WRI INDIA

CONFERENCE PROCEEDING

Roadmap for Alternative Batteries and Financing Ecosystem for E-Rickshaws in India

A SUMMARY OF EXPERT PERSPECTIVES

August 23, 2023 | New Delhi | Compiled by: Garima Agrawal, Aprajita Verma, and Chaitanya Kanuri

BACKGROUND

India's transition to electric vehicles (EVs) is spearheaded by electric three-wheelers, particularly e-rickshaws. E-rickshaws have become a popular choice for accessible and affordable last-mile connectivity. To promote the sustainable development of e-rickshaws in the country, WRI India conducted two workshops in New Delhi to initiate a dialogue on the specific challenges facing the sector and potential solutions.

The first workshop, titled "E-Rickshaw Finance and Investment Ecosystem", was held on September 7, 2022, to assess the challenges associated with e-rickshaw financing and to discuss potential strategies and innovative financial instruments to accelerate e-rickshaw adoption in India. Participants in this workshop included e-rickshaw original equipment manufacturers (OEMs), e-rickshaw financiers, electric vehicle (EV) industry associations, e-rickshaw dealers, and investors (see Appendix A).

The topics of discussion included the following:

- Lack of access to affordable finance for purchasing e-rickshaws.
- Challenges hindering the availability of affordable finance for the purchase of e-rickshaws.
- Potential strategies for improving the finance ecosystem for e-rickshaws.

The second workshop, titled "Roadmap for Alternate Battery Technologies for E-Rickshaws in India", was held on August 23, 2023. The panel consisted of e-rickshaw OEMs, battery manufacturers, battery recyclers, battery swapping service providers, regulatory authorities, and representatives from EV manufacturers association (see Appendix B).

CONTENTS

These conference proceedings reflect the presentations and discussions of participants and do not necessarily represent the views of WRI India or other participating institutions.

The workshop highlighted action points to develop a safe and sustainable ecosystem for e-rickshaws. The topics of discussion included the following:

- Coexistence of lead-acid batteries (LABs) and lithium-ion batteries (LIBs) for e-rickshaws.
- Emerging battery technologies suitable for e-rickshaw applications.
- Potential pathways, opportunities, and challenges associated with the transition to alternative battery chemistries for e-rickshaws.
- Challenges in establishing a circular economy for e-rickshaw batteries.

In this note, we outline the key learnings and action points identified from the abovementioned workshops. Access to affordable financing and battery sustainability are critical challenges in the e-rickshaw ecosystem, which must be addressed to reduce the lifecycle emissions of the e-rickshaw sector and to promote the creation of more equitable livelihood opportunities.

AN OVERVIEW OF THE E-RICKSHAW ECOSYSTEM

Electric three-wheelers, especially e-rickshaws, are leading the way in India's EV revolution. E-rickshaws were formally introduced on Indian roads during the Commonwealth Games in 2010 to help cycle rickshaw pullers shift to e-rickshaws. Between 2015 and 2022, the annual registration of e-rickshaws grew at a compounded annual growth rate (CAGR) of nearly 80 percent (MoRTH n.d.). As of March 2023, more than 2.26 million EVs had been registered in the country, of which 43 percent were passenger e-rickshaws (MoRTH n.d.). The actual number of e-rickshaws on the roads is much higher, because a large proportion of e-rickshaws in India is estimated to be unregistered.

E-rickshaws are primarily concentrated in the northern states of India. Uttar Pradesh accounted for close to 43 percent of all the e-rickshaws registered in India (as of March 2023), followed by Delhi, Bihar, and Assam, which together contributed more than 34 percent (MoRTH n.d.).

E-rickshaws play a vital role in providing easily accessible and affordable last-mile connectivity for commuters, with a typical operating range of 4–5 km. Over 3 million people travel daily using e-rickshaws (IEA 2020). E-rickshaws are not only popular in major cities, but also in several remote areas, where they provide vital connectivity between small towns and villages.

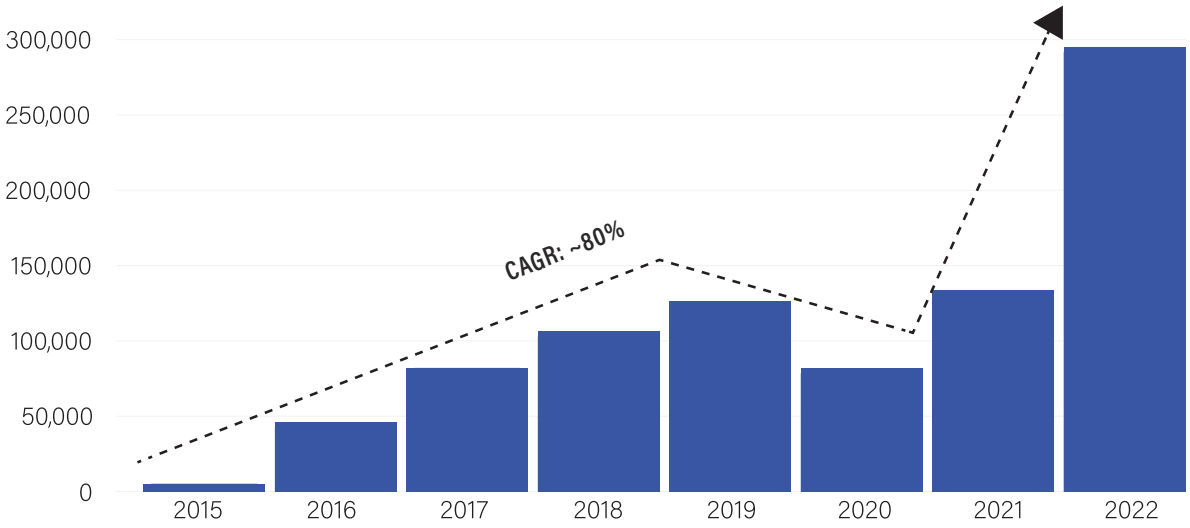
E-rickshaws are responsible for significant livelihood generation and income augmentation among drivers, who are mainly unskilled laborers from factory jobs, cycle rickshaws pullers, or daily wage workers. E-rickshaws are characterized by low up-front cost, low operational costs, and minimal skill requirements, making them a low-barrier mode of employment. According to WRI India's analysis, the total cost of ownership (TCO) of e-rickshaws per km (1.30/km) is substantially lower than that of their internal combustion engine three-wheeler counterparts, which run on compressed natural gas (CNG), diesel, or petrol (Kumar and George 2020).

E-rickshaws offer environmental benefits because they are a zero-tailpipe emission mode of transport. An e-rickshaw can save more tonnes of CO_2 emissions each year (2,534 tonnes) than a CNG autorickshaw (Shandilya et al. 2019). The growth of e-rickshaws has been supported through subsidies, permit exemptions, and favorable policies at the national and state levels.

However, the unchecked and informal growth of e-rickshaws and the lack of supporting infrastructure have led to a growing spectrum of negative impacts alongside their popularity. These drawbacks include the proliferation of poor-quality products (due to the dominance of informal and fly-by-night OEMs), diminished driver earnings due to oversupply, lack of affordable finance, unsafe charging practices, and adverse environmental impacts due to informal recycling practices.

Among these drawbacks, the battery ecosystem and lack of affordable finance for e-rickshaws are critical barriers for sustaining the socioeconomically and environmentally sustainable operations of e-rickshaws. They are discussed in greater detail in the following sections titled "Transition to advanced battery chemistries" and "Finance ecosystem for e-rickshaws."

FIGURE 1 | Annual registrations of e-rickshaws in India during 2015-2022



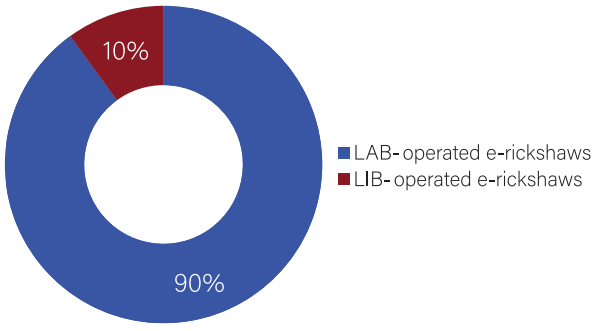
Note: CAGR = compounded annual growth rate.

Source: The Vahan dashboard (MoRTH n.d.).

Transition to advanced battery chemistries

E-rickshaws have largely been operating on LABs since their formal introduction on Indian roads in 2010. LABs have been the dominant choice in the e-rickshaw market due to their low up-front cost, mature technology, established resale market, safer operation, and easy availability, since it is an indigenous battery technology that has a well-developed supply chain. However, LABs are also bulky and generate a lot of e-waste because they typically need to be replaced every year. As a result, the e-rickshaw industry generates approximately 6.5 million end-of-life (EoL) LABs every year. The e-rickshaw industry is also characterized by the significant presence of informal LAB manufacturers and recyclers.

FIGURE 2 | Classification of Indian e-rickshaw market by battery type for 2022–23



Note: LAB = lead-acid battery; LIB = lithium-ion battery.

Source: Calculated from the total number of registered e-rickshaws (obtained from the Vahan dashboard [MoRTH n.d.]), Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) subsidies given by the government for LIB e-rickshaws, and secondary sources (Gulia et al. 2022).

In recent years, there has been a gradual adoption of LIBs in e-rickshaws, with LIBs accounting for almost 10 percent of the e-rickshaw market in 2022–23. The government is promoting the usage of LIBs in EVs, which is evident from the subsidies being provided only for advanced battery chemistries in the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles

(FAME-2) policy and various state EV policies. In October 2022, the Delhi government announced a ban on the registration of LAB e-rickshaws in the state, which is the second-largest market for e-rickshaws in India (Times of India 2022).

LIBs generate less EoL battery waste than LABs due to their longer service life (typically 3 years in e-rickshaw usage). LIBs are also lighter and offer advantages such as higher energy density, less charging time, and a battery swapping facility. However, the higher up-front cost of LIBs, an underdeveloped service network, and heavy dependence on raw material imports are some of the serious hurdles to the adoption of LIBs in e-rickshaws.

Several alternative battery technologies (e.g., sodium-ion and zinc-gel) are also emerging, with benefits, such as increased sustainability, lower costs, reduced resource consumption, and potential for a localized supply chain. However, their suitability for e-rickshaw operations, alongside their commercial viability and adoption potential, remain to be demonstrated at scale.

TABLE 1 | Performance indices of lithium-ion batteries and lead-acid batteries

PERFORMANCE INDICES	LITHIUM-ION	LEAD-ACID
Energy density (Wh/kg)	90–220	30–40
Number of cycles	1,000–3,600	400–800
Expected life	2–3 years	8–24 months
Round trip efficiency (%)	87.37	76.36
Daily self-discharge rate (%)	0.17	0.266
Average depth of discharge (%)	80	50
Weight (kg)	35	120 (four batteries)
Cost (INR/kWh)	~14,000	~6,600
Import dependence	Yes	No

Note: INR = Indian rupee; kg = kilogram; kWh = kilowatt-hour; Wh= watt-hour.

Source: Anuphappharadorn et al. 2014; Flux Power 2020; Kebede et al. 2021.

Finance ecosystem for e-rickshaws

According to Reserve Bank of India (RBI) data, about 75 percent of the vehicles sold in India are financed, and 60 percent of auto loans are provided by banks.[2] However, only a small number of banks offer loans for e-rickshaw purchases, and most of the lending for e-rickshaws is done by non-banking financial companies (NBFCs). According to data from a few e-rickshaw financiers,[3] the rate of interest charged on e-rickshaw loans can go up to 20 percent, the repayment period is about 24 months, and the maximum loan amount sanctioned is INR 150,000, which means a loan-to-value (LTV) ratio or down payment requirement of about 20 percent (PNB n.d.).

The e-rickshaw segment comprises individuals from low-income and vulnerable groups, who often lack credit history and assets for loan guarantees. E-rickshaw owners are often not able to make timely equated monthly installment (EMI) payments due to situational factors, such as insufficient income and the need

to prioritize other expenditure. This results in situational defaults or delays in EMI payment. There are also risks associated with vehicle quality and performance due to the predominance of informal OEMs. Further, the e-rickshaw ecosystem lacks a safe and formal charging infrastructure and reliable after-sales service.

These risks usually result in a low LTV ratio, high interest rates, and high EMIs for e-rickshaw drivers. Higher EMIs impact the earnings of e-rickshaw drivers, which in turn impacts their capacity to pay the EMI on time, producing a vicious circle of unfavorable lending terms for the e-rickshaw driver. Lack of affordable finance also promotes the uptake of cheaper and poor-quality e-rickshaws and batteries, which in turn promotes informal manufacturing, informal recycling, and safety compromises.

WEBINAR OUTCOMES: KEY LESSONS AND ENTRY POINTS FOR ACTION

This section highlights the key insights and recommendations put forward by the panelists in the roundtable discussions. The discussions highlighted the importance of facilitating a sustainable e-rickshaw ecosystem and brought to light the challenges, opportunities, and potential pathways for improving the finance and battery ecosystem.

Access to affordable financing for e-rickshaws

- **Understand the risks associated with new technologies and develop risk-sharing mechanisms**
  Financiers highlighted that they face challenges in underwriting new battery technologies such as LIBs because they do not completely understand the risks associated with them. For traditional battery technology, that is, LABs, the financing risk is lower due to the proven technology, low up-front cost, large number of service centers, known resale value of batteries, and so on. Unlike LAB e-rickshaws, LIB e-rickshaws are still an emerging technology with an underdeveloped support ecosystem, which can further restrict access to affordable finance.

  Entry points for action: Participants emphasized that measures such as underwriting technology risk can help financiers build a comprehensive understanding of new battery chemistries and their potential risks and opportunities. This can potentially help set fair borrowing rates and premiums for loans to purchase e-rickshaws. They suggested that OEMs should ensure that financiers have a good understanding of their product.

  It is also important to develop accessible and affordable finance through innovative business models and financial products. Financiers suggested that product risk should be collectively shared by different stakeholders in the e-rickshaw ecosystem in the form of OEM buy-back guarantees, fleet aggregation, residual value assurances, and so on.

- **Explore low-cost funding for e-rickshaw financiers**
  Financiers highlighted that their cost of funds for EV lending is higher due to the higher product and market risk (it is typically about 9 percent for NBFCs). This high cost of borrowing ultimately trickles down to the end customers in the form of high interest rates. The smaller portfolios of NBFCs also make it difficult for them to access climate finance, which is often available at concessional interest rates.

  The lack of affordable finance impacts the overall adoption of e-rickshaws. It also hinders the transition to advanced battery chemistries such as LIBs in e-rickshaws, because LIB e-rickshaws have a higher up-front cost than conventional LAB e-rickshaws.

  Entry points for action: There is a need to explore strategies to reduce the cost of funds for financiers, so that the benefit can be passed on to end customers in the form of lower interest rates. To reduce the cost of borrowing for EV finance, there is a need to assess the feasibility of using climate finance with the help of international financing institutions.

Because the smaller portfolios of NBFCs make it difficult for them to access climate finance (which is usually focused on large projects), there is a need to explore collective approaches that would enable a group of NBFCs to access climate finance or similar sources of finance. These mechanisms can make e-rickshaw financing more attractive to financial institutions and hence help e-rickshaw buyers access finance more easily. These mechanisms could also facilitate the transition to advanced battery chemistries which have lower lifecycle greenhouse gas (GHG) emissions.

- **Enhance product quality to improve the overall financing of e-rickshaws**
  Financiers have highlighted low product quality as one of their major concerns because it impacts borrowers' earnings and credit repayment capacity. Although e-rickshaw adoption has grown rapidly in India, the sector faces persistent challenges with product quality, performance, and safety. The e-rickshaw market in India is still dominated by unorganized and opportunistic OEMs who enter this high-growth market without a long-term strategy. Hence, financiers work with only select OEMs who provide good-quality products and after-sales service.

  Entry points for action: There should be strict implementation of homologation standards for e-rickshaws in India. The enforcement of safety standards and regulatory oversight can play a key role in bringing a level of standardization to the e-rickshaw market, further improving the safety and reliability of e-rickshaws.

Transition to advanced battery technologies for e-rickshaws

- **Develop reliable supply chain and service networks for advanced battery chemistries to facilitate their greater adoption**
  Because LAB is an indigenous battery technology with a reliable supply chain, it enjoys the advantages of easy availability, stable battery prices, easy repair and maintenance, and fair resale value. Unlike LABs, LIBs are dependent on imports and hence are vulnerable to price fluctuations. This in turn can result in greater price variations for LIB e-rickshaws and for replacing used LIBs.

  The repair network for LIB e-rickshaws is also at a nascent stage in the country. In the case of LAB e-rickshaws, drivers approach their local e-rickshaw repair shops and dealerships for battery repair and maintenance services. In the case of LIB e-rickshaws, however, battery repair services are not readily available in every region, and the battery must be sent to its manufacturer or to authorized service centers. Due to this, the turnaround time for repair services is currently higher for LIB e-rickshaws, resulting in daily revenue loss for e-rickshaw drivers.

  One of the financiers highlighted that the share of LIB e-rickshaws had increased from 3 percent to 25 percent of their portfolio at one point. However, due to several reasons, such as high cost for price-sensitive customers and lack of service, the demand for them dropped. Financiers also experience higher default rates for LIB e-rickshaws. These dynamics led to a reduction in the share of LIB e-rickshaws in the portfolios of financiers.

  Entry points for action: Because e-rickshaw drivers are a low-income and vulnerable group, a phased transition to advanced battery technologies such as LIBs is essential to ensure the maturity of supply chains and to develop battery recycling practices, charging infrastructure, and other required support. This will ensure lower and stable battery prices and improve the resale value of batteries.

  Also, the wider adoption of LIBs or any other alternative battery technology will depend on the ready availability of a trained workforce and service centers around major e-rickshaw hubs and at the dealers' shops. There is a need to upskill the existing workforce and train new workers in the e-rickshaw sector for servicing and repairing LIBs and their electronic components. It is important to build a network of

skilled local workers who can understand and service LIB e-rickshaws at the dealership level, so that batteries do not have to be sent to the manufacturer. This would reduce the turnaround time for repair and maintenance of LIB e-rickshaws, thereby eliminating any negative impact on the driver's income.

- **Establish policy support for the creation of battery swapping networks to reduce the purchase cost of LIB e-rickshaws**

  The up-front cost of an LIB e-rickshaw is higher than that of an LAB e-rickshaw. Also, there is no way to finance the purchase of batteries when spent batteries have to be replaced. Financiers highlighted the fact that LAB replacement does not require financing due to its low cost (about INR 25,000) after adjusting the fair scrap value (about INR 10,000) of the old batteries. Financiers also stated that they have not experienced any demand for financing LIBs because the market for LIB e-rickshaws is still evolving. However, the high replacement cost of an LIB (about INR 80,000), coupled with the lack of an established and fair residual value may become a roadblock in future, because arranging that amount at one go may be challenging for e-rickshaw drivers.

  Participants of the roundtable discussions advocated switching to battery swapping models rather than buying an LIB, because the cost of the battery accounts for roughly 50 percent of the total cost of the vehicle. Switching to battery swapping will reduce the cost of the vehicle and hence the capital investment required by the buyer. However, there is a need to develop reliable battery swapping service networks for e-rickshaws.

  Entry points for action: The participants suggested that the government should provide subsidies or incentives for setting up battery swapping stations because it is a highly capital-intensive business. Swapping service providers keep two batteries for each vehicle that they need to serve. The participants also suggested that the government should promote the sale of vehicles without batteries by providing a FAME subsidy for the sale of vehicles without batteries. This will give e-rickshaw drivers the freedom to choose alternatives. Currently, e-rickshaw drivers swap batteries after the lifetime of their first battery. The government has allowed the sale of vehicles without batteries; however, there is still a long way to go before swapping models become mainstream in the Indian market.

- **Promote coexistence of LABs and LIBs, and build awareness among drivers to enable them to choose the battery technology that best suits their requirements**

  Drivers need to be made more aware of the advantages and disadvantages of different battery technologies, the TCO of the vehicle, and the economic benefits that can accrue over a period of time. LABs have been the standard choice for e-rickshaws due to their affordability and proven usage, and their advantages are well understood. However, there is a lack of awareness about the potential benefits of advanced battery chemistries, such as lower operating costs and higher driving range, which can increase the earnings of drivers.

  Entry points for action: Panelists suggested a free market, that is, coexistence of both LAB and LIB e-rickshaws, where e-rickshaw drivers can choose the battery chemistry that best suits their requirements. A phased transition to advanced battery technologies such as LIB is essential to ensure the maturity of supply chains, local servicing, safe charging, and the battery recycling ecosystem of e-rickshaws.

  The discussion also highlighted the need for a detailed analysis of the TCO of LAB and LIB e-rickshaws and for creating awareness among drivers regarding the advantages and disadvantages of different battery chemistries.

- **Formulate a robust policy framework and roadmap for e-rickshaw battery technologies**

  Participants emphasized that because e-rickshaws are low-speed vehicles meant for short-distance travel, higher-energy-density batteries are not as important for them as they are for other EV segments. Hence, there are various alternative battery chemistries such as zinc-gel and sodium-ion that may meet the requirements of the e-rickshaw industry, which needs an indigenous battery technology that is cost-

effective, provides good performance, and is sustainable. For instance, the zinc-gel battery provides better range and better charging at a lower cost than the LIB. Because India is one of the largest miners of zinc, import dependence may not be an issue. However, to bring nascent battery technologies to market at an accelerated pace, it is critical to have policy frameworks and investments with a longer-term outlook.

Entry points for action: Participants highlighted the need for a policy framework, a focus on research and development (R&D), and a technology roadmap for e-rickshaw battery technologies.

Circular economy for e-rickshaw batteries

- **Promote a formal ecosystem for battery recycling**

  LABs continue to be the dominant choice in the Indian e-rickshaw market. They have a high recycling rate, and the informal sector is estimated to account for about 80 percent of LAB recycling in India. This raises serious concerns about the safe handling of hazardous materials, worker safety, and environmental degradation. Only 20 percent of batteries are returned to the manufacturers. This is primarily because, by saving on operational costs and taxes, unauthorized recyclers offer higher purchase prices than formal recyclers, who have to adhere to specified standards and therefore incur higher capital expenditure and taxes (18 percent Goods and Services Tax [GST]). Participants also highlighted the lack of strict implementation of recycling regulations, which allows unauthorized scrap dealers and recycling units to flourish.

  Entry points for action: It is crucial to create an enabling policy and regulatory environment to promote a formal circular economy for batteries in India. It is essential to incentivize the scrapping of batteries through authorized recyclers and strictly implement the scrapping policy to curb unauthorized recycling operations. In addition, participants also emphasized the need to reduce the tax burden (18 percent GST) on authorized recyclers.

- **Develop the resale value of LIBs**

  The resale value of LABs has been fairly established in the market. A set of four LABs used in one e-rickshaw fetches a significant scrap value (about INR 10,000). In contrast, the resale value of LIBs is not known, because the market for LIBs is only picking up now due to the growth of EVs. Establishing a resale value for LIBs is important because it impacts the TCO, terms of financing, and overall adoption of LIB e-rickshaws in the country.

  Entry points for action: Participants emphasized that efficient stakeholder collaboration is essential for transforming the battery recycling ecosystem in India. For example, better labeling of battery packs would help recyclers accurately understand the materials arriving at their facility and promote their recyclability. Participants also highlighted that a labeling system displaying relevant details of the battery packs can increase the resale value of batteries by aiding residual value estimation. Informative labels can thus play a significant role in improving the circular economy of batteries in India. This will be especially useful in the case of LIBs, where the resale value of batteries after usage in e-rickshaws is not known.

NEXT STEPS

The key objective of both discussions was to initiate a dialogue around the opportunities and challenges involved in developing a safe and sustainable ecosystem for e-rickshaws in India. As the highlights from the roundtable discussions suggest, a multi-stakeholder approach is essential to achieve this goal. The following are the key action points and recommendations put forward by stakeholders during the roundtable discussions:

- Create a technology roadmap to develop supporting infrastructure for emerging battery technologies such as LIBs in the e-rickshaw segment.
- Collaborate with large financing and investment institutes (such as climate funds) for providing cheaper finance to NBFCs.
- Establish a framework to incentivize the establishment and operation of battery swapping stations.
- Develop strategies to incentivize the scrapping of batteries through authorized recyclers and promote a circular economy for batteries in India.
- Build awareness among e-rickshaw drivers about the advantages and disadvantages of different battery technologies and the TCO.
- Implement product quality and safety standards strictly for e-rickshaws, and plan e-rickshaw operations in different cities to create a sustainable roadmap in order to scale up the e-rickshaw ecosystem and optimize its socioeconomic and environmental benefits.

APPENDIX A: PARTICIPANTS OF THE WORKSHOP TITLED "E-RICKSHAW FINANCE AND INVESTMENT ECOSYSTEM" IN SEPTEMBER 2022

Policymakers

Vinod Kumar Yadav, Deputy Commissioner, Transport, Government of the National Capital Territory of Delhi (GNCTD)

Industry representatives

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Divya Jain, State Project Head, United Nations Development Programme (UNDP)

Hardip Singh Goindi, COO, Three Wheels United (TWU)

Karan Mittal, Partner, Ev2 Ventures

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APPENDIX B: PARTICIPANTS OF THE WORKSHOP ON "ROADMAP FOR ALTERNATE BATTERY TECHNOLOGIES FOR E-RICKSHAWS IN INDIA" IN AUGUST 2023

Policymakers

Mayank Jyoti, Deputy Transport Commissioner, Agra Zone, Government of Uttar Pradesh

Sanjay Singh, Deputy Transport Commissioner, Bareilly Zone, Government of Uttar Pradesh

Sudhendu J. Sinha, Advisor (Infrastructure Connectivity & E-Mobility), NITI Aayog

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Rajiv Tuli, President & General Secretary, Electric Vehicles Manufacturers Society

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Trupti Deshpande, Senior Program Manager, Shakti Foundation

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ENDNOTES

[1] WRI India calculation based on number of LAB e-rickshaws registered every year (MoRTH n.d.), estimated sales of unregistered LAB e-rickshaws (Gulia et al. 2022), and LAB consumed by the two types.

[2] Calculated from Reserve Bank of India (RBI) data for 2020.

[3] Terra Motors India "https://terramotors.in/finance"; Shivakari Finance Private Limited "https://shivakarifinance.co.in/e-rickshaw-loans/"; E-Rickshaw Loans pnbindia.in - "https://www.pnbindia.in/downloadprocess.aspx?fid=/dKuPBIWDClMiTNEg8vpAw=="

REFERENCES

Anuphappharadorn, S., S. Sukchai, C. Sirisamphanwong, and N. Ketjoy. 2014. "Comparison the Economic Analysis of the Battery between Lithium-Ion and Lead-Acid in PV Stand-Alone Application." *Energy Procedia* 56: 352–58. https://doi.org/10.1016/j.egypro.2014.07.167.

Flux Power. 2020. "What Is the Energy Density of a Lithium-Ion Battery?" Blog. August 21. *Flux Power.* https://www.fluxpower.com/blog/what-is-the-energy-density-of-a-lithium-ion-battery.

Gulia, J., N. Gupta, A. Jadhav, and V. Garg. 2022. *Lithium-Ion Battery (LiB) Manufacturing Landscape in India.* Haryana and New Delhi: JMK Research & Analytics and IEEFA (Institute for Energy Economics and Financial Analysis). https://jmkresearch.com/wp-content/uploads/2022/02/Lithium-Ion-Battery-Manufacturing-Landscape-in-India_January-2022.pdf.

IEA (International Energy Agency). 2020. *Global EV Outlook 2020.* Paris: IEA. https://www.iea.org/reports/global-ev-outlook-2020.

Kebede, A.A., T. Coosemans, M. Messagie, T. Jemal, H.A. Behabtu, J. Van Mierlo, and M. Berecibar. 2021. "Techno-Economic Analysis of Lithium-Ion and Lead-Acid Batteries in Stationary Energy Storage Application." *Journal of Energy Storage* 40. https://doi.org/10.1016/j.est.2021.102748.

Kumar, P., and T.C. George. 2020. "Busting the Cost Barrier: Why Electric Three-Wheelers Make Business Sense" Blog. November 3. WRI INDIA. https://wri-india.org/blog/busting-cost-barrier-why-electric-three-wheelers-make-business-sense.

MoRTH (Ministry of Road Transport & Highways). n.d. "*Vahan Dashboard.*" Vahan Dashboard. https://vahan.parivahan.gov.in/vahan4dashboard/vahan/dashboardview.xhtml.

PNB (Punjab National Bank). n.d. "Scheme for Financing E-Rickshaws – PNB Green Ride." https://www.pnbindia.in/downloadprocess.aspx?fid=/dKuPBIWDClMiTNEg8vpAw==.

Shandilya, N., V. Saini, and A.R. Ghorpade. 2019. *E-Rickshaw Deployment in Indian Cities*. ICLEI South Asia (ICLEI – Local Governments for Sustainability, South Asia). https://shaktifoundation.in/wp-content/uploads/2019/07/Handbook-ERickshaw-deployment-in-Indian-Cities.pdf.

Times of India. 2022. "Delhi HC's No to Use of Lead Acid Batteries in E-Rickshaws." *Times of India*, October 21. https://timesofindia.indiatimes.com/city/delhi/delhi-hcs-no-to-use-of-lead-acid-batteries-in-e-rickshaws/articleshow/95003301.cms.

ACKNOWLEDGMENTS

We would like to extend our gratitude to all the experts who participated in the discussions and shared their valuable inputs for the development of the e-rickshaw ecosystem.

We would like to thank Lalit Mudholkar, Junior Program Associate, Electric Mobility, WRI India, for his contribution to the research work for the background presentation during the discussions. We would also like to extend our thanks to Parveen Kumar, Senior Program Manager, Electric Mobility, WRI India, for guidance and support regarding battery research.

We also thank Madhav Pai, CEO, WRI India, and Pawan Mulukutla, Executive Director, Integrated Transport, Clean Air and Hydrogen, WRI India, for their inputs during the discussions.

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WRI India, an independent charity legally registered as the India Resources Trust, provides objective information and practical proposals to foster environmentally sound and socially equitable development. Our work focuses on building sustainable and liveable cities and working towards a low carbon economy. Through research, analysis, and recommendations, WRI India puts ideas into action to build transformative solutions to protect the earth, promote livelihoods, and enhance human well-being. We are inspired by and associated with World Resources Institute (WRI), a global research organization. Know more: www.wri-india.org

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