ENERGY MANAGEMENT CENTRE KERALA

CSTEP

Electrifying School Buses in Kerala

Electrifying School Buses in Kerala

Vivek Gavimath

Vandana Nair

Spurthi Ravuri

Thirumalai N C

Center for Study of Science, Technology and Policy (CSTEP)

June 2026

Edited and Designed by CSTEP

Disclaimer

Generative AI declaration

Generative AI tools were used for literature review and data collection and processing. All AI-assisted outputs were reviewed and validated by the authors, who retain full responsibility for the accuracy, originality, and integrity of this document.

Suggested citation: CSTEP. 2026. *Electrifying school buses in Kerala*. (CSTEP-RR-2026-03).

June 2026

Editors: Garima Singh and Reghu Ram R

Designer: Alok Kumar Saha

Bengaluru

No. 18, 10th Cross, Mayura Street

Papanna Layout, Nagashettyhalli

RMV Stage 2, Bengaluru 560094

Karnataka (India)

Noida

1st Floor, Tower-A

Smartworks Corporate Park

Sector 125, Noida 201303

Uttar Pradesh (India)

Tel.: +91 (80) 6690 2500

Email: cpe@cstep.in

Acknowledgements

We would like to thank the International Sustainable Energy Foundation (ISEF) for providing the financial support for this work.

We are grateful to Dr R Harikumar, Director; Mr B V Subhash Babu, Registrar; Mr Anoop Surendran, Energy Technologist; and Mr Sarath Krishnan, Energy Technologist from Energy Management Centre Kerala for their support and guidance.

We also thank Dr Ravi Gadepalli, Independent Consultant, World Bank, for his critical review and feedback on the report.

We are grateful to Dr Jai Asundi, Executive Director, CSTEP, and Mr Munish Sapra, Director, Strategy and Corpus Generation, CSTEP, for their encouragement, guidance, and support throughout this study.

Finally, we would like to thank the Communication and Policy Engagement (CPE) team at CSTEP, particularly, Ms Sreerekha Pillai, Sector Head, CPE; Ms Garima Singh, Senior Editor; Mr Reghu Ram R, Senior Editor; and Mr Alok Kumar Saha, Dy Manager, Communication Design, for their valuable assistance in editing and designing this report.


BUS
SCHOOL BUS
SCHOOL BUS
124
116
156

Foreword

The transition to clean and sustainable mobility is a critical component of Kerala's broader energy and climate goals. In this context, the electrification of school transport presents a unique opportunity to safeguard the health of our children while reducing emissions and advancing the State's commitment to environmental stewardship.

This report, *Electrifying School Buses in Kerala*, prepared by the Center for Study of Science, Technology and Policy (CSTEP), is a timely and comprehensive effort that examines the technical, financial, and institutional pathways for enabling this transition. The study provides valuable insights into stakeholder perspectives, procurement models, financing mechanisms, and policy interventions required to accelerate the adoption of electric school buses in the State.

The Energy Management Centre (EMC) is pleased to have supported this initiative, particularly in facilitating stakeholder engagement and capacity-building efforts among schools and related institutions. The findings of this report underline both the opportunities and challenges in scaling up electric mobility in the school transport segment, while also highlighting innovative approaches such as demand aggregation and vehicle-to-grid integration.

We believe this report will serve as a useful reference for policymakers, educational institutions, transport operators, and financial institutions in making informed decisions towards a cleaner and more sustainable transport ecosystem in Kerala.

EMC remains committed to promoting energy efficiency and clean energy solutions across sectors, and we look forward to continued collaboration with stakeholders to translate these insights into actionable outcomes.

Dr R Harikumar
Director
EMC Kerala


AJYAL
09
MBZ
73

Executive Summary

About one-third of students in India use school buses. School buses are vital to India's education sector, including Kerala's, enabling safe and timely transportation of students and staff. Nearly all school buses in the state of Kerala currently operate on diesel, contributing significantly to local air pollution and climate change caused by greenhouse gas emissions. Electric school buses (e-school buses) with zero tailpipe emissions and less noise offer a cleaner and healthier mobility alternative, especially for children who are vulnerable to vehicular pollution.

To support Kerala's climate and air quality goals and build awareness and readiness among key stakeholders, this study undertook a comprehensive capacity-building programme, targeting school administrators and associated stakeholders. The study—led by the Center for Study of Science, Technology and Policy with support from the Energy Management Centre Kerala—focused on enabling an informed transition to electric fleets across private, aided, and government-run schools in the state.

Through consultations with about 100 schools in Thiruvananthapuram and Kochi districts, as well as discussions with original equipment manufacturers, charge point operators, electricity distribution companies, and education department officials, the study found that schools were willing to consider e-school buses, particularly for health and environmental reasons. However, high upfront costs and limited awareness about available procurement and financing models emerged as key gaps to adoption.

To address these gaps, the study analysed multiple procurement models, such as outright purchase, battery leasing, dry leasing, gross cost contracts, and retrofitting, and evaluated their economic viability using a total cost of ownership framework. The analysis showed that while outright purchase offers complete control over assets and operational flexibility, leasing models and gross cost contracts offer more feasible pathways for schools with limited capital. Retrofitting emerged as a promising option for schools with ageing diesel fleets. Further, to make the capital accessible for schools, the study identified several financing avenues such as green loans from the Energy Management Centre Kerala, concessional interest rates from banks and financing institutes, corporate social responsibility funds, and MP/MLA funds.

Demand aggregation—consolidating demand for e-school buses from multiple schools located in the same neighbourhood—will enable schools to benefit from economies of scale (lower price discovery) and shared charging facilities.

This approach makes e-school bus adoption attractive in early market phases when demand is low. Suitable government policies are crucial in enabling this.

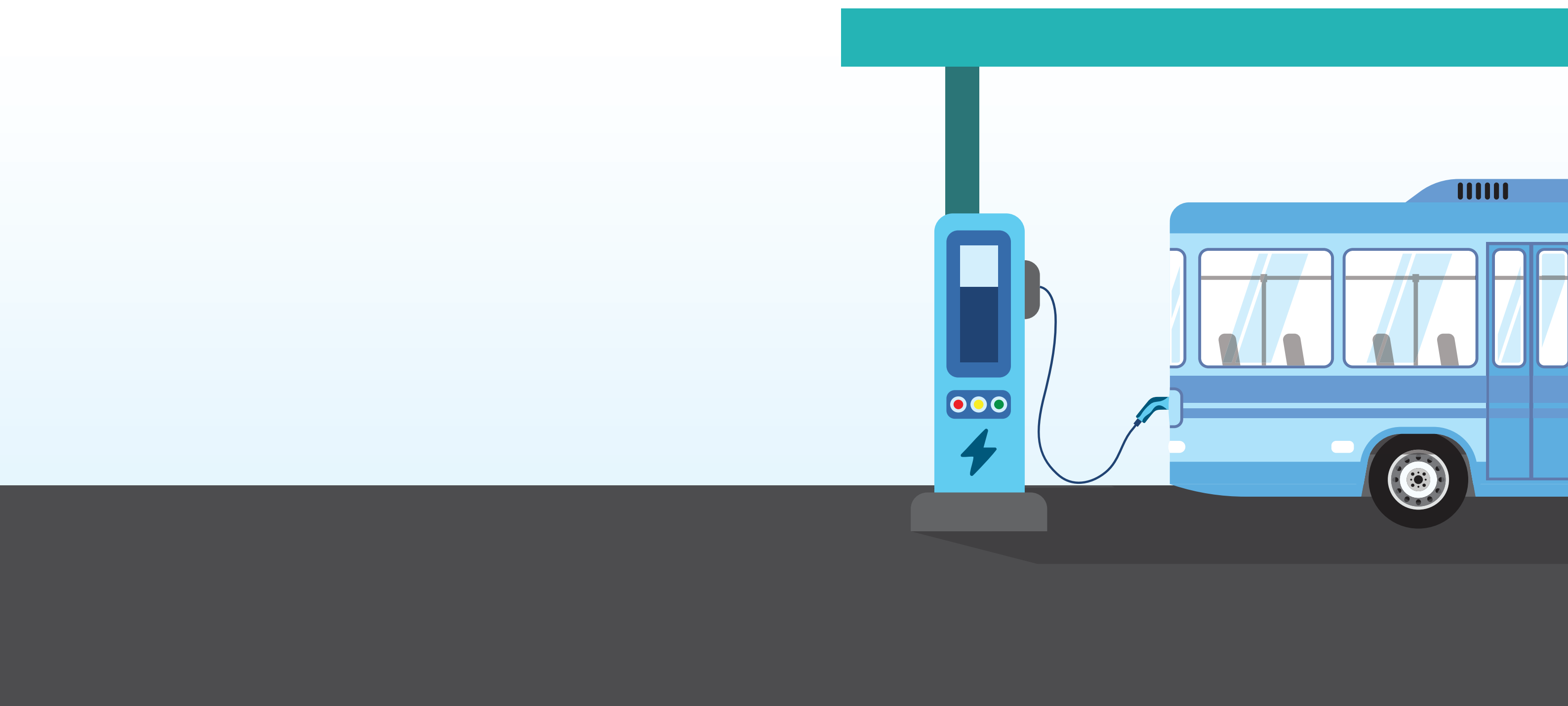
Demand-side policy support may include non-financial incentives, such as creating recognition frameworks for green schools, setting phase-wise adoption targets, and establishing low-emission zones around schools. Enabling access to low-interest green vehicle loans, especially for government and government-aided schools, is also recommended. Extending fiscal incentives to e-school buses based on battery capacity under national and state EV policies and the initiation of pilots can also be considered. These policy measures will be critical to scale up this transition.

As e-school bus adoption picks up, other opportunities, such as vehicle-to-grid applications, which have a bearing on the state's energy transition, will become viable. Therefore, the study also assessed the technical and economic potential of deploying e-school buses for vehicle-to-grid applications. Given their fixed operational hours and substantial idle time, e-school buses can serve as viable assets for grid services, such as frequency regulation during peak hours and renewable energy storage. The analysis found that a fleet of 24–240 e-school buses, across the state, could meet up to 5% of the state's peak unmet demand and contribute to frequency regulation, depending on charger capacity and participating levels.

Overall, this report presents the details of engagements with relevant stakeholders and capacity-building workshops carried out for schools in Thiruvananthapuram and Kochi districts. To bridge the lack of awareness about e-school buses among schools, practical insights on procurement, financing, technology, and policy were offered during these workshops and are presented in the report. The report details viable procurement pathways for e-school bus deployment and assesses their potential for vehicle-to-grid applications to accelerate clean mobility and green energy transition in Kerala.

Table of Contents

Figures



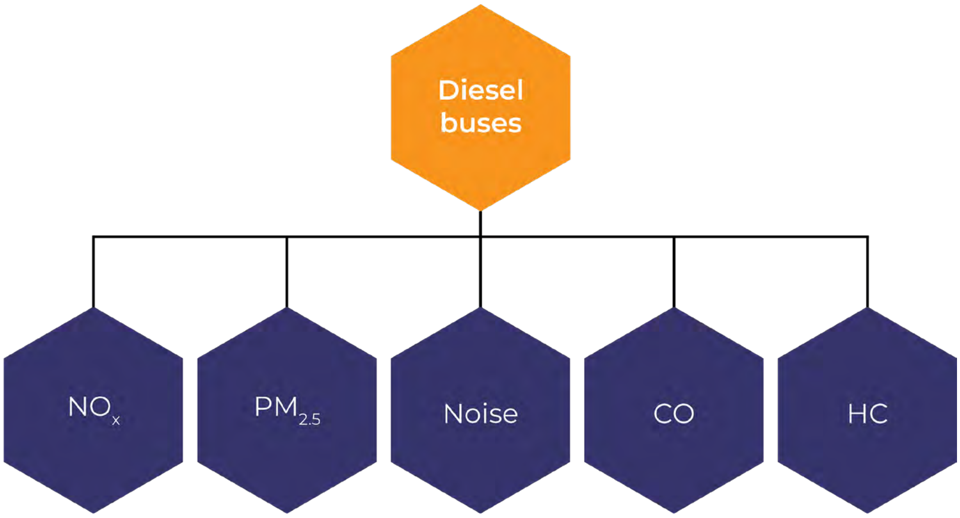
Tables

1. Introduction

Nearly one-third of students in India commute by school buses, which account for 20% of the domestic bus market and are predominantly diesel-powered (SaveLIFE Foundation, 2021; India Smart Grid Forum, 2023). These diesel buses pollute the air and pose a serious health risk for students. Kerala has more than 15,000 schools (Kerala Infrastructure and Technology for Education, n.d.) and several colleges, universities, and institutes of eminence. Given the large number of schools in the state and the health risks to students posed by diesel buses, the Department of Power, Kerala, is eager to promote the transition to electric school buses (e-school buses), which produce zero tailpipe emissions.

School buses[1] enable vital and timely commutes between residences and educational institutions for both students and staff. Data sourced from the Vahan portal (Ministry of Road Transport and Highways, n.d.-b) show that approximately 3,200 school buses registered in Kerala over the last 8 years were diesel-run. A recent study (Aishree, 2024) on diesel-run Bharat Stage VI (BSVI) buses revealed that they emit 1.3 g/km of carbon monoxide (CO), 0.13 g/km of hydrocarbons (HC), and 8.78 g/km of nitrogen oxides (NOx) into the atmosphere. Diesel buses also emit about 2 g/km of particulate matter of diameter 2.5 micrometres or less ($PM_{2.5}$; CSTEP, 2023) and have a high carbon footprint (849 g/km of carbon dioxide [CO_2]).

***Figure 1**: Pollution from diesel buses*

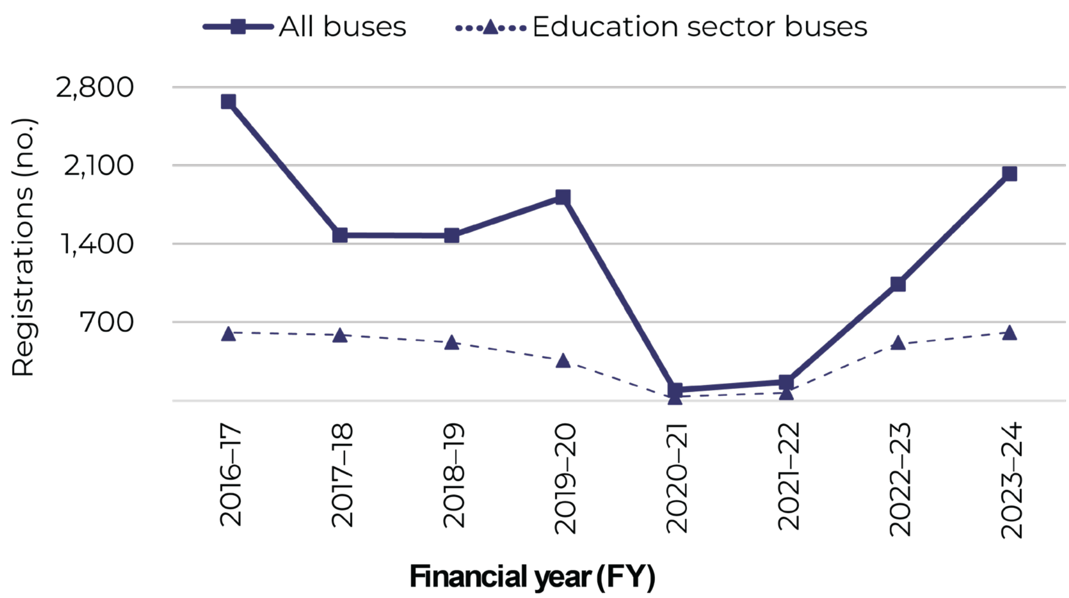


These emissions (Figure 1) adversely impact the environment and human health. The International Agency for Research on Cancer (2012) has classified diesel exhaust as carcinogenic, as it increases the risk of lung cancer.

The bus fleet in Kerala numbered 14,300 in 2023, according to a Kerala State Planning Board (2023) report. Bus registrations in Kerala in recent years were reviewed based on data sourced from the Vahan portal (Ministry of Road Transport and Highways, n.d.-b). Barring the years affected by the COVID-19 pandemic, on average, about 1,500 buses are registered in the state annually. Approximately 30%–40% of these are for educational institutions, such as schools, colleges, and universities (Figure 2).

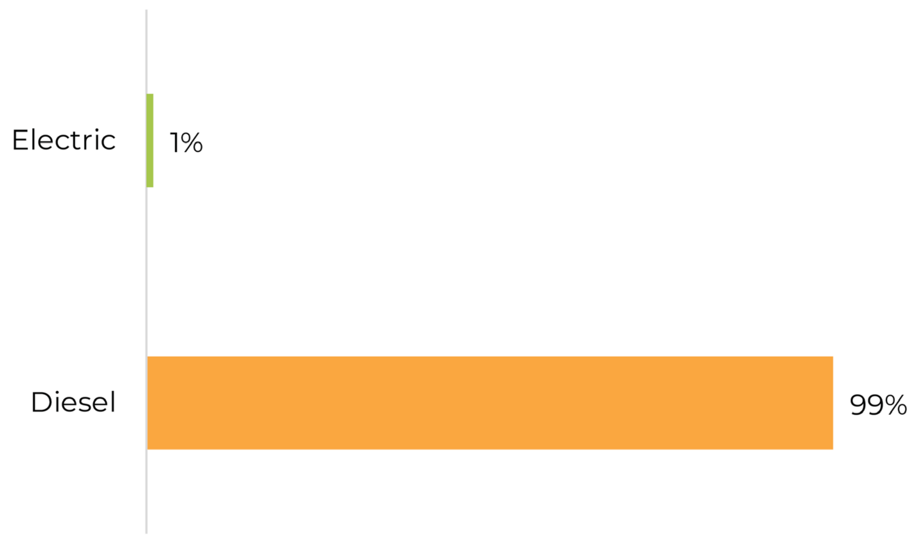
1 This refers to all buses registered for use by schools, colleges, and other educational institutions. For simplicity, the term 'school buses' is used throughout this report.

Figure 2: *Bus registrations in Kerala from financial year (FY) 2017 to FY 2024*



Of the current bus fleet, the majority are diesel buses, and only 1% (155) are electric buses, or e-buses (Figure 3). E-buses are mainly adopted by state-run transport entities.

Figure 3: *Fuel-wise breakup of buses registered in Kerala from FY 2017 to FY 2024*



Given the vulnerability of children whose organs and immune systems are not as developed as adults' (Gavimath, 2024), and the fact that they breathe twice the volume of air per kg of body mass than adults (Dobric et al., 2022), transitioning of school buses from fossil fuels to cleaner technology and fuels can help minimise health threats, besides reducing environmental pollution (air and noise). E-school buses, with zero tailpipe emissions and relatively silent operations, are a readily available potential solution in this context, making a case for electrifying school buses in Kerala, one of India's most literate states.

1.1. Project relevance

Government policies have played an important role in boosting demand for electric vehicles (EVs) in India, especially e-buses, through purchase subsidies, the establishment of charging infrastructure, and awareness initiatives (Press Information Bureau, 2025).

To date, e-buses have been predominantly adopted by government-run transport utility companies (International Council on Clean Transportation, 2024) to provide clean public transport in cities. However, their uptake in segments such as school transport, office shuttles, and tourism services remains limited. This slow adoption can primarily be attributed to the lack of awareness about emerging e-school bus technologies and their environmental and economic benefits, including zero tailpipe emissions and lower operating costs. In addition, concerns persist regarding high upfront capital expenditure (CAPEX), battery lifespan and replacement costs, and the availability of charging infrastructure.

1.2. Project objectives

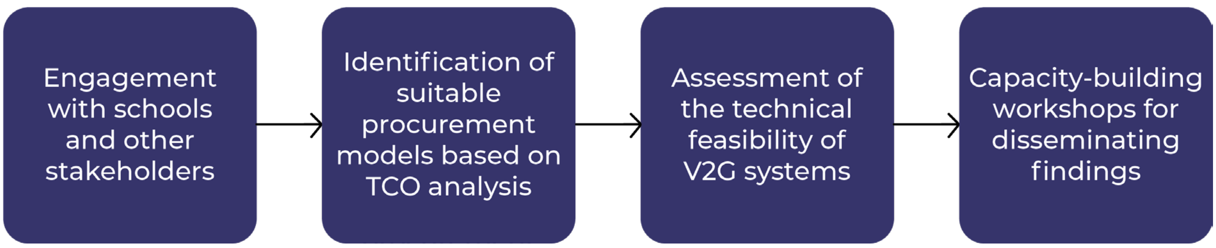
In this context, the Center for Study of Science, Technology and Policy (CSTEP) conducted a capacity-building programme for about 100 schools in the Thiruvananthapuram and Kochi districts of Kerala. The objective was to, through stakeholder engagements, bridge the awareness gap, alleviate the concerns about e-school buses, and enable schools to smoothly transition to e-bus fleets with suitable procurement and financing pathways.

Additionally, the project aimed to assess the potential of using e-school buses for vehicle-to-grid (V2G) applications in Kerala, with the intention to increase the utilisation of the buses.

1.3. What we did

To enable the electrification of school buses in Kerala, four key activities (Figure 4) were undertaken.

***Figure 4**: Key activities*



a. **Stakeholder engagement:** The CSTEP team engaged with original equipment manufacturers (OEMs) of e-school bus products and charge point operators (CPOs) operating in the study area. The Directorate of General Education, Government of Kerala, and the Kerala State Electricity Board (KSEB) were also consulted to understand the opportunities in scaling up electric school transport in the state. Initial engagement with school administrators, individually, in Thiruvananthapuram and Kochi districts was carried out to raise awareness on e-school buses. This engagement with schools was supported by the Energy

Management Centre (EMC) Kerala. Data on current bus fleet size, procurement, financing, operations, and maintenance practices were collected from school representatives through questionnaires circulated.

b. **Identification of suitable procurement models:** Based on the analysis of the data collected from school representatives, a total cost of ownership (TCO) analysis was performed. The TCO for diesel and e-school bus models with similar seating capacity was estimated for varying daily travel demands and different procurement mechanisms. The TCO comparison helped in identifying suitable pathways for e-school bus adoption by schools in the future.

c. **Assessing the potential of V2G technology:** To utilise e-school buses during their non-operational hours (i.e., between schedules and after school hours), their potential for returning the stored energy to the grid via V2G applications—providing grid support during peak hours and frequency regulation services to the grid—was evaluated. The minimum and maximum numbers of buses that the state could deploy for catering to a part of the peak unmet demand and secondary frequency reserve were derived.

d. **Capacity building:** To empower schools and other stakeholders, CSTEP and EMC Kerala, along with e-school bus OEMs and CPOs, held detailed discussions on e-school bus procurement, financing, operations (including charging), and maintenance during the workshops held in Thiruvananthapuram and Kochi. Further, a handbook titled *Electrifying School Buses in Kerala*, a compilation of project findings and recommendations on pathways for school bus electrification, was prepared as a reference guide for schools. It was launched during the International Energy Festival of Kerala 2025 (IEFK 2025), the annual flagship event of EMC Kerala, for wider dissemination and outreach.

18

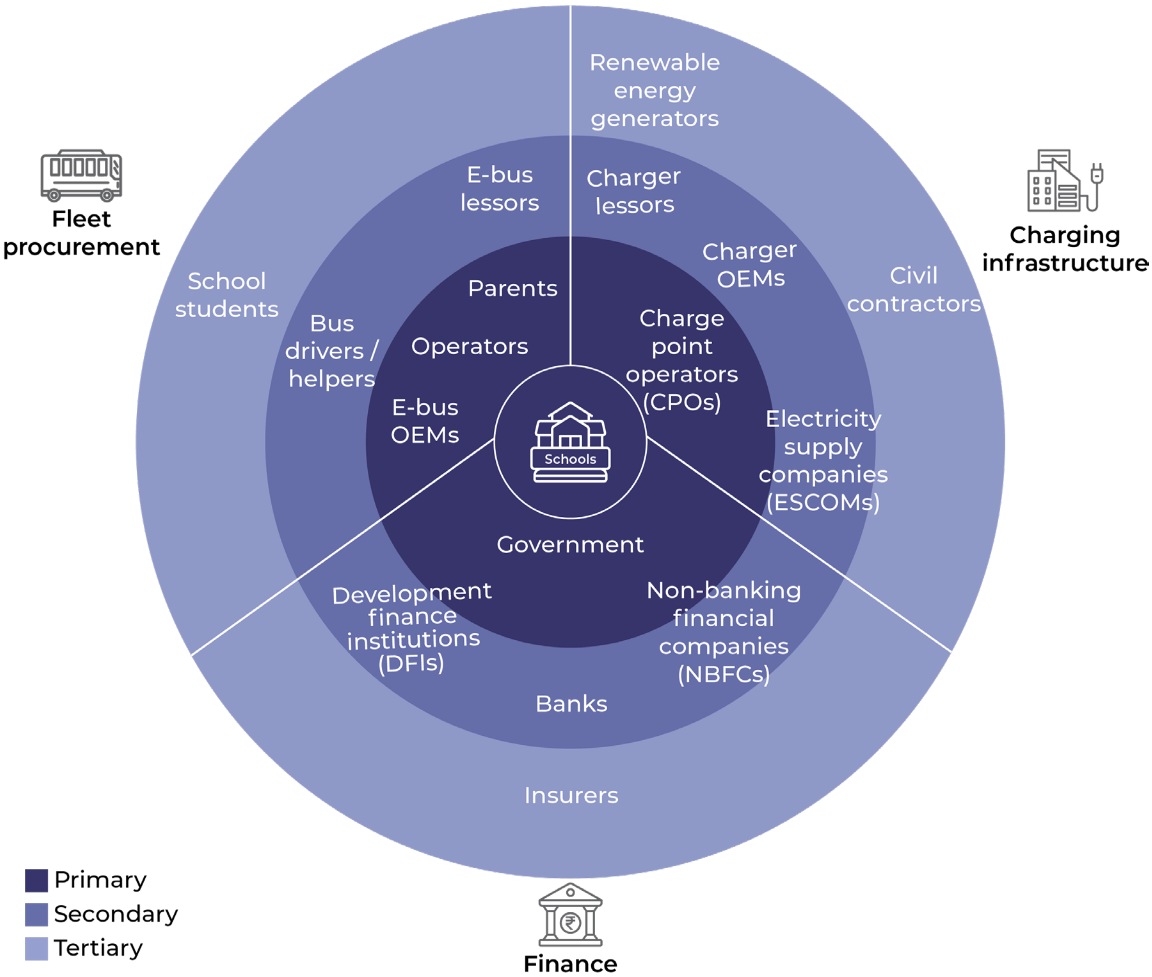
2. Stakeholder Engagements

The deployment of an e-school bus fleet is a systemic transition that requires initiative, commitment, and coordination from all stakeholders concerned. These stakeholders were identified, mapped (Figure 5), and consulted. Stakeholders were mapped based on their role and level of influence in enabling the transition to e-school buses.

Primary stakeholders: Decision-makers and key actors who directly influence e-school bus adoption
Secondary stakeholders: Service providers and enablers who support e-school bus deployment and operations
Tertiary stakeholders: End users and entities that support e-school bus operations but do not influence the adoption

Understanding the background, perspective, and constraints of each stakeholder helps to ascertain the potential of transitioning to electric fleets. This section outlines the efforts undertaken to support these engagements.

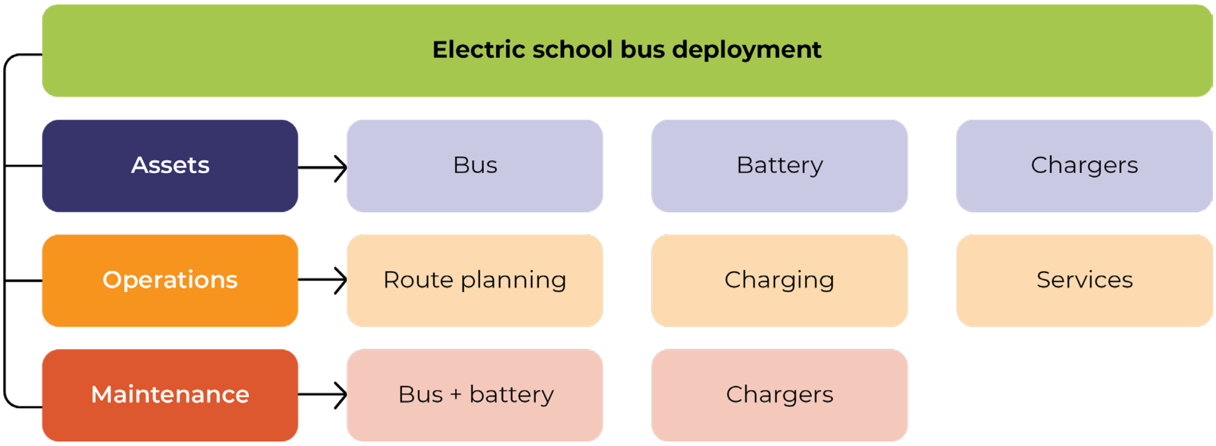
***Figure 5**: Ecosystem players*



2.1. Stakeholder identification

The assets, their operations, and maintenance requirements involved in e-school bus deployment are presented in Figure 6.

***Figure 6**: Aspects of e-school bus deployment*



Given the early phase of e-school bus adoption in Kerala, only primary players (Figure 5) were engaged during this project. As adoption picks up momentum, other players can be engaged accordingly.

Primary stakeholders who play a vital role in fleet procurement, charging infrastructure, and financing of e-school buses are detailed in the subsequent sections.

2.2. Fleet procurement stakeholders

School managements, bus operators, parents, and e-school bus OEMs are the primary players in e-school bus fleet procurement.

Schools: Administrators and management of schools providing bus service to students, faculty, and staff are the primary stakeholders for this project. The schools can be public (government-run), private with government aid, or fully private. Schools were also grouped on the basis of the curriculum they follow (such as the state board or the central board). These are the main stakeholders who decide to deploy e-school buses in their fleets. Their decision would be made considering the cost of the procurement and infrastructure and nature and ease of operations.

Bus operators: In instances where school managements outsource school bus operations, private entities with bus fleets operate bus schedules for schools according to requirements. As primary stakeholders, these operators can aggregate demand and deploy e-school buses to address it.

E-school bus OEMs: Manufacturers of e-school buses develop and supply battery-powered buses. They can influence demand for e-school buses by developing products and service packages suitable for school transportation. They develop buses to meet diverse demands from schools, such as the length of the bus (7 m, 9 m, 12 m), number of seats, and configuration (2 x 2, 3 x 2). E-school bus OEMs are

20

also liable for providing a battery warranty, that is, the total number of kilometres (or cycles) run over a battery's life. In some cases, such as in long-term contracts, OEMs also provide maintenance services, including battery health checks.

Parents: Parents or guardians of school students who pay for school bus pick-up and drop-off services represent key demand-side stakeholders in the deployment of e-school buses. As primary stakeholders, they have a strong interest in the health, safety, and well-being of children and are likely to support initiatives that reduce emissions and improve air quality. Moreover, they can play an influential role by advocating for the adoption of clean mobility solutions through engagement with school administrators. However, due to operational and logistical constraints, parents were not directly engaged in this study.

2.3. Charging infrastructure stakeholders

Charging point operators (CPOs): CPOs, including private entities and distribution companies (DISCOMs), play a critical role in establishing and operating the charging infrastructure required to support e-school bus operations. They are responsible for installing and maintaining charging stations and for recharging e-school bus batteries during daily operations. The scale and geographic coverage of their charging networks, along with the cost of charging (INR/kWh), significantly influence the operational feasibility and financial viability of e-school bus deployment.

2.4. Finance

Government: The Directorate of General Education, Government of Kerala, oversees the academic, co-curricular, and extracurricular activities of schools (affiliated to the state board), including their governance, infrastructure, and facilities (school bus). Additionally, KSEB is responsible for EV adoption in the state through its EV policy. Together, they can play a key role in promoting the adoption of e-school buses through initiatives and directives, such as support for e-school buses (fiscal, non-fiscal) and recognition for schools transitioning to e-school buses. In addition to the state education directorate, the CBSE regional office in Thiruvananthapuram that oversees CBSE schools in the state can play a similar role.

2.5. Other stakeholders

In addition to these stakeholders who play a direct role in e-school bus adoption, various other players, such as banks, insurers, contractors, and renewable energy (RE) generators, are also essential. DISCOMs that supply the required energy (electricity) to charge e-school buses ensure smooth operations. Finally, students—the end users—benefit from zero tailpipe emissions of e-school bus services.

3. Capacity-Building Workshops

In this study, CSTEP primarily engaged with school administrators/managements, e-school bus OEMs, and CPOs. We held meetings with officials from the Department of General Education of Kerala, the CBSE regional office in Thiruvananthapuram, and KSEB. This was followed by day-long capacity-building workshops for school representatives (Figure 7).

***Figure 7**: Delegates at a workshop in Thiruvananthapuram*

The workshops were held in Thiruvananthapuram and Kochi, and representatives from the government and private schools in the districts participated. The CSTEP team, along with representatives from e-school bus OEMs and CPOs, created awareness on e-school buses and conducted specific sessions on procurement, financing, and operations of e-school buses. School representatives interacted with e-school bus OEMs and CPOs and got clarifications regarding their queries.

3.1. Observations

Key observations from workshop participants are listed in this section (the details can be found in Appendix A):

School representatives lacked knowledge and awareness of the health, environmental, and economic advantages of e-school buses.

The high upfront cost (two or more times that of diesel buses) of e-school buses is a major hindrance to electrifying school buses as most schools (~65%) lack the required CAPEX capacity, especially government and aided schools.

A range of 100 km would suffice for the travel needs of more than 80% of schools.

Most schools (70%) have sufficient area required for setting up charging infrastructure within their campus.

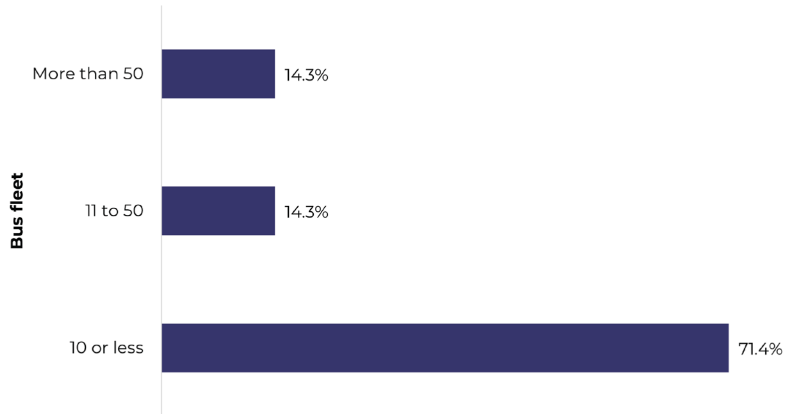
A majority (75%) of schools expressed interest in adopting e-school buses for the health benefits of students and faculty and to lower operating costs.

3.2. Stakeholder inputs and feedback

School representatives were asked about their existing bus procurement procedures, fleet size, and operations at their schools. Feedback on key aspects of school bus operations was collected and is summarised in this section.

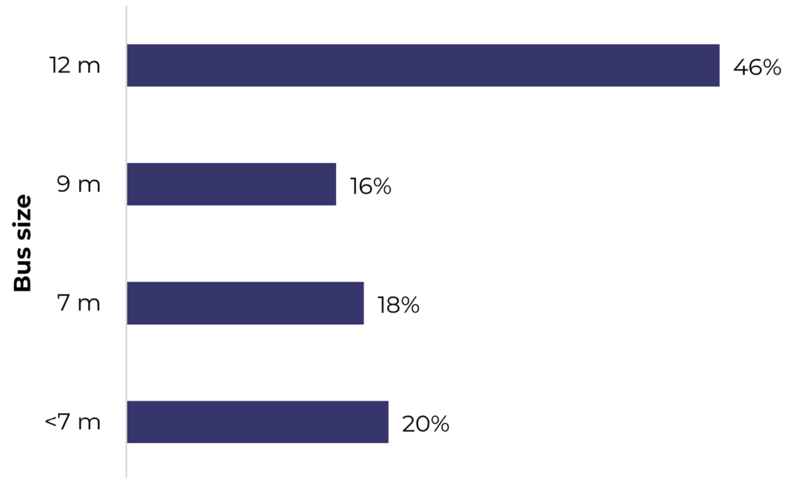
Fleet size: About 45%–50% of students opt for school bus services. The majority of schools have 10 or fewer buses (Figure 8). The number of buses in each school varies based on the administration (private or government) and the number of students in the school. It was noticed that most government-run schools have fewer than 10 buses with 1,000 or fewer students, and private schools with more than 3,000 students have 50 or more buses.

***Figure 8**: Existing bus fleet size at schools*



Fleet specifications: In terms of bus length, 12 m buses are most popular (46%) among schools (Figure 9). All schools reported using diesel buses, and none of them had CNG or electric buses.

***Figure 9**: Distribution of school buses based on their length*

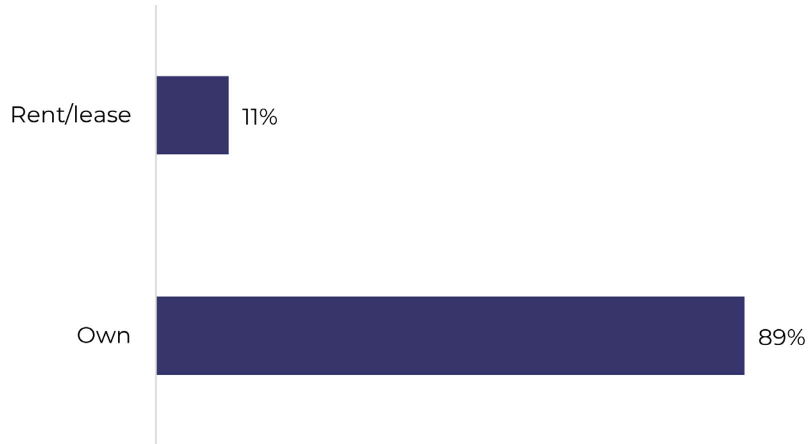


Fleet procurement: Most schools (89%) own buses, and very few schools opt for leasing/rental of buses (Figure 10). The lease agreements are usually for 1 year.

Financing of bus fleet: While government schools depend heavily on government grants to finance school buses, private schools (90% of them) rely on their own corpus. Bank loans are the least preferred (less than 20%) for school bus financing.

Furthermore, more than 40% of school representatives revealed they find it very difficult to finance and operate school buses and would **prefer to outsource** school bus operations.

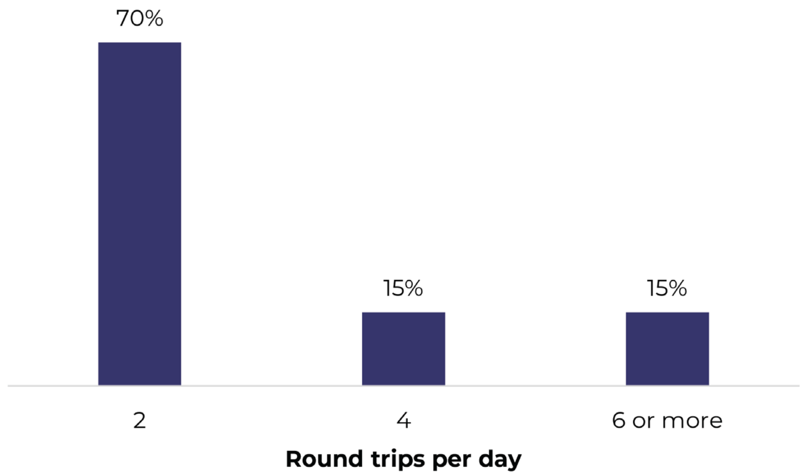
Figure 10: *Bus fleet ownership at schools*



The number of round trips[2], the daily distance travelled, and the operating hours of school buses are vital to assess the suitability of the transition to electric fleets.

Number of trips: We gathered through engagements with school representatives that about 85% of school buses do four or fewer round trips in a day and operate for at most 6 hours per day (Figure 11).

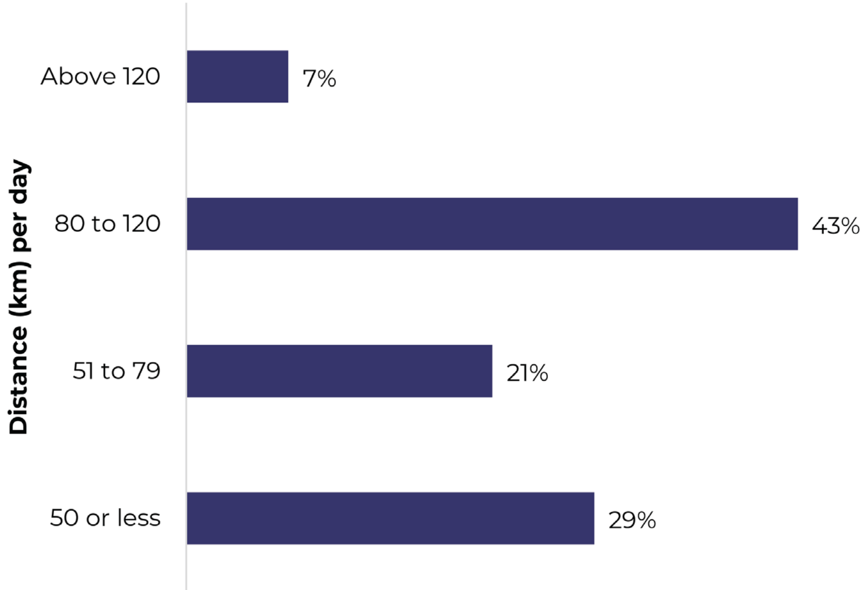
Figure 11: *Round trip by school buses*



2 A round trip is defined as a trip from an origin to a destination and the return trip back to the origin.

Daily kilometres: More than 90% of schools reported operating buses for 120 km or less per day (Figure 12). While most school buses travel between 80 and 120 km each day, some reported travelling beyond 120 km as well.

***Figure 12**: Distance travelled per day by school buses*



Parking: More than 75% of schools revealed having ample parking space (~10 buses) for their bus fleets within the school campus.

Power connections: It was noticed that the sanctioned load (kW) of schools needs to be increased (in some cases) to facilitate the establishment of chargers on campus.

3.3. Types of school bus operations

Based on the data collected from schools, the following types were identified for school bus operations:

Type 1 – Large fleet with medium utilisation: Schools with large student enrolments (≥3,000), mostly private-run, fleet of 30 or more buses, and each bus travelling 100 km or less per day

Type 2 – Small fleet with high utilisation: Schools with small student enrolments (≤1,000), mostly government-run or aided, fleet of fewer than 10 buses, and each travelling up to 150 km a day

Type 3 – Medium fleet with low utilisation: Schools that are private or government, fleet size between 10 and 50, and each bus travelling 50 km or less per day

4. Components of E-School Bus Deployment

The deployment of e-school buses at a school entails fleet procurement and their financing; trip planning; setting up the charging infrastructure; and scheduling e-school bus charging, operations, and maintenance (Figure 6). This section provides information related to fleet procurement, financing, and charging infrastructure.

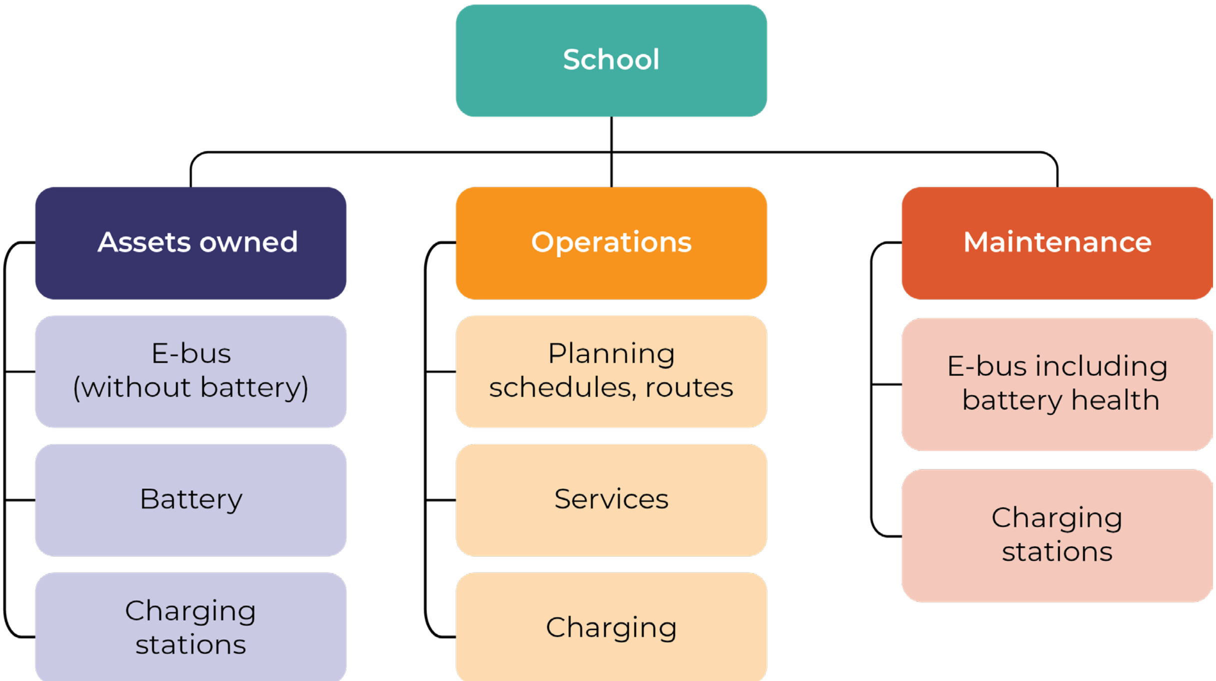
4.1. Fleet procurement pathways

E-school buses can be procured in different ways, and each of them has advantages and disadvantages for schools. Four procurement models that are relevant to schools have been considered and are discussed in this section.

4.1.1. Outright purchase

In this model, a school buys, operates, and maintains the e-school bus, giving it full control over assets and greater operational flexibility (Figure 13). However, this requires a high upfront CAPEX, at least twice that of a diesel bus. Additionally, the e-school bus, battery, and chargers are recorded in the school's balance sheet, increasing risk[3]. The school is responsible for operations and must also invest in setting up the charging infrastructure, adding to the deployment complexity and cost.

***Figure 13**: Outright purchase model*



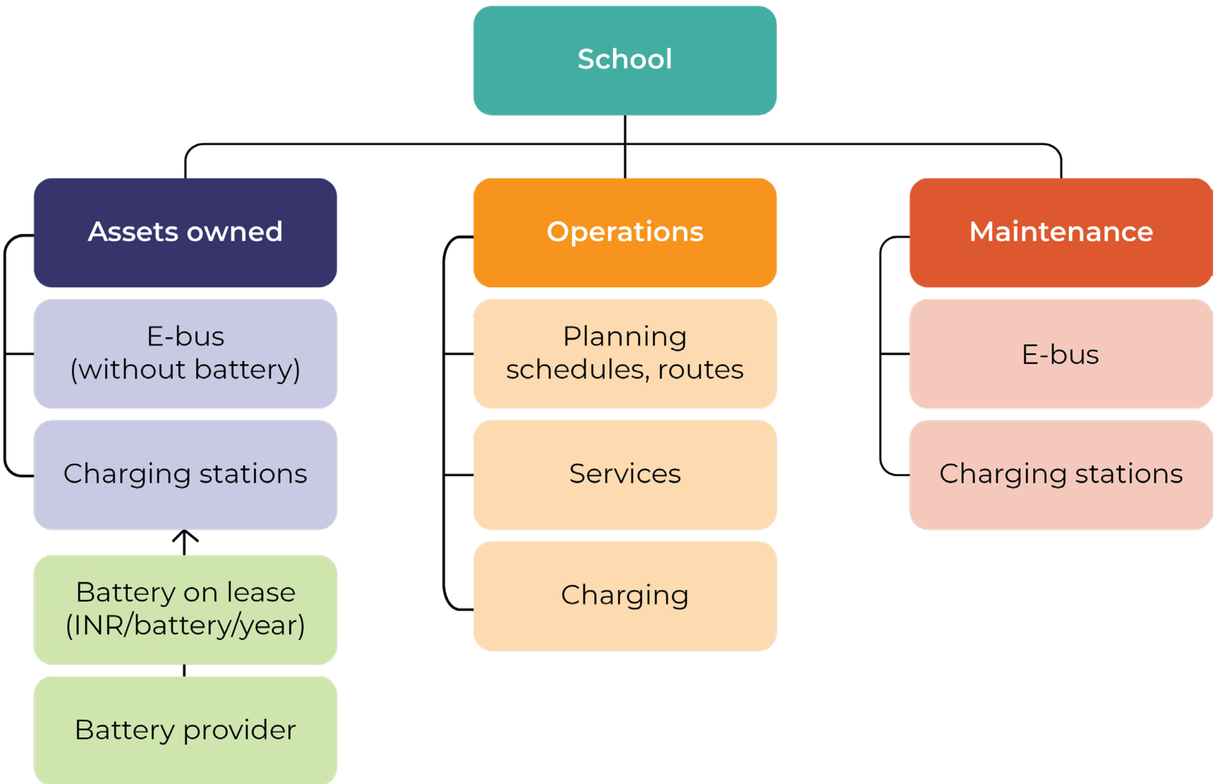
3 For example, a battery accounts for 30%–40% of CAPEX and is susceptible to failure or accidents such as thermal runaway, battery management system (BMS) failure, or short circuits. Any battery-related incident could therefore result in substantial financial losses for schools.

4.1.2. Battery leasing

Under this model, the school purchases the e-school bus without its battery pack and procures the battery on lease from a battery-as-a-service (BaaS) provider, paying fees per unit of battery used annually or monthly (Figure 14). This model lowers upfront costs by approximately 30% compared to the outright purchase model and reduces risk while allowing control over operations. However, the required CAPEX remains higher than that for a diesel bus, and the e-school bus remains in the school's balance sheets. Additionally, the school is responsible for operations and the setting up of charging infrastructure.

The BaaS provider sources the required battery packs, ensures their optimal supply for unhindered e-school bus operations, and is responsible for battery health and performance.

***Figure 14**: Battery leasing model*

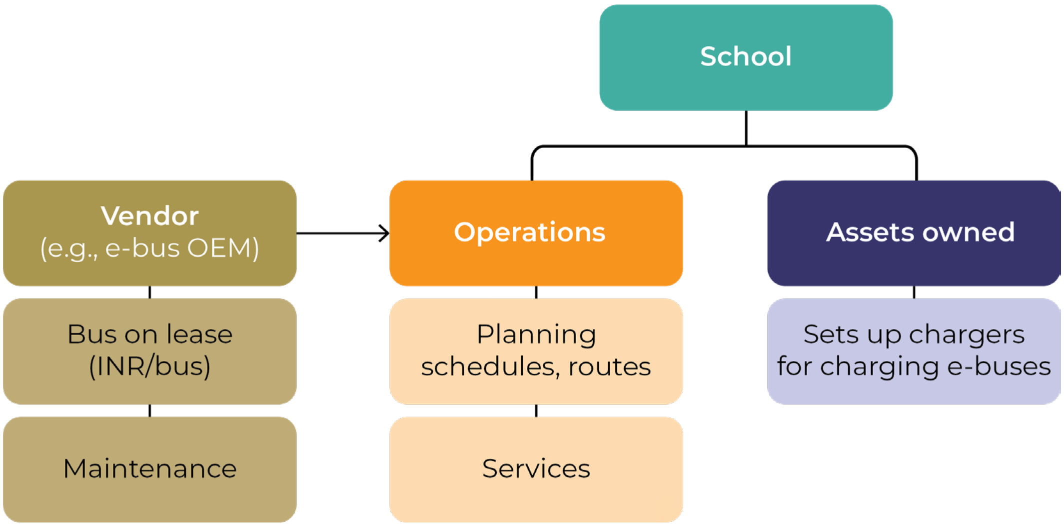


4.1.3. Bus leasing (dry)

In this approach, the school procures e-school buses on rent or lease from a fleet owner (vendor), paying a monthly or annual fee per bus (Figure 15). This model eliminates the financial risk associated with owning the bus and its battery, and the required CAPEX is lower than that for battery leasing. However, the school still bears responsibility for operating the e-school buses and must establish the necessary charging infrastructure, which adds to operational complexity and costs. The vendor supplies the e-school buses, meeting the school's requirements (seating capacity, range, etc.) and is responsible[4] for ensuring the uptime of buses, with proper maintenance and servicing.

4 In the case of an e-bus dry lease, maintenance is usually with the lessor, unlike diesel bus dry leasing, mainly because of the specialised systems, including battery, spares, and the skill set required for e-bus maintenance and service.

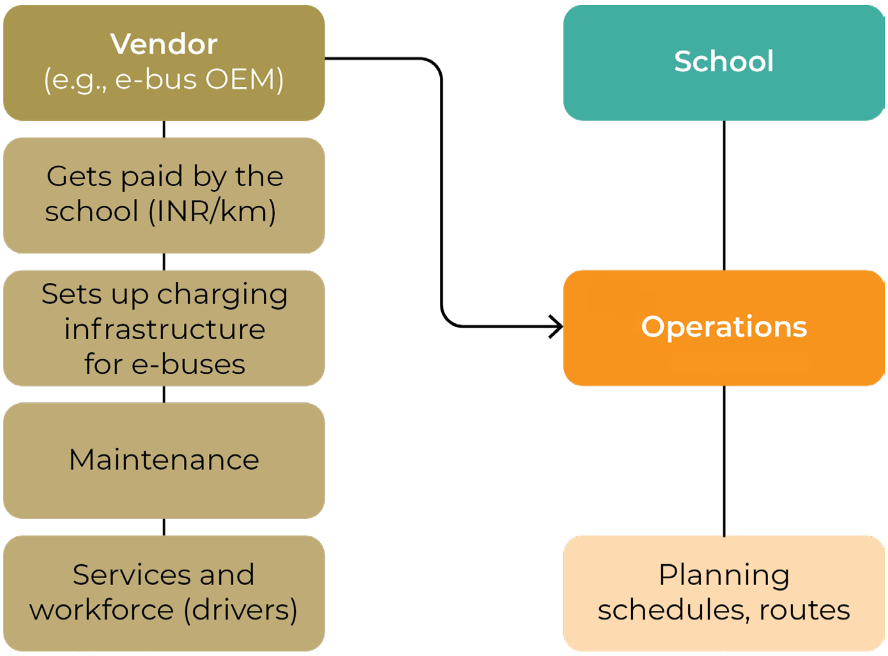
***Figure 15**: Bus (dry) leasing model*



4.1.4. Gross cost contract (GCC)

Under this model, the school hires an operator to run the e-school bus fleet on pre-determined routes and schedules, paying on the basis of distance travelled at a per-kilometre payment rate (Figure 16). This approach minimises CAPEX and eliminates financial and operational risks as the school neither owns nor manages assets and does not need to set up charging stations. However, this model offers the least flexibility in operations since route, frequency, and service parameters are pre-fixed by the contract.

***Figure 16**: Gross cost contract (GCC) model*



4.1.5. Retrofitting

Under this model, schools owning old diesel buses can decommission them, buy retrofit kits from vendors in the market, and retrofit old buses with a battery electric powertrain. Vendors are responsible for the testing, certification, and installation/integration of kits (these activities can take several months). Schools can commence operations post-testing and certification. Other aspects are similar to the outright purchase model described earlier. The retrofitting model can help schools salvage their ageing diesel-powered fleets and offer an electrification pathway at a relatively lower CAPEX than is needed for buying a new e-school bus. Inadequate availability of certified, reliable, and compatible kits is a major challenge for this model.

Table 1: *A comparison of e-school bus procurement models*

Procurement model	CAPEX	School assets (on school balance sheet: bus, battery, chargers)	Risks and responsibilities
Outright purchase	Highest among all	All assets (e-buses, batteries, chargers)	High financial risk and more operational responsibilities for schools
Battery leasing	About 30% lower than outright purchase	E-school bus (without battery) and chargers	Reduced financial risk than the outright purchase model but similar operational responsibilities
Dry leasing	Lower than outright purchase and battery leasing	Only chargers	Reduced financial risk and fewer responsibilities than outright purchase and battery leasing
GCC	Least among all	School is asset-free	Minimal financial risk and operational responsibilities for schools

Among the procurement models discussed in this section, it is vital to ascertain their suitability based on schools' requirements. Models differ in their CAPEX, payment mechanisms, assets, responsibilities, and risks, and the appetite for them also differs among schools.

To provide a fair and easy comparison (single metric for comparison), we perform a total cost of ownership (TCO) analysis to compare diesel bus and e-school bus costs under different procurement models and varying daily travel demand.

4.1.6. TCO analysis

The TCO of a bus (in INR/km) is the ratio of the sum of purchase, operating, maintenance, and financing costs incurred over a bus's lifetime to the distance travelled by the bus in its lifetime (Vijaykumar et al., 2018):

$$TCO/km = \left(\frac{Purchase\ cost + Financing\ cost + Operating\ cost + Maintenance\ cost}{Distance\ travelled}\right)_{Over\ lifetime}$$

Key inputs and assumptions used for TCO analysis are presented in Table 2. Models with the same seating capacity[5] (that is, the number of seats) were considered to ensure a fair and reasonable comparison between diesel and e-school buses. Further, a 7-year holding period was considered for both powertrains. The e-school bus specifications considered in the analysis are based on the interactions with e-school bus OEMs and available e-school bus models in the Indian market as of December 2024. Also, as no national-level or state-level incentives are available for e-school buses, no subsidy was considered in the estimation. Slow chargers (25 kW to 50 kW) were considered without additional CAPEX for analysis. An additional scenario with fast chargers (120 kW or above) was considered for the estimation, wherein an additional CAPEX of INR 10 lakh was considered for e-school buses under all procurement models for fast charger establishment. Further, the price of retrofit kits was assumed to be in the range of INR 25 to 40 lakh, as per stakeholder inputs.

***Table 2**: Inputs and assumptions for the TCO analysis (7 m and 12 m buses)*

Metric	Diesel bus	Electric bus
7 m, 35-seater		
Battery (kWh)	Not applicable	100 (PMI Electro Mobility, n.d.)
Ex-showroom price (INR)	20 lakh (Eicher Trucks and Buses, n.d.)	40–50 lakh (PMI Electro Mobility, n.d.)
Road tax	INR 100 per seat per quarter (Motor Vehicle Department, n.d.-b)	Exempt (Government of Kerala, 2019)
Motor Vehicle (MV) tax	0.9% per MoRTH (Ministry of Road Transport and Highways, n.d.-a)	Exempt (Government of Kerala, 2019)
Registration fee (INR)	1,500 (Motor Vehicle Department, n.d.-a)	Exempt (Ministry of Road Transport and Highways, 2021)
Annual maintenance cost (INR)	4 lakh (20% of CAPEX; Vijaykumar et al., 2018)	4 lakh (10% of CAPEX; Vijaykumar et al., 2018)

5 Road tax for school buses is based on the number of seats.

Metric	Diesel bus	Electric bus
Annual insurance cost (INR)	18,000 (0.9% of CAPEX; Vijaykumar et al., 2018)	36,000 (0.9% of CAPEX; Vijaykumar et al., 2018)
Depreciation rate (% per annum)	10	10
12 m, 42-seater		
Battery (kWh)	Not applicable	200 (PMI Electro Mobility, n.d.)
Ex-showroom price (INR)	43 lakh (BusesDekho, n.d.)	90–120 lakh (PMI Electro Mobility, n.d.)
Road tax	INR 100 per seat per quarter (Motor Vehicle Department, n.d.-b)	Exempt (Government of Kerala, 2019)
MV tax	1.4%, as per MoRTH (Ministry of Road Transport and Highways, n.d.-a)	Exempt (Government of Kerala, 2019)
Registration fee (INR)	1,500 (Motor Vehicle Department, n.d.-a)	Exempt (Ministry of Road Transport and Highways, 2021)
Annual maintenance cost (INR)	4 lakh (10% of CAPEX; Vijaykumar et al., 2018)	4 lakh (3.5% of CAPEX; Vijaykumar et al., 2018)
Annual insurance cost (INR)	39,000 (0.9% of CAPEX; Vijaykumar et al., 2018)	81,000 (0.9% of CAPEX; Vijaykumar et al., 2018)
Depreciation rate (% p.a.)	10	10
Fuel/energy price	INR 97/litre	INR 5.9/kWh (LT-VI-General-A connection; Kerala State Electricity Board, 2024)

Suitable procurement models based on the school bus operation type (daily travel distance per bus), along with corresponding TCO values, are presented in Table 3. Based on the TCO analysis, Type 3 schools, where each bus runs for 50 km or less per day, are infeasible (i.e., TCO of an e-school bus is higher than a diesel bus) for electrification because of lower asset utilisation.

31

Table 3: *Procurement models suitable for schools (based on TCO and school characteristics)*

School characteristics and requirements						Suitable e-school bus procurement model based on TCO parity with similar diesel buses	Cost per kilometre (INR/km)	
Administration type	Student enrolment	Bus fleet size	Preferred bus size	Minimum daily kilometres travelled	Existing bus financing		Diesel bus	E-school bus*#
Private	3,000+	50+	7 m	100 km	Self-finance / school corpus	Outright purchase	41	41–59
			12 m	240 km			39	39–55
Government-aided or private	1,500–3,000	10–50	7 m	80 km	Bank loan	Battery leasing	47	39–58
			12 m				84	77–111
Government	Up to 2,000	1–10	7 m	100 km	Government funds	Contract basis	54	54–73
			12 m	240 km			51	51–68
		NA		90 km		Retrofitting	77	62–87

** No subsidy was considered for e-school buses*
 # The range of values indicates scenarios of varying e-school bus CAPEX, without and with fast chargers (additional 10 lakh CAPEX)

(green)	Lower than a diesel bus
(orange)	Price parity achieved

Our TCO analysis shows that the outright purchase of a 7 m e-school bus is economically viable if it travels at least 100 km per day. Similarly, for a 12 m e-school bus, the daily travel demand must be beyond 240 km to break even with a diesel bus. Given the high CAPEX required for e-school bus purchase, this procurement pathway is suitable for private schools because of their ability to source funds compared to government or aided schools. We estimate that procuring e-school buses through the battery leasing model will cost 8% (12 m) to 17% (7 m) less than diesel buses when the daily travel is at least 80 km. For schools not able to afford the high upfront cost of e-school buses, hiring e-school buses on a contract basis (GCC model) is an economically feasible option if the daily travel is a minimum of 100 km for a 7 m bus and 240 km for a 12 m bus. A 12 m retrofitted bus will have 19% lower TCO than a diesel bus if the minimum travel is 90 km per day and the retrofit kit price is assumed to be INR 25 lakh. For the same distance, with an INR 40 lakh kit, retrofitting is about 13% costlier.

4.2. Financing options

Based on literature and market reviews, the following options for financing e-school buses have been identified:

Schools' self-corpus: Schools with good financial health (e.g., private schools) can utilise their own corpus for e-school bus deployment. This way of financing ensures minimal or zero financing cost (i.e., interest rate).

Bank loans: Schools that do not have the ability to make high CAPEX investments but possess good credit-seeking ability can opt for bank loans. Some banks also offer attractive interest rates and concessions for green vehicles. For example, the State Bank of India offers up to 0.5% concession on EV loans.

Corporate social responsibility (CSR) funds: Schools (government or government-aided) can explore and seek CSR funds from industries for e-school bus deployment as it is a climate and environment friendly initiative. Some examples of CSR initiatives from Cochin Shipyard Ltd. (2017), related to improved access to education in the state, are as follows:

- CSR funds used for the renovation of Devaki Memorial Senior Basic School, Kakkayur, Palakkad
- CSR funds used for the purchase of a school van for transporting differently abled children of Deenadaya Seva Trust, Thodupuzha

Members of Parliament (MP) / Member of Legislative Assembly (MLA) funds: Constituency-wise MP/MLA funds can be sought by schools (especially government-run schools) to support e-school bus operations under the GCC model.

Green loan by EMC Kerala: EMC provides various grants and loans for energy efficiency projects in the state under the Kerala State Energy Conservation Fund (Government of Kerala, 2010). Schools in the state can utilise the green/soft loans offered by EMC Kerala at low interest rates (lower than that of scheduled commercial banks) to adopt e-school buses.

4.3. Choice of charging infrastructure for e-school buses

E-school buses come with customisable battery capacities ranging from 100 to 200 kWh, based on the desired range. These buses are assumed to operate for at most 6 hours a day, staying idle for the remaining duration. To recharge these batteries, the following are the common methods available (for DC charging):

- A DC charger of 50 kW, offering a usual charging time of 2 to 4 hours
- A DC charger of 150 kW, offering a usual charging time of 1 to 2 hours

Heavy-duty EVs are often charged using 150-kW chargers. Moreover, because of the requirements of shorter recharging times in the near future, DC chargers of 350 kW are anticipated to make a significant presence. However, since e-school buses have significant downtime because of the nature of their operations, they can be recharged using a 50-kW charger, which provides a recharge time of around 2 to 4 hours, and are advantageous for schools because of the lesser impact (than 150 kW or higher) on battery health and the grid.

The area required for the installation of a charger is approximately 45 sq. metres per bus. Hence, an EV charging station with two such chargers requires an area of approximately 90 sq. metres. The area required for setting up charging stations within a school campus can be easily allocated since most schools (75%) have reported sufficient space availability (for 10 buses) within their premises. The installation of solar panels on school premises could also provide energy for recharging these e-school buses. Such a mechanism would lead to clean charging of EVs and lower power losses compared to recharging from the grid. These buses can also lend V2G services to the grid when the ecosystem is available in the future.

34

5. V2G Services From E-School Buses

E-school buses are a possible provider of V2G services (Electric School Bus Alliance, 2023), the mechanism by which EVs can provide power back to the grid. School buses operate on a fixed schedule, and the downtime hours generally comprise the time spent in parking, which is around 18 hours a day. Further, they are operational only for 240 days a year and idle for the remaining 125 days, aligning with academic calendars. Due to the underutilisation of these e-school buses, especially after school hours, they are regarded as potential candidates for providing V2G services. For example, when the grid encounters peak demand in the late evening hours, these e-school buses can discharge their energy into the grid for demand management and alleviate the stress on the grid.

The establishment of a V2G system requires the following:

- The use of a bidirectional charger (on-board/off-board)
- A modified battery management system (BMS), which is V2G compatible
- An independent entity that collectively sells V2G services to the utility (aggregator)
- An established digital payment infrastructure

A V2G system can provide ancillary services, which are services necessary to support power quality, reliability, and security of the grid, such as grid support during peak hours (reverse power flow from EVs to the grid to address the unmet demand), frequency regulation (injecting active power to the grid to correct grid frequency disturbances), and voltage regulation (supporting the grid with reactive power to maintain grid voltage within permissible limits). For details, refer to Appendix B. A few case studies of e-school buses being employed for V2G services have been explained in Appendix C.

A V2G system is expected to lend the following advantages to stakeholders:

Schools

Additional revenue stream: By rendering ancillary or other V2G services to the grid or utility, schools can earn additional revenue, which can aid in lowering the TCO of the e-school bus, improving the utilisation of the asset, and enhancing the profitability of its usage.

Vehicle to building (V2B): The batteries of e-school buses can function as a battery backup and help provide power/energy to school buildings, other vehicles, or any other load if there is a system in place, which is compliant with V2B. This can provide power or energy under emergency situations, such as long spells of power cuts or natural disasters.

Utilities

Easing grid congestion and investment deferral: The discharge of energy from EVs into the grid during peak hours manages the demand on the grid. This eases the stress on the grid in such hours, deferring the establishment of lines and substations with higher capacity or the erection of completely new assets.

Ancillary services: E-school buses present a source of power, certain to be available after school hours (late in the evenings), for the provision of ancillary and other V2G services. Thus, the utility may count on e-school buses as a reliable and readily available source.

These are the drawbacks of V2G services:

Currently, there are very few models available among chargers or vehicles that are compatible with V2G. The market is in its infancy, which might pose a roadblock to schools in terms of procurement (Rather et al., 2023).

Schools might be quite apprehensive that range reduction adversely impacts the e-school bus's day-to-day functioning. Concerns about advanced battery degradation also loom large in users' minds (Briones et al., 2012; National Renewable Energy Laboratory, 2017).

V2G systems might pose a host of technical barriers for the utility in terms of interoperability requirements and unclear standards, among others (Briones et al., 2012).

E-school buses cost up to two times that of a diesel equivalent and present an exorbitant upfront investment for an individual school. In addition to this, vehicles equipped with V2G compatibility add to the cost (Rather et al., 2023).

They also pose non-technical hurdles to the utility in terms of the incorporation of new business models, the availability of capital for communication infrastructure, additional administrative work for compliance, and an unclear demarcation of responsibilities and accountability for ensuring grid reliability (Briones et al., 2012).

There are very few clear regulations in place for enabling the V2G ecosystem. Moreover, there are only a few pilot demonstrations/projects to lend awareness or evidence for decision-making (Briones et al., 2012).

5.1. V2G applications for Kerala

On average, about 450 to 600 buses are registered every year for educational purposes in Kerala. This presents an opportunity for electrification and a low-hanging fruit to tap into for V2G services.

Through this project, CSTEP aims to assess the potential of V2G services from e-school buses in Kerala. The broad objectives are as follows:

- Identify potential applications for V2G
- Assess the scale of e-school bus adoption required in Kerala to provide these services

36

The following V2G applications have been considered based on the state's historic electricity demand data and frequency profile:

Supporting the grid during peak hours: It was found that the maximum unmet demand that Kerala had witnessed in the past 5 years was 72 MW (India Climate & Energy Dashboard, n.d.), indicating scope for targeted V2G deployment using e-school buses.

Frequency regulations: Every control area in India is mandated to provide primary response (Central Electricity Regulatory Commission, 2023). Since e-school buses can provide a quick response to the grid through V2G services, they could support these generating stations in providing secondary responses.

The analysis of the potential of V2G for grid support during peak hours (6 p.m. to 10 p.m.; Kerala State Electricity Board, n.d.) is explained here.

5.1.1. Data collection

From the India Climate & Energy Dashboard (n.d.), data on the monthly peak demand (MW) and peak demand met (MW) were obtained and compiled for Kerala over the past 5 years (2019–2024). From these data sets, it was observed that the maximum unmet demand was 72 MW, thereby presenting a potential case for V2G.

From the reserve requirements of Secondary Reserve Ancillary Services (SRAS) and Tertiary Reserve Ancillary Services for the year 2025–26, estimated by the National Load Despatch Centre (Grid Controller of India Limited, 2025), the following values were obtained for the state of Kerala to analyse frequency regulation application:

SRAS-up within Inter-State Generating Station (ISGS): 188 MW

SRAS-up within the state: 70 MW

Since the e-school buses are most likely to ply within state limits, it is expected to contribute to the SRAS-up within the state. Considering the above inputs, we have analysed how V2G can address this demand for 70 MW.

5.1.2. Assumptions

Considering the current predominant charging trends, e-school buses were assumed to be charged using 50-kW or 150-kW chargers, as mentioned in section 4.3. As a likely development in the near future, based on projected market trends, 350-kW chargers were considered a scenario. The participation factor (α) denotes the share of the rated charger power that the users are willing to supply to the grid:

$$\alpha = \frac{Power\ output\ from\ the\ charger}{Power\ rating\ of\ the\ charger}$$

For example, a participation factor of 0.3 with a 150-kW charger means that the power provided to the grid is 0.3 × 150 = 45 kW. To consider diverse scenarios of usage, three distributed values of participation factors were considered: 0.3, 0.6, and 1.

E-school buses were considered to provide active power input into the grid as part of V2G services.

These e-school buses were considered to be connected to smart chargers during all their downtime (non-operational hours). When a battery's state of charge exceeds 80%, chargers are expected to prioritise discharging to the grid if the demand arises.

5.1.3. Methodology

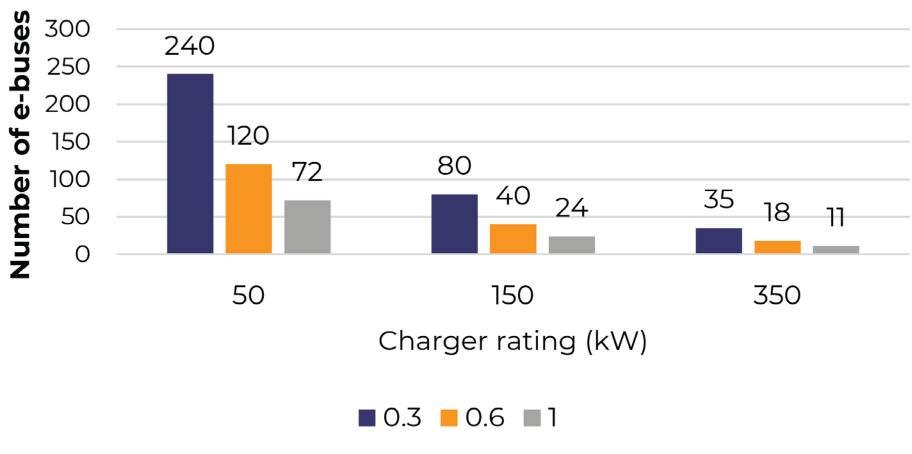
The number of e-school buses required to address these requirements with V2G can be calculated by

$$Number\ of\ buses = \frac{(\beta * P_{reqd.})}{(\alpha * P_{rated})}$$

Here, P_{reqd} denotes the power required to be provided to the grid (i.e., 72 MW for grid support during peak hours and 70 MW for frequency regulation in this case), β denotes the share of power required met by V2G (assumed to be 5% in this case), P_{rated} denotes the rated charger power (considered as 50 kW and 150 kW in line with the current market practices and a futuristic value of 350 kW), and α denotes the participating factor of the EV charger, that is, the share of the rated charger power that the users are willing to supply to the grid (assumed as 0.3, 0.6, and 1 here).

Using these equations, the number of e-buses required to bridge 5% of the estimated unmet demand or secondary reserve (70 MW) was computed. The following graph (Figure 17) is an illustration of the number of e-buses required at varying values of α and P_{rated}.

***Figure 17**: Number of e-buses required for fulfilling 5% of the requirement at different participating factors*



38

5.1.4. Inferences

This presents the scope of application of V2G for grid support in Kerala. Buses, specifically, e-school buses, as illustrated in Figure 17, could be deployed to curtail the surplus demand on the grid during peak hours or under stressed grid conditions.

- With the current EV charging technology, the number of e-school buses needed is in the range of 24 to 240.
- With advanced charging technology (350-kW chargers), the number may approximately be reduced to 11.
- As per regulations, every SRAS provider is expected to provide a minimum threshold power of 1 MW (Central Electricity Regulatory Commission, 2022). To address about 5% of the SRAS requirement within the state (~70 MW), which corresponds to 3.5 MW, and assuming every school provides 1 MW, four schools with seven e-school buses each would be required.
- Similarly, these four schools with seven e-school buses each (a total of 28 e-school buses) can also cater to about 5% of the peak unmet demand in the state.

5.1.5. Conclusion

Based on our analysis, the following action points are suggested:

Schools

- To ascertain the viability of V2G services from e-school buses, pilot projects can be conducted in which schools can play an important role in the procurement and operations of e-school buses.
- To be eligible to provide frequency regulation services to the grid, a school (or a group of schools) shall have at least 7 e-school buses equipped with 150-kW chargers on the premises.
- Schools shall install chargers at appropriate locations that are bidirectional in nature for charging buses during off-peak hours and allowing them to discharge during peak hours.

Utilities

- As a first step, utilities can conduct pilots with e-school buses to assess the technological and financial feasibility of V2G.
- They can coordinate with charger CPOs, ICT providers, and other entities and help roll out or define grid codes, interconnection requirements of V2G systems with the grid, communication protocols and interoperable standards and implement them for bidirectional charging.
- Utilities can roll out differential tariffs for EV charging and discharging to nudge customers towards grid-friendly charging behaviour.

6. Policy Recommendations

Policy support is crucial for boosting e-school bus demand among schools. Based on interactions with various stakeholders (Figure 5), study of school bus operations, and review of market and policy landscape, the following suggestions are put forward:

Pilots and targets: To increase awareness about e-school buses, the state government (KSEB, EMC, or other competent bodies) can initiate and support e-school bus pilot projects and facilitate widespread dissemination of the learnings. Further, in line with the state's climate and energy goals, phase-wise e-school bus adoption targets for schools can be set. State-specific and phase-wise targets (%) can be estimated based on local school bus operations and fleet sizes and the state's climate and environmental policies. These are beyond the scope of the current study.

Incentives: E-school buses cost at least twice as much as diesel buses. Purchase subsidies can help overcome this capital cost barrier. The current PM E-DRIVE subsidies for e-buses under state or city transport undertakings based on battery capacity (kWh) can be extended to e-school buses as well, since e-school buses also offer shared mobility (help curb traffic congestion) and avoid diesel consumption (help fight climate change and reduce air pollution and fuel imports). Indirect fiscal incentives can include exemptions for e-school buses from road tax, MV tax, and registration fee, among others, to make e-school buses more attractive than diesel buses. Relaxation to electric powertrain retrofitted diesel buses on fleet age limit rules can also help e-school bus adoption.

Green loans: To overcome the barrier of high CAPEX of e-school buses, the government can enable their financing through green loans—low interest rate and long-term loans. EMC Kerala provides green/soft loans for projects related to energy efficiency, which can be used for e-school bus projects.

Demand aggregation: Given the low demand for e-school buses in early market phases, aggregating demand from multiple schools co-located in the same neighbourhood will be an effective strategy to drive adoption. It will enable schools to benefit from economies of scale (lower price discovery) and minimise expenditure with shared charging infrastructure.

Low-emission zones, or LEZs: Air pollution is a major health and environmental concern in urban areas, and LEZs are one of the potential solutions to combat it (Institute for Transportation and Development Policy, 2023). Implementation of LEZs around schools can help boost e-school bus adoption.

Green certification: Recognition and certification for schools adopting green initiatives, such as e-school buses, the use of solar energy, and LED bulbs, among others, are vital. This will have a ripple effect and encourage other schools to adopt e-school buses to acquire green certification.

40

As a follow-up to the recommendations and for their effective implementation, some action points are proposed in Table 4.

Table 4: *Action points for e-school bus adoption*

Concerned entity	Suggested action(s) for e-school bus adoption
Energy Management Centre, Kerala	Serve as a nodal agency for aggregating demand from schools across the state Consult with Convergence Energy Services Limited (CESL), which is experienced in demand aggregation at a pan-India level Announce the eligibility of e-school buses for green loans. Extend green loans to schools adopting e-school buses
Urban local bodies (ULBs), such as municipal corporations and the traffic police	Explore the implementation of LEZs around schools on a trial basis
Directorate of Environment and Climate Change, Government of Kerala	Commission a study to determine sector-wide EV adoption targets, including school buses, in line with the state's net-zero goals and energy independence ambitions
Motor Vehicle Department, Government of Kerala	Consider an amendment to Rule 153D of the Kerala Motor Vehicle Rules 1989 to permit e-school bus usage for other transport applications, such as office shuttle, to increase asset utilisation
Directorate of General Education, Government of Kerala and/or Kerala State Electricity Board	Explore green certification programme for schools adopting e-school buses
Ministry of Heavy Industries, Government of India	Examine the feasibility of including e-school buses under the PM E-DRIVE scheme to receive a subsidy based on battery capacity (INR/kWh)
School administrators	Include e-school bus deployment along with rooftop solar projects in the application to carbon credit programmes

7. References

Aishree. (2024). *Assessing real-world emissions from BS-VI diesel buses in Indian urban and sub-urban traffic*. Urban Mobility India Conference. https://www.urbanmobilityindia.in/Upload/Conference/3_AISHREE_08022024.pdf

Briones, A., Francfort, J., Heitmann, P., Schey, M., Schey, S., & Smart, J. (2012). *Vehicle-to-grid (V2G) power flow regulations and building codes review by the AVTA (INL/EXT-12-26853)*. Idaho National Laboratory. https://avt.inl.gov/sites/default/files/pdf/evse/V2GPowerFlowRpt.pdf

BusesDekho. (n.d.). *Ashok Leyland 12M FE staff bus 40 seater/6200*. Retrieved April 10, 2025, from https://buses.cardekho.com/buses/ashok-leyland/12m-fe-staff-bus/40-seater6200

Center for Study of Science, Technology and Policy. (2023). *Bengaluru 2030: Impact of EVs on vehicular emissions* (CSTEP-RR-2023-7). https://cstep.in/drupal/sites/default/files/2023-05/Bengaluru%202030_Impact%20of%20EVs%20on%20Vehicular%20Emissions_1.pdf

Central Electricity Authority. (2023). *Electric vehicles utilization for vehicle-to-grid (V2G) services*. https://cea.nic.in/wp-content/uploads/gm_and_npc/2023/11/V2G_Report.pdf

Central Electricity Regulatory Commission. (2022). *Ancillary services regulations, 2022*. https://cercind.gov.in/Regulations/Ancillary-Service-Regulations-2022.pdf

Central Electricity Regulatory Commission. (2023). *Approval of "Detailed procedure for assessment of quantum of secondary & tertiary reserve capacity, along with information exchange and timelines" under Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2023*. https://posoco.in/wp-content/uploads/2024/03/A-1.pdf

Cochin Shipyard Ltd. (2017). *45th annual report 2016–2017*. https://cochinshipyard.in/uploads/investor/b99057251f19b714beb97dd60837e098.pdf

Dobric, J., Stroh, E., Isaxon, C., Wollmer, P., Dencker, M., & Rissler, J. (2022). Preschool children's inhalation rates estimated from accelerometers: A tool to estimate children's exposure to air pollution. *Aerosol and Air Quality Research, 22*, Article 220067. https://doi.org/10.4209/aaqr.220067

Eicher Trucks and Buses. (n.d.). *Starline 2070 E*. Retrieved April 10, 2025, from https://www.eichertrucksandbuses.com/buses/school-bus/starline/starline-2070-e

Electric School Bus Alliance. (2023). *Vehicle-to-grid (V2G) and electric school buses*. https://eschoolbusalliance.ca/wp-content/uploads/2023/09/V2G-and-Electric-School-Buses.pdf

Gavimath, V. V. (2024, January 18). *Breathing in Bengaluru: Silent killer on wheels*. CSTEP. https://cstep.medium.com/breathing-in-bengaluru-silent-killer-on-wheels-4d2648940fab

Government of Kerala. (2010). *Kerala state energy conservation fund rules, 2010* (G.O.(P) No. 7/2010/PD). Energy Management Centre Kerala. https://keralaenergy.gov.in/files/pdf/EC%20Fund%20Rule%20Gazette%20Notification.pdf

Government of Kerala, Transport Department. (2019). *Kerala electric vehicle policy 2019*.https://anert.gov.in/sites/default/files/inline-files/go20190310_Trans-24-Ms_e_vehicle_policy_.pdf

Grid Controller of India Limited. (2025). *Reserves requirement of SRAS and TRAS for 2025–26*. https://grid-india.in/en/operations/year-ahead

India Climate & Energy Dashboard (n.d), NITI Aayog https://iced.niti.gov.in/

India Smart Grid Forum.(2023). *Electrification of school buses*. https://indiasmartgrid.org/isgf/public/banner_img/1703925449n7e1vRflAPxXNpanq6zuLrekTvk9RISRGMyf6hxh.pdf

Institute for Transportation and Development Policy. (2023). *What is a low emission zone?* https://itdp.org/2023/02/22/what-is-a-low-emission-zone/

International Agency for Research on Cancer. (2012). *IARC: Diesel engine exhaust carcinogenic* (Press release No. 213) [Press release]. https://www.iarc.who.int/wp-content/uploads/2018/07/pr213_E.pdf

International Council on Clean Transportation. (2024). *Facilitating electric bus adoption by private bus operators across India* . https://theicct.org/facilitating-electric-bus-adoption-by-private-bus-operators-across-india-nov24/

Jhawar, P. (2020). *Renewable energy: Curtailment is a bane*. Down to Earth. https://www.downtoearth.org.in/energy/renewable-energy-curtailment-is-a-bane-68857

Kerala Infrastructure and Technology for Education. (n.d.). *Sametham: Kerala school data bank*. Retrieved April 10, 2025, from https://sametham.kite.kerala.gov.in/

Kerala State Electricity Board Limited. (2024). *Latest Gazette notifications: Tariff and energy charge schedule*. Kerala State Electricity Board Ltd. https://kseb.in/uploads/Subsubmenu/Latest%20Gazette%20Notifications1712202411:10:11.pdf

Kerala State Electricity Board Limited. (n.d.). *Vehicle-to-grid pilot project by KSEBL*. https://kseb.in/sbuarticledetail/

Kerala State Electricity Regulatory Commission. (2024a). *Order on modified proposals submitted by KSEB Ltd to revise schedule of tariff and terms and conditions for retail supply of electricity with effect from July 1, 2024 to March 31, 2027* (OP No. 18/2023). https://dev.erckerala.org/api/storage/orders/o0sDy6ZmrpxIKwgD9dz8lMNuYvVEq11l9P1VcHeP.pdf

Kerala State Electricity Regulatory Commission. (2024b). *Schedule of tariff and terms and conditions for retail supply of electricity by Kerala State Electricity Board Limited and all other licensees with effect from December 5, 2024 to March 31, 2027* (OP No. 18/2023). https://dev.erckerala.org/api/storage/orders/vnp1XnN5z47r0dCh18rj3s2e1q2utii3T8AtwUMm.pdf

Kerala State Planning Board. (2023). *Fourteenth five-year plan (2022-2027): Working group on transport report*. Government of Kerala. https://spb.kerala.gov.in/sites/default/files/inline-files/Layout-Transport%20final%2009.05.2023.pdf

Lion Electric. (n.d.). https://thelionelectric.com/lionc/

Ministry of Power, Government of India. (2024). *Guidelines and standards for electric vehicle charging infrastructure*. https://powermin.gov.in/sites/default/files/Guidelines_and_Standards_for_EVCI_dated_17_09_2024.pdf

Ministry of Road Transport and Highways, Government of India. (2021). *Central motor vehicles (Sixteenth amendment) rules, 2021* [Notification G.S.R. 525(E)]. The Gazette of India: Extraordinary, part II, section 3, sub-section (i) https://static.pib.gov.in/WriteReadData/specificdocs/documents/2021/aug/doc20218311.pdf

Ministry of Road Transport and Highways. (n.d.-a). *Know your MV tax*. Retrieved April 10, 2025, from https://vahan.parivahan.gov.in/vahan/vahan/ui/eapplication/form_show_tax.xhtml

Ministry of Road Transport and Highways. (n.d.-b). *VAHAN dashboard report view*. Retrieved April 10, 2025, from https://vahan.parivahan.gov.in/vahan4dashboard/vahan/view/reportview.xhtml

Moore, A., & Crolius, S. (2022). *Vehicle-to-grid electric school bus commercialization project*. https://doi.org/10.2172/1959341

Motor Vehicle Department, Government of Kerala. (n.d.-a). *Fees*. Retrieved April 10, 2025, from https://mvd.kerala.gov.in/en/fees

Motor Vehicle Department, Government of Kerala. (n.d.-b). *Tax*. Retrieved April 10, 2025, from https://mvd.kerala.gov.in/en/tax-0

PMI Electro Mobility. (n.d.). *Products*. Retrieved April 10, 2025, from https://pmielectro.com/products/

44

Press Information Bureau. (2025, March 25). *Revolutionizing mobility: Growth and transformation in India's automobile and auto component industries*. Government of India. Retrieved April 10, 2025, from https://www.pib.gov.in/PressReleasePage.aspx?PRID=2114919

Rather, Z., Nath A.P., & Patankar P. (2023). *Executive summary: Implementation of vehicle-to-everything (V2X) in India*. https://www.ese.iitb.ac.in/~gil/reports/exec_summary.pdf

SaveLIFE Foundation. (2021). *SLF report: National study on safe commute to schools*. https://savelifefoundation.org/wp-content/uploads/2021/10/SLF%20Report%20digital%2005Oct.pdf

Steward, D. (2017). *Critical elements of vehicle-to-grid (V2G) economics*. National Renewable Energy Laboratory. https://docs.nlr.gov/docs/fy17osti/69017.pdf

Vijaykumar, A., Kumar, P., Mulukutla, P., & Agarwal, O. P. (2018). *Procurement of electric buses: Insights from total cost of ownership (TCO) analysis*. World Resources Institute.https://wri-india.org/sites/default/files/WRI_EBus_Procurement_Commentary_FINAL_0.pdf

8. Appendix A: Capacity-Building Workshops

8.1. The workshop in Thiruvananthapuram

Details of the capacity-building workshop held in Thiruvananthapuram

Workshop title	Stakeholder Consultation Workshop on Electric School Buses
Venue	Seminar Hall, Energy Management Centre (EMC) Kerala, Sreekrishna Nagar, Sreekariyam, Thiruvananthapuram, Kerala 695017
Date and time	6 November 2024 (Wednesday), 10:00 a.m. to 2:00 p.m.
Inauguration	Shri K Krishnankutty, Honourable Minister for Electricity, Government of Kerala
Opening remarks	Dr R Harikumar, Director, EMC Kerala
Speakers	Ms Anjali Saxena, Manager – Business Development, PMI Electro Mobility Solutions Pvt Ltd Mr Advaith, Co-founder and CEO, chargeMOD CSTEP team: Vandana Nair, Vivek Gavimath, and Spurthi Ravuri
Attendees	Forty representatives from 21 government, government-aided, and private schools in the Thiruvananthapuram district.

Discussion points	Shri K Krishnankutty inaugurated the workshop and highlighted the need for electrification of school buses. Dr R Harikumar made the opening remarks and highlighted the need for sustainable financing mechanisms for e-school bus adoption, beyond subsidies. He highlighted ongoing initiatives by EMC for schools, such as electric cooking and RTPV installations. He emphasised state-level efforts to decarbonise various sectors, including energy efficiency improvements. The CSTEP team presented an overview of e-school bus procurement, financing, and charging infrastructure for schools. Ms Anjali Saxena presented e-school bus model features and specifications and answered queries from school bus operators on battery health, warranty, and pricing. Mr Advaith explained in detail the charging requirements of EVs in general and e-school buses in particular. He answered questions related to the EV charging infrastructure at schools, including its operations and safety.

Glimpses from the Thiruvananthapuram workshop

Shri K Krishnankutty delivering the inaugural address through video conference, displayed on the projected screen

Dr R Harikumar (second from the left) making opening remarks

Mr Advaith (first from the right) addressing school representatives

Workshop delegates

8.2. The workshop in Kochi

Details of the capacity-building workshop held in Kochi

Workshop title	Stakeholder Consultation Workshop on Electric School Buses
Venue	Kensington Banquet Hall, The Renai Cochin Hotel, Palarivattom, Kochi, Kerala, 682025
Date and time	4 March 2025 (Tuesday), 10:00 a.m. to 2:00 p.m.
Inauguration	Shri K Krishnankutty, Honourable Minister for Electricity, Government of Kerala (through video conference)
Opening remarks	Dr R Harikumar, Director, EMC Kerala
Speakers	Mr Ravi Shankar, Business Development and Relationship Manager (South) – Electromobility, Volvo Eicher Commercial Vehicles Pvt Ltd CSTEP team: Vandana Nair, Vivek Gavimath, and Spurthi Ravuri
Attendees	Representatives from 10 private schools in the Kochi district
Discussion points	Shri K Krishnankutty inaugurated the workshop and highlighted the need for electrification of school buses. Dr R Harikumar made the opening remarks and highlighted ongoing efforts by EMC in the state to decarbonise various sectors and improve energy efficiency. He shared details about the initiatives underway for schools in the state, such as rooftop photovoltaic (RTPV) systems and electric cooking. He encouraged schools to take advantage of the low-interest loans being offered by EMC to support e-school bus deployment.

Discussion points	The CSTEP team presented an overview of e-school bus procurement, financing, and charging infrastructure for schools. Mr Ravi Shankar presented the ongoing work on the deployment of e-school buses in Amritsar and Coimbatore by Volvo Eicher Commercial Vehicles Pvt Ltd. He explained the end-to-end solutions offered by the company, including planning, operations, charging, and maintenance. He answered the questions of school representatives on battery warranty, gross cost contract rates, and the setting up of charging infrastructure.

Glimpses from the Kochi workshop

Shri K Krishnankutty delivering the inaugural address through video conference, displayed on the projected screen

Dr R Harikumar (rightmost, with the microphone) making opening remarks

Ms Spurthi Ravuri addressing representatives from various schools in Kochi

Mr Ravishankar (first from the left, with microphone) presenting case studies on e-school bus deployment

9. Appendix B: Vehicle-to-Grid Systems

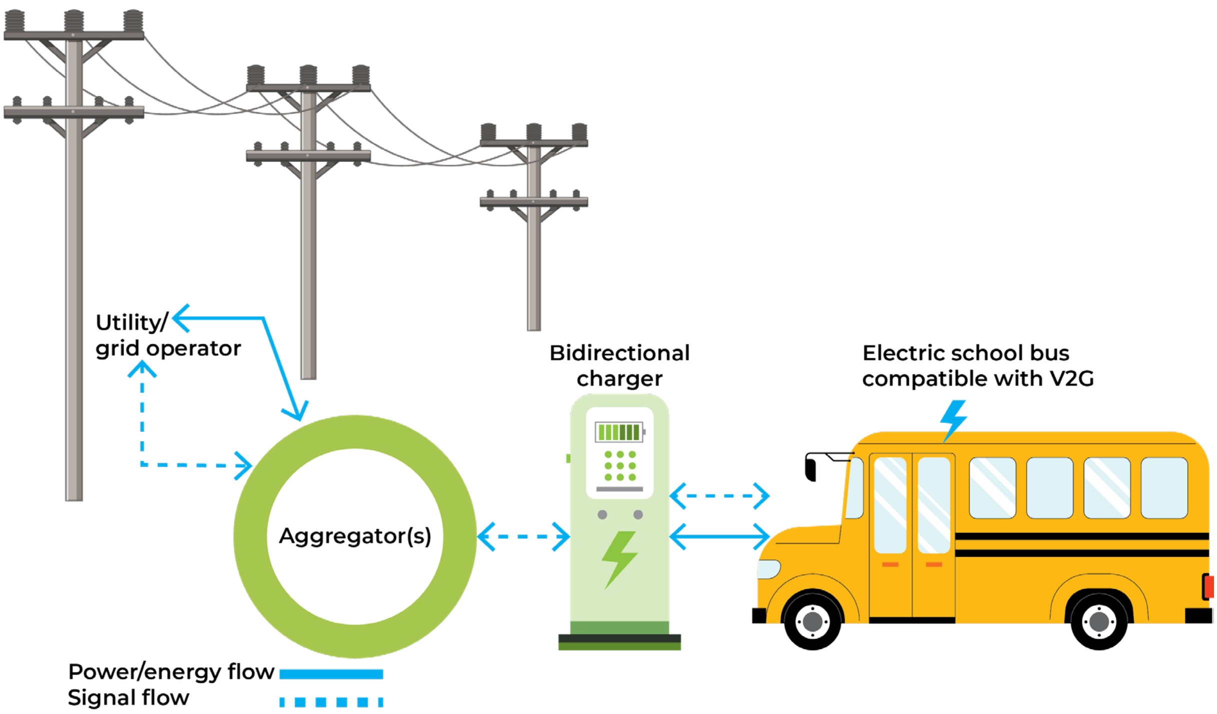
Traditional electric power systems and automobiles have functioned as two distinct sectors, independent of each other. However, the advent of electric mobility has connected the two closely. For instance, EVs draw power from the grid for charging, which, at scale, might cause overloading, leading to reduced efficiency of power transmission and distribution. On the other hand, when the appropriate infrastructure is in place, e-school buses also have the potential to function as mobile energy storage units (Central Electricity Authority, 2023) that are capable of supporting the grid in different ways, such as frequency correction, reactive power support, and demand management.

A vehicle-to-grid (V2G) system is a mechanism through which EVs can provide power back to the grid (Briones et al., 2012). It falls under a larger class of technologies, collectively referred to as 'vehicle-to-everything, or V2X', in which the vehicle can provide power to other devices or loads, such as buildings, houses, and other vehicles. Through bidirectional power converters, EVs can supply power back to the grid for purposes such as improving the voltage and frequency profiles and demand management.

9.1. Structure and components of V2G systems

Figure A1 provides a glimpse of the V2G system.

***Figure A1**: Structure and main components of a V2G system*



The main components of a V2G system are described in this section (Rather et al., 2023; Briones et al., 2012):

Chargers: EV chargers are an essential power electronic component that converts AC power to DC power and transfers energy to the battery while charging. For V2G implementation, AC and/or DC EV chargers that enable bidirectional flow of power are used.

Battery management systems (BMSs): It is an electronic component of EVs that performs the crucial function of monitoring and protecting a battery to ensure its safe, efficient, and lasting operation. V2G systems use BMSs that are modified to cater to the additional demands of the bidirectional flow of power.

Aggregators: Aggregators are entities that aggregate demand from several EVs for supplying V2G services to the grid. Since an individual EV is too small a V2G supplier, an aggregator combines the supplies from several EVs by optimising and catering to the demand of the grid operator or utility and the preferences of the EV owners (Rather et al., 2023).

Power grid: The power grid determines where, when, and how much of active or reactive power shall be provided to the grid through V2G. While V2G happens at the distribution level predominantly, the systems can also lead to benefits at the transmission level.

Information and communication technology (ICT) infrastructure: There are several communication pathways and protocols required between the components of a V2G system, for which suitable infrastructure should be in place.

9.2. Stakeholders

The following section maps an array of stakeholders from different categories/sectors: grid sector, digital infrastructure sector, and supply sector.

DISCOMs: They operate the distribution grid, the physical infrastructure through which power flows from generators to consumers. During the provision of V2G services, EVs would be connected to the grid for the supply of active and/or reactive power.

Power regulators: They spell out a slew of standards, codes, rules, and regulations associated with power flow. EVs connected to the grid for V2G, too, would have to comply with the regulations rolled out by these bodies. In India, they primarily comprise the Central Electricity Regulatory Commission and State Electricity Regulatory Commissions, among others.

RE generators: Since EVs would aid in the abatement of RE curtailed, renewable power producers, too, would have an important say in the progress of V2G.

Aggregators: Aggregators are entities that aggregate demand from different EV users who subscribe to V2G services to fulfill the requirements of the grid. This is done by optimising the energy demand and supply criteria and EV users' preferences.

State Load Despatch Centre (SLDC): SLDC monitors the real-time operation of the grid and ensures optimal scheduling and despatch of electricity within the state. It ensures that various grid parameters, such as frequency and voltage, comply with the grid code and implement real-time operations for their control within the permissible ranges. This is achieved through coordination with other entities or stakeholders.

Energy exchange platform: Organisations such as the Indian Energy Exchange (IEX) and Power Exchange India Limited provide a platform for the trading of energy between generators and consumers in long-term, medium-term, day-ahead, and real-time markets. As EVs represent a decentralised, scattered, and variable source and sink for energy trading, such platform providers prove to be stakeholders.

Telecommunication/ICT providers: The success of V2G systems would rest on the quality and the speed of communication between different entities, between the utility and aggregators, between the aggregators and EV owners, between the EV and the chargers, and between the EV owners and the EV, which calls for the establishment of communication pathways and protocols. Hence, ICT providers have an important say in the V2G ecosystem.

EV fleet owner/operator: The timing and quantity of V2G services available depend on the operating schedule and willingness of the EV owner.

OEMs: The e-school buses and on-board chargers would have to be manufactured for compatibility with V2G services. The manufacturers of these products constitute a prime strata of stakeholders, voicing perspectives through the lens of manufacturing.

Charge point operators (CPOs): CPOs set up charging stations, decide the number of AC and/or DC chargers, and arrange for the augmentation of the upstream infrastructure, if needed. Hence, from the point of view of V2G, CPOs are to shoulder the responsibility of installing V2G-compatible chargers and arrange space for EVs to provide V2G services to the grid, if needed.

9.3. Applications of V2G

V2G services can provide ancillary support, such as voltage and frequency corrections, as well as other functions including demand management and the mitigation of RE curtailment. Representative V2G applications are outlined in this section:

Voltage correction: The voltage level of points along feeders often tends to deviate from the recommended range of 0.95 to 1.05 per unit (p.u.), owing to increased loading or being far away from the substation. Voltage level below the recommended values can adversely affect the performance of connected loads, such as motors, lights, and even computers. Owing to their capacitance, inductance, and controller design, EV chargers have the potential to provide reactive power that can be employed to enhance the voltage profile of the feeder.

Frequency correction: Because of the occasional imbalances between supply and load, the frequency of the grid deviates from the recommended range of 49.95 to 50.05 Hz. A grid frequency below the lower limit is usually corrected by employing spinning reserves or rotating generators that generate power to meet the deficit. Instead of this, EVs that are available for V2G services can be deployed to supply this power collectively, as also highlighted in a report by the National Renewable Energy Laboratory (Steward, 2017). Such EV batteries have much lower inertia than conventional spinning reserves or generators and thus are capable of providing quick responses. On the other hand, in the event of a frequency increase beyond the recommended limit, EVs can also be employed as an extra charging load that draws power and thus corrects the grid frequency. The ancillary services deployed for frequency correction are usually of three types: primary, secondary, and tertiary. The details are listed in Table B1 (Central Electricity Regulatory Commission, 2023).

***Table B1**: Types of reserves and their activation*

Reserve type	Start of activation	Full availability/ deployment	Ability to sustain the full deployment
Primary response	As soon as the frequency crosses the dead band	Within 45 seconds	Up to 5 minutes
Secondary response	Within 30 seconds after the receipt of Automatic Generation Control (AGC) signal	Within 15 minutes	Up to 30 minutes or until replaced by tertiary reserves
Tertiary response	Within 15 minutes of dispatch instruction from National Load Despatch Centre or Regional Load Despatch Centre		Up to 60 minutes

RE curtailment: RE plant generators are often forced to cut down the renewable power input to the grid because of the unavailability of simultaneous demand. For instance, a solar project in Karnataka had an average curtailment of 9 hours a day in 2019, and for wind, an annual loss of 2,000 to 2,500 million units because of curtailment (Down to Earth, 2020). As a result, several kWh of energy, otherwise injected by renewable plants, stand unutilised. This curtailed energy can be stored by charging EV batteries, which would ensure that the valuable RE generated is stored in EV batteries. This energy can be utilised later by a vehicle or to provide V2G services.

Demand management: The grid is usually stressed during periods of high or peak demand and underutilised during periods of low demand. EVs can be deployed during the periods of high demand for discharging (V2G) and during the periods of low demand for charging. This enables levelling of the load on the grid.

9.4. Challenges to stakeholders

The challenges to implementation faced by some of the stakeholders are listed here:

Utility: As EVs present an indispensable resource for the storage of RE and the provision of grid support, utilities are motivated to foster a V2G ecosystem. However, they are also apprehensive of the technological advancements required and non-technological barriers such as approvals, clearances, lack of clarity of responsibilities, and unavailability of investment capital.

OEMs: Because of the uncertain demand, OEMs are apprehensive of investing in new bidirectional technology, raising the prices of the products even further. Moreover, the possibility of battery life reduction is also likely to have an adverse impact on the warranty provided by EV OEMs.

EV owners and fleet operators: This category is motivated by the potential of revenue generation from V2G and the availability of backup power for homes, buildings, other vehicles, and other loads through the V2X mechanism. However, concerns about the curtailment of battery life and range and the escalated costs of such V2G-compatible EVs and chargers loom large in the minds of consumers.

9.5. Regulatory landscape

The Ministry of Power, Government of India, rolled out the *Guidelines for Installation and Operation of EV Charging Infrastructure* on 17 September 2024 (Ministry of Power, Government of India, 2024). It highlights directions for the implementation of V2G technology.

- As per the requirements of the distribution licensee, V2G shall be enabled and the subsequent electricity tariffs shall be determined by the respective Electricity Regulatory Commissions.
- Energy storage and bidirectional electricity flow between vehicles and the grid shall be enabled in the EV charging station.
- The possibility of the incorporation of V2G functionality in EVs and EV chargers shall be looked into by OEMs.

Other regulations that may have a bearing on V2G or may be used as the basis for weaving regulations for it are as follows:

Tariff structure for RTPV: As per the order rolled out by KSEB on 5 December 2024 (Kerala State Electricity Regulatory Commission, 2024a), the tariff for supplying surplus solar power to the grid was INR 3.15/unit in 2023–24. A similar tariff structure may be explored for the energy supplied by EVs back to the grid for peak-shaving applications.

Payment for ancillary services: The Central Electricity Regulatory Commission notified the Ancillary Service Regulations in 2022 (Central Electricity Regulatory Commission, 2022), which delineates the rate structure for secondary reserve ancillary service and tertiary reserve ancillary service (through bidding). This may be used as a basis to estimate the revenue for ancillary services from V2G.

Recently, KSEB introduced different energy charges during solar and non-solar hours for low tension (LT) EV charging stations (Kerala State Electricity Regulatory Commission, 2024b). This might be instrumental in incentivising EV users to shift their charging to daytime hours in the future, thus making EVs available for V2G in the evening when the demand is higher.

CEA also published a report providing an overview of charging standards, V2G technology, key players or stakeholders, challenges for implementation, and further requirements for grid integration (Central Electricity Authority, 2023). Some of the key recommendations from the report are as follows:

- Standardisation, interoperability, and bidirectionality in the EV charging ecosystem are to be carried out.
- Integrated planning of transport and power sectors is to be carried out on an advanced basis to avoid network congestion.
- Building of charging hubs in optimal locations to facilitate bidirectional flow between mobility and the grid
- To facilitate bidirectional flow between mobility and the grid, charging hubs can be built at optimal locations. The charging and discharging processes should be controllable with a central monitoring system and accompanied by a smart strategy, tailor-made for the power mix.
- Policy directions for sharing controls between various providers should be provided to ensure the optimal utilisation of charging infrastructure and avoid network congestion
- Pilot studies should be conducted in India to assess the practical implications of V2G.

A V2G project was also proposed by KSEB to integrate EVs into the grid for bidirectional power flow (Kerala State Electricity Board Limited, n.d). It involves the following:

- KSEB has established strategically located charging infrastructure for EVs.
- Advanced charging technologies and smart grid management technologies will be deployed to achieve grid stability through the optimisation of charging and discharging of EVs.
- KSEB plans to collaborate with automakers (OEMs) to ensure the bidirectionality of battery charging capability and the seamless integration of V2G functionalities.

10. Appendix C: Case Studies of Vehicle-to-Grid Systems From Electric School Buses

Two case studies of e-school buses providing V2G services are provided here:

10.1. Case study 1

Electric School Bus Alliance (2023), Canada, details a high-level analysis to estimate the potential revenue from V2G; that is, the potential revenue from utility-side V2G services provided by e-school buses for three provinces in Canada (New Brunswick, Quebec, and Ontario).

The three V2G services chosen were as follows:

Avoided capacity: Reducing the need for peaking power plants to avoid or delay the need for new investments

Arbitrage: Purchasing energy during low-price (off-peak) periods and selling it during high-price (on-peak) periods

Ancillary services: Operating reserve, frequency regulation, voltage regulation, and black (out) start reserve

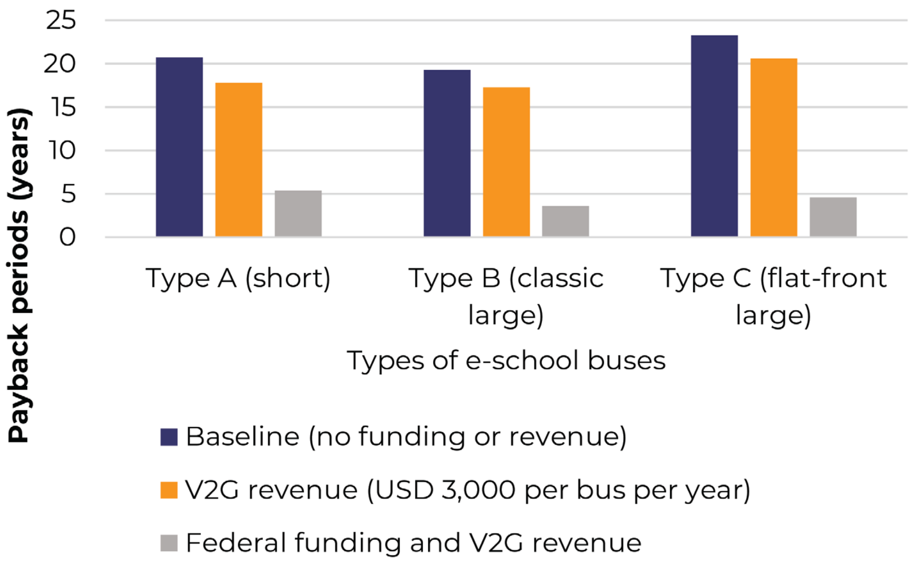
Since Type C, an e-school bus model that has a range up to 250 km and a battery capacity up to 210 kWh (Lion Electric, n.d.), constitutes over 70% of the school buses on Canada's roads, it was selected to assess the revenue potential from V2G services offered in the three provinces during mid-shift on weekdays and weekends and during summer holidays.

The following were observed:

- In the province with the highest earning potential, the value for the avoided capacity was found to be the largest contributor.
- V2G revenue can reduce the payback period of an e-school bus by 2 to 3 years compared to a diesel bus. However, even with this revenue, the upfront cost of an e-school bus is typically not recovered within its 12-year lifetime without additional federal funding.
- To prevent V2G activities from interfering with the bus's primary transportation role, managers must use smart charging platforms to set 'Departure Time' and 'Minimum State-of-Charge' constraints.

Assuming an average revenue of USD 3,000 (INR 2,72,262), the following are the estimated payback periods under various scenarios:

Figure B1: *Payback periods of e-school buses under various scenarios*



10.2. Case study 2

Moore and Crollius (2022) was a V2G commercialisation project conducted using e-school buses in Oakland, United States, for over 5 years from 1 February 2017 to 31 March 2022, involving six entities: Blue Bird Corporation, National Strategies, Nuvve, Rialto Unified School District, National Renewable Energy Laboratory (NREL), and South Coast Air Quality Management District.

The project aimed to accomplish the following objectives:

- Advance the energy efficiency of EVs by 28%
- Envision the different components of bidirectional charging at high power or capacity and monitor their system integration
- Aid the formulation of a policy, permitting EVs to function as distributed energy resources (DERs).

As per the initial plan/proposal, a charging system ought to have a 200-kW on-board bidirectional inverter. However, after weighing the development costs against the likely market demand and incorporating energy efficiency and regulatory considerations, it was decided to replace this inverter with an off-board inverter of 125 kW capacity.

It was observed that the profits yielded from the V2G system (USD 5,000 per e-school bus per year) would not make e-school buses commercially attractive drastically. It also encountered regulatory hiccups on the path to execution. The regulatory frameworks under the California Public Utility Commission and the Federal Electricity Regulatory Commission (FERC) cannot consider DER-enabled V2G vehicles under their purview. Hence, after stakeholder consultations, the project team devised the concept of a split tariff, which is accurate and fair in design and execution. The driving kWh would be billed under the current applicable retail tariff and the exported kWh under the wholesale tariff.

Moreover, a system impact study was performed, which determined several upgrades for the distribution circuit, catering to the Rialto School Bus fuelling facility, which cumulatively amounted to a figure of USD 777,000.

From the case studies, the following can be understood:

- EVs, especially e-school buses, have the potential to serve as DERs and support the grid in different ways. This calls for smart systems and other hardware requirements.
- Although V2G does not make a significant contribution, government incentives can play a crucial role in enabling e-school buses with V2G capability to achieve price parity.

Implementation of V2G systems, especially from e-school buses, calls for a multitude of policy provisions.


SCHOOL BUS
80
SCHOOL BUS
SCHOOL BUS

CSTEP

Center for Study of Science, Technology & Policy

Bengaluru

#18, 10th Cross, Mayura Street, Papanna Layout,

Nagashettyhalli (RMV II Stage),

Bengaluru – 560094, Karnataka, India

Noida

1st Floor, Tower-A, Smartworks

Corporate Park, Sector-125,

Noida – 201303, Uttar Pradesh, India

+91-8066902500 www.cstep.in cpe@cstep.in