the technical and regulatory conditions to be fulfilled for e-retrofitment and even though the ARAI standards technically allow vehicles of 1990 vintage to be e-retrofitted, Delhi government policy does not allow diesel vehicles that are more than 15 years old to be retrofitted. Petrol vehicles are allowed to be retrofitted only if they fulfil fitness criteria.

Need effective screening of internal combustion vehicles for retrofitment: There are also concerns around maintaining the structural integrity of the chassis of a used ICE vehicle being considered for retrofitting. This needs very stringent screening and prevention of retrofitting of already compromised vehicles. The chassis will require proper testing for static and dynamic loads, fatigue and durability, etc to assess the prospects of packaging battery pack etc on the old chassis. Even though AIS-123 addresses these aspects in the respective models, its on-ground enforcement will be critical.

Build consumer awareness about quality of retrofitment: Customers need to do a thorough background check of the retrofitter including aspects such as the location of their workshop and headquarters, certification and audits, whether their financials are capable of supporting the warranties they are offering on their components, especially the battery. Due diligence must be mandated to ascertain the retrofitter's supply chain feasibility and whether their vendor systems are capable of handling the particular request and also to find out whether the retrofitter is taking up projects based on their own technical expertise or has outsourced most of the work to third party with no quality control. These necessary checks have to be incorporated into regulation set up by the government.[6]

Making state-level fiscal incentives performance linked for quality control and issues related to financing: As state governments are providing fiscal incentives, it may be linked with the performance and audit. Moreover, retrofitters also highlight the challenge of inadequate fiscal support and financing instruments for retrofitment, which is a common challenge in the EV sector. Several three-wheeler retrofitters have pointed out that it is only recently that private financiers have begun to show interest in financing this strategy. In fact, one of the business models where retrofitters retrofitting a vehicle are also providing batteries on a rental basis has drawn interest of the financiers.

Frame comprehensive guidelines for state-level implementation: It will be beneficial if states have a national guidance framework for the implementation of retrofitment to guide the efforts and ensure effective quality control. This is important especially in view of the possibility of decentralized small enterprises and outsourcing of practices to third parties.

Nonetheless, retrofitment is usually a transitory business, and continues till new technology is fully and firmly established in the market, achieves cost parity with the ICE counterparts and the production base is scaled up adequately for the new technology. But while this is happening, the regulatory, technical and compliance frameworks need to robust and implementable.

E-retrofitment must also not delay the scaling up of the market for new EVs at a time when India's policies are expected to upscale the EV production and market for the transformative changes that are needed for an ambitious net-zero goal. The effectiveness of the FAME and production-linked incentives for advanced chemistry batteries, which aim to scale up production and meet ambitious decarbonization targets, could be impacted if the strategy for renewing the old fleet leans significantly towards e-retrofitment. Therefore, finding the right balance in planning will be crucial.

Next steps

As this nascent market begins to scale it is necessary to define and enforce the regulatory terms for a robust and an effective programme.

- E-retrofitment requires alignment with stringent safety standards to prevent the risk of an accident. Any episode of a safety-related accident in the retrofitment segment can jeopardize the overall EV market and its progress.
- The state governments need to notify and adopt detailed guidelines on the conditions to be fulfilled for quality control of e-retrofitment. Like Delhi, state EV policies need to specify the vehicle vintage and types that are eligible for e-retrofitment and also those that do not qualify.
- It is important to ensure that the method of screening of the vehicles for fitness of chassis, overall structural stability and strength etc are assessed adequately before e-retrofitment is undertaken. Assessing the adequacy of the infrastructure at the automated fitness testing centres that are to undertake the screenings is also important.
- The fiscal incentives being offered by the state governments for e-retrofitment need to be performance linked and the conditions need to be clearly laid down.
- There should be an oversight and monitoring body to audit the e-retrofitment workshops.
- Notify the list of prospective e-retrofitment agencies/vendors at the central and state level after proper verification and certification of the facilities.
- Ensure after-market maintenance services and fulfilment of the warranty conditions.
- New private financing models for e-retrofitment and their terms and conditions need to drive quality control and put in place proper checks.
- The financing models can also help to establish residual value for sprucing up financing mechanism.
- The central government may also help to frame a comprehensive guidance on e-retrofitment to guide implementation in states.
- The retrofitment agencies also need to be brought within the fold of end-producer responsibility for disposal of the spent batteries.

1. EV policies and e-retrofitment

Currently, states don't have a national-level programme to support e-retrofitment with central incentives. On the other hand, all Indian states and five Union Territories have framed electric vehicle (EV) policies to promote state-level electrification of vehicles. Broadly, these have provided for incentives for new EVs, support for charging infrastructure and strategies for promoting local manufacturing with some variations. Out of these, about eight states including, Delhi, Assam, Chandigarh, Rajasthan, Telangana, Tamil Nadu, Uttar Pradesh and Kerala have provided for e-retrofitment. Barring Delhi, other states in this group are also providing fiscal incentives that include tax rebates and additional fiscal support (*see Table 1: State electric vehicle policies on retrofitment*).

Table 1: State electric vehicle policies on retrofitment

State	Policy notification and validity	Policy highlights
Delhi	2020	Retrofitment of 10-year-old diesel vehicles and 15-year-old petrol vehicles. Empanelled eight different retrofitting kits, having certified retrofitting products and services, and authorizing the conversion centres. There is no incentive for the programme.
Assam	2021 (five years)	Incentive of 15 per cent (up to INR 15,000) for three-seater auto-rickshaws
Chandigarh	2022 (five years)	E-cart: 15 per cent of cost (up to INR 10,000) for the first 1,000 vehicles registered during the policy period. E-auto:15 per cent of cost (up to INR 15,000) for the first 1,000 vehicles registered during policy period. E-goods carrier: L5N 15 per cent of cost (up to INR 15,000) for first 1,000 carriers registered during the policy period. Goods carrier N1: 15 per cent of cost (up to INR 25,000) for the first 1,000 carriers registered during the policy period.
Rajasthan	2022 (five years)	e-3W (e-rickshaw, e-cart, e-goods carrier and e-auto) 15 per cent of retrofitting cost (including taxes), up to Rs 10,000 vehicles for 3,000 vehicles e-4W (personal cars, taxi, commercial vehicle, light goods vehicle 15 per cent of retrofitting cost (including taxes), up to Rs 15,000/vehicle for 2,000 vehicles e-bus 15 per cent of retrofitting cost (including taxes), up to Rs 250,000/ vehicle for 2,000 vehicles.
Telangana	2020 (10 years)	3-seater auto-rickshaw up to Rs. 15,000/vehicle for first 5,000
Tamil Nadu	2023 (five years)	E-2 wheelers up to INR 15000/vehicle for first 30,000 vehicles E-3 wheelers up to INR 20,000/ vehicle for first 15,000 vehicles
Uttar Pradesh	2022	Supports three wheelers
Kerala	State Budget 2022	INR 15,000 per vehicle for three-wheelers

Source: https://evyatra.beeindia.gov.in/state-govt/

The scope of these programmes varies. Most states have prioritized two/three wheelers as the priority segment for retro-fitment. Assam, Uttar Pradesh, Telangana and Kerala allow e-retrofitment of three-wheelers and e-rickshaws. Chandigarh supports retrofitment of e-carts, e-autos, and goods carriers. Tamil Nadu supports the retrofitment two/three-wheelers. Rajasthan supports all categories including e-autos, four wheelers and buses. The Delhi programme also includes two/three-wheelers and four-wheelers. The conditions for retrofitment vary across states.

In most states, e-retrofitment strategies have been adopted without a proper guidance framework for quality control. Guidelines for implementation are yet to be released in several states.

Only the Government of the National Capital Territory (NCT) of Delhi has taken some steps to organize the e-retrofitment market (*see Box: The key elements of e-retrofitment in the EV policy of the Government of NCT Delhi*). The Delhi Electric Vehicle Policy that was notified on 7 August, 2020 and expired on 8 August, 2023, has now been extended to 30 June, 2024. The Delhi EV Policy 2.0, currently in development, is anticipated to incorporate incentives for both scrapping and retrofitting vehicles.[7]

The Delhi Government permits the conversion of diesel vehicles up to 10 years old and petrol vehicles up to 15 years old to electric vehicles. At the same time, the transport department has empanelled retro-fitment kits for different vehicle categories and models, and identified the agencies or conversion centres who will be providing these services in Delhi.[8] The policy defines a standard operating procedure for registration of retrofitted vehicles and lays down clear guidelines for eligibility. For example, diesel four-wheelers up to 15 years old can be retrofitted and continue to operate until they reach their 15th year, but not beyond that.

Prior approval is needed for getting the vehicle retrofitted (as per rule 47A of CMVR, 1989) by submitting a vehicle retrofitment request to the registering authority. Once permission is granted, the vehicle owner is advised to approach an approved Electric Retrofitment Centre to get their vehicle retrofitted using an approved electric kit. All the above are subject to the availability of type approval with respect to the make and model of the vehicle and the retro-fitment centre being duly authorized by the kit manufacturer and the transport department.

Although the government has established an online platform for registration, the process is not fully digital. It involves multiple approvals, making it both time-

THE KEY ELEMENTS OF E-RETROFITMENT IN THE EV POLICY OF THE GOVERNMENT OF NCT DELHI

1. Vehicle categories that are permitted/not permitted to be retrofitted

- The policy recognizes the risks involved in retrofitting very old vehicles and therefore does not allow vehicles older than 15 years old to be retrofitted.
- Diesel vehicles that have been registered for over 10 years but less than 15 years are allowed.
- Diesel vehicles that have been registered for less than 10 years of registration are allowed.
- Petrol and CNG vehicles older than 15 years can be re-registered and continue to operate if they pass a certificate of fitness. Re-registration is allowed after 15 years, contingent upon the vehicle's fitness.
- Petrol/CNG vehicles less than 15 years are allowed to be retrofitted.
- Transport (commercial) vehicles that are older than 15 years are not allowed irrespective of fuel type.

2. Legal requirements for retrofitment

- Retrofitting kits shall have the approval of a designated testing agency as specified in Rule 12b of CMVR, 1989.
- Retrofitment will be subjected to availability of type-approved kits with respect to the make and model of the vehicle models and the retrofitment centre duly authorized by the kit manufacturer and the transport department.
- For 10-year-old diesel vehicles and 15-year petrol/CNG vehicles, the approval/endorsement of electric fuel and registration certificate shall be carried out simultaneously.

3. Criteria for identifying a retrofitter

- Identifying the manufacturer or importer of pure electric retrofitment kits for specific vehicle makes and models, and consulting the list of authorized retrofitment dealers on the Switch Delhi website for corresponding vehicle models.
- Obtain prior approval for getting vehicles retrofitted (as per rule 47A of CMVR, 1989)
- Vehicle retrofitment request to be submitted through FORM 22 PART-I to the registering authority.

4. Responsibility of the vehicle owners

- After the permission is granted, the vehicle owner will approach the approved Electric Retrofitment Centre (ERFC) as per details submitted in Form 22 C, Part-I and get their vehicle retrofitted by an approved pure electric kit.

5. Post-retrofitment requirements

- The vehicle owner must apply for an endorsement of electric fuel in the Registration Certificate using the VAAHAN software by submitting Form 22D and paying the appropriate fee.
- The vehicle owner must apply for a re-registration certificate using Form 25 and pay the required fee. Re-registration will be carried out by the registration authority, subject to the vehicle's certificate of fitness. The vehicle owner should also apply for an endorsement of electric fuel in the Registration Certificate via the VAAHAN software, submitting Form 22D and paying the appropriate fee.
- The authorized ERFC will submit a compliance report for Alteration/Retrofitment in Form 22F to VAAHAN.
- The authorized ERFC will submit compliance report for Alteration/Retrofitment in Form 22F to VAAHAN.

Source: CSE

Battery test rig in a retro-fitment workshop in Delhi NCR

consuming and cumbersome. In 2022, an empanelled e-retrofit vendor in Delhi received certification for retrofitting the TVS Zest two-wheeler model. Despite handling retrofitment inquiries in the two-wheeler segment initially, the company had to halt services due to low demand. Nevertheless, they continue to service the 50 to 60 scooters they retrofitted two years ago.

Even though retrofitment is legally and technically possible, the scale of the market is still very limited and largely confined to small vehicles like three-wheelers in most states.

In Chandigarh, retrofitment facilities were expected to be set up soon after the EV policy was released. However, financial feasibility continued to be a challenge. Retrofitting three-wheelers in Kerala, however, has witnessed some traction. The Kerala government has offered incentives for retrofitting three-wheeler in its 2022 State Budget. A few companies, namely Voltas EV, ME Drive and RAC Energy, responded to budget incentives and offered solutions for old auto rickshaws with both fixed and swappable batteries.

Retrofitment is also being carried out for some niche-use cases. For instance, in Madhya Pradesh, the Forest Department has retrofitted a few Maruti Gypsy safari

Retrofitted Maruti Suzuki Gypsy of forest department in Madhya Pradesh

vehicles with a 35 kWh LFP battery and 21 kW motor at the Van Vihar National Park in Bhopal (*see Retrofitted Maruti Suzuki Gypsy*).

Retrofitment is also feasible for larger vehicles, such as buses and trucks. In fact, as early as 2015, a retrofitted bus was launched in Delhi, but the initiative did not progress far. Strong support for new electric bus programmes, including those under the FAME initiative and the current PM e-Bus Sewa scheme, along with state government commitments to base future expansions solely on new electric buses, has invigorated the e-bus market and brought it closer to achieving price parity with diesel buses. Now, it's crucial to maintain and build on this momentum.

There are also instances of medium-duty truck fleet being retrofitted for specific use cases. But this is still very niche and small.

Despite some state governments offering financial incentives for retrofitment, the market for this technology has yet to achieve significant scale. Industry representatives note that although financial incentives for retrofitment are available in some states like Chandigarh, the process may still be cost-prohibitive for targeted consumers due to additional expenses that are not covered by these incentives. Financing may be an impediment in the absence of a well-defined mechanism to ascertain the residual value of retrofitted EVs.[9]

Emerging retrofitment industry

The e-retrofitment industry is in its early stages of growth and is dominated by small companies and start-ups. Retrofitment centers have been established in key metropolitan areas and industrial hubs, such as Delhi NCR, Bangalore, Hyderabad, and Pune.

The retrofitters are experimenting with different business models and powertrain configurations in a bid to achieve economic viability. The most common model involves the retrofitter converting a pre-owned ICE vehicle to electrical by utilizing a customized retrofitment kit. Retrofitters usually offer services for selected vehicle models, since the retrofitment kits are unique to each model and are required to undergo separate homologation procedure that incur significant costs.

For individual vehicle retrofitment, the primary consumers are owners of high-end luxury or vintage vehicles. These owners seek to avoid government-mandated scrappage requirements, provided their vehicles' chassis meet adequate fitness standards.

In the commercial segment, retrofitment business is largely confined to small vehicles like three-wheelers. In the two-and three-wheeler segments, few retrofitters have also attempted a battery subscription/swapping model to reduce the upfront cost of the retrofitted vehicle.

Challenges such as expensive certifications and low consumer awareness/ confidence have hindered the scaling up of the industry. Recently a large automotive component group, Bharat Forge (Kalyani Powertrain), has invested in a retrofitting line with plans to target medium and heavy commercial vehicles.

2. Regulatory framework for retrofitment

Just like the new EVs, concerns about safety, integrity and performance are crucial for e-retrofitment technology and kits. The regulatory framework for e-retrofitment aims to ensure quality control, safety, stability, and reliable on-road performance. Therefore, a range of technical standards and norms have evolved to regulate this market. The Automotive Research Association of India (ARAI) has developed these technical standards, and testing, homologation, and certification of retrofitment systems are conducted by ARAI and other bodies such as the International Centre for Automotive Technology (ICAT). Understanding the nature and scope of these regulations is essential for advancing this market.

Certification of e-retrofitment

The method for testing and certification of e-retrofitment kits has already evolved. The ARAI had first published Automotive Indian Standard (AIS)-123 as a standard for e-retrofitment of vehicles with a hybrid electric powertrain in 2013. Subsequently, in 2016, it laid down guidelines for type approval of electric propulsion kit intended for conversion of vehicles for pure electric operation under the Central Motor Vehicle Rules (CMVR). This includes a range of important tests such as vehicle weighment, coast down test and brake performance that are necessary for a new EV as well.

The scope of the standard includes the requirements specific to the electric propulsion kit intended for conversion of vehicles of L1, L2, L5, M, N1, N2 and N3 category for pure electric operation.[10] This caters to vehicles that were manufactured on and after 1 January, 1990, and are not provided with permits for carrying dangerous or hazardous goods, as defined in CMVR.

- AIS-123 (Part 1) regulates type approval of vehicles retrofitted with hybrid electric system for L, M and N category < 3,500 kg.
- AIS-123 (Part 2) is a standard for Type Approval of hybrid electric system for retrofitment of vehicles of M and N Category with GVW > 3,500 kg
- AIS-123 (Part 3), lays down guidelines for CMVR Type approval of electric propulsion kit intended for conversion of vehicles (L, M, N category) for pure electric operation.

AIS 123 draws on considerably from European regulations UN ECE R 100 which contains provisions concerning approvals of construction and functional safety of

EVs; and UN ECE R 101 which contains provisions regarding the measurement of electric energy consumption and electric range.

The goal of AIS 123 is to prevent unsafe conversions from internal combustion engines (ICE) to electric vehicles (EVs), to establish standardized retrofitment procedures, and to mitigate hazards associated with integrating an electric powertrain into existing vehicle chassis.

Indian regulations treat homologation of retrofitment kits in a manner similar to the homologation of new vehicles. AIS 123 establishes the technical, mechanical and safety tests a retrofitted vehicle must undergo. It stresses on regulating the change in vehicle weight due to the electric propulsion kit to within a permissible limit. The regulation includes all the major procedures required to test the dynamics at a vehicle level, such as coast down test, grade ability test, brake performance.

A notable omission is the lack of environmental testing. Current retrofitment kit component approval tests cover traction motor performance, battery testing, electromagnetic compatibility (EMC), and wiring harness compliance. Additionally, the vehicle undergoing retrofitting must possess a valid certificate of fitness.

Importantly, authorized retrofitters must adhere to a code of practice that governs the design, installation, operation, inspection, and maintenance of retrofitment kits. For instance, AIS 123 requires that the layout of the retrofitted vehicle be submitted for approval. Additionally, the testing agency is required to verify the weight distribution post-retrofit and assess any potential adverse effects on the vehicle's structure.

Testing and certification challenges

Certification: For a retrofitted vehicle to be certified roadworthy, it needs to be homologated by a competent authority such as ARAI and ICAT. The fitness tests ensure that the vehicle matches the requirements of the Indian market in terms of emission, safety and road-worthiness as per the CMVR. But with only two testing authorities, the sector is wanting in capacity to service large numbers of certification requests.

The homologation process is time-consuming and involves high costs. It could take anywhere between a few months to a year to get done. Often the certifying body has to begin by buying the equipment required to test technology-rich vehicles. The cost of homologating a retrofitted vehicle can vary from INR 10 lakh to 35

lakh, depending on the segment. This substantial expense can pose a profitability challenge for retrofitters if there is insufficient demand for retrofitting the same vehicle model.

Certification of one kit for a particular vehicle model cannot be used for another variant of the same model. Also, if the kit fails the certification process, the retrofitter must re-apply by paying the certification fee again. To make retrofitting a profitable operation, the cost of certification needs to be spread over several vehicles of the same model. A dearth of demand in relevant models makes conversion a costly affair.

While the high registration homologation fee effectively deters the proliferation of an unregulated sector, it also creates a significant barrier for retrofitters looking to offer retrofitment kits for multiple vehicle models.

Disconnect with latest EV Battery safety regulations (AIS-038 and AIS-156 amendments): The retrofitment standards, AIS-123, refers to the AIS-048 standard for battery testing and certification and not to EV safety standards AIS- 038(Rev 2) and AIS- 156. The AIS- 048 standard was suited for lead-acid batteries and not lithium-ion batteries that are used in retrofitted EVs. AIS-123 also does not cover safety and integrity of the battery in the system. There are no tests prescribed for ensuring lower vibration levels with secure installation of the battery in the old vehicle chassis. That needs to be mandated.

Aditionally, the AIS 156 was designed to strengthen the safety parameters for testing batteries used in electric vehicles. The standard included specific requirements for L category electric vehicle certification and AIS 038 (Rev 2) for M and N categories. Following the fire incidents in 2022, amendments to AIS 156 and AIS 038 (Rev 2) were notified to make the regulations more stringent to address safety risks posed by lithium-ion batteries in harsh operating environments. The amendments came into force from December, 2022. To enable safe operations in retrofitted vehicles, AIS 123 needs to be mandatorily complemented with AIS 038(Rev 2) and AIS 156.

Thus, for regulations to be enabling and stringent enough for the manufacture of safe EV retrofit kits, it is important to link AIS-123 to AIS-038(Rev 2) and AIS-156, which regulate lithium-ion batteries, commonly included in retrofitment kits. Additionally, it is important to release a list of empanelled vendors and make the re-registration process seamless, clear and easy.

Registration of e-retrofitted vehicles: Changing the registration of a vehicle from the Regional Transport Office (RTO) after converting from ICE vehicle to electric throws up its own challenges. A change in the fuel category for a specific vehicle model translates into a change in the colour of the number plate to green, even though the number remains the same. This process is reportedly not yet available online and offline transactions lead to errors in the paperwork stretching the timeframe for conversion. In addition, the process requires multiple approvals, making it extremely time-consuming. Installation of a new kit and registration could take as long as three months to a year.

Empanelment of verified vendors: The safety and quality standards of retrofitment kits is a legitimate concern. In order to change the registration of a retrofitted vehicle from ICE to EV at the RTO, the vehicle needs to be installed with an ARAI certified retrofitment kit. However, lack of clarity and understanding of the market poses the risk of uncertified or unsafe retrofitment kits finding a market. This issue could be resolved with a publicly available valid list of ARAI-certified retrofitment companies. Responding to this challenge, the Delhi government has empanelled eight retrofitment kits in a bid to simplify the process.

Assessing chassis worthiness: The chassis is the load-bearing base of the vehicle. Consequently, the structural integrity of the chassis in a used internal combustion engine (ICE) vehicle proposed for retrofitting must be thoroughly examined for defects like cracks, rust, and previous accidental damage. It is essential to conduct relevant testing on the chassis to assess its performance under static and dynamic loads, as well as its fatigue, durability, and impact on noise, vibration, and harshness (NVH) levels.

Typically, the chassis and transmission of the used vehicle is designed and built to be powered by an ICE with pre-defined cavities for the ICE-based powertrain components like fuel tank, engine accessories and exhaust system. Retrofitment entails the incorporation of an electric propulsion-based powertrain on a non-native platform. These powertrain modifications introduce challenges of packaging of the battery pack onto the old chassis, maintaining optimum weight distribution of the overall vehicle, and also result in reduced on-road efficiency (compared to a new EV) due to presence of dead weights.

AIS-123 covers these aspects comprehensively by mandating retrofit kit manufacturers/suppliers to provide a layout plan for retrofitment of kits in the respective models. The layout is required to indicate the locations of key elements

including the placement of the batteries, motor, controller, wiring harness routing and charging socket. It further declares that the retrofitment of the kit shall be on the basis of such approved layout plan only. Retrofitted vehicles shall be subjected to electric range, electric energy consumption tests and physical verification of the converted vehicle as per the layout submitted by the kit manufacturer/supplier during initial type approval. Additionally, the testing agency must verify the weight distribution resulting from the installation of the Electric Propulsion Kit to ensure there are no adverse effects on the vehicle's structure.

In fact, packaging of components is more challenging for bigger vehicles compared to smaller vehicles. For heavy duty vehicles it is important to look at the overall driveline, installation of electronic components and vibration concerns. On the other hand, 3Ws and LCVs with low duty cycles, running about 70–80 km/day, are technically more suitable for retrofitment.

3. Understanding technical aspects of e-retrofitment

E- retrofitting involves conversion of a vehicle from a fuel-based propulsion[11] to battery-based propulsion.[12] For e-retrofitment, the most important consideration in the evaluation and determination of vehicle system architecture is the modification required to attain the most optimum solution for the vehicle (*see Table 4: Components affected by retrofitment*). The system architecture includes a vehicle propulsion system, electric motor and controllers, outer dimensions and power requirement of the vehicle, brakes and suspension system.

Often, retrofitters avoid too many modifications to the existing arrangement of systems such as brakes and suspension to avoid cost escalation and associated handling risk. Retrofitting involves the removal of engine-driven accessories and the instalment of electric drive components to replace the drivetrain. It is important to evaluate whether the existing suspension and brakes system will be able to manage the modified vehicle load after replacing the engine driven accessories.

An e-retrofitting kit typically includes component aggregates such as traction motor, battery, inverter, wiring harness, connectors, state of charge indicators, vehicle control unit and on-board chargers.

Table 2: Components affected by e-retrofitment

Components to be removed	Components to be added
• Engine • Fuel tank • Fuel pipe • Exhaust • Engine accessories	• Battery • Motor • Motor controller • Wire harness • Charging socket

Retrofitters opting for minimal modifications to a vehicle often opt for a hybrid system instead of an all-electric conversion. This involves the integration of a hybrid-electric retrofit kit (battery, controller and motor) to the existing ICE powertrain. Thus, the vehicle uses a combination of an ICE and the motor to improve efficiency.

RETROFITMENT STANDARD AIS-123 (PART 3)

Following are the requirements mandated to be passed by an EV retrofitment kit for it to obtain a type approval certificate.

Vehicle Weighment: The relevant test agency shall verify the weight distribution resulting from the installation of electric propulsion kit to identify any adverse impact on vehicle structure, using best engineering practices (see Table 3: Permissible increase in vehicle unladen weight due to electric propulsion kit).

Table 3: Permissible increase in vehicle unladen weight due to Electric Propulsion Kit

Vehicle category	Permissible increase in ULW (%)	Remarks
L5M	25	–
M1/M2	25	–
M3	25	
L5N/N1/N2	Equal to weight of electric propulsion kit	Increase in FAW shall not be more than 10 per cent and all axle loads shall be within laden limits prescribed in APPENDIX XII of CMV Rule 1989.

Coast down test: Coast down test is done to find out vehicle Road Load Coefficients for range and electric energy consumption tests.

Visual indication: The standard mandates that the electric propulsion kit manufacturer/supplier must provide a minimum of the following indications on the retrofitted vehicle:

- Rechargeable Energy Storage System State of Charge (REESS SOC)
- Motor temperature
- Electric kit fault

Gradeability test: A car's gradeability is its ability to climb slopes. Gradeability is measured either in degrees or percentage. A 45-degree gradient is equivalent to 100 per cent. According to this standard, the gradeability requirement in case of electric powertrain vehicles shall be as follows.

- Two wheeled electric powertrain vehicles having net motor power less than or equal to 1,000 W: 3.81°
- All other electric powertrain vehicles: 7°

Measurement of electric range and electric energy consumption: The electric range and electric energy consumption of vehicles fitted with electric propulsion kits are measured and reported as per AIS – 040 and AIS–039 respectively.

Brake performance: The retrofitted vehicle must meet the requirements of the brake performance test as defined in the annexure of AIS-123.

Measurement of pass-by noise level: The vehicle fitted with an electric propulsion kit shall meet the requirement of pass-by noise level as per IS 3028-1998 with additional test conditions as specified

in AIS-049. As new regulations constantly decrease the levels for acceptable noise, it has become increasingly important to minimize the exterior noise level of cars and trucks.

Traction motor test: The following tests are carried out on the traction motor of the electric propulsion kit—motor power test, environmental validation tests, namely, thermal shock test, media resistance test, impact test, dust test and water immerse test.

EMC test: This is an electromagnetic compatibility test for electronic components in the vehicle.

Vertical orientation of dipped beam-headlamp: The kit supplier is mandated to carry out headlamp levelling adjustment on converted vehicles. This requirement is not applicable for L5 category converted vehicles.

Requirements for constructional and functional safety: These standard mandates compliance with constructional and functional safety requirements as per AIS-038(Rev 1). AIS 038 specifies standards for M, N category vehicles with regard to specific requirements for the electric powertrain, including safety of the traction battery.

Requirements Ror rechargeable Energy Storage System (REESS): The REESS of the electric propulsion kit must meet the requirements of AIS-048.

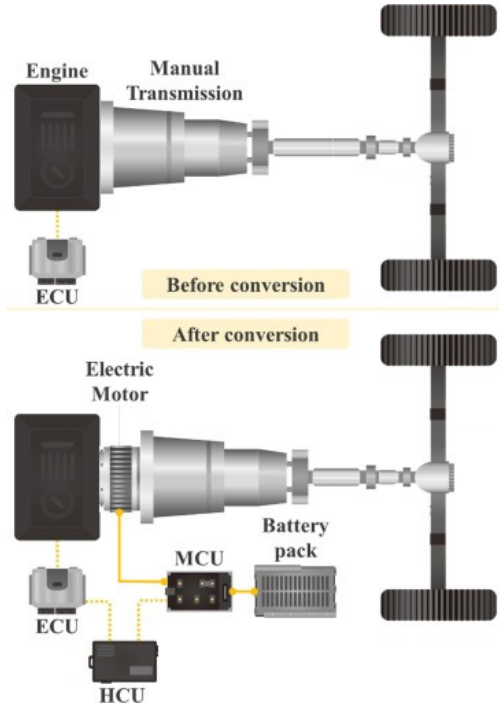
Wiring harness/cables/connectors: The cables used in the harness are mandated to comply with the following tests: electrical characteristics-withstand voltage, low temperature characteristics, heat ageing-thermal overload, resistance to chemicals, fluid compatibility, resistance to flame propagation. The layout of the wiring harnesses shall be such that they are secured tightly and shall be properly insulated or contained in a loom (non-flammable corrugated tube) along its length to avoid any metal contact of body, damage by any means (e.g. sharp metallic edges) or sagging.

Code of practice: It includes third party authorization of kit manufacturers/suppliers, kit layout reports, owner's manual, service manual, warranty information, labelling information etc.

In a hybrid kit, the battery and motor size are smaller than an all-electric kit since the electric powertrain is only supplementing the ICE which remains the prime mover of the vehicle. However, the additional load can pose a challenge and the retrofitter has to ensure that the vehicle possesses adequate payload capacity to account for the added weight and meets space requirements of the hybrid system components. Hybrid powertrains also require complex algorithmic controls for optimized dual-utilization of the ICE and the motor.

Hybrid retrofit technologies differ based on the vehicle segment, with variations in the level of hybridization and the complexity of integrating the powertrain, whether it's a series or a parallel system. This has potential for application in heavy duty vehicles. These require extremely large batteries considering the range and payload considerations (*see Figure 3: Hybrid Powertrain retrofitment*). Hyllion,

Figure 3: Hybrid powertrain retrofitment



Source: https://ars.els-cdn.com/content/image/1-s2.0-S136192092100256X-gr1.jpg

a powertrain manufacturer in the US, has commercially deployed hybrid retrofit solutions for heavy duty trucking.

Selection of battery and motor: A retrofitted vehicle needs to deliver the established performance benchmarks of ICE powertrain. The selected electric motor must have power capabilities that meet the operating conditions of the vehicle. The peak power of the selected motor is determined by three driving conditions: maximum speed, acceleration from standstill and maximum gradient.

As the battery significantly impacts weight, it must be chosen with consideration for the vehicle's gross weight, within a range of ffl25 per cent as per AIS 123 regulations. The battery's specifications must meet endurance mileage requirements and the maximum power needed. To use larger batteries, the retrofitter must find suitable chassis spaces for installation while also adjusting for changes in weight distribution.

The main cell chemistries for traction batteries available currently are Lithium Iron Phosphate (LFP), Lithium Nickel Manganese Cobalt (NMC) and Lithium

Titanium Oxide (LTO). NMC batteries have high energy density and thus provide the highest driving range. LFP batteries have better thermal stability and longer cycle life but moderate energy density. LTO batteries have low energy densities but exhibit exceptional cycle life and C- rate[13] capabilities and thermal stability. Short cycle life will necessitate battery replacements which will result in an increase in total cost of ownership (TCO) values of retrofitment. The mechanical and thermal integrity of the battery system is critical to prevent degradation and ensure safe operation in harsh operating conditions (particularly, extreme heat or cold, road spray, dust and unmetalled roads).

Drivetrain configuration: The drivetrain of the retrofitted vehicle converts electrical energy stored in the battery to mechanical torque which is delivered to the vehicle's wheels. Drivetrain modification is the most crucial and complex step of e-retrofitting an ICE vehicle.

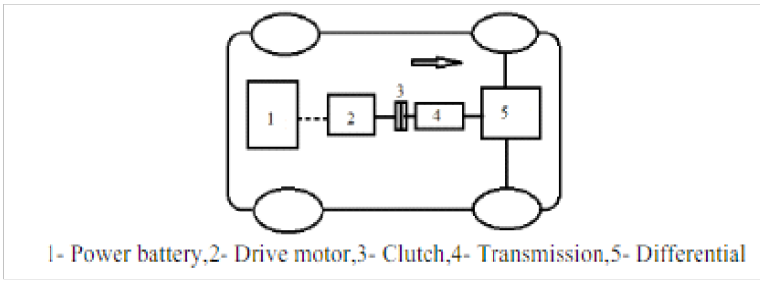
Since the prime mover of the vehicle is being replaced, it is important to understand how the associated drivetrain gets impacted. The simplicity of retrofitting depends on the number of drivetrain components and the type of available vehicle chassis. For example, in two-wheelers, retrofitting is a simpler process due to a relatively simpler transmission system (no axle and differential). Therefore, the drivetrain evaluation must include careful selection of the position of all electric retrofitted drivetrain components because allocation of space required for each item is the primary concern.[14]

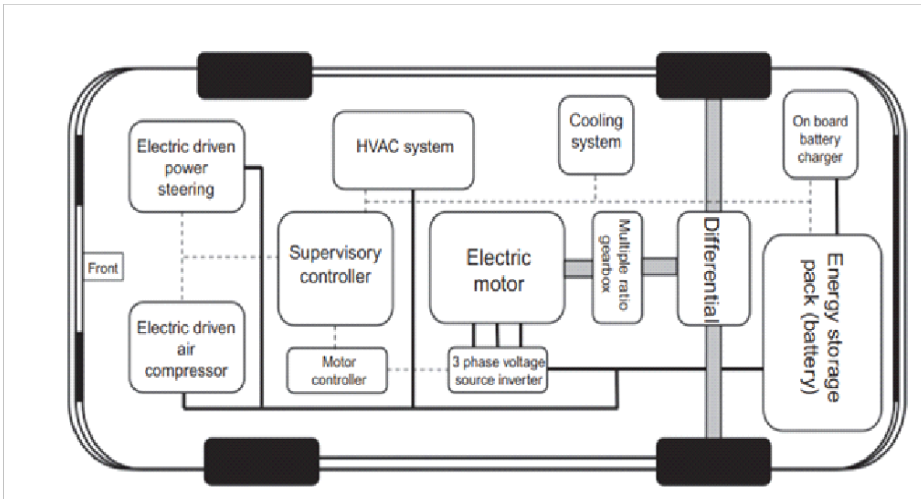
Based on the requirements of vehicle performance, cost, chassis design and desired driving experience, the choice of drivetrain configuration for retrofitting an ICE vehicle can adopt various approaches, depending on the vehicle segment. This is because an electric drivetrain allows flexibility in installation of different propulsion arrangements. Two examples are shown below.

In this case, the ICE is replaced by the motor whose drive shaft is connected with the existing multi-speed gearbox (*see Figure 4: Centralized drive - retain existing ICE transmission)*. Leveraging the existing gearbox minimizes disruption to the vehicle chassis and reduces costs. This system also provides the option of selecting the most suitable gear ratio in the powertrain so that the motor can operate efficiently for diverse driving conditions. Employing multiple gear ratios also lowers the maximum torque required from the electric motor. Furthermore, it maintains a driving experience similar to that of a manual transmission for those accustomed to it.

Figure 4: Centralized drive-retain existing ICE transmission

1. **Approach 1: Centralized drive - Retain existing ICE transmission**





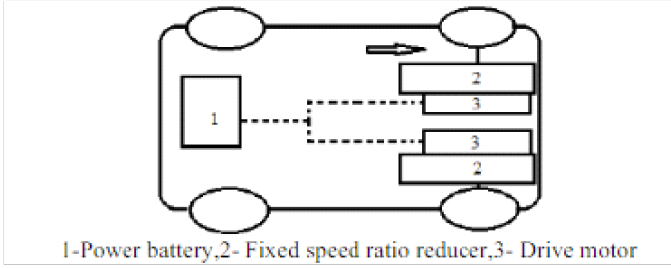
Source: Heavy-duty Electric Vehicles-From Concept to Reality, Sun, Yuechao & Li, Man & Liao, Cong. (2017). Analysis of Wheel Hub Motor Drive Application in Electric Vehicles. MATEC Web of Conferences. 100. 01004. 10.1051/matecconf/201710001004

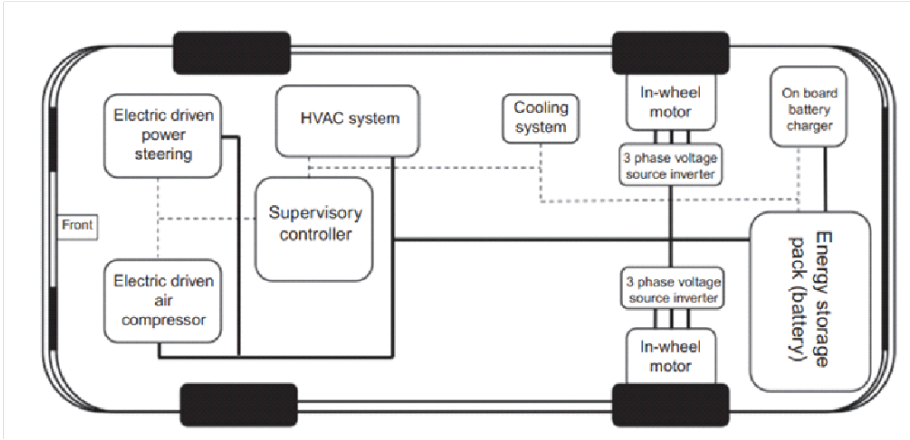
The main engineering challenge is to securely achieve mechanical coupling of the motor shaft with the flywheel of the gearbox. This system would also require periodic maintenance of the drivetrain.

In this concept, two motors drive rear wheels separately *(see Figure 5: Removing the ICE drivetrain and using hub motors)*. The wheel hub motor drive completely eliminates the powertrain components such as clutch, transmission, differential and axle shafts improving the transmission efficiency, reducing the vehicle mass and facilitating the realization of intelligent electronic torque control *(see Table 4: Powertrain comparison of different vehicle segments)*. The reduction in the number of moving parts involved in the transmission system also reduces maintenance costs.

Figure 5: Removing the ICE drivetrain and using hub motors

1. **Approach 2: Distributed drive - Remove the ICE drivetrain and use wheel hub motors**

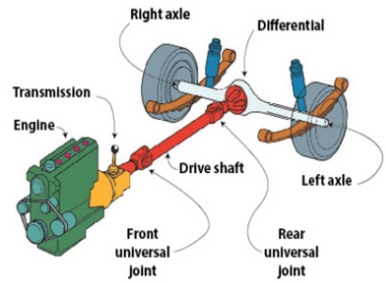
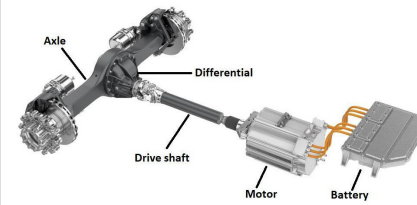




Source: Heavy-duty Electric Vehicles-From Concept to Reality, Sun, Yuechao & Li, Man & Liao, Cong. (2017). Analysis of Wheel Hub Motor Drive Application in Electric Vehicles. MATEC Web of Conferences. 100. 01004. 10.1051/matecconf/201710001004.

However, this requires more chassis modification as the old drivetrain is removed and the installation could introduce complexities such as matching motor dimensions with existing wheel hubs. It increases unsprung weight[15] and rotary inertia of wheels, thereby increasing the vibration amplitude. Costs might increase due to the requirement of multiple motors (depending on whether the vehicle has a two-wheel drive or four-wheel drive system).

Table 4: Powertrain comparison of different vehicle segments

Vehicle category	ICE powertrain	Retrofitted EV powertrain
Two-wheeler	 Honda Vision 11; Source: Motors Town • Gearless two wheelers use Continuous Variable Transmission • Geared two wheelers use a sequential gearbox	 5.5 KW 2000-6000 RPM Electric Propulsion Kit; Source: India Mart[16] • Retrofitted two-wheeler eliminates the CVT/gearbox and utilises a belt/chain drive motor or a hub motor
Three-and four- wheeler	 Rear wheel drivetrain; Source: Drive Smart Warranty[17] • Majority of on road vehicles in M,N category are equipped with manual transmission which includes a clutch assembly and a multi-speed gearbox.	 Electric Drive; Source: Dana[18] • Retrofitted vehicles have an option to integrate with the existing manual gearbox or incorporate CVT/two speed gearbox or utilise a hub motor system

4. Cost of e-retrofitment

Predictably, the cost of e-retrofitment of older ICE vehicles is much cheaper than the upfront cost of new EVs. The cost components of a new EV include the upfront purchase cost and the battery replacement cost after five to eight years. Also, in case of new vehicles, the total cost of ownership covers the entire useful life on the road. In the case of retrofitment the useful life includes the extra four to five years gained after the date of retrofitment. It is not yet clear from real world evidence the extent to which the life of the new vehicles can be extended, and the durability of the real-world performance.

If a new electric two-wheeler costs between INR 80,000 to INR 1.65 lakh, a retrofitted unit will be priced between INR 25,000 to INR 65,000, including registration fees. Similarly, three-wheelers used for commercial purposes can be retrofitted within the range of INR 50,000 to INR 1.25 lakh, compared to INR 2.5 lakh to INR 4 lakhs for a new one. Similarly, at INR 19.5/km, as against INR 62.18/km for a new one, a retrofitted bus costs less.

The financial viability of four-wheeler retrofitment is based on usage. A passenger car (commercial) typically runs at least 150 km/day while a three-wheeler (3W) is used for last mile connectivity and runs much lesser distances of 60 km/day. A retrofitted passenger car can outperform a new electric car by INR 3.25/km and a CNG car by INR 2.46/km if the total cost of ownership for the applicable period is considered.

While there is a big difference in the capital cost of a new EV and a retrofitment cost of an older vehicle, the common costs include registration costs, purchase taxes, maintenance, insurance, home charger installation cost, electricity charges and residual value (*see Table 5: Cost components of a retrofitted EV*).

Purchase taxes in a retrofitted vehicle are limited to the GST, both on auto components and service costs charged by the retrofitter. The GST on a new EV is five per cent while on spare parts (other than batteries), it is 28 per cent. Thus, currently, retrofitment companies and consumers pay 28 per cent GST on retrofitment kits. The retrofitters also usually include registration fees in their overall retrofitment cost.

Currently, EV buyers pay very high premiums for EV insurance because the methodology of determining the residual value of an EV battery is not set in

Table 5: Cost components of a retrofitted EV (estimates based on market information)

S. No.	Cost Components	2W	3W	Passenger Car	Bus
2	Retrofitment cost (Rs.) Inclusive of taxes and registration fee	50,000	200,000	650,000	5,000,000
5	Electricity charges for 5 years RUL (Rs.) Electricity Cost- Rs. 4/kWh RUL- Remaining Useful Life	13,160	30,316	53,642	620,000
7	Insurance for 5 years (Rs.)	60,000	100,000	150,000	200,000
8	Lifetime Maintenance Cost (Rs.)	30,000	30,000	32,000	1,687,500
9	Resale value (Rs.)	3,000	7,000	40,000	200,000
10	Net Cost over RUL (Rs.) Sum of (1) to (9)	153,160	360,316	885,642	7,507,500

Source: CSE compilation

stone yet. Insurance companies attach a very high risk-factor to EVs because of the newness of the technology as it is still not fully understood, and consequently charge higher than justified insurance premiums. This leads to higher total cost of ownership. It is important to establish how an EV depreciates in the accounting books of manufacturers, owners, governments, insurers and recyclers.

Preliminary investigations reveal that insurance companies treat retrofitted electric vehicles not very differently from their original ICE versions. Thus, the insurance premium of a retrofitted EV is similar to their ICE versions.

Residual value is a very important consideration while calculating the total cost of ownership of a vehicle. Depreciation is the largest cost component, especially in the first few years of the vehicle's life. The resale value of the vehicle can be considered to be zero, although there may be some battery recyclers ready to buy the batteries for their second-life usage. In 2025, second-life batteries may be 30 to 70 per cent less expensive than new ones in these applications, tying up significantly less capital per cycle.[19]

This is opposed to the trend in three-wheeler retrofitment, where the low gain in TCO is offset by the availability of government subsidies in some states. A significant supply of retrofitment kits is observed in the four-wheeler fleet and luxury car segments. This is likely to happen because of high customer demand in these segments.

However, a retrofitted EV would also require battery replacement after a few years and does not offer a Remaining Useful Life (RUL) of more than five years in most cases.

Cost of certification*:* For a retrofitted vehicle to be certified roadworthy, it needs to be homologated by a competent authority such as ARAI and ICAT. The fitness tests ensure that the vehicle matches the requirements of the Indian market in terms of emission and safety and road-worthiness as per the CMVR. But with only two testing authorities, the sector is wanting in capacity to service large numbers of certification requests.

The standard for type approval of hybrid and pure electric propulsion retrofit kits is AIS 123. However, the homologation process is lengthy and costly. If a kit fails certification, the retrofitter must reapply and pay the certification fee again. While the high registration fee helps prevent unsuitable applicants and controls the growth of an unregulated sector, it also poses a significant barrier for retrofitters who want to develop kits for multiple vehicle models.

Industry representatives argue that to address the profitability challenge in retrofitting, certification costs should be distributed across multiple vehicles of the same model. The limited demand for specific models makes conversions expensive and less economically viable.

5. E-retrofitment: Issues to be addressed

While e-retrofitment is technically possible, feasible, and there are regulatory mechanisms in place for certification of retrofitted vehicles, there is ongoing policy debate around the conditions to be fulfilled for quality, safety and performance. Addressing these issues is crucial, as the cost-effectiveness of retrofitting could make it a more appealing and widely adopted option. To support this, a robust regulatory framework, clear guidance on quality control, and criteria for what can be retrofitted are essential.

This matter was initially discussed and incorporated in the Clean Air Policy 2022 of the Air Commission of Delhi-NCR which mentioned that 'while technically and principally e-retrofitment is possible and feasible, several safeguards and preparedness are needed for its conditional implementation for safe and reliable conversion.'[20]

This policy has recommended that retrofitment may be allowed subject to some key conditions. This needs certification of retrofitment kits of specified make and model of vehicles by the ARAI and as per the standards and provisions being notified under CMVR. This needs to be performance linked. Based on the central government rules, the state governments need to further define and notify the implementation mechanism for retrofitment. The Ministry of Road Transport and Highways (MoRTH) may reform the CMVR and AIS rules related to certification and verification of retrofitment as needed and notify the makes and models that qualify for retrofitment.

As previously mentioned, some regulatory requirements are already established. For instance, Delhi's EV policy specifies the technical and regulatory conditions for e-retrofitment. Despite ARAI standards permitting e-retrofitment of vehicles as old as 1990, Delhi's policy restricts diesel vehicles older than 15 years from being retrofitted, and permits retrofitment of petrol vehicles only if they meet certain fitness criteria. It is necessary that all other state governments develop detailed guidelines and conditions for quality control of the programme.

Additionally, the Clean Air Policy from the Commission of the Air Quality Management stipulates that since the focus is on retrofitting older vehicles, there should also be incentives for replacing end-of-life vehicles with new electric ones,

including scrappage incentives. This may bring more parity in cost of new electric vehicles and discourage retrofitted vehicles. Delhi's electric vehicle policy has adopted this strategy and can be extended across the region.[21]

The bigger concern that several market observers and industry representatives have expressed relate to the safety and on-road performance of e-retrofitment. As noted earlier, the retrofitting standard AIS-123 an AIS-048 standard for battery testing and certification are in place, but these have not incorporated EV safety standards AIS- 038 (Rev 2) and amended AIS-156 that are more stringent and apply to new vehicles. The AIS- 048 standard was originally designed for lead-acid batteries and not lithium-ion batteries that are used in retrofitted EVs. AIS-123 also does not cover safety and integrity of the battery in the system. There are no tests for ensuring lower vibration levels with secure installation of the battery in the old vehicle chassis. This needs to be mandated.

The concern is that if the updated and more stringent safety standards under AIS 156 are not enforced, it may compromise safety performance. It is mandatory that the amended AIS 156 and AIS 038 (Rev 2) be mandatorily aligned with AIS 123.

On the other hand, the representative of the retrofitment industry claim that application of the amended AIS 156 will make the cost of retrofitment prohibitive and nullify the cost advantage of retrofitment.

There are also concerns around maintaining the structural integrity of the chassis of a used ICE vehicle being considered for retrofitting. This needs very stringent screening and prevention of retrofitting of already compromised vehicles. The chassis will require proper testing for static and dynamic loads, fatigue and durability, etc to assess the prospects of packaging battery pack and other aspects on the old chassis. Although AIS-123 addresses these aspects in the respective models, its on-ground enforcement will be critical.

The stakeholder consultation also brings out the responsibility of the customers. They need to do a thorough background check of the retrofitter, including aspects such as the location of their workshop and headquarters, certification and audits, and whether their financials are capable of supporting the warranties they are offering on their components, especially the battery. A customer would be interested in information about other retrofitted vehicles that are well-documented and can be accessed on request.

Due diligence must be required to evaluate the retrofitter's supply chain feasibility, ensuring their vendor systems can handle specific requests. It should also determine whether the retrofitter relies on their own technical expertise or has outsourced the majority of the work to third parties without effective quality control. These necessary checks have to be incorporated into regulation set up by the government.[22]

There is an additional concern that the option of retrofitment will flood the market with lead acid batteries that have other environmental consequences.[23] However, new generation e-retrofitment, as is evident from the market, is largely based on li-ion batteries.

The compromises in exchange for cost advantage can potentially be old-fashioned design, lack of state-of-the-art safety and electronic assistance systems, unoptimized driver area, noise levels and thermal isolation of the chassis that can be sub-optimal. Aditionally, not every vehicle is suitable for retrofitment. If the original vehicle is too old, corroded and used to the extent that the refurbishment costs get too high, that makes retrofitment unviable.

Retrofit are not offered by the OEMs themselves. A lot of start-ups are offering these services. This is not a problem for vehicles that have been produced as prototypes or in small volumes, e.g., for feasibility studies or pilot activities. But informalization or large-scale conversion needs quality control efforts. Delhi government's empanelment of verified vendors is a step in the right direction. Such a list needs to be released at the national level. It is often contested that large-sized batteries in EVs add inefficiency to vehicle performance because of the extra weight, especially in retrofitted vehicles.[24]

As per expert opinion, e-retrofitment of heavy-duty vehicles (HDVs) is a challenging task in terms of vehicle engineering and packaging. There are fewer companies getting into HDV e-retrofitment. Retrofitting a large number of bigger buses, with high investments and a projected lifetime of seven to ten years requires an established supplier.[25]

The e-retrofitment industry is additionally concerned about the lack of adequate fiscal support for e-retrofitment and a lack of financing. This is a unique challenge of the EV sector.

GLOBAL EXPERIENCE: E-RETROFITMENT

There is a nascent growth of retrofitment industry globally.

The USA: The market is miniscule and limited to hobbyists and small businesses. However, retro fitment of old ICE vehicles to EVs is allowed by law. Such kits used for converting vehicles to plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs) require certifications from the US Environmental Protection Agency (EPA), the National Highway Traffic Safety Administration, and state agencies like the California Air Resources Board.

Germany: Germany launched a legal framework for retrofitting old diesel cars in 2018. It has built regulations and processes to approve retrofitted vehicles for use on public roads by organisations such as TÜV SUD Inspection. Retrofitting prices in the country range from about EUR 8,000 for small cars to about EUR 13,000-15,000 for mid-sized passenger cars.

France: The French government incentivises retrofitment with a subsidy and mandates that the user must get the vehicle retrofitted from an authorised dealer and the vehicle must be at least 1 year old. Also, the user must not resell the converted vehicle before one year from the date of retrofitment. French retrofitters laud the move and reaffirm that this will create more jobs in the country apart from reining in air pollution and carbon emission.[26]

Belgium: Retrofitment is allowed in Belgium but this involves getting the modified vehicle approved abroad in Europe and then pass a technical inspection in the country. It is currently a complicated, long and expensive procedure. The legislation is yet to be presented to the EU and sent to the Council of State.[27] The process requires a manufacturer's agreement or a no objection certificate, which would be possible if other regional European governments issue such approvals.

Africa: Africa has shown interest in large-scale retrofitment and fleet electrification. Uganda and Rwanda have begun retrofitting ICE motorcycles.[28] Uganda is manufacturing new electric motorcycles, retrofitting existing ICE motorcycles, and assembling electric motorcycles and battery packs. Rwanda is retrofitting ICE motorcycles to become electric.[29]

Unique partnership with an OEM: Stellantis N.V. and French sustainable mobility solutions firm Qinomic partnered in 2022 to create a proof of concept to convert ICE light commercial vehicles to electric drivetrain. The companies have signed a strategic partnership agreement in this regard. A collaboration between Circular Economy and Commercial Vehicle Business Units, the retrofit solution aims to extend vehicle life and usage, ensuring sustainability and affordability at the same time. OEM quality and specifications on safety and durability are maintained in the conversion process, the companies claimed.[30]

Refuse collection truck in the UK: Refuse Vehicle Solutions have carried out electric conversion of diesel refuse collection vehicles in Islington, London, using electric powertrain technology of a Dutch company Emoss *(See Figure 6: Retrofitted refuse collection truck in the UK)*.

Retrofitted refuse collection truck in the UK

Conversation with the retrofitters of three-wheelers particularly, has suggested that it is only recently that private financiers have begun to come forward to show interest in financing this strategy. In fact, a business model outlines retrofitters retrofitting a vehicle and also providing batteries on a rental basis. This has drawn the interest of financiers.

Manufacturers of new EVs and market observers also have certain specific concerns. E-retrofitment may delay the scaling up of the market for new EVs at a time when India's policies are designed to upscale EV production and market for transformative changes. The FAME and production-linked incentives for advanced chemistry batteries that have been designed to support scaling up of the new production base to meet bigger targets for decarbonization may be affected if the potential strategy of old fleet renewal is dominated sizeably by e-retrofitment.

It is also important to note that there are some lessons from the Compressed Natural Gas programme in Delhi and other states that were rolled out earlier, even though CNG technology and electric propulsion are not directly comparable. Retrofitment is usually a transitory business, and continues till the time the new technology is fully established in the market, cost parity is achieved with the ICE counterparts and the production base scales up adequately. But while it is happening, regulatory, technical and compliance framework needs to be robust and implementable (*see Box: CNG retrofitment in Delhi: A few takeaways*).

CNG RETROFITMENT IN DELHI: A FEW TAKEAWAYS

It may be recalled that Delhi has already gone through one phase of fuel substitution with the introduction of compressed natural gas programme (CNG) for public transport buses, para transit including taxis and three-wheelers and local commercial vehicles. This was implemented after the Supreme Court directed replacement of all diesel buses, taxis and three-wheelers to CNG in its order of 28 July, 1998. Subsequently local commercial vehicles were also brought within the fold.

CNG technology is not directly comparable with the electric power trains therefore direct parallels are not being drawn. But there are a few lessons to be drawn from the approaches taken to set up the systems for retrofitment.

In the initial stages of this programme there was a growth of CNG retrofitment industry in Delhi. Initially it had begun informally targeting small vehicles like three-wheelers. But soon after certification rules for retr-fitment kits were laid down by make and model. In fact, this was a regulatory innovation that insisted that conversion kits be designed for specific make and model of vehicles and must not be generically applied to all models.

During the initial phases a few diesel buses were retrofitted with CNG kits. But there were safety and emissions concerns due to poor quality control and technical glitches as was evident from the audits. Therefore, after a few retrofits the Delhi Transport Corporation decided not to retrofit anymore but to expand the CNG programme based on only new buses from the OEMs.

Thereafter, most of the retrofitment was confined to small vehicle segments including three-wheelers and small commercial vehicles. But there were concerns around emissions from excessive leakages from lube oil and poor quality retrofitment etc that led to visible smoke emissions. While there were well established retrofitment companies capable of doing proper retrofitment, there were also small informal operators. This in fact led to the demand for proper auditing of the retrofitment workshops.

However, only in the case of passenger cars, with consumer interest growing in CNG cars after the strictures against diesel cars and growing diesel prices, the OEMs like Maruti Udyog Ltd started to offer factory retrofitted CNG cars initially. Subsequently, with the growth of consumer demand for CNG cars, Maruti Udyog Ltd and Tata Motors began to produce new CNG cars.

Next steps

E-retrofitment, though still nascent, is likely to grow depending on the roadmap of the central and state government policies in the future. The state governments are more likely to encourage e-retrofitment to leverage the low-cost option for the older ICE vehicle phase out and fleet renewal.

This review shows that technology for e-retrofitment is in place and is evolving and regulatory framework and technical standards are also taking shape. But there are concerns about quality control and on-road safety performance in large scale application especially in a more informal and decentralised set up. There is also an additional concern that this strategy must not derail acceleration of electrification of new vehicle fleet that requires accelerated transition across all vehicle segments and also leverage fleet renewal policies. The states will have to strike a balance.

Nonetheless, usually, retrofitment markets are transitional in nature as they begin to lose prominence once the technology begins to get mainstreamed, achieves cost parity, and has established production base. But till the time this approach remans, it is necessary to ensure a robust and comprehensive regulatory and compliance framework.

It is therefore recommended that the following critical steps are taken urgently for a robust programme:

- E-retrofitment requires alignment with stringent safety standards to prevent accident risk. Any episode of a safety-related accident in the retrofitted segment can jeopardize the overall EV market and its progress.
- The state governments need to notify and adopt detailed guidelines on the conditions to be fulfilled for quality control of e-retrofitment. Like Delhi has done, state EV policies need to specify the vehicle vintage and type that are eligible for e-retrofitment and also those that do not qualify.
- Ensure that the method of screening of the vehicles for fitness of chassis, overall structural stability and strength etc are assessed adequately before e-retrofitment is undertaken. Assess the adequacy of the infrastructure of the automated fitness testing centres to undertake such exercise.
- The fiscal incentives being offered by the state governments for e-retrofitment need to be performance linked and the conditions need to be laid down.
- There should be an oversight and monitoring body to audit the e-retrofitment workshops.

- Notify the list of the prospective e-retrofitment agencies/vendors at the central and state level after proper verification and certification of the facilities.
- Ensure after-market maintenance services and fulfilment of the warranty conditions.
- New private financing models for e-retrofitment and their terms and conditions need to drive quality control and put in place proper checks.
- The financing models can also help to establish residual value for sprucing up financing mechanism.
- The central government may also help to frame a comprehensive guidance on e-retrofitment to guide implementation in states.
- The retrofitment agencies also need to be brought within the fold of end-producer responsibility for disposal of the spent batteries.

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    Category L2: Means a motorcycle other than Category L1.

    Category L5: Passenger/goods carrier (Auto rickshaw) and Gross vehicle Weight is equal to 1500 kilograms.

    Category M: means a motor vehicle with at least four wheels used for the carrying passengers.

    Category N1: means a motor vehicle used for carriage of goods and having a Gross vehicle Weight not exceeding 3.5 tons.

    Category N2: Means a motor vehicle used for carriage of goods and having a Gross vehicle Weight exceeding 3.5 tons but not exceeding 12 tons.

    Category N3: Means a motor vehicles used for carriage of goods and having a Gross vehicle Weight exceeding 12 tons.

11. The chemical energy of the fuel is transformed to mechanical energy in an Internal Combustion Engine.

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India is aiming to achieve a target of 30 per cent fleet electrification by 2030. Many states are exploring the option of retrofitting ICE vehicles with electric propulsion kits to meet their targets. While there is no subsidy support for retrofitting vehicles, technical standards are in place, so is the capacity to issue certification for road-readiness. However, concerns regarding certification costs in some vehicle segments and safety in informal installations continue to be a challenge. In this report, CSE investigates the possibilities of EV retrofitting.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phone: 91-11-40616000 Fax: 91-11-29955879
E-mail: cse@cseindia.org Website: www.cseindia.org