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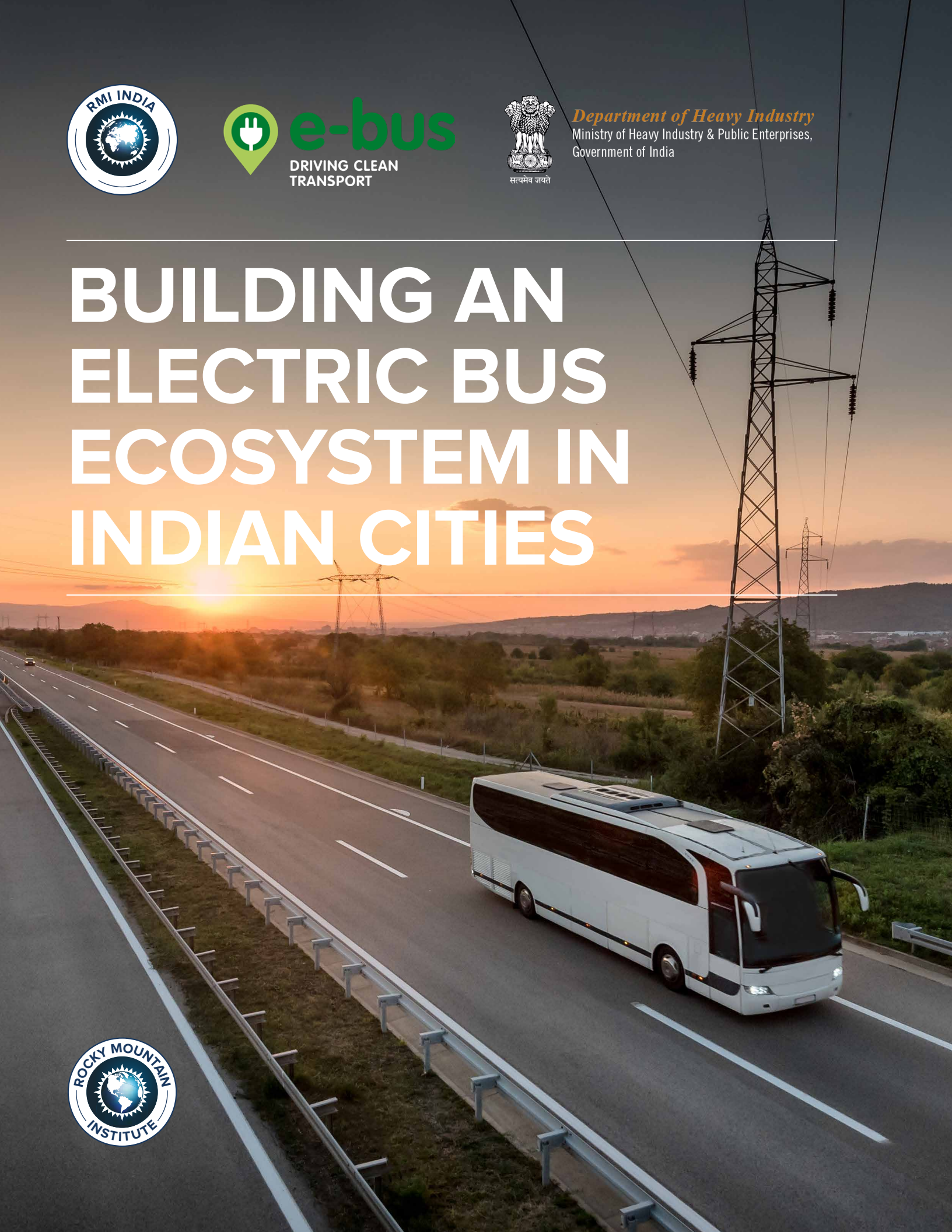
Department of Heavy Industry
Ministry of Heavy Industry & Public Enterprises,
Government of India

BUILDING AN ELECTRIC BUS ECOSYSTEM IN INDIAN CITIES



ROCKY MOUNTAIN INSTITUTE

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ABOUT DEPARTMENT OF HEAVY INDUSTRY

Department of Heavy Industry (DHI) under the Ministry of Heavy Industries and Public Enterprises, Government of India strives to bolster profit-making public sector enterprises as well as restructure and revive the loss-making ones under its administrative control. DHI seeks to achieve its vision of global automotive excellence through creation of state-of-the-art research and testing infrastructure through the National Automotive Testing and R&D Infrastructure Project (NATRIP). DHI seeks to achieve its vision by providing necessary support to the auto, heavy engineering, heavy electrical, and capital goods sectors.

ABOUT ROCKY MOUNTAIN INSTITUTE (RMI)

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has been supporting India's mobility and energy transformation since 2016.

ABOUT RMI INDIA

RMI India is an independent nonprofit organization. RMI India takes inspiration from and collaborates with Rocky Mountain Institute, a 40-year-old non-governmental organization. RMI India's mission is to accelerate India's transition to a clean, prosperous and inclusive energy future.

BUILDING AN ELECTRIC BUS ECOSYSTEM IN INDIAN CITIES

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FORWARD

On behalf of the DHI and RMI, it is our pleasure to introduce this report, *Building an Electric Bus Ecosystem in Indian Cities*, a summary of insights that were generated at a workshop hosted by DHI and RMI on November 21, 2019, in New Delhi.

India's economic growth and the build-out of its urban infrastructure are coinciding with dramatic cost reductions in clean energy technologies—creating an opportunity for India to leapfrog energy and mobility development pathways that other nations have pursued.

In the public transport sector, meeting the mobility needs of citizens with clean passenger kilometers must be among the highest priorities for India. As demand for public transport rises in this decade, a significant opportunity exists to electrify this new demand.

By pursuing this opportunity, India will become one of the largest electric bus (e-bus) markets in the world. As it has done before with other technologies, India can leverage the size of its markets to drive down costs and shape supply chains. The 5,595 e-buses that have been sanctioned for subsidy under the FAME II scheme represent a significant step in the right direction.

While adoption of e-buses at scale will not be without challenges, certainly, the health, economic, and environmental benefits that these buses can deliver to India's cities are worth the effort. Early success will require collaboration and experimentation, a commitment to learning, and steadfast persistence.

We would like to express our gratitude to all those stakeholders who generously contributed their time and expertise to the workshop and look forward to working together to continue building India's e-bus ecosystem.

Sincerely,

Pravin Aggarwal

Clay Stranger

EXECUTIVE SUMMARY

ABOUT THIS REPORT

E-buses offer many value propositions to Indian cities: they are more efficient, cleaner, quieter, and increasingly cost-competitive.[1] By 2030, if four out of 10 buses sold in India are electric, the country could emerge as the second largest e-bus market in the world after China. The increasing priority and support for e-buses from the central government and active response from states, cities and industry, as being witnessed under FAME II, are encouraging India to achieve this adoption path.[2]

The recent sanctioning of subsidies for 5,595 e-buses across 64 cities and State Transport Undertakings (STUs) by the DHI under the Faster Adoption and Manufacturing of Electric Vehicles in India (FAME) Scheme, Phase II, represents a major milestone in India's electric vehicle (EV) transition. Over their lifetime, these buses will run nearly 3 billion kilometers (km) without tailpipe emissions, produce oil import savings of 55 lakh barrels equivalent to ₹3,600 crore (about $500 million), and avoid 12 lakh (1.2 million) tons of carbon dioxide (CO_2) emissions. Yet many challenges must be overcome by Indian cities and industry players to successfully deploy these buses and ensure robust processes and planning for their tendering, contracting, and operations.

In an effort to support early success and learning related to e-bus adoption in Indian cities, DHI and RMI convened stakeholders involved in the electrification of city bus services for a workshop on November 21, 2019, in New Delhi. The intention of the workshop was to support the efficient rollout and operation of the 5,595 e-buses sanctioned by DHI and prepare for the next round of tenders by collecting and sharing the lessons learned.

Over 30 cities and more than 100 senior leaders from public and private sectors and civil society participated, representing all levels of the government, transport and power sectors, and a range of geographies. They made valuable connections, generated insights to inform and advance the work, and shared suggestions for ways to further support the ecosystem moving forward. This report is a reflection of the discussions that took place at the workshop. It aims to capture insights generated during the workshop by sharing common challenges and solutions proposed by stakeholders working on early stage e-bus implementation in Indian cities. DHI and RMI hope it can help inform the actions of stakeholders across the e-bus ecosystem in India and beyond.

SUMMARY OF KEY DISCUSSION POINTS

The workshop demonstrated that there is high interest and considerable momentum in the electrification of city bus services in India. Key discussion points from the workshop included:

> **How to address city-specific needs in tenders and contracts:** As authorities issue tenders and execute contracts with Original Equipment Manufacturers (OEMs) and operators under FAME II, how can these documents address certain city-specific needs?

> **How to take a long-term planning approach to fleet electrification and demand creation:** As cities prepare to implement e-buses on the Gross Cost Contract (GCC) model[4] today and potentially on other models moving forward, how can the planning process emphasize long-term fleet conversions and demand creation that OEMs require to make large-scale investments in manufacturing capacity?

> **How to treat charging standards and electric grid upgrades:** As the ecosystem adds EV loads to the grid, how can distribution companies, operators, equipment suppliers, and government actors work together to develop charging standards and plans for charging infrastructure and electric grid upgrades?

> **How to build technical and operational capacity within government bodies:** As city STUs procure e-buses under the GCC model, how can training programs and resources support officials with their transition to a new technology and business models?

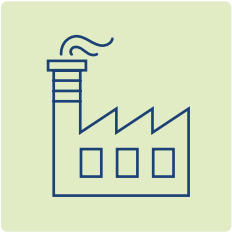
> **How to support a process for capturing and sharing successes and learnings:** As this emerging market grows, how can the ecosystem support peer learning and leverage valuable insights to improve contracts, operations, products, and more?

PATH FORWARD

As India's e-bus market evolves, opportunities exist for government, industry, and civil-society actors to support efficient rollout and operation.

Government

For the public sector, opportunities exist to address city-specific needs through tendering and contracting terms and negotiations. For example, modifications to the Model Concession Agreement (MCA)[5] can offer greater flexibility to cities while making contracts more bankable for financial institutions. Central, state, and city government actors can also work together on long-term fleet and infrastructure planning and targets to create the demand and market growth. Several participants indicated 5,000 units per OEM per year as a critical threshold for the industry to scale up investments in domestic manufacturing capacity.



Industry

For the private sector, there is potential to make reasonable contract adjustments that can create greater buy-in from cities without causing significant business disadvantages. In addition, the industry can work with Urban Local Bodies (ULBs) and STUs on capacity-building programs related to e-buses, as city officials can benefit from greater access to technical and financial knowledge, as well as operational best practices. There may also be opportunities for the industry to inform the design of new policy measures to support long-term demand creation.

Civil society

For transport experts and civil society organizations, many cities stand to benefit from the guidance and support related to e-bus procurement under the GCC model. Civil society can develop peer learning and training programs, tools, and resources that help build technical capacity of officials, especially on the topics of depot and route selection and charging infrastructure planning. In addition, consultants can provide valuable tendering and contracting services to ULBs.

Streamlining tenders and contracts, ensuring efficient rollout and operation, training and capacity building and long-term fleet and infrastructure planning in the context of e-buses will require collaboration and learning. Working together towards these outcomes has the potential to accelerate India's transition to clean public transport.

CONTEXT AND OPPORTUNITY

India has gained global recognition for its efforts towards a clean energy and mobility future. As the country undergoes rapid urbanization, policymakers and business leaders have been working on ambitious plans to reduce emissions in the power and transport sectors, which together contribute over 65% of India's annual CO_2 emissions.[6] These plans include the mass adoption of EVs in cities to improve local air quality and reduce CO_2 emissions. According to India's Economic Survey for 2018–2019, EVs represent the next generation of sustainable mobility.[7] One of the use cases with the greatest potential for electrification is buses operated by STUs for intra and intercity operations, which cater to 70 million passengers per day with nearly 170,000 buses.[8]

The country's EV initiatives started with the launch of the National Mission for Electric Mobility, followed by the National Electric Mobility Mission Plan 2020 (NEMMP) in 2013. To incentivize EV adoption, the DHI created the FAME scheme in 2015. According to the National Automotive Board's data, 280,988 EVs have been sold under the FAME I scheme in four years.[9]

FAME II SCHEME

With an aim to support the electrification of passenger kilometers, India announced the second phase of the FAME Scheme starting April 2019, with a significant focus on public transport.[10] The government has allocated ₹10,000 crore ($1.4 billion) for demand incentives and charging infrastructure. Around ₹3,545 crore (about $500 million USD) has been allocated for supporting adoption of 7,090 e-buses by STUs. In August 2019, DHI invited an Expression of Interest (EOI) under FAME II for electric city bus services on an operating expense (Opex) basis, also known as the GCC.[11] DHI received 86 proposals from 26 states and Union Territories and sanctioned 5,595 e-buses to 64 cities on September 15, 2019.[12]

Following the sanction, authorities have issued Requests for Proposals (RFPs). States and cities have started commissioning e-buses after a thorough evaluation of proposals by OEMs.

THE BREAKDOWN INCLUDED:

5,095

E-BUSES FOR INTRACITY ROUTES (SUMMARIZED IN TABLE 1)

400

E-BUSES FOR INTERCITY OPERATION

50

E-BUSES FOR LAST-MILE CONNECTIVITY FOR DELHI METRO RAIL CORPORATION (DMRC)

TABLE 1

State-wise distribution of the number of e-buses sanctioned for subsidy support under the FAME II scheme

STATE TRANSPORT UNDERTAKING	NUMBER OF E-BUSES SANCTIONED
Andhra Pradesh	300
Assam	100
Bihar	25
Chhattisgarh	50
Dadra	25
Delhi	300
Gujarat	550
Haryana	50
Himachal Pradesh	100
Jammu and Kashmir	150
Karnataka	350
Kerala	250
Maharashtra	725
Madhya Pradesh	340
Odisha	50
Rajasthan	100
Telangana	325
Tamil Nadu	525

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STATE TRANSPORT UNDERTAKING	NUMBER OF E-BUSES SANCTIONED
Tripura	50
Uttarakhand	30
Uttar Pradesh	600
West Bengal	100
INTER CITY OPERATIONS	**NUMBER OF E-BUSES SANCTIONED**
Andhra Pradesh State Road Transport Corporation	50
Kadamba State Road Transport [STU, Govt.of Goa]	50
Gujarat State Road Transport Corporation	50
Karnataka State Road Transport Corporation	50
Maharashtra State Road Transport Corporation	50
Rajasthan State Road Transport Corporation	50
Uttarakhand Transport Corporation, Dehradun	50
Transport Department, Govt. of West Bengal	50
LAST MILE CONNECTIVITY	**NUMBER OF E-BUSES SANCTIONED**
Delhi Metro Rail Corporation	50
TOTAL	**5,595**

State and city governments have also been building on the central government's initiatives by developing individual strategies towards EV adoption, including adoption of e-buses. In their state EV policies, states such as Andhra Pradesh, Karnataka, Kerala, Maharashtra, the National Capital Territory of Delhi, Telangana, Uttarakhand, and Uttar Pradesh have emphasized the importance of electrifying current and future bus services.[13] Other states are in the process of drafting their EV policies and have also highlighted the importance of e-buses in their strategies.

The transition to e-buses has the potential to create significant economic, social, and environmental benefits for India's cities. Over their lifetime, the 5,595 e-buses sanctioned for subsidy support by DHI will run nearly 3 billion km without tailpipe emissions, produce oil import savings of 55 lakh barrels equivalent to ₹3,600 crore (about $500 million, and avoid 12 lakh (1.2 million) tons of CO_2 emissions. With local air quality becoming a growing concern in many cities, switching from diesel engines, which produce high levels of fine particulate matter and nitrogen oxide emissions, to electric powertrains will help improve air quality and public health.

WORKSHOP OVERVIEW

PURPOSE AND OBJECTIVES OF THE WORKSHOP

Early adoption of new technologies requires a commitment to experimentation, feedback, and learning in order to overcome initial barriers. Ensuring early success in the electrification of city bus services is critical to establishing a durable foundation for faster adoption and greater scale. To support this vision, DHI and RMI hosted a workshop on November 21, 2019, in New Delhi on the topic "Accelerating Rollout of Electric Buses under FAME II".

The workshop aimed to support the efficient rollout and operation of the 5,595 buses sanctioned for subsidy support by DHI and to help prepare for the next round of tenders by convening stakeholders across the ecosystem to:

> Discuss current state of India's e-bus ecosystem

> Identify common challenges and lessons learned across stakeholder groups

> Develop potential solutions to challenges and identify champions to carry forward follow-up work

As India moves beyond its first implementation of e-buses, the insights from the workshop intend to help stakeholders address barriers and support early success and scaling up.

Participation and Workshop Structure

The workshop convened representatives from over 30 cities and STUs from across the country and more than 100 senior leaders from government bodies, manufacturing sector, electricity distribution companies, and civil society. During the workshop, these participants discussed issues, proposed solutions, and shared their experiences.

The workshop focused on fundamental themes related to the process of procuring e-bus services under FAME II: tendering, contracting, procurement, and financing; depot and route selection and operations; charging infrastructure planning and electricity supply; and products and supply chain. These four themes were prioritized as current areas of challenge and opportunity related to India's transition to e-buses.

Honorable dignitaries and participants working together at the Electric Bus workshop to accelerate roll out of buses under FAME II Scheme on Novemeber 21, 2019 in Delhi.

THEMATIC SUMMARIES AND SOLUTIONS PROPOSED BY STAKEHOLDERS

OVERVIEW OF THEMES AND SUMMARY OF KEY TAKEAWAYS

The workshop focused on four themes:

> Tendering, contracting, procurement, and financing

> Depot and route selection and operations

> Charging infrastructure planning and electricity supply

> Products and supply chain

These themes were identified and prioritized as key areas of challenge and opportunity based on pre-workshop stakeholder interviews. Together, they cover a range of topics related to e-bus adoption, from planning for e-bus procurement to requesting for tenders and evaluating them, negotiating with selected bidders, commissioning infrastructure and services, managing operations and long-term market creation. Breakout groups discussed challenges, proposed solutions, and shared learnings related to the four themes.

Discussions at the workshop clearly indicated the high interest and considerable momentum in the electrification of city bus services in India. Key takeaways from the workshop centered on enhancing e-bus tenders and contracts under the GCC model, building capacity to plan for e-bus infrastructure and services, and identifying pathways towards long-term e-bus planning and demand creation.

> Enhancing e-bus tenders and contracts under the GCC model: With the Government of India sanctioning 5,595 e-buses for subsidy support on the GCC model, many discussions focused on tender and contract terms, specifically on how to accommodate city-specific needs by negotiating reasonable adjustments and how to make the current contract model more bankable by modifying certain clauses, structures, and timelines.

Workshop participants engaged in discussions on tendering, contracting, procurement, and financing of electric buses.

> **Building capacity to plan for e-bus infrastructure and services:** Given the change in business model and technology, there is a need for capacity building and training programs and resources for government officials and other stakeholders to better understand depot and route selection and charging infrastructure planning to minimize cost and improve operational performance.

> **Identifying pathways towards long-term e-bus planning:** At the early stage and scale of the market and considering the diversity of actors and needs, there is no one-size-fits-all solution. Solutions will need to be customized to city needs as best as possible to ensure early success before growing the market. There is, however, a need to start emphasizing the long-term fleet transition to e-buses to ensure planning and processes are supportive and cognizant of transition at scale. States and manufacturers could consider developing a transition plan for bus fleet electrification in their cities to enable smooth transition.

TABLE 2

Summary of key needs and opportunities shared by stakeholders throughout the one-day workshop on e-buses in Indian cities

DISCUSSION AREAS	KEY NEEDS SHARED BY STAKEHOLDERS	KEY OPPORTUNITIES IDENTIFIED BY STAKEHOLDERS
Contracting, Procurement and Financing	• Some aspects of tenders and contracts may not align with certain city needs • Some terms of the MCA could be more acceptable to lenders financing the project than participants	• Reasonable tender and contract adjustments can increase confidence without causing significant disadvantages • Opportunities exist to modify parts of the MCA to make it more bankable
Depot and Route Selection and Operations	• Many authorities anticipate they would need guidelines, handholding, and training for depot and route selection	• Develop depot and route selection guidelines and structured training programs for city officials
Charging Infrastructure and Electricity Supply	• Some authorities could benefit from greater ` understanding of batteries and charging infrastructure • Grid upgrades to support e-bus charging could be a challenge	• Develop training materials and programs on e-bus and charging infrastructure technology for government officials • Engage state governments (power depts.) and DISCOMS to plan for electric grid upgrades for EV charging

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DISCUSSION AREAS	KEY NEEDS SHARED BY STAKEHOLDERS	KEY OPPORTUNITIES IDENTIFIED BY STAKEHOLDERS
Products and Supply Chain	• City buses represent a small share of OEMs' overall demand • Greater visibility into future demand for e-buses would build confidence to invest in manufacturing capacity	• There is a critical threshold that would make large- scale e-bus production viable: 5,000 units per OEM per year was indicated as a potential threshold by industry participants

Following sections provide summaries from each of the four workshop themes: tendering, contracting, procurement, and financing; depot and route selection and operations; charging infrastructure planning and electricity supply; and products and supply chain.

Tendering, Contracting, Procurement and Financing

Following the DHI sanction of subsidy support to 64 cities and STUs for 5,595 e-buses, authorities are required to deploy the approved number of e-buses on a wet-lease model, with the goal of having e-buses plying on the roads within 12 months of the issue of the supply order. To procure the e-buses, each authority has been requested to issue a tender on the GCC model and invite bids from operators. In doing so, they were encouraged to issue Requests for Proposals (RFPs) and adopt the MCA developed by NITI Aayog to enter a contract with the preferred bidder (i.e., the eligible bidder with the lowest per-kilometer rate).[14] Cities, operators, and other stakeholders have identified challenges and questions as they have taken these steps. The flexibility of the MCA, the degree of customization of service-level agreements (SLAs), challenges with the minimum payment amount required in escrow accounts, and low bidder turnout have been raised by cities. OEMs and operators have raised points related to the need for greater consistency, lack of understanding in pricing, and challenges with late payments and high interest rates and bank guarantees. Ironing out the details of such terms will be critical to effective tendering and contract execution with this new technology and business model.

Considering the urgency and importance, during the workshop, all participants focused on challenges experienced and lessons learned from tendering, contract execution, procurement, and financing under the GCC model. Table 3 summarizes the issues raised and solutions proposed by stakeholders who participated in a breakout group that focused on the theme of contract execution, procurement, and financing.

TABLE 3
Summary of issues and solutions from stakeholders who participated in the breakout group on the theme of contract execution, procurement, and financing

DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Model Concession Agreement (MCA)	Opex and capital expenditure (Capex) models may favor industry	A few STUs indicated the need for flexibility in choice of procurement model under FAME II	Collect concerns and experiences with Opex model after the first round of procurement and identify adjustments required in Opex model /procurement model
	Contract Period	16 years may be too long for city authorities	Consider reducing contract period to 7–10 years
	Termination Clause	Current clauses can be unclear and favor industry in some cases	Revise clauses to prevent ambiguity and ensure fair and equal accountability of all parties involved
	Penalty Clauses for Performance Shortfall	Current clauses are unclear and have direct financial implications for businesses	Clarify and reduce penalty amount

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DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Request for Proposals (RFPs)	Delivery Timeline	Several RFPs have compressed delivery timelines to 5–6 months	All RFPs should adhere to the 9-month delivery timeline prescribed under MCA
	Qualifying Criteria	Need for standardized EV-specific bidder qualifying criteria	Create model RFP with EV-specific qualifying criteria for bidders
	Online Tendering	GeM has been underutilized for tendering so far	Encourage use of GeM portal to ensure transparent bid evaluations
	Data	Need for clarity regarding owner of bus performance data	Clarify data ownership and sharing requirements in RFPs and MCA
Financing	Bank Guarantee (BG)	Currently, high BGs can be a financial burden on the industry	BGs could be reduced each year to reduce cost of capital
	Escrow Account	3 weeks of minimum payment can be a financial burden on some city authorities	1 week of minimum payment could be more reasonable
	Repayment Timeline	15-day payment window can be too short for some city authorities	Payment timelines could be extended (up to 30 days as suggested)
	Viability Gap Funding (VGF)	Some states are not offering adequate or timely VGF	States could pledge VGF at the tendering stage or DHI could make VGF an eligibility criterion for subsidy

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DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Batteries	Performance, Replacement, and Recycling	Need for clarity on battery provisions under GCC model	Model RFPs and MCA could outline performance metrics, replacement and recycling processes
Capacity Building	GCC Model	Need for providing better understanding of procurement and implementation under GCC model	Design and deliver discussion forums, tools and resources, and structured training for stakeholders

A practical matter of discussion was the flexibility in implementing the MCA. Clarifying the allowable degree of flexibility and offering clarity on contract duration, financing, termination, and penalty clauses can help cities and operators achieve greater alignment during contract negotiations. Entities such as UITP have conducted reviews of these tendering and contract structures and offered suggestions for consideration by different stakeholders. Using the Government of India's online marketplace (GeM) can also help ensure efficient and transparent tendering.

While the GCC (i.e., Opex) model has been identified as the choice for issuing the subsidy to improve operational efficiency, address financial constraints and regulatory issues, and remove the upfront cost barrier for cities, some cities expressed interest in procuring e-buses on the Capex model, including several with experience doing so.

Finally, there are several financial measures that could support early electrification of city bus services in India. Low-interest loans from institutions and timely subsidy, viability gap funding, and regular payments can support everyone's financial success.

Depot and Route Selection and Operations

For e-buses, depot and route selection are critical precursors to cost-effective and efficient operations. Proper depot selection has the potential to reduce upfront investment cost in electricity infrastructure and support higher utilization of charging infrastructure. Proper route selection has the potential to reduce the replacement ratio (i.e., the need for spare buses), ensure scheduling adherence, and increase profitability. Together, depot and route selection have considerable implications for e-bus economics and operational feasibility. Understanding how to approach depot and route selection, how to incorporate appropriate details in tender RFP documents, and how to evaluate operational performance represent critical challenges and opportunities for successful e-bus adoption in India.

During the workshop, the depot and route selection and operations breakout group focused its discussions on selecting optimal routes for the e-buses sanctioned under the FAME II scheme and preparing for operational readiness. Table 4 summarizes the issues raised and the solutions proposed by these stakeholders.

TABLE 4
Summary of issues and solutions from stakeholders who participated in the breakout group on the theme of depot and route selection and operations

DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Request for Proposals (RFPs)	Investment Costs	OEMs need clarity on inputs to accurately assess actual asset and infrastructure costs	Create model RFPs that require details of tendered depots, routes, and schedules
	Route Modification	Need for clarity on whether routes outlined in contracts can be changed	Consider whether STUs can modify routes post-contract
	Dead Kilometers	Per-km service payments cover only revenue-making km	Explore compensation mechanism for dead km and encourage depot route selection to minimize dead km
Operational Performance	Metrics	Need for clarity on metrics indicative of high versus low performance	Develop benchmark drive cycles for different cities to outline metrics for high operational performance
In-house Technical Capacity	Training for Depot and Route Selection	Some authorities anticipate they would need guidelines, handholding, and training for depot and route selection	Develop depot and route selection guidelines and structured training programs for city officials
Real-time Data	Safeguarding Data	Concerns related to ownership and data usage	Ensure data protection and create secure data-sharing platforms

Stakeholders in this group focused mainly on two points: how route and depot selection criteria should be for revenue-generating routes and the need for appropriate training for e-bus operators and STUs.

In the short term, the central government can offer clarity on whether route modification can be permissible under the FAME II contract structures and explore potential for a compensation mechanism for dead kilometers (and/or encourage depot and route selection that minimize dead kilometers). In the medium term, opportunities exist to support city officials with the creation of guidelines and training programs to inform their depot and route selection efforts. Civil society organizations can take the lead in the development of such programs. OEMs can help by sharing what information they require to more accurately assess the costs of their service offerings. In the long term, standards for measuring operational performance and sharing operational data should be developed.

Charging Infrastructure and Electricity Supply

E-bus charging will represent a new and considerable load for India's electric grid. This load poses financial and operational challenges and opportunities for cities, distribution companies (DISCOMs), equipment manufacturers and service providers. City authorities are facing challenges with respect to charging technology options, standards, and land availability for charging at bus depots. Electric grid upgrades and charging infrastructure represent significant potential upfront costs for certain parties to bear. Understanding how to calculate current and future peak load related to e-bus charging, determining appropriate electric grid upgrades and optimal charging solutions, structuring financial and business services to pay for infrastructure and utilize it efficiently and cost-effectively, are areas where cities and operators are looking for support. Opportunities exist around streamlining processes related to identification of land for depots by cities, wider technology options for STUs, enhanced battery standards, and infrastructure upgrade for DISCOMS. The Make in India scheme for batteries that is being developed under the National Mission on Battery Storage and Transforming Mobility could play a vital role in supporting the growth of the whole ecosystem. During the workshop, the charging infrastructure and electricity supply breakout group focused its discussions on planning for charging infrastructure and ensuring quality, reliable power supply. Table 5 summarizes the issues raised and the solutions proposed by the stakeholders.

TABLE 5
Summary of issues and solutions from stakeholders who participated in the breakout group on the theme of charging infrastructure planning and electricity supply

DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Request for Proposals (RFPs)	Infrastructure Costs	OEMs need clarity on inputs to accurately assess actual asset and infrastructure costs	Create model RFPs to specify tendered depots, routes, schedules, land and power requirements

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DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Electric Grid and Charging Infra	Funding Mechanism	Transmission line and land costs can be expensive for STUs	Intervention from state governments (power depts.) and DISCOMS can support electric grid upgrades for EV charging
	Infrastructure Planning	Lack of planning for future infrastructure requirements	Opportunity to plan electricity infrastructure for current and future e-bus loads
	Infrastructure Costs	Bid prices have escalated due to charging infrastructure costs needing to be recovered over the contract period	STUs could consider creating a separate contract for charging infrastructure with a focus on interoperability
Batteries	Battery Standards	Need for standardizing battery charging	Bureau of Indian Standards is developing AC and DC charging — opportunity to make suggestions
In-house Technical Capacity	Training	Need for issuing guidelines, handholding, and training for charging and electricity infra	Develop an EV charging primer with the basics of charging infrastructure planning
Integration	Renewable Energy	Opportunity to make charging sustainable via renewables	Design programs to promote charging via renewable energy

Dealing with the high upfront cost of electric grid upgrades and the reality that charging infrastructure's equipment lifetime is longer than that of the bus were two topics that were of highest interest to participants. Regarding the former, there are opportunities for state governments to support authorities in paying for these expensive but critical upgrades. For the latter, authorities may want to consider issuing separate tenders for EV Supply Equipment (EVSE) given its longer lifetime to avoid unnecessarily high costs. Entrepreneurs can take advantage of this opportunity by offering e-bus charging services that not only provide charging but also seek to

monetize grid benefits such as demand response. They could also aim to provide an end-to-end clean energy solution with integrated renewables.

Beyond infrastructure, experts should weigh in on the Bureau of Indian Standards (BIS) Sectional Committee for EV Charging Standards, dedicated to heavy EV charging standards. The Department of Science and Technology's efforts towards developing standards for both AC and DC charging and potentially batteries point in the right direction. These standards could potentially help DISCOMS in load estimation and aligning with EV and industrial charging tariffs. Overall, a need was expressed by all participants that STUs could use help in familiarizing themselves with new technologies, standards, electricity requirements, and products through a form of capacity building.

Products and Supply Chain

Engagement between manufacturers and customers is critical to establish a balance between supply and demand of e-buses. If demand exceeds supply or if supply exceeds demand, there could be setbacks in India's e-bus movement. Greater communication and coordination between suppliers and customers can support the creation of a well-managed pathway for e-bus adoption in India.

During the workshop, the products and supply chain breakout group focused its discussions on reviewing product specifications, product availability, and current and future demand.

TABLE 6
Summary of issues and solutions from stakeholders who participated in the breakout group on the theme of products and supply chain

DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Standards	Bus Design	Need for common design specifications — such as Urban Bus Specifications II	ARAI could develop standard specifications for e-buses
	Batteries	Need for domestic standards related to areas such as form factor, electrode connections, thermal cutoff, etc	Potential to work with the Bureau of Indian Standards to develop such standards

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DISCUSSION AREAS	DISCUSSION AREAS	ISSUES RAISED BY STAKEHOLDERS	SOLUTIONS PROPOSED BY STAKEHOLDERS
Range	Actual Range	Significant difference in rated versus actual range and per-km energy consumption	Opportunity to develop procedures/norms for measuring actual range of e-buses under real-time operating scenarios
Long-term Planning	Demand Creation and Supply Chain Investments	Manufacturers and operators are facing difficulties in conducting a volume forecast study	• Authorities could consider framing long-term fleet conversion targets to encourage OEM investments in manufacturing capacity • Opportunity to develop targets for adoption • Opportunity to develop guidelines for Public Service Obligation • Opportunity for identifying other use cases for e-buses (such as school buses, company buses for employee commute)

The initial round of e-buses sanctioned under FAME II represents an important initial demand signal to manufacturers. While demand guarantee assurance or guarantees might be challenging, it was acknowledged that long-term government targets for bus electrification would add confidence to manufacturers and potentially help spur investment. A target-based program for adoption was discussed as a potential measure to support higher volumes of production and sales.

During the discussions, it became clear that near and long-term visibility into demand for e-buses (and EVs more broadly) can support manufacturers' planning and production processes. A volume of approximately 5,000 buses per manufacturer per year was indicated by several participants as a threshold for realizing economies of scale. If realized, this threshold would enable manufacturers to shift e-bus production to the equivalent of main production lines that are currently being used to produce conventional buses.

Another challenge identified by manufacturers is the variation in requested specifications from customers. Given the current low volumes, significant differences in specifications requiring extensive customizations are not feasible. There is a need to align with common specifications, which will meet most needs and account for Indian driving conditions for the current generation of buses.

STUs expressed their concerns around variation in e-bus prices quoted by manufacturers in different cities. They also expressed the need for an understanding in these differences and conditions that could enable competitive pricing.

Lastly, the difference between rated versus actual range is creating challenges related to route selection and vehicle performance. Measuring and reporting actual range under real-world operating conditions will allow operators to more accurately pair buses with appropriate routes.

PATH FORWARD

The workshop created a forum for discussion and community building around India's e-bus ecosystem. It offered participants an opportunity to engage in conversations and debates on their current experiences, learnings, and future ambitions. In addition to the specific recommendations, which have been summarized in the previous section, four opportunities were identified for the ongoing support of India's e-bus ecosystem over the next year:

> **Regional capacity-building workshops:** A series of regional capacity-building workshops with STUs and other relevant stakeholders to address state and region-specific challenges and opportunities.

> **Technical guidance documents:** A compilation of current resources from first movers and industry experts related to e-bus adoption and the four themes covered at the workshop, plus technical primers on best practices for addressing challenging topics such as depot and route selection, charging infrastructure and load calculation.

> **Energy and emissions data tracker:** A data tracker to capture the energy and emissions savings from e-buses that are deployed under the FAME II scheme.

> **Charging infrastructure planning tool:** A dynamic charging infrastructure planning tool to support DISCOMs and STUs in preparing for e-bus adoption

These activities and other potential opportunities for impact are under consideration by DHI, RMI, and partners. They intend to support the important work, which is already underway, by establishing a community of practice and learning. Ultimately, it will take the full community to ensure effective adoption and scaling up. This document intends to serve as a resource to support and inspire further action in the ecosystem's efforts to bring e-buses to Indian cities.

END NOTES

[1] Khandekar, Aditya, Deepak Rajagopal, Nikit Abhyankar, Shruti Deorah, and Amol Phadke, "The Case for All New City Buses in India to Be Electric," July 2018. www.doi.org/10.2172/1485102.

[2] RMI analysis

[3] ETAuto.com, "DHI Sanctions Subsidy for 5,595 Electric Buses in 64 Cities," August 8, 2019. www.auto.economictimes.indiatimes.com/news/commercial-vehicle/mhcv/mohi-sanctions-subsidy-for-5595-electric-buses-for-64-cities/70589225

[4] The Gross Cost Contract or GCC (also known as opex or wet lease) model is a contract structure for public transport services in which a transit authority pays a bus operator on a per-kilometer basis for a city bus service with specific route concessions. The authority keeps the fare revenue. The authority handles scheduling, route planning, fare collection, plus sets service standards while the operator handles operations and maintenance. With respect to risks, the authority assumes the revenue risk while the operator assumes the financial, technology, and operational risks. Procurement on the GCC model is currently a requirement for FAME II subsidy for e-buses.

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[11] Department of Heavy Industry, "Expression of Interest Inviting Proposals for availing incentives under Fame India Scheme Phase II for Deployment of Electric Buses on Operational Cost Model Basis," June 4, 2019. www.dhi.nic.in/writereaddata/UploadFile/Final%20EOI%2004%20June%202019%20Published.pdf

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