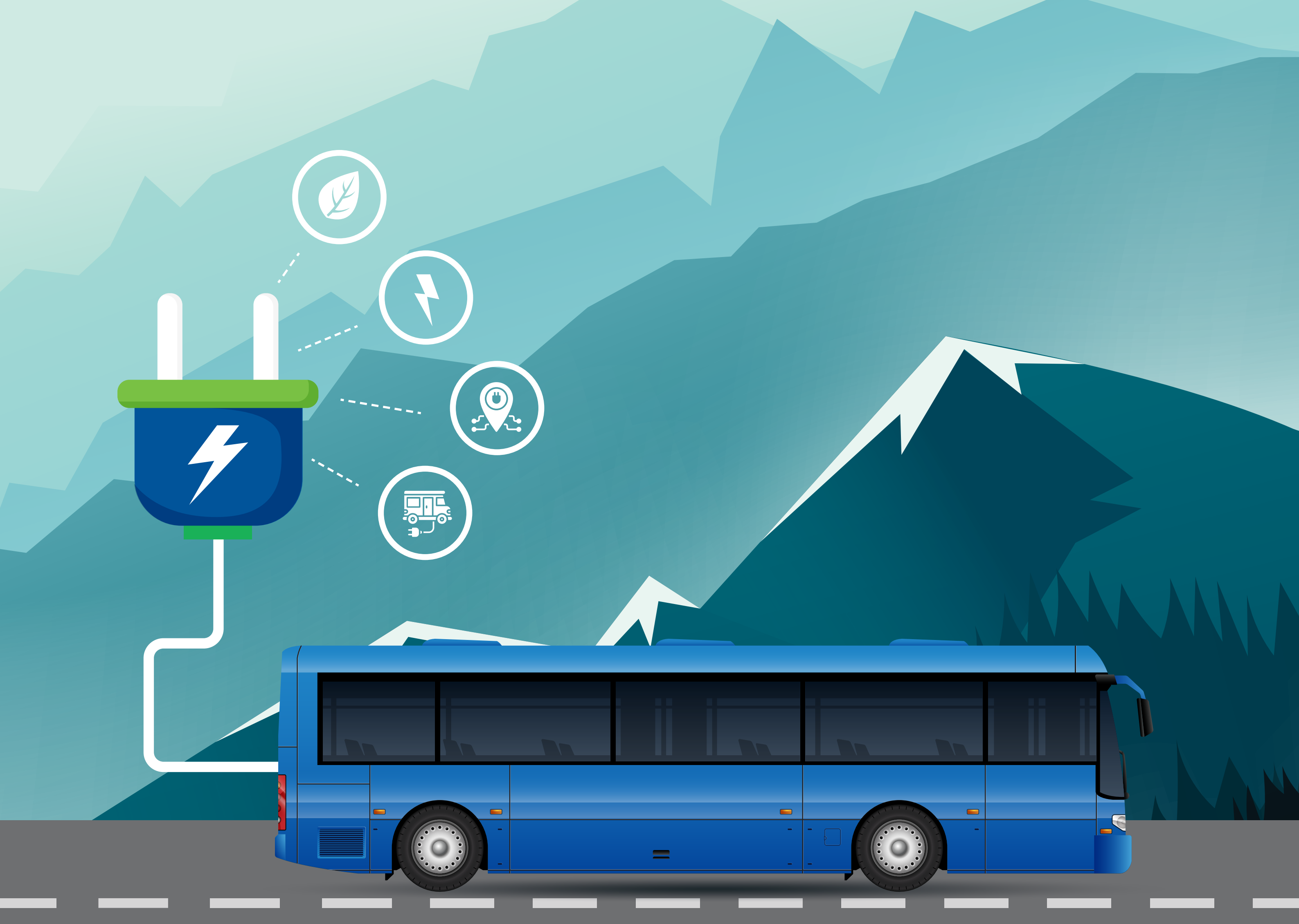
TOWARDS CLIMATE-RESPONSIVE AND LOW CARBON DEVELOPMENT

Addressing the Critical Urban Issues in Residential and Transport Sector in Uttarakhand

Transitioning to Green Mobility in Public Bus Space- A case study of Uttarakhand State



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October 2022

Jointly prepared by: National Mission on Himalayan Studies (NMHS), Alliance for an Energy Efficient Economy (AEEE) and Union Internationale des Transports Publics (UITP).

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Executive Summary

National Mission on Himalayan Studies

The Government of India launched the National Mission on Himalayan Studies (NMHS) in 2015 with four broad objectives, to preserve the Indian Himalayan Region, which are outlined as follows:

- To build a body of scientific and traditional knowledge through demand-driven action research and technological innovations along with institutional strengthening and capacity building
- To strengthen technological innovations leading to sustainable management of natural resources of the Himalayas for ensuring the ecological, water, and livelihood security at the local, regional and national levels
- To create science-policy-practice connected through a network of policymakers and practitioners engaged in working solutions to problems in the thematic areas
- To demonstrate workable/implementable/replicable solutions to the problems in the priority thematic areas.

The project aims to address the challenges concerning two major sectors ***viz.*** the residential and transport sectors. This report is prepared as part of the urban transport sector which intends to address vehicular air pollution and Greenhouse Gases (GHG) emissions in urban areas of the Himalayan region. For this study, the state of Uttarakhand is assessed across its transport and energy ecosystem and the associated emissions.

Learnings from the current and past experience of e-bus operations in hilly terrain can provide valuable learnings while planning for future deployments. Uttarakhand has conducted trial runs for e-buses since 2018, while Himachal Pradesh, a state with similar topography and operational requirements has been operating e-buses since 2017. Data available from the operations of these two states is collected as input for the current study. While the data was not exhaustive, it still provides insights into a few key aspects of the e-bus operation.

The total electrical energy consumed during the trial, conducted by UTC in two of its popular routes - Dehradun-Mussorie and Haldwani-Nainital between October and December 2018, using buses from Olectra, was 10,410 kWh. The emissions associated with the said energy consumption were analysed using the grid emissions factor of India, which was 0.705 kg-CO2/ kWh in 2018. However, as Uttarakhand has rich hydro resources, the grid emissions factor for the state is almost half of the national value i.e. 0.353 kg-CO2/ kWh. Using this grid emissions factor, the emissions calculated were around 3.68 t-CO2 eq. On the flip side, if these kilometres were catered by a diesel bus the emissions would have been around 19.43 t-CO2 eq. The emissions abated through this pilot implementation were around 15.74 t-CO2 eq.

Within the e-buses, the relative TCO results of alternative business models vary for 12m and 9m buses. In the case of 12m AC buses, in-house operations were observed to have a lower TCO compared to GCC operations, while in the case of 9m Non-AC buses, GCC operations were observed to be cheaper. Typically, GCC operations are observed to be cheaper than in-house operations across vehicle types because of the lower staff cost of private operators. However, UTC already deploys contractually hired staff as drivers, thereby reducing staff costs substantially, making further savings through GCC only marginal. At the same time, the cheaper cost of finance on the higher cost 12m AC bus leads to lower TCO for in-house operations. In the case of 9m Non-AC buses, the cost of the bus and its finance is lower, therefore, leading to the marginal staff cost reduction through GCC still resulting in a lower TCO.

Deployment of public e-buses requires advanced level planning of various key areas including the assessment of charging infrastructure requirements. Charging infrastructure for e-buses differs slightly from the e-2W/3W/4W vehicles, primarily due to the unavailability of "home" charging infrastructure. Also, due to the high battery capacities associated with buses, the power infrastructure requirements are significantly higher compared to other EVs, generally of the order 50kW and above.

The planning of charging infrastructure for public e-buses requires the evaluation of the following:

i. "where" the charging will take place,

ii. "when" the charging will occur and

iii. "how" the charging is facilitated.

It is expected that Uttarakhand will have an electric bus fleet of ~3,352 by 2030. The calculation of the emissions from the electric buses based on the grid emissions factor is given in Annexure 1. Since the grid emissions factor for Uttarakhand is already half of the national average, we have retained the same for the assessment tenure. However, any improvement will only result in improving the prospect of deploying electric buses in the state.

Uttarakhand as a state stands to accrue several benefits from the electrification of its bus fleets. One of the primary benefits is the emission savings for this pristine state. The state had experienced an increase in emissions from 3.6 MtCO2e to 19.8 MtCO2e during the period 2005 - 2013 at an estimated CAGR of 23.81%. It is important to note that in Uttarakhand, emissions arose only from Fuel Combustion, and transport and industries are the leading contributors.

The factor that distinguishes Uttarakhand from the rest of India is that the power sector emissions are very low. India's grid emission factor is 0.8 kg-CO2/ kWh, primarily due to the significant amount of coal-based power generation. However, as Uttarakhand has rich hydro resources, the grid emissions factor for the state is less than half of the national value i.e. 0.35 kg-CO2/ kWh. In Uttarakhand, an analysis of the power generation mix for the past 5 years shows that close to 46% of the electricity demand is met by hydro sources, and the grid emission factor is reducing with the increase in penetration of renewable energy in the state. This implies that emission reduction from the electrification of bus fleets will be twice the emission reduction at the national level.

The government of India is betting big on the electrification of buses, and through Convergence Energy Services Ltd. (CESL) initiatives, plans are being rolled out to tender 50,000 electric buses on behalf of states in the next five years. The first phase of the tender with a demand aggregation of 5000+ buses for Bengaluru, Delhi, Surat, Hyderabad, and Kolkata resulted in the lowest prices. Uttarakhand can benefit from aligning with the government plans and this is recommended as the near-term action for the state.

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Acronyms

- ACC – Advanced Chemistry Cell
- AEEE – Alliance for an Energy Efficient Economy
- BEST – Brihanmumbai Electric Supply and Transport Undertaking
- BMTC – Bangalore Metropolitan Transport Corporation
- CAGR – Compound Average Growth Rate
- CAPEX – Capital Expenditure
- CESL – Convergence Energy Services Ltd
- CNG – Compressed Natural Gas
- DSCL – Dehradun Smart City Ltd.
- DTC – Delhi Transport Corporation
- E–buses – Electric buses
- EVSE – Electric Vehicle Supply Equipment
- FAME – Faster Adaption of Manufacturing of Electric Vehicles
- GCC – Gross Cost Contract
- GHG – Greenhouse Gases
- GoI – Government of India
- GSDP – Gross State Domestic Product
- GVW – Gross Vehicle Weight
- HRTC – Himachal Pradesh Road Transport Corporation
- ICCT – International Council on Clean Transportation
- ICE – Internal Combustion Engine
- IHR – Indian Himalayan Region
- IPK – Income per Km
- km – kilometre
- kWh – kilowatt–hours
- LFP – Lithium Iron Phosphate
- MoHUA – Ministry of Housing and Urban Affairs
- MV – Motor Vehicle
- NEBP – National Electric Bus Program
- NMC – Nickel Manganese Cobalt
- NMHS – National Mission on Himalayan Studies
- OEM – Original Equipment Manufacturers
- OR – Operating Ratio
- PLI – Performance Linked Incentives
- PMPML – Pune Mahanagar Parivahan Mahamandal Limited
- RFP – Request for Proposals
- RR – Replacement Ratio
- RTC – Road Transport Corporations

- sq. km – square kilometre
- STU – State Transport Undertaking
- TCO – Total Cost of Ownership
- UERC – Uttarakhand Electricity Regulatory Commission
- UITP – International Association of Public Transport
- ULB – Urban Local Bodies
- UPCL – Uttarakhand Power Co. Ltd
- UTC – Uttarakhand Transport Corporation
- VGF – Viability Gap Funding

01 Project Context: Need for electric buses in Uttarakhand

1.1 Project introduction- National Mission on Himalayan Studies

The Indian Himalayan Region is home to a variety of flora & fauna and plays a significant role in terms of a life-support system for millions of people in the uplands and regulating the climate for much of Asia. Growing urbanization trends, reckless deforestation, and increased tourist activities have led to a severe deterioration of air quality and have put the Himalayan ecosystems at high risk, especially from floods, avalanches, and landslides resulting from glacier melting. There exists a dire need to preserve this ecosystem while ensuring the development of the states in the Himalayan region.

Realizing its importance, the Government of India (GoI) launched the National Mission on Himalayan Studies in 2015. It was envisioned to support the sustenance and enhancement of the ecological, natural, cultural, and socio-economic capital assets and values of the Indian Himalayan Region (IHR). The IHR represents 16.2% of India's total geographical area and plays a key role in regulating the climate for much of Asia due to its diverse biophysical and socio-cultural richness.

The National Mission on Himalayan Studies (NMHS) is formulated with four main objectives to preserve the IHR which are outlined as follows:

- To build a body of scientific and traditional knowledge through demand-driven action research and technological innovations along with institutional strengthening and capacity building
- To strengthen technological innovations leading to sustainable management of natural resources of the Himalayas for ensuring the ecological, water, and livelihood security at the local, regional and national levels
- To create science-policy-practice connected through a network of policymakers and practitioners engaged in working solutions to problems in the thematic areas
- To demonstrate workable/implementable/replicable solutions to the problems in the priority thematic areas.

1.2 Objectives of the current study

Considering the sensitivity of the region of implementation of this study, the planning for such activity needs to be unique and must respect the local environment and ecological aspects by avoiding resource misuse and environmental degradation while also improving the quality of life of the local population. The project "Towards climate-responsive and low-carbon development: Addressing the critical urban issues in the residential and transport sector in Uttarakhand" aims to address the following key points:

- Foster conservation and sustainable management of natural resources
- Enhance the overall economic well-being of the region
- Support building human and institutional capacities and the knowledge and policy environment in the region
- Strengthen the development of climate-resilient core infrastructure and basic services assets

The project aims to address the challenges concerning two major sectors ***viz.*** the residential and transport sectors. This report is prepared as part of the urban transport sector which intends to address vehicular air pollution and Greenhouse Gases (GHG) emissions in urban areas of the Himalayan region. For this study, the state of Uttarakhand is assessed across its transport and energy ecosystem and the associated emissions.

Uttarakhand is a northern state encompassing the Himalayan range is vital for the Indian landmass. It provides a large forest cover and feeds perennial rivers that are the source of drinking water, irrigation, and hydropower, conserving biodiversity, providing a rich base for high-value agriculture, and spectacular landscapes for sustainable tourism. At the same time, it is also vulnerable to the impacts and consequences of climate change.

The study is carried out in a way that can be replicated for other Himalayan states as well. This report addresses the transport-related emission in the state of Uttarakhand by facilitating the rollout of electric public buses on identified intra-city or inter-city routes which are currently catered by Internal Combustion Engine (ICE) buses.

Overall, the objectives of the urban transport sector study are:

- Support in the decision-making of the concerned authority in Uttarakhand regarding the deployment of electric buses for public transport on specific intra-city or inter-city routes
- Support in building the institutional capacity of relevant state actors in Uttarakhand regarding the implementation of electric mobility in the state

In this regard, Alliance for an Energy Efficient Economy (AEEE) has partnered with the International Association of Public Transport (UITP) – India to facilitate the roll-out of electric public buses in Uttarakhand state. It includes formulating a plan for phase-wise deployment of electric buses and strengthening the capacity of relevant stakeholders for the efficient operations of electric buses. The transition to electric buses (e-buses) presents the opportunity to convert the maximum passenger kilometre (km) of travel to zero-emission transport in Indian cities and has the potential to yield a variety of benefits, including improved energy efficiency and air quality, along with longer-term climate change mitigation benefits.

This white paper is prepared as part of the project in the form of electric bus planning and deployment strategy. The interventions proposed for Uttarakhand will be implementable across all Himalayan states.

1.3 Introduction to Uttarakhand

Uttarakhand state is located in the foothills of the Himalayan Mountain Ranges of which 86% of the area is classified as mountain terrain and 65% of the area is covered by forests. It is the 21st most populous state in India[1] with a population of about 1.14 Cr (11.4 million) inhabitants of which about 70% of the population reside in rural areas. The population density of the state is about 213 people per square km (sq. km) and has grown at a Compound Average Growth Rate (CAGR) of 1.2% between 2011 and 2021.

1 https://uidai.gov.in/images/StateWiseAge_AadhaarSat_Rep_31122021_Projected-2021-Final.pdf

Figure 1 presents the major urban centers in Uttarakhand.There are 7 urban agglomerations in Uttarakhand with a population of more than 1 Lakh (0.1 million) inhabitants namely Dehradun, Haridwar, Roorkee, Haldwani-cum-Kathgodam, Rudrapur, Kashipur, and Rishikesh. Further, there are 8 municipal corporations and 25 municipal councils governing the urban centers in Uttarakhand. Dehradun, the capital city of Uttarakhand, is also selected as a 'Smart City' under the Smart Cities mission of the Ministry of Housing and urban Affairs (MoHUA), Government of India.

The Gross State Domestic Product (GSDP) of Uttarakhand has witnessed a steady growth of 7.8% over the past six years[2]. The growth in population and economic activity has led to an increased travel needs over the years which has resulted in an increasing number of motor vehicles at a CAGR of 13% between 2007 and 2016 against the national average of 10% for the same period. There are a total of 27.5 lakh registered vehicles as of March 2019[3], of which 72% are two-wheelers followed by 16% of cars. The buses form a meager 0.4% of the total vehicles in the state. The total number of buses, accounting for both public and private ones, in the state of Uttarakhand is 13,132.

Figure 1: Major urban centers in Uttarakhand

2 https://www.ibef.org/states/uttarakhand-presentation

3 Ministry of Road Transport and Highway (MoRTH) year book 2017-18 and 2018-19

1.4 Approach for developing a long-term e-bus deployment strategy

The low-carbon development in the public transport sector study involves the following steps:

- Review of national and international e-bus deployment in hilly regions
- Conduct existing situation analysis of bus services in the state and assess the operations and service levels
- Evaluate the availability of required support infrastructure for setting up charging stations in Uttarakhand
- Recommend electric bus specifications for hilly regions
- Formulate a near-term implementation plan for rolling out an electric public bus fleet in a case study state over a 3 to 5 years' time-horizon that can be adopted by other states

This report is prepared as part of the low-carbon development in the urban transport sector in Uttarakhand in the form of global case studies and cases of electric bus deployment in hilly regions. The review of international practices is expected to assist in the development of a techno-economic framework for the deployment of electric public bus fleets in hilly terrain towns.

This report is discussed in seven chapters including the current one. The second chapter presents a detailed analysis of the operational and financial performance of Uttarakhand Transport Corporation (UTC) while chapter three provides an overview of learnings from e-bus deployments in hilly terrains in India and across the world. Chapter four focusses on the e-bus roadmap for Uttarakhand using per-km and fleet-level Total Cost of Ownership (TCO) modeling along with long-term fleet needs assessment for UTC. Chapter five presents the operational assessment of potential e-bus routes and depots along with the technical specifications recommended for different bus dimensions. Chapter six focuses on the power infrastructure readiness for e-buses and the report is concluded by Chapter seven which summarises the key learnings and way forward from the project.

02 Performance analysis of Uttarakhand Transport Corporation

2.1 Public bus transport in Uttarakhand

Uttarakhand Transport Corporation (UTC), the State Transport Undertaking (STU) of Uttarakhand is the leading public transport provider in Uttarakhand, supplemented by commercial bus services provided by private operators. It has a fleet size of 1,225 buses in March 2022, which is lower than the 1,314 buses held in December 2019, and is among the best-performing STUs for hilly regions in India. It's operational and financial performances are analyzed in detail towards developing a context-specific e-bus roadmap for Uttarakhand.

The Covid-19 pandemic impacted UTC operations from the end of March 2020 and the demand and supply patterns post the pandemic are yet to stabilize. Therefore, the 2019-20 patterns, which represented the peak demand and supply catered by UTC were used as the reference for this study. Operational performance data is available for December 2019 and financial performance until March 2020, i.e., the end of the financial year 2019-20 was used as a reference to analyze UTC's performance.

Uttarakhand also has a significant presence of private buses which are estimated to have a much larger fleet size of about 3,000 buses, operating under a union called Garhwal Motor Union Pvt. Ltd. While UTC services provide affordable access to mobility to rural as well as intercity destinations, private buses offer commercial services with a profit motive predominantly in tourist areas. As a result, their routes are restricted to a few high-demand nodes, which are also served by UTC. Hence the analysis presented in this report and the lessons learned are also applicable to the electrification of private buses.

2.2 Operational performance of UTC

UTC provides its services through a combination of buses owned and operated by in-house staff and hired buses, wherein the bus is owned, operated, and maintained by a private operator but the tariff, revenue collection, and service planning are carried out by UTC. Out of its fleet size of 1,314 by the end of December 2019, 1,016 buses were UTC-owned buses and the remaining 298 were hired from private operators. Table 1 presents an overview of UTC operations. UTC operations are facilitated through 3 administrative divisions, i.e., Dehradun, Nainital, and Tanakpur, and 22 depots. The total number of routes is 348 with an average route length of 300 km. The longest route is 787 km i.e. Tanakpur-Amritsar and the shortest route is 26 km i.e. Bhowali-Nainital.

Table 2 depicts a list of the administrative divisions and depots out of which UTC operations are carried out. Out of the 22 depots, 7 depots have only STU-owned buses while the remaining have both STU as well as hired buses. UTC has a total of 23 workshops for the maintenance of its fleet. Out of these, 20 are depot-level workshops that are used for periodic maintenance and minor repairs while 3 are regional workshops in Dehradun, Kathgodam, and Tanakpur used for major maintenance activities.

Table 1 Overview of Uttarakhand Transport Corporation (December 2019)

Parent Department	Department of Transportation, Government of Uttarakhand
Service Areas	Uttarakhand, Himachal Pradesh, Chandigarh, Punjab, Haryana, Delhi, Rajasthan, Uttar Pradesh, and Jammu & Kashmir
Depots	22
Divisions	03
Vehicles	1016 (UTC Owned)+ 298 Hired
Coverage per day (Kms)	3.87 Lakhs
Routes	348
Services	735
Average traffic revenue per day (₹)	165 Lakh
Staff	6,521
Staff per bus	5.22

Table 2 UTC divisions and depots

Division	Depots
Dehradun	Dehradun B, Dehradun Hill, Dehradun Rural, Roorkee, Hardwar, Rishikesh, Kotdwar
Nainital	Almora, Ranikhet, Bhowali, Kathgodam, Haldwani, Rudrapur, Kashipur, Ramnagar
Tanakpur	Tanakpur, Lohaghat, Pithoragarh

Owned Vs Hired Buses: Table 3 presents the relative performance of owned and hired UTC services across a few key indicators. Owned services perform better on fleet utilization, i.e. the percentage of buses on-road every day while the hired services perform better on the ridership achieved per bus on-road. The average fleet utilization across the two types of services types is 88% leading to the total number of buses operating on the road of about 1,162 daily.

Table 3 Performance of UTC's owned and hired services

Indicator	UTC owned buses	Hired buses	Total
Fleet size	1,016	298	1,314
Fleet size (in %)	77%	23%	100%
Fleet utilization (% fleet on-road)	92%	78%	88%
Annual operated km (in Lakh)	1152	352	1504
Annual operated km (in %)	77%	23%	100%
Ridership (Avg. passengers per day	0.9 lakhs	0.31 lakhs	1.21 lakhs
Ridership (in %)	74%	26%	100%
Passengers per bus per day	96	134	105

Service category-wise performance: Table 4 presents more disaggregated service category-wise operational characteristics of owned and hired buses. UTC's own buses operate under 'ordinary' services which provide affordable fare transport services for rural and intercity passengers while their hired buses provide a wider range of services, predominantly deployed on intercity routes and premium AC services. The seating capacity of these buses varies from 34 to 51 depending upon the service type and the terrain of operation. It is observed that UTC's cancelled-km out of the scheduled-km of operation is about 10-15% across different service types as well as ownership (owned and hired) of buses. This points to the need for improved scheduling practices incorporating the various operational constraints more accurately. The average occupancy of UTCs own buses is 73% indicating high patronage for the buses and reflecting the need to augment services to reduce crowding.

Table 4 Service category-wise operational characteristics (December 2019)

Type of bus	Type of service	No. of buses	Avg. route length (in km)	Avg Vehicle utilization (km/bus/day)	Vehicle utilisation (Max/Min) (km/bus/day)	Load Factor	Cancelled-km as a % of Scheduled-km
Owned	Ordinary	931	300	333	632/49	73%	14.5
Hired	AC	23	248	464	657/362	67%	11.4
	AC Sleeper	1	553	1106	1106	68%	0
	AC Deluxe	2	214	343	343	50%	19.9
	AC Jan Rath	19	239	418	561/280	63%	11.7
	Volvo	39	333	517	1154/250	64%	9.5
	Ordinary	140	178	364	617/237	80%	12.9
	Minibus	7	157	445	445	103%	0

Vehicle utilization patterns: The daily vehicle utilization, i.e., the km performed per bus per day is a key input in determining the range required when planning for electric buses, their battery size, charging technology, and other specifications. Higher vehicle utilization results in greater energy savings by shifting from ICE to electric buses but would also necessitate larger battery requirements, thereby increasing the cost of the bus. Table 4 shows that the average vehicle utilization across service types is a minimum of 333 km. However, a schedule-wise analysis shows that the average numbers are skewed by the long-distance routes. 41% of UTC-owned buses operate less than 300 km per day and 67% operate less than 400 km per day. In the case of the hired buses, 31% of the scheduled buses operate less than 300 km per day, 66% less than 400 km per day while the remaining operate more than 400 km per day. While some services operate more than 1,000 km per day they constitute a small fraction of the total fleet and may be transitioned to e-buses in the long term when the technology evolves further. Therefore, the battery size, charging location, and charger technology specifications need to be planned to meet such operational needs and thereby optimize the cost of transition to e-buses.

2.3 Financial performance of UTC

UTC's financial readiness for e-buses was analyzed based on its cost and revenue trends between the years 2014-15 and 2019-20. Figure 2 presents the absolute and percentage cost split of UTC between 2014-15 and 2019-20. On average, staff cost and fuel costs contribute to about 37% and 36% of the total cost of operations. UTC is adopting the practice of moving from in-house staff to contractual staff to operate owned buses and reducing staff costs. However, fuel costs remain relatively the same across owned and hired buses. The proposed transition to e-buses can substantially reduce the fuel costs of UTC and thereby improve its financial position.

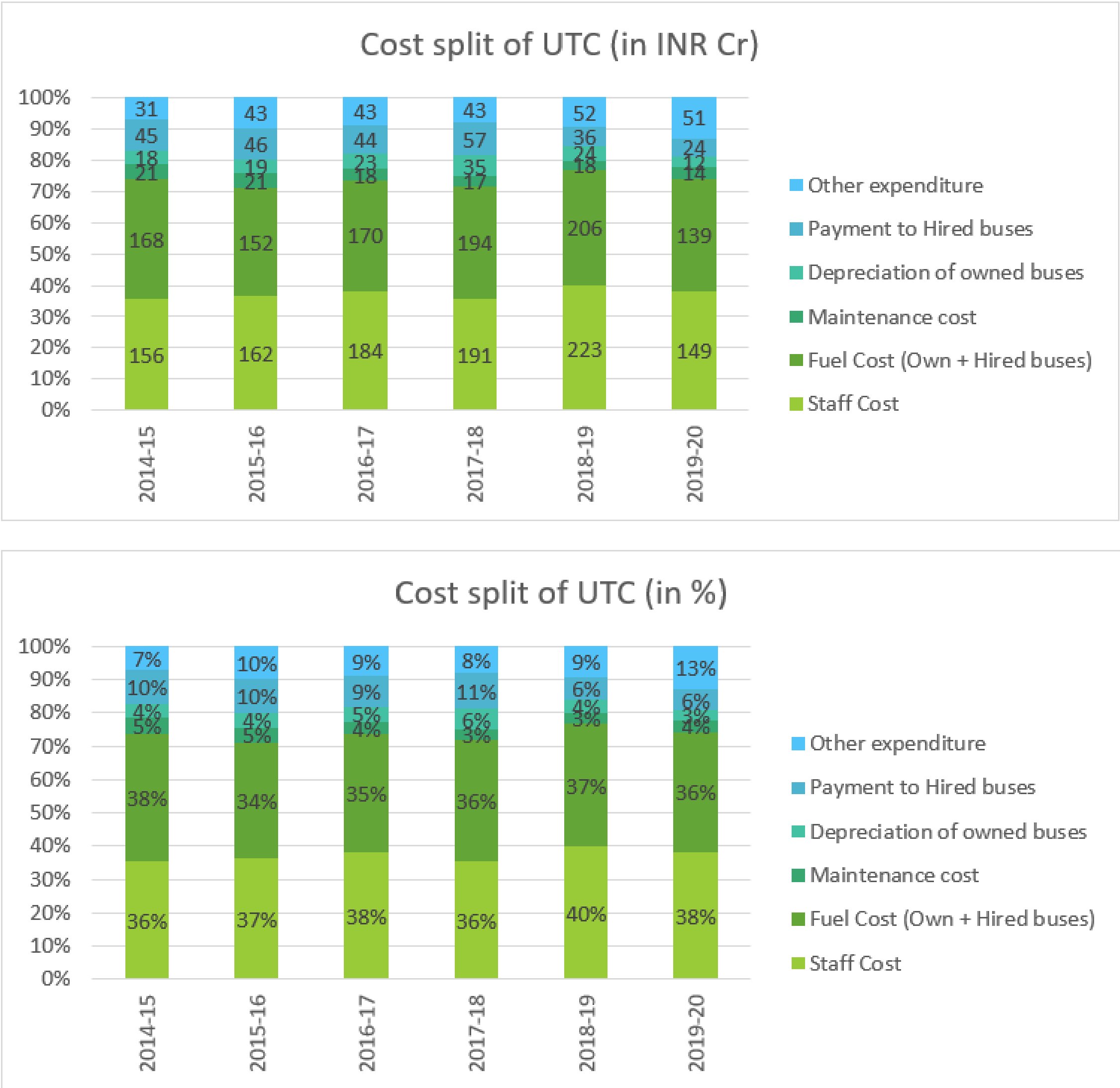

Figure 2 Cost split trends of UTC between 2014-15 and 2019-20

For the deployment of electric bus fleets in the state of Uttarakhand, it is critical to review and understand the performance of UTC operations and assess its financial capabilities and operational requirements. The data for December 2020 is used for the analysis. However, the operating ratio trend is generated using 10-year data between 2009-10 and 2019-20.

The yearly financial report consists of income and expenditure details of the UTC. The income is further segregated into corporation income, income from contracted buses, and miscellaneous income. The expenditure subheads consist of income & allowances, fuel cost on STU buses, spare parts & tires, 'other' expenditure, devaluation, head office expenditure, expenditure on contracted buses, and fuel cost on contracted buses. The financial performance is measured in terms of overall profit/loss as well as operating profit/loss. The devaluation cost when subtracted from operational profit will provide the overall profit.

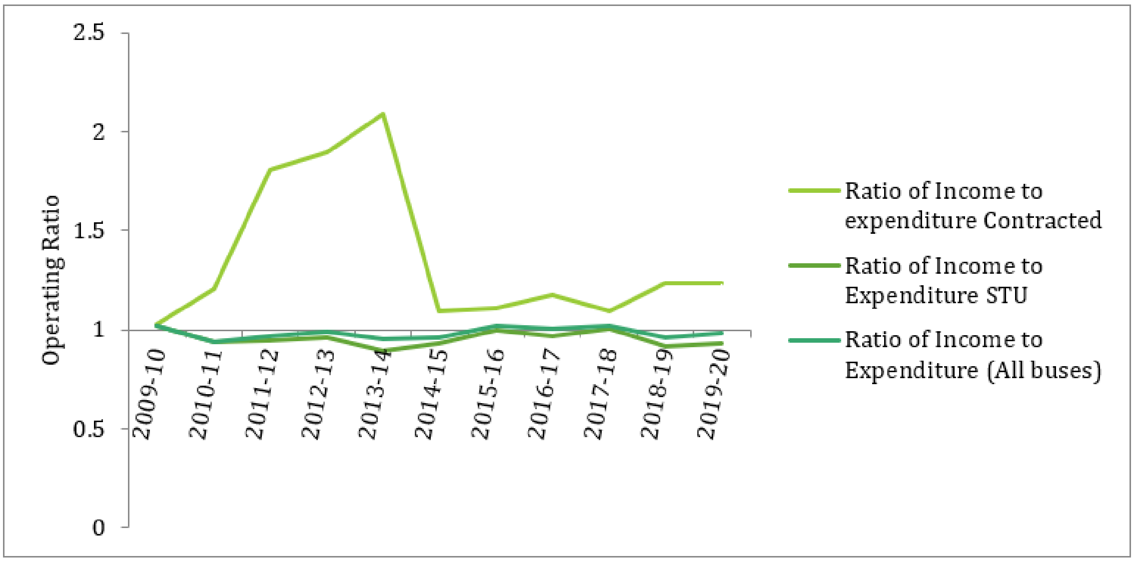

Figure 3 Operating Ratio trends of UTC's own and hired buses

Even though UTC made losses, their Operating Ratio (OR) (Ratio of income to cost) ranged between 0.92 to 0.95, indicating a relatively efficient financial performance. The OR was derived separately for owned and hired buses as presented in Figure 3. It was observed that the hired buses have better OR compared to the owned buses, possibly because they operate premium services that fetch better revenues.

UTC is primarily dependent on farebox revenues, which contribute 97% of its total earnings while the rest is contributed by commercial revenues and government support. UTC needs to consider alternate financing for expanding fleet capacity to meet the rapid growth in travel demand.

2.4 Conclusions from performance analysis

The overview of public transport in Uttarakhand and the review of UTCs performance analysis shows that the overall service levels of UTC stagnated at around 1,250-1,300 buses over the past decade, despite increasing population and economic activity. As a result, the bus services are unable to meet the increased travel demand effectively, as evident from the load factor of 73% against a commonly recommended load factor of 60%. However, within the available fleet, UTC is providing efficient services in terms of both operational and financial performance metrics. The vehicle productivity, load factor, and operating ratio are all indicating a well-run organization. The lack of financial support from the government to meet the gap between increasing costs and lack of revenue increase commensurate to cost increase has led to UTC making financial losses in recent years. UTC is taking up measures to reduce its staff cost through outsourcing crew recruitment. A transition to e-bus can reduce fuel costs as well as improve financial position.

In summary, UTCs performance analysis indicates the need to improve their overall service levels, the requirement of transition to e-buses, and a need for consistent government support to provide high-quality services.

03 Electric buses in Hilly Terrain: Learnings from Indian and International examples

3.1 Electric buses in India

India and other countries such as Columbia, Chile, and others in Europe are now inducting electric buses in large volumes intending to decarbonize their public transport services as well as benefit from the lower-energy costs of electric buses. E-buses are gaining increasing popularity in India through a combination of fiscal and regulatory incentives by the GoI, reducing the price of batteries and facilitating economies of scale. GoI has committed financial support of more than ₹54,000 crores (USD 6.8 billion) in the form of the Faster Adaption of Manufacturing of Electric Vehicles (FAME) (₹10,000 crores (USD 1.3 billion)) scheme for end-user incentives, Performance Linked Incentives (PLI) scheme for electric vehicle and component manufacturing (₹25,938 crores (USD 3.2 billion)) and Advanced Chemistry Cell (ACC) (₹18,100 crores (USD 2.3 billion)) manufacturing in India. Apart from these, reduced Goods and Services Tax (GST) on the purchase and contracting of electric vehicles, waiver on Motor Vehicle (MV) Tax, permit fees, and state-level subsidies have all contributed to reducing the price of e-buses in India.

As a result of these policy measures, in April 2022, the GoI concluded the largest global tender for an aggregated procurement of 5,450 electric buses to be deployed across five cities on a Gross Cost Contract (GCC) model. The tender has, for the first time in India, discovered 23-27% cheaper price per km for electric buses compared to their Internal Combustion Engine (ICE) counterparts, marking a key milestone in India's journey towards e-buses.

Therefore, electric buses now offer the benefit of lower costs in addition to their energy and emission efficiency benefits paving the way for their larger-scale induction in the future. As of June 2022, India is estimated to have about 2,000 operational electric buses while another 7,000 buses, including 4,051 buses under the aggregated procurement mentioned above, 2,100 buses contracted in Mumbai and several other independent procurements across India, are likely to be operationalized by the end of 2023.

Building on the success of the previous procurements, the GoI has now launched a National Electric Bus Program (NEBP) which aims to induct 50,000 new electric buses in the coming years. Simultaneously, GoI is providing incentives up to USD 5.5 billion for electric vehicles through PLIs for the manufacturing of electric vehicles, their components as well as ACC batteries. Together, these initiatives are likely to reduce the cost of electric buses significantly in the future and make them the primary technology choice for Road Transport Corporations (RTCs) across India. Therefore, UTC needs to plan for electric buses as their preferred technology choice to reduce their emission intensity as well as benefit from the energy efficiency of these buses.

3.2 Learnings from Indian e-bus operations in hilly terrains

Learnings from the current and past experience of e-bus operations in hilly terrain can provide valuable learnings while planning for future deployments. Uttarakhand has conducted trial runs for e-buses since 2018, while Himachal Pradesh, a state with similar topography and operational requirements has been operating e-buses since 2017. Data available from the operations of these two states is collected as input for the current study. While the data was not exhaustive, it still provides insights into a few key aspects of the e-bus operation.

3.2.1 E-bus trials in Uttarakhand, 2018

UTC conducted trials on two of its most popular routes: Dehradun-Mussorie and Haldwani-Nainital between October and December 2018, using buses from Olectra, one of the leading Original Equipment Manufacturers (OEMs) in India. These routes also represent the typical hilly terrain observed across the state. The Dehradun-Mussorie route was trialed in two phases in October and November of 2018 while the Haldwani-Nainital route trial was conducted in December 2018. Table 5 summarises the performance data from these trials.

Table 5 Performance of e-buses during trials in Uttarakhand, 2018

Attribute	Route under trial		
	Dehradun to Mussorie (Trial 1)	Dehradun to Mussorie (Trial 2)	Haldwani- Nainital
Period of trial operations	09-Oct-2018 to 04-Nov-2018	15-Nov-2018 to 27-Nov-2018	09-Dec-2018 to 31-Dec-2018
Route length	35 km	35 km	43 km
Operated kms	5,840	2,320	3,440
Electricity consumed (kWh)	4,909	1,926	3,576
Energy efficiency (kWh/km)	0.84	0.83	1.04
Income per Km	₹ 40.31	₹ 39.82	₹ 40.03
Staff and Electricity cost per km	₹ 12.88	₹ 14.57	₹ 19.08
Amount paid to OEM	₹ 27.43	₹ 25.25	₹ 20.95

The total electrical energy consumed during the entire trial phase was 10,410 kWh. To calculate the emissions associated with the said energy consumption we use the grid emissions factor. In 2018, India's grid emission factor was 0.705 kg-CO2/ kWh. However, as Uttarakhand has rich hydro resources, the grid emissions factor for the state is almost half of the national value i.e. 0.353 kg-CO2/ kWh. Using this grid emissions factor, the emissions calculated were around 3.68 t-CO2 eq. On the flip side, if these kilometers were catered by a diesel bus the emissions would have been around 19.43 t-CO2 eq. The emissions abated through this pilot implementation were around 15.74 t-CO2 eq.

3.2.2 E-bus deployment in Uttarakhand through the FAME scheme

Uttarakhand carried out two separate procurement exercises as a part of the FAME-II scheme in 2019. One of them was conducted by UTC which intended to procure 50 e-buses initially and reduced it later to 30 e-buses to be operated out of Dehradun and Nainital. The price discovered through the tender was ₹ 62.10 per km. UTC estimated that these buses would require a Viability

Gap Funding (VGF) of ₹ 12 per km to meet the revenue deficit, assuming a 20% increase in the fare and achieving 90% occupancy rates. At present due to funding issues, UTC is not going ahead with the electric bus project. The details of the GCC rate quoted by the bidder under FAME-II and the Viability Gap Funding (VGF) required are given in Table 6.

Table 6 FAME-II cost breakup

S.No	Parameter	Parameter value
1	Bus specification	9 meter, 36-seater, A.C
3	Ticket pricing	₹ 1.72/km
5	Income per Km (I.P.K) at 90% load factor	₹ 54.31/km
6	Conductor fees and other expense	₹ 8/km
7	Income after deducting expense	₹ 46.31/km
8	Price discovered during bidding	₹ 62.10/km
9	VGF required	₹ 15.79/km

E-bus deployed by Dehradun Smart City Ltd. (DSCL): DSCL procured and contracted 30 Air Conditioned (AC) e-buses through the FAME scheme, with depot infrastructure support provided by UTC for parking, charging, and maintenance of the buses. These buses were deployed for urban services within Dehradun between 2021 and 2022 with scheduled kilometers of 200 km per bus per day. The energy efficiency of these buses is reported to be around 0.8 kWh/ km during the winters and 0.9 kWh/ km during the summers, possibly due to the additional energy required for the AC.

The project team visited Dehradun Rural Depot (Figure 4) wherein the electric buses procured by DSC are operating. The e-buses are manufactured by Olectra and the chargers are provided by BYD with a rated output of 80 kW (2 guns, each delivering 40 kW) for a single unit of Electric Vehicle Supply Equipment (EVSE). The total number of such EVSEs installed is 14 chargers for 30 buses. BYD chargers can adjust the output power and current which will be useful for optimizing the charging pattern of the buses. However, the charging output can only be set through a manual process. The depot currently has a sanctioned load of 1.4 MVA and the chargers and workshop are being fed with a 1250 kVA independent feeder. Uttarakhand Power Co. Ltd (UPCL) indicated that a maximum of 3-3.5MVA of sanctioned load can be provided to the depot without any additional infrastructure requirements by the UPCL.

Figure 4: Electric Bus Operations by DSCL

3.2.3 E-bus experiences from Himachal Pradesh (HP)

Himachal Pradesh Road Transport Corporation (HRTC) has been among the pioneering states in deploying e-buses in India beginning with their initial deployment of 25 e-buses for commercial operations in November 2017. While the initial buses deployed were supplied by Olectra, the state has subsequently procured 50 e-buses from Foton-PMI in their second round of procurement. The operations of the 25 Olectra e-buses were reviewed for this study. These buses are 8.9m long and have a Gross Vehicle Weight (GVW) of 13,500 kgs with a seating capacity is 25 passengers and a rated battery capacity of 180 kWh. The buses were procured in an outright purchase model at a cost of ₹ 1.90 Cr at the time of procurement.

HRTC deployed the 25 e-buses across fourteen routes in Kullu (14 buses), Manali (5 buses), and Mandi (6 buses) regions. The route lengths varied between 11 and 70 km with an average of 20 stops per route. The energy efficiency of these buses was in the range of 0.86-0.91 kWh/km across routes. On average, 21 of the 25 buses were operational daily and they performed around 110 km of the 120 km scheduled to be operated per bus per day, while the remaining scheduled-km were canceled due to several reasons. These buses witnessed 10-12 breakdowns in a year. The average steering hours per bus per day was 15 hours while the buses spent the remaining 9 hours at the depot for overnight charging and maintenance.

For charging electric buses new line of 500 KVA was built in Kullu and 650 KVA in Manali. The cost of electricity is paid by HRTC. A total of 17 Alternating Current (AC) chargers were used for the 25 buses, with a capacity of 80 kW each provided by BYD.

3.2.4 Other key findings from Uttarakhand and Himachal Pradesh e-bus operations

Apart from the performance data presented in the previous sections, consultations with the e-bus operators in Uttarakhand and Himachal Pradesh provided the following key insights which can inform the future e-bus deployments in Uttarakhand and other Hilly States in India:

- **The functional specifications** for e-buses such as the range in a single charge, fleet availability, etc. need to match their ICE counterparts especially due to the hilly terrain where depot and charging infrastructure is available in fewer locations
- **The technical specifications** such as vehicle dimensions also need to be similar to ICE buses or better in the hilly terrain where the road characteristics are not identical to plain terrain. It was observed that aspects like the angle of approach and front overhang of some of the buses created operational challenges in rural and hilly areas with poor road conditions. The angle of approach is approximately 20 degrees for an ICE bus whereas for an electric bus it is around 8-10 degrees.
- Indian STUs suffer from a lack of **consistent financial support** from the state and municipal governments. It was observed across e-bus deployments that the lack of financial support combined with limited ticketing revenue was impeding timely contractual payments to the operators and was a key impediment to their plans to procure new e-bus fleets.

3.3 Learnings from International examples of e-buses in Hilly terrains

Indian experience of deployment of e-buses, in hilly terrains as encountered in Uttarakhand, is limited to the state of Himachal Pradesh and the initial deployments carried out in Uttrakhand, at the time of conducting this study. Therefore, we collected quantitative data as well as conducted interviews with the key stakeholders managing their operations to understand the key learnings on e-bus operations in hilly terrains to derive key learnings for Uttarakhand. Additionally, a total of 12 International cases with e-buses in Hilly terrain were reviewed for their technical specifications and operations performance. A detailed questionnaire-based interview covering infrastructure, operations, and funding aspects of e-buses was conducted to derive the key lessons applicable for Uttarakhand".

Overall, it was observed that it is feasible to operate e-buses across several hilly terrains and high-altitude locations in Asia, Europe, and Latin America including Lhasa in Tibet, China which is one of the highest altitude locations across the world. While the technical and functional requirements vary contextually, some of the factors affecting the success of the project are common across regions. The following are the key learnings from the data collected and the interviews:

1. **Technical specifications** of the e-bus systems varied widely between cities. These include aspects like battery capacity, type of battery (Lithium-Iron-Phosphate (LFP)/ Nickel-Manganese-Cobalt (NMC)), charger capacity, charger technology (pantograph based vs plug-in charging), type of charging (overnight Vs opportunity charging during the day), location of charging, etc. are significantly different between cities.

2. **Functional requirements** of e-buses in hilly terrains such as the daily km operated, whether the buses operating are depot or route specific, e-buses allocated per route, whether it is a pilot or large scale operations also varied significantly between cities.

3. **Matching technical and functional specifications:** Bus and charging technology readiness to meet local operational requirements is quite crucial and adequate planning towards ensuring that needs to be carried out at the time of procurement.

4. **Power supply:** One of the most important factors affecting the deployment of electric buses is the availability of power infrastructure in proximity to the charging locations as well as the availability of quality power.

5. **Financial readiness assessment:** Bus agencies procuring e-buses need to carry out a Total Cost of Ownership (TCO) analysis which covers the lifecycle costs of implementing e-buses including capital costs on buses and infrastructure, operational costs on staff, electricity, and other variable expenses. Comparing the TCO of e-buses with Internal Combustion Engine (ICE) alternatives like diesel and CNG buses will allow for comparing the overall cost to the agency while moving from low capital and high operational cost ICE buses to high capital and low operations cost e-buses. This will allow them to make an informed technology choice.

6. **Business models:** Cities adopted alternative business models such as outright purchase, Gross Cost Contract (GCC), and leasing models to induct buses. A context-specific choice based on local market conditions would be needed at the time of procurement. The TCO analysis mentioned above needs to be customized for alternative business models to understand the relative financial implication of each of the models to allow for an informed choice.

04 Roadmap for electric bus deployment in Uttarakhand

The ICE buses currently operated by UTC will gradually be phased out as they reach their end of life. Additionally, UTC will need to increase its fleet size to meet the currently unmet public transport demand. Therefore, a phase-wise transition plan to induct electric buses for ICE fleet replacement and service augmentation is required. This chapter presents the long-term fleet needs assessment of UTC, a comparative Total Cost of Ownership (TCO) analysis of electric and diesel buses and uses the results to understand the financial implications of the proposed long-term fleet needs assessment.

4.1 Total Cost of Ownership (TCO) of electric buses compared to diesel buses

Diesel, CNG, and e-buses are the key technology options for STUs to meet the projected fleet needs. The choice between these technologies can be made objectively using TCO models that incorporate various capital and operational costs to be incurred throughout the life of the bus. By taking the lifecycle cost approach for evaluation, TCO models help address the fundamental differences in cost structure between e-buses and other buses—e-buses are more capital-intensive but have lower operational costs than diesel/CNG buses. The TCO estimation at the bus level is carried out to compare the per-km costs of diesel vs electric buses, as well as the fleet-level estimates to determine the overall financial requirements at the state level.

The total cost of owning and operating an e-bus for public transport applications depends on the technical and operational aspects, as well as the financial conditions associated with the business models available for the tendering of the service. One such TCO model is used here, developed by the International Council on Clean Transportation (ICCT) with inputs from UITP India to assess the TCO of electric and diesel buses taking the case study of Karnataka. A typical e-bus with a battery capacity of 320 kilowatt-hours (kWh), which has previously been deployed in intercity operations in India, is assumed as the technology choice. The model incorporates the replacement ratio (RR) of e-buses needed to meet the current diesel bus operational requirements into the TCO, i.e. the number of e-buses needed to serve the current number of trips served by diesel buses, and the cost associated with it.

The cost component categories of the TCO model are:

Capital costs: Bus, battery, and charging infrastructure costs

Financing costs: Interest payments over the loan period

Operational costs: These include energy/fuel costs, crew costs, insurance costs on buses where applicable, and other operations & maintenance (O&M) costs (including administrative costs).

The bus-level TCO estimate has been undertaken for diesel buses and e-buses for alternative business models for the case of a 12m AC bus and a 9m non-AC bus, which comprise the majority of the public bus fleet in Uttarakhand. The base-case TCO was estimated for the case of the STU owning and operating a diesel bus and is compared with the TCO of an e-bus under two business models: in-house operations and Gross Cost Contract (GCC). In GCC-based operations, the capital, operations, and maintenance expenditure on the bus, battery, and charger, including the provision of a driver, is taken up by the contracted operator. Across business models, STUs are in charge of revenue collection, upstream electrical infrastructure, and depot provision. The taxes and overhead expenses are considered to be similar across business models, as they are the responsibility of the STU irrespective of the business model.

4.1.1 Assumptions for TCO analysis

Table 7 presents the key assumptions for diesel buses and e-buses that are common across business models, while Table 8 presents business model-specific assumptions. The assumptions for STU-specific variables are based on data from UTC for December 2019, while the remaining assumptions are based on market consultations by UITP India. The technology risks related to the bus, battery, and charger are assumed to be covered by the OEM across business models, through warranties and contractual specifications. The key variables that vary between business models are the financing terms and staff costs.

Financing terms: It is assumed that STUs, with the support of their respective government, would be able to attract better financing terms like interest rates and debt share of total investment, while private operators would get less favourable terms due to the commercial nature of their operations. The fleet-level financial analysis presents more detailed analysis of the impact of these financing terms on the overall project cost.

Staff costs: Staff costs are another key difference between STUs and private operators; private operators have lower staff costs, as well as lower annual growth rates in salaries, compared to STUs, as observed from prevailing market practices. The conductor cost remains the same across business models, as revenue collection is the STU's responsibility.

Table 7 Key assumptions for bus-level TCO analysis

Variable for TCO estimation	Diesel BSVI, 12m, AC	BEB, 12m, AC	Diesel BSVI, 9m, Non-AC	BEB, 9m, Non-AC
Bus life (in years)	12	12	12	12
Vehicle utilisation (km/bus/day)	300	300	300	300
Annual operating days	350	350	350	350
Annual vehicle-km per bus	1,05,000	1,05,000	1,05,000	1,05,000
Total cost of bus (w-battery) (in INR)	35,00,000	1,20,00,000	32,00,000	90,00,000
Cost of bus (ex-battery) (in INR)	NA	1,11,60,000	NA	68,40,000
Cost of battery (in INR)	NA	38,40,000	NA	21,60,000
Capex cost of battery/kWh (in INR)	NA	12,000	NA	12,000
Annual decrease in battery cost	NA	5%	NA	5%
Capex cost of charger (in INR)	NA	18,00,000	NA	18,00,000
GST payable on purchase of bus and battery	18%	5%	18%	5%
GST payable on purchase of charging infrastructure	NA	18%	NA	18%

Variable for TCO estimation	Diesel BSVI, 12m, AC	BEB, 12m, AC	Diesel BSVI, 9m, Non-AC	BEB, 9m, Non-AC
Energy cost (diesel price (INR/L) or electricity price (INR/kWh))	80	5	80	5
Electricity price annual growth rate (%/yr)	5%	5%	5%	5%
Energy efficiency ((km/L) or (kWh/km))	4	0.93	4	0.93
Applicable subsidy on capex	0	0	0	0
End of life salvage value of e-bus as % of original cost	0%	0%	0%	0%
Vehicle maintenance cost/km	8	7	3	3
Charging infrastructure maintenance cost (INR/DLE)	0	1	0	1
Other administration costs per km	4.4	4.4	4.4	4.4
Annual change in other operations costs/year	5%	5%	5%	5%
Conductor costs (INR/km)	3.6	3.6	3.6	3.6
Conductor cost annual growth rate (%/yr)	10.00%	10.00%	10.00%	10.00%
Years for battery replacement	NA	6	NA	6
Type of charger	NA	Fast (260 kW)	NA	Fast (260 kW)
Charging infra life (years)	NA	20	NA	20
Rated battery capacity (kWh)	NA	320	NA	180
Effective e-bus/ICE bus to be replaced ratio	NA	1	NA	1
Cost of depot infrastructure per bus for STU (civil and upstream electrical infrastructure)	NA	INR 5 lakhs per bus	NA	INR 5 lakhs per bus

Table 8 Business model-specific TCO assumptions

Variable for TCO estimation	Diesel STU in-house operations	Electric STU in-house operations	GCC
Driver costs (INR/km)	8	8	5
Driver cost annual growth rate (%/yr)	10%	10%	6%
Debt share for capex on e-bus ex-battery	95%	95%	90%
Debt share for capex on battery	95%	95%	100%
Debt share for capex on charging infra	100%	100%	100%
Debt share for capex on ICE bus	95%	95%	90%
Interest rate on loan against bus, battery, charging infra	9%	9%	10%
Tenure for all loans (yrs)	6	6	6

4.1.2 Results of TCO analysis for alternative vehicle types and business models

Table 9 presents the per-km TCO results for the 12m AC buses while Table 10 presents the per-km TCO results for 9m non-AC buses. It was observed that in both cases the TCO of e-buses is lower than diesel buses even for the use case of 300 km per bus per day. Despite e-buses having higher capital costs on buses, batteries, and the charging infrastructure, the TCO reduction observed is primarily driven by the fuel/ energy cost efficiency of e-buses. These savings would increase with an increase in daily km operated. As mentioned in Chapter 2, the average daily utilization of UTC buses is 343 km per bus per day, which would lead to a more favorable result for the e-bus transition.

Table 9 Per-km TCO of 12m AC diesel and electric buses (300 km per bus per day)

Cost Item	TCO per km (in INR)			TCO per km (in %)		
	Diesel (BS-VI) In-house	E-bus In-house	E-bus GCC	Diesel (BS-VI) In-house	E-bus In-house	E-bus GCC
Bus	6.4	11.4	12.0	9%	17%	17%
Battery	0	5.2	5.2	0%	7%	7%
Charging Infrastructure	0	0.6	0.6	0%	1%	1%
Total Interest	2.6	6.1	6.8	4%	9%	10%
Insurance	0.0	0.0	2.4	0%	0%	3%
Crew	23.6	23.6	21.3	32%	34%	30%
Fuel/ Energy	26.5	8.4	8.4	36%	12%	12%
Maintenance & Administration	13.8	13.8	13.8	19%	20%	20%
Total	73.0	69.1	70.5	100%	100%	100%

Table 10 Per-km TCO of 9m Non-AC diesel and electric buses (300 km per bus per day)

Cost Item	TCO per km (in INR)			TCO per km (in %)		
	Diesel (BS-VI) In-house	E-bus In-house	E-bus GCC	Diesel (BS-VI) In-house	E-bus In-house	E-bus GCC
Bus	2.0	4.8	5.1	4%	11%	11%
Battery	0.0	2.9	2.9	0%	6%	7%
Charging Infrastructure	0.0	0.6	0.6	0%	1%	1%
Total Interest	0.8	3.0	3.3	1%	7%	7%
Insurance	0.0	0.0	1.1	0%	0%	2%
Crew	19.4	19.4	17.0	34%	43%	38%
Fuel/ Energy	26.5	4.8	4.8	46%	11%	11%
Maintenance & Administration	8.8	9.8	9.8	15%	22%	22%
Total	57.6	45.3	44.6	100%	100%	100%

Within the e-buses though, the relative TCO results of alternative business models vary for 12m and 9m buses. In the case of 12m AC buses, in-house operations were observed to have a lower TCO compared to GCC operations, while in the case of 9m Non-AC buses, GCC operations were observed to be cheaper. Typically, GCC operations are observed to be cheaper than in-house operations across vehicle types because of the lower staff cost of private operators. However, UTC already deploys contractually hired staff as drivers, thereby reducing staff costs substantially, making further savings through GCC only marginal. At the same time, the cheaper cost of finance on the higher cost 12m AC bus leads to lower TCO for in-house operations. In the case of 9m Non-AC buses, the cost of the bus and its finance is lower, therefore, leading to the marginal staff cost reduction through GCC still resulting in a lower TCO.

In summary, the favorable TCO of e-buses compared to diesel buses highlights the need for UTC to take an e-bus-first approach for their future procurements, with adequate analysis of the technological and business model feasibility for the selected routes for deployment.

4.2 Approach for fleet and financial planning

The fleet demand estimation planning is done for UTC for the year 2022-2032. In this planning process, the UTC bus services parameters from the year 2019-20 and fleet size from 2021-22 are considered. UTC has a fleet size of 1354 buses including hired buses. The objectives of preparing the fleet-wide strategy are the following:

a. Fleet demand estimation and planning of electric buses into the fleet: The demand is estimated based on an increase in demand coupled with UTC vision and staggered induction of electric buses is planned up to the horizon year 2032.

b. Infrastructural needs: The presently available resources will not be sufficient to meet the demand in the future. It is pertinent to estimate the infrastructure need and upgradation e.g., bus stop, depot, etc. considering the increase in fleet size to cater to the ridership demand with an improved level of service.

c. Estimating investment outlay**:** It is reasonable to estimate fleet-level future investment needs for transitioning to electric fleets including estimation of capital cost requirements for the purchase of electric buses or procuring electric bus services, supporting infrastructure, etc. Based on the current financial overview of UTC, the viability gap funding for operational and capital needs is estimated.

4.3 Long-Term Fleet Planning for UTC

The long-term fleet needs assessment for UTC has been developed assuming 2033 as the horizon year, i.e., one decade from the year of acceptance of this roadmap. The fleet needs assessment is carried out such that UTC meets the objective of improving service levels to address current backlogs and meet future needs. A 4% annual growth in ridership is identified as the target to achieve this objective based on consultations with UTC and ridership scenario analysis. Therefore, Scenario 1 for 2032 estimates the fleet needs of UTC to achieve a 4% CAGR in ridership. Additionally, the estimated 3,000 private buses operating under the Garhwal Motor Union Pvt. Ltd. would find it difficult to transition to e-buses without government support. Therefore, an alternative Scenario 2, wherein the government of Uttarakhand, either through UTC or through alternative mechanisms procures e-buses to enable a clean technology transition for the 3,000 private buses is also analyzed.

The age profile of the existing UTC fleet is used to estimate the fleet replacement timeline and is combined with the fleet augmentation needs to meet the targeted increase in ridership in each scenario to estimate the fleet to be procured in each year until 2033. Given the favorable TCO of e-buses, as explained above, it is assumed that all the new fleets would be e-buses. While acknowledging that e-buses may not be technologically ready to replace all UTC routes immediately, it is assumed that the technology would evolve in the coming years to meet operational needs. Based on these assumptions, Table 11 presents the annual fleet to be procured and the share of the total fleet electrified in each year is presented for Scenario 1 and Scenario 2.

Table 11 Uttarakhand bus fleet targets for alternative service improvement scenarios

Scenario	Scenario 1: Incremental Growth			Scenario 2: Growth including private buses		
Year	Fleet Target	E-buses procured in the year	E-bus as % of total fleet	Fleet Target	E-buses procured in the year	E-bus as % of total fleet
2023	1,434	87	6%	1,434	87	6%
2024	1,498	94	12%	1,648	244	20%
2025	1,566	168	22%	1,866	318	35%
2026	1,636	80	26%	2,086	230	42%
2027	1,709	138	33%	2,309	288	51%
2028	1,785	551	63%	2,535	701	74%
2029	1,865	84	64%	2,765	234	76%
2030	1,949	86	66%	2,999	236	78%
2031	2,036	164	71%	3,236	314	82%
2032	2,127	309	83%	3,477	459	89%
2033	2,222	100	84%	3,722	250	90%

4.4 Financial planning to meet long-term fleet needs targets

The financial modeling for this fleet was carried out under four alternative scenarios of procurement, i.e. combinations of outright purchase and GCC models for diesel (BS VI (Euro VI equivalent)) and electric buses. The per-km TCO was converted into fleet-level TCO estimates to meet the fleet growth needs mentioned above. A spreadsheet-based financial model was developed by UITP India in partnership with EcoForge Advisors Pvt Ltd. The TCO for the 9m Non-AC bus was used as a fleet-wide average TCO to demonstrate the results of the model. These can be altered for alternative fleet mix scenarios as desired by UTC.

The model considers inputs for two business models for bus procurement—outright purchase and GCC—, including the operational and financial estimates for each of the models to estimate the fleet-level financials such as income statement, cash flow statement, TCO, and other key metrics such as earnings before interest, taxes, depreciation, and amortization (EBITDA), debt service coverage ratio (DSCR), etc., which are crucial for financial assessment of the project. Based on these, the debt schedule for the STU, as well as other key financials, are derived. The model also provides outputs on the viability gap funding (VGF) needed by UTC in each scenario based on the assumption that the revenue patterns observed over the past few years continue over the next decade.

Table 12 presents the key outputs derived from the financial model for the two fleet growth scenarios. It is estimated that Scenario 1 would require a government investment of INR 7,478 Cr over the next decade in case they adopt in-house-based operations for e-buses and INR 2,140 Cr in case they adopt a GCC-based strategy. Scenario 2 which includes the private buses into UTC would require a higher investment compared to Scenario 1, with INR 12,538 Cr as the estimated VGF over the next decade for the in-house operations scenario and INR 3,453 Cr of VGF in the GCC scenario.

The per-km TCO of buses presented in section 4.1 shows the capital-intensive nature of e-buses; about 18-19% of the total costs are related to the capital expenditure on buses and their charging infrastructure and the associated financing costs. Therefore, reducing the TCO of e-buses and making them more attractive to STUs requires decreasing their capital costs. Government

Uttarakhand is urged to build in necessary mechanisms such as loan guarantees and payment guarantees to encourage financial institutions to invest in e-buses with favorable financing terms, thereby reducing the TCO significantly.

Table 12 Summary of Fleet-level TCO between 2022 and 2030 for the three STUs in Uttarakhand

Financial Metric	Scenario 1 BAU		Scenario 2 VB	
	EV purchase	EV on GCC	EV purchase	EV on GCC
Total current fleet size	1354	1354	1354	1354
Total number of new buses to be procured until 2032	1861	1861	3361	3361
Present Value (PV) of Capital Expenditure TCO	1,292	485	2,570	1,232
PV of Opex TCO	3,608	1,581	5,353	2,363
PV of Financing Costs TCO	652	-	1,097	-
Total TCO	5,553	2,066	9,020	3,594
VGF needed until 2033	7,478	2,140	12,538	3,453

05 Operations assessment and technical specifications for e-buses

Chapter 4 discusses the relative TCO of diesel and e-buses assuming average operating conditions of 300 km per bus per day. However, as established in Chapter 2, UTC has a wide range of vehicle utilization for various routes and service types within its operation. These routes may require a higher or lower range offered by the e-bus, compared to the average bus assumed for TCO analysis, to meet their operational requirements. Routes with the higher required range as compared to the maximum offered range by buses will require opportunity charging during the day, which will require additional infrastructure as well as time away from serving the passengers, posing additional constraints to the operators. In some cases, this may require additional buses to be deployed to meet the operational needs within available technologies, thereby increasing the TCO of e-buses significantly. Therefore, suitable depot and route selection are crucial for the cost-effective and efficient deployment of e-buses. Conversely, the selection of appropriate technical specifications to meet the priority routes to be electrified plays a key role in optimizing the TCO for the route.

In the case of UTC, the priority routes have already been identified and hence this study focused on analyzing the operational needs of these routes and their prioritization. The 'Chardham yatra' connecting the four popular pilgrim centers of Uttarakhand i.e., Yamunotri, Gangotri, Kedarnath, and Badrinath is a priority for UTC. The GoI is upgrading the highway connectivity at these locations, which will ensure high-quality operating conditions for buses as well in the near future. UTC intends to capitalize on this and attract more tourists to their services using e-buses. Additionally, Dehradun and Kathgodam depots are selected as priority locations for e-bus deployment. Therefore, the routes operating from these depots have also been analyzed.

Subsequently, the electric bus specifications available in the Indian market at the time of carrying out this study that can meet the operating requirements of depots and routes selected are presented. UTC can use this to specify the most suitable technology specifications at the time of procuring these buses.

5.1 CHARDHAM YATRA- Route Feasibility

The four pilgrim centers that comprise the Chardham yatra are Kedarnath, Badrinath, Yamunotri, and Gangotri. Yamunotri and Gangotri are situated in Uttarkashi district, Kedarnath is situated in Rudraprayag district and Badrinath is situated in Chamoli district. The tourist season for these locations starts in May and ends in November. Currently, the government of Uttarakhand organizes public transport on these routes using UTC buses as well as private operators hired for the tourist season. While Haridwar is the traditional point for pilgrims to start their Chardham Yatra, bus services typically start from Rishikesh to all four centers separately. A detailed trip-wise analysis of the routes was analyzed as a part of this study to identify the potential depots, charging needs, locations for overnight and opportunity charging as well as the time needed to charge and operate these routes. The analysis was carried out for the currently operating 9m buses as well as 12m buses which are likely to be more popular once the current highway work in the region is complete. Table 13 provides a summary of the findings from the route-wise analysis. 12m buses are more suited to these locations compared to 9m buses given the larger battery availability and therefore the limited need for opportunity charging in such a constrained terrain.

Table 13 Chardham route analysis

S.No	Route	Route length (km)	Potential e-bus depots for the route	Potential opportunity charge locations
1	Rishikesh-Kedarnath	210	Rishikesh, Srinagar	Gaurikund/ Sonprayag
2	Rishikesh-Badrinath	300	Rishikesh, Srinagar	Joshimath bus station
3	Kotdwar-Badrinath	330	Kotdwar, Srinagar	Joshimath bus station
4	Rishikesh-Yamunotri	247	Rishikesh, Dharasu	To be developed at terminals
5	Rishikesh-Gangotri	270	Rishikesh, Dharasu	To be developed at terminals

5.2 Depot wise - Route analysis summary

The e-bus feasibility based on operational needs, commercially available vehicle models, and charging time available is analyzed for the case of six of the UTC depots. Table 14 presents the results from these analyses, segregating the analyzed depots into 'limited' implying that only limited routes are expected to be immediately operationally feasible while 'Good' indicates the presence of several routes within the range offered by the commercially available e-buses in the Indian market. It was observed that the Dehradun-Hill operations, Kathgodam urban, and the Haridwar depots are best placed to receive their awards.

Table 14 UTC depot-wise prioritisation based on e-bus feasibility

S. No.	Name of the depot	Route feasibility for commercially available e-buses
1	Dehradun-Rural Depot	Limited
2	Dehradun-Hill Depot	Good
3	Kathgodam Rural	Limited
4	Kathgodam Urban	Good
5	Haridwar Depot	Good
6	Rishikesh Depot	Limited

5.3 Electric bus specifications- Availability in Indian Market

India has more than six OEMs offering a wide range of e-bus products in the market. The vehicle specifications of each of the OEMs offering e-buses in India are compared to summarise the specifications needed to meet UTC requirements as summarised in Table 15. Out of all the specifications available, the following features are key for the city to decide -

5.3.1 Bus length

The bus length and wheelbase are used interchangeably. Although the STUs classify the bus length based on wheelbase. The addition of the front overhang and rear overhang to the wheelbase will give bus length. However, not many options are available for electric buses in comparison to their ICE counterparts. At present, the available model comes in 7 meters, 9 meters, and 12 meters. However, most of the OEMs provide 9 meters i.e., 9000 mm, and 12 meters i.e., 12000 mm. As per ARAI electric bus technical specifications, the recommended length for the midi bus is greater than 7000 mm and lesser than 9400 mm whereas for standard buses it should be 12000mm.[4]

5.3.2 Seating capacity and Layout

The seating capacity as per ARAI is from 23 to 34 excluding the driver seat for the midi bus while for the standard bus it should be greater than 35**.** As per AIS O52: Code of practice for bus body design and approval [5], the seating layout is 2x2 for the midi bus. The seating layout for standard buses depends on the combination of the type of bus and service type. There are four types of bus and are explained below:

1. Type 1: Medium vehicles designed and constructed for urban/ sub-urban/ city transport.
2. Type 2: Designed for inter-urban/ inter-city transport without specified area for standing
3. Type 3: Designed for long-distance passenger transport
4. Type 4: Designed for special purpose use such as school bus, sleeper coach, etc.

5.3.3 Floor height

The height of the floor measured relative to the ground with the vehicle unladen is known as floor height. Based on floor height, buses are classified as low-floor buses and high-floor buses. As per AIS-052, a low-floor vehicle is defined as a vehicle in which at least 35% of the area available for standing passengers forms a single area without steps, reached through at least one service door by a single step from the ground.

As per ARAI, the proposed floor height for the midi bus can be 650mm/ 900mm while for standard buses the floor height can be 400mm/ 650mm/ 900mm. Most of the OEMs are providing 900mm floor height for the midi bus with a few of them having both 650mm as well 900mm. In the case of standard buses, the available models have 400mm and 900mm floor heights.

5.3.4 Battery capacity

There are no standard battery capacity specifications proposed for midi buses and standard buses. The battery capacity can be scaled up as per STU requirements. At present, the battery capacity for a 9m bus varies between 150 kWh and 240 kWh. For a 12m bus, it varies from 150 kWh to 350 kWh and can be further scaled up. Nearly every STUs have decided not to mention the battery capacity in the Request for Proposals (RFP) but it should match the vehicle utilization on a single charge.

5.3.5 Battery Type

The battery type means battery chemistry used in the electric buses for driving the powertrain. The ARAI proposes Li-ion as a type of rechargeable electrical energy storage system (REESS). In

4 ARAI Electric bus technical specifications proposal_Annexure I.
5 https://www.araiindia.com/cpanel/Files/PUB_10~4~2011~10~12~04~AM~AIS-052_Rev_1_and_Amd_1.pdf

addition to it, a few of the RFP from FAME-II tenders were referred to understand the perspective of the public transport provider[6]. The observations are mentioned below:

1. Brihanmumbai Electric Supply and Transport Undertaking (BEST): Li-ion/ Li-ion Phosphate/ Li-ion NMC (Nickel Manganese Cobalt)
2. Delhi Transport Corporation (DTC): Lithium polymer, Lithium Iron Phosphate, Lithium Cobalt Oxide, Lithium Titanate, Lithium Nickel Manganese, etc.
3. Bangalore Metropolitan Transport Corporation (BMTC): Li-ion/ Li-ion Phosphate/ Li-NMC or superior
4. Pune Mahanagar Parivahan Mahamandal Limited (PMPML): Li-ion/ Li-ion Phosphate/ Li-NMC or superior

The OEMs provide either Li-ion phosphate or Li-ion NMC in their electric bus models.

5.3.6 Battery mounting

The battery can be placed either at the top of the bus i.e., rooftop, or below the floor. The battery placement varies from OEM to OEM as some have the battery mounted at the top while others provide it below the floor. For battery placement, there is no standard space in terms of location.

5.3.7 Mode of charging

The mode of charging refers to the slow charging, fast charging, flash charging, and battery swapping facility for the electric bus model. The availability of all types of battery charging or a combination of any two gives flexibility to the operator for the bus operations. The availability of both fast charging as well as slow charging can lead to a combination of depot charging and opportunity charging to have the desired vehicle utilization in a day with lesser battery capacity. The larger battery size will increase the gross vehicle weight leading to a decrease in energy efficiency and an increase in bus cost. The battery swapping facilities in addition to slow and fast charging was available for one OEM while other OEMs have only slow and fast charging modes.

5.3.7.1 Time of Charging

The time to charge an electric bus is important as the majority of STUs have bus operations varying from 16 hours to 20 hours a day. The time to charge especially, the time to fast charge the bus becomes important for inter-city and inter-state bus operations. As per ARAI, the time for slow charging should not be more than 6 hours whereas the time for fast charging should be less than 2 hours. Even for current electric bus models, the slow charging time is within 6 hours whereas the fast charging time is within 2 hours. The minimum time required for fast charging of selected electric bus models is within 1 hour.

5.3.7.2 Charging Cycles

The charging cycles denote the battery life i.e. the number of times the charge of a battery can be replenished fully. As per ARAI recommendations, it is defined as 6 years for both the midi bus and standard buses. However, it is more appropriate to define the battery life in terms of the number of charging cycles. The minimum charging cycles assured by OEM is 2500 which can translate to approximately 7 years considering 350 operational days with one charging per operational day. The maximum charging cycles assured is around 8000.

6 RFP & MCA of BEST, DTC, BMTC and PMPML

5.3.7.3 Operating range

The range as per ARAI proposed specifications is a minimum of 150 km in a single charge for air-conditioned (A.C) midi as well as standard buses. The range for Non-A.C. buses is 200 km and 225 km respectively for midi and standard buses.

However, the range requirement is specific to the STUs deploying them. The vehicle utilization and time for opportunity charging determine the range requirement. Based on the analysis of RFP floated under FAME-II, the range requirement varies from 120 km to 300 km[7]. Most of the OEMs are providing e-buses with a range of around 200 km for both the midi as well as standard buses.

5.4 Checklist for electric bus selection

To plan the electric bus rollout effectively and efficiently in the future, the selection of a suitable electric bus model becomes imperative. Therefore the wheelbase data provided by UTC is used to segregate the fleet and is mapped against various vehicle specifications along with the names of OEMs offering these products in Table 15, Table 16, and Table 17. These tables provide a ready reference for UTC to identify the specifications that suit their operating requirements as well as the OEM offering these products for easy reference.

7 UITP report on Electric bus procurement under FAME-II

Table 15 UTC Bus Specification Framework Part1

Wheelbase (mm)	Number of buses currently	Length of the bus			Air Conditioning		Floor Height			Maximum speed	Seating capacity			
		≤ 7	>7 m & ≤ 9 m	12 metres	Yes	No*	400mm	650mm	900mm	≥ 70 km/hr	≤ 30	31-35	36-50	>50
3810	6		✓ Recommended length 9 m.			✓	✓	✓	✓	✓	✓	✓	✓	
4216	414		✓			✓		✓	✓	✓		✓		
5156	18		✓			✓		✓	✓	✓		✓		
5207	206			✓	✓	✓	✓	✓	✓	✓			✓	
5334	272			✓	✓	✓	✓	✓	✓	✓			✓	
5537	113			✓	✓	✓	✓	✓	✓	✓				✓
	OEM with same features		TATA, Olectra, JBM, Ashok Leyland, Foton PMI, Edison Electra	TATA, Ashok Leyland, Olectra, Foton PMI, Axis Mobility, Edison Electra, AMS E-mobility	TATA, Olectra, JBM, Ashok Leyland, Foton PMI, Edison Electra, AMS E-mobility		TATA, Olectra, Photon PMI,	TATA, Olectra, Foton PMI, Edison Electra	TATA, JBM, Ashok Leyland, Foton PMI, VECV	Olectra= 70 kmph, TATA= JBM= 75 kmph	Foton PMI	Tata, Ashok Leyland, Olectra, VECV, Edison Electra	TATA, Ashok Leyland, Olectra, Edison Electra	M/s Elpro

Table 16 UTC Bus Specifications Part 2

Wheelbase (mm)	Number of buses currently	Seating layout		Grade ability	Frame		Angle of approach		Battery range (kms)		
Wheelbase (mm)	Number	2X2	2x3	17°	Monocoque	Chassis Frame	≥8-10° ≤	>10°	> 250 ≤	>250-300≤	>300
3810	6	✓		✓	✓			✓	✓	✓	
4216	414	✓		✓	✓			✓	✓	✓	
5156	18	✓		✓	✓			✓	✓	✓	
5207	206	✓		✓	✓	✓	✓	✓	✓	✓	
5334	272	✓		✓	✓	✓	✓	✓			✓
5537	113		✓	✓	✓	✓	✓	✓			✓
				✓	✓	✓	✓	✓			✓
	OEM with same features	TATA, Olectra, JBM, Ashok Leyland, Foton PMI, Edison Electra, AMS E-mobility		Tata	Edison Electra, JBM, Olectra, AMS E-moblility	Tata, Ashok Leyland	OEM details not available with exact angle of approach		Edison Electra (9m & 12m), Ashok Leyland (9m & 12m), TATA (9m), Olectra (9m & 12m), AMS (12m)	Edison Electra (9m & 12m), Ashok Leyland (9m & 12m), Olectra (9m), M/s Elpro	Olectra (9m), M/s Elpro

Table 17 UTC Bus Specifications Part3

		Battery life (years)		Location of battery		Type of charging		AMC
Wheelbase (mm)	Number	5	> 5	Below floor	Roof top	Slow/ Fast	Swapping	Yes
3810	6	✓	✓	✓		✓	✓	✓
4216	414	✓	✓	✓		✓	✓	✓
5156	18	✓	✓	✓		✓	✓	✓
5207	206	✓	✓	✓		✓	✓	✓
5334	272	✓	✓	✓		✓	✓	✓
5537	113	✓	✓	✓		✓	✓	✓
		✓	✓	✓		✓	✓	✓
	OEM with same features	JBM, Ashok Leyland, Tata	Edison Electra, Olectra Greentech, M/s Elpro	Olectra, JBM, Ashok Leyland, Foton PMI, Edison Electra, AMS E-mobility	Tata	TATA, Olectra, JBM, Ashok Leyland, Foton PMI, Edison Electra, AMS E-mobility	Ashok Leyland	TATA, Olectra, JBM, Ashok Leyland, Foton PMI, Edison Electra, AMS E-mobility

06 Power infrastructure assessment for electric buses

6.1 Overview of Uttarakhand Power

Uttarakhand Power Corporation Limited (UPCL) is the entity responsible for the distribution of power in the state of Uttarakhand. It supplies electricity to over 25 lakh customers across the state and is the sole distribution licensee of the state. A summary of UPCL data is given in Table 18.

Table 18 UPCL numbers at glance

S. No.	Particulars	Unit	As on 31-March-2021
1	Electricity Consumers	lac	26.11
2	Contracted Load	MW	7205
3	Turnover (2020-21)	Rs. Cr.	6454
4	AT&C Losses	%	15.25
5	33/11 kV Sub-stations	Nos.	357
6	Capacity of 33/11 kV Sub-stations	MVA	4906
7	33 kV Line	Km.	5577
8	11 kV Line	Km.	44359
9	LT Line	Km.	68032
10	11/0.4 kV DTRs	Nos.	78579
11	Capacity of 11/0.4 kV DTRs	MVA	5037

The Uttarakhand Electricity Regulatory Commission (UERC) had approved the total power purchase cost of ₹ 5465 Crores for UPCL for FY 20-21. This expense is inclusive of the Inter-State Transmission charges and Intra-State and State Load Despatch Centre (SLDC) charges. The UPCL buys its power from multiple sources and a brief generation mix[8] for FY 20-21 is shown below:

Table 19 UPCL Power Procurement for FY 2021-22

Organization	Type	Energy (MU)
UJVN	Hydro	4034.5
NHPC	Hydro	880.9
THDC	Hydro	677.58
NTPC	Thermal	2879.62
SJVN	Hydro	293.81
NPCIL	Nuclear	299.62

8 UERC - Order on True up for FY 2019-20, Annual Performance Review for FY 2020-21 & ARR for FY 2021-22, UPCL

Organization	Type	Energy (MU)
Gama Infraprop	Gas	776.8
Sravanthi	Gas	1553.61
Sasan UMPP	Thermal	757.26
Meja	Thermal	288.1
Greenko Budhil Hydro	Hydro	225.68
Vishnu Prayag HEP	Hydro	221.61
GVK Srinagar	Hydro	134.16
Vyasi	Hydro	136.23
L&T	Hydro	40.84
Renewables (Solar, Wind)	Renewable	1172.83

Figure 5, Figure 6, and Figure 7 depict the location of substations and their installed capacity range present in Rishikesh, Haridwar, and Dehradun respectively. The maps could assist UTC and UPCL plan for their infrastructure development in a way that is both technically feasible and economically viable.

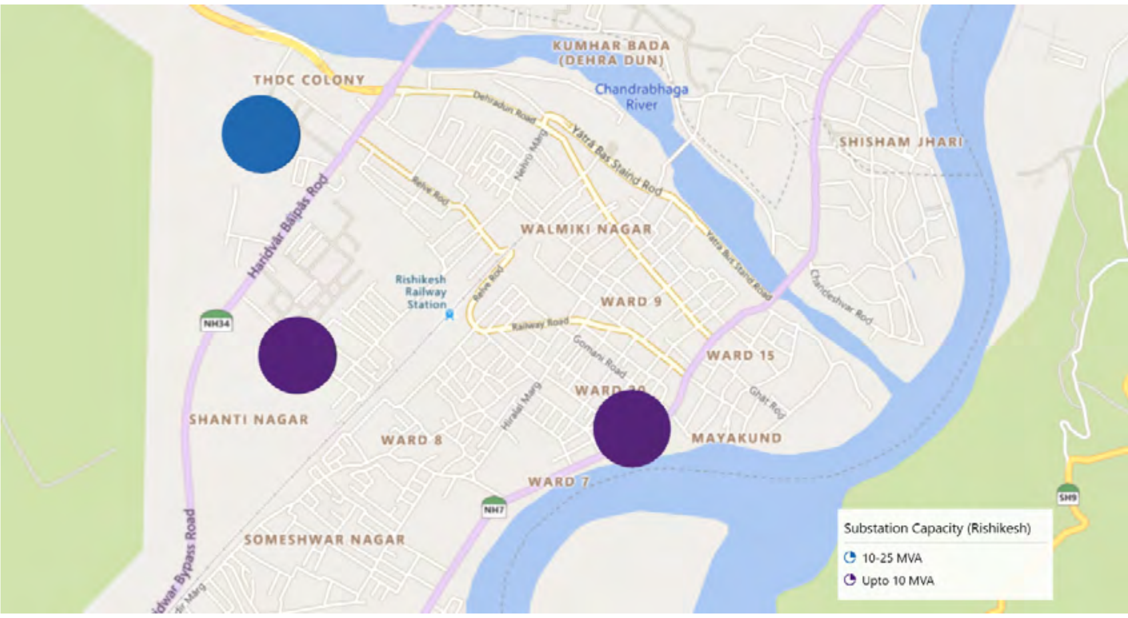

Figure 5: Substation location and capacity - Rishikesh

Figure 6: Substation location and capacity - Haridwar

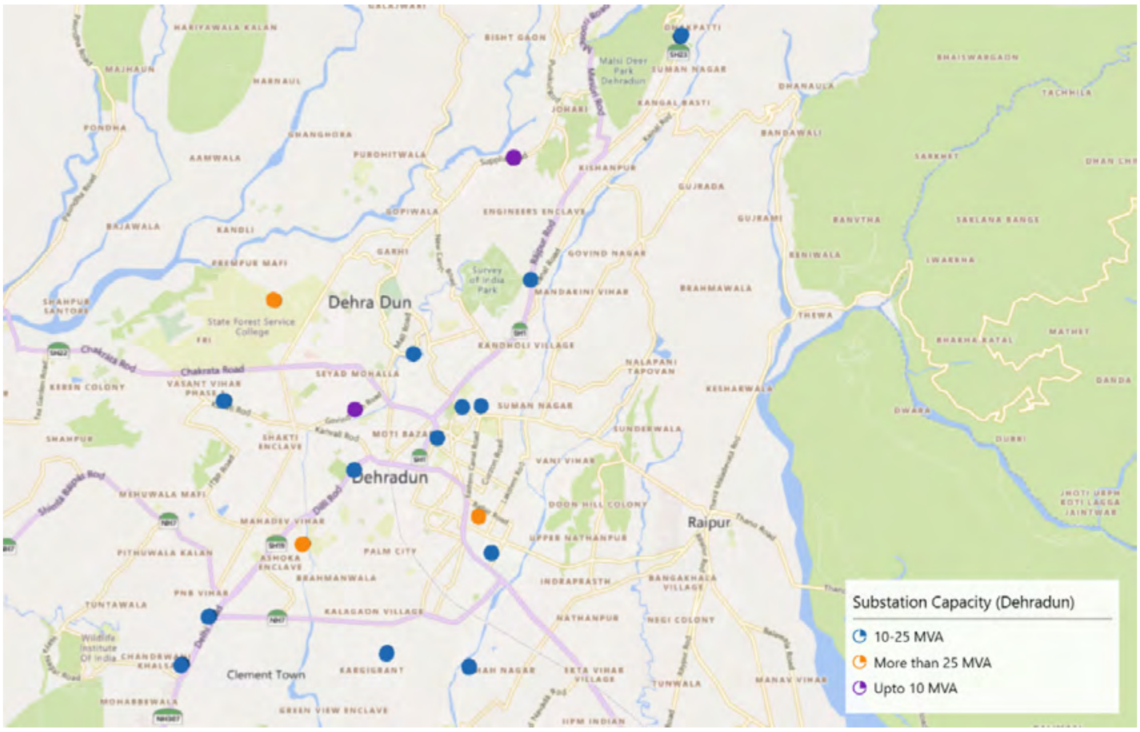

Figure 7: Substation location and capacity - Dehradun

6.2 Key factors and investment requirements for charging stations

Deployment of public e-buses requires holistic and meticulous planning of various key areas which also includes the assessment of charging infrastructure requirements. Charging infrastructure for electric buses differs slightly from the e-2W/3W/4W vehicles, primarily due to the unavailability of "home" charging infrastructure. Also, due to the high battery capacities associated with buses, the power infrastructure requirements are significantly higher compared to other EVs, generally of the order 50kW and above.

The planning of charging infrastructure for public e-buses requires the evaluation of the following:

i. "where" the charging will take place,

ii. "when" the charging will occur and

iii. "how" the charging is facilitated.

"where" & "when": While planning for inter-city bus transport, there are two possibilities for charging buses *viz.* depot charging (departing and arrival stations) and en-route charging. A bus being utilized for inter-city transport is expected to spend a significant time on the road, covering large distances with some key stoppages for passenger break time. The time associated with key stoppages between starting and stopping points usually ranges between 15 minutes and 1 hour. Therefore, en-route charging should be facilitated at a rate that ranges from 1C-2C. Considering the large battery capacities of the bus, this translates to infrastructure requirements amounting up to 100kW – 300kW for a single unit of electric vehicle supply equipment (EVSE).

Depot charging is facilitated when the bus has completed its trip and there is a long overlay before departing onwards its next journey. Such overlays usually occur during the night time and usually span from 4-8 hours. During this period, the bus charging can occur with rates that are between 0.1C-0.5C, translating to power infrastructure requirements with a rating between 15 kW and 100 kW for a single unit of EVSE. If a certain depot houses 10 buses for overnight charging, the power infrastructure requirements can go as high as 1 MW without considering smart or optimized charging behaviors.

"how": The required charging infrastructure is mainly dependent on the type of power output required – AC/DC; power output levels – Level 1, Level 2, and Level 3; type of connector guns; and type of charging provided – conductive (wired), inductive (wireless) charging or battery swapping. Planning and design of charging stations for public e-bus fleets need to incorporate the financial impact as the charging stations, being commercial, require high sanctioned loads of the range of 2-10 MWs for fleets consisting of a minimum of 10 buses. The current market trends in India point towards DC charging as the most suitable choice to allow for fast charging of buses, thereby ensuring adequate operational hours for the buses to serve passenger needs.

6.3 Assessment of required supporting infrastructure for captive charging

As mentioned above, charging infrastructure is a critical factor while planning for electric bus fleet deployment. Various charging technologies and their associated costs have already been discussed in Section 2.2. This section dives in deeper to understand the requirements of charging infrastructure at the depot for electric bus charging. In this regard, Uttarakhand Electricity Regulatory Commission (UERC) in their notification No. F-9 (22)/RG/UERC/2008/1197 established the regulations for "Release of New HT & EHT connections, enhancements and reduction of loads" in 2008[9]. The regulations define HT as voltages above 650 V and up to 33 kV under normal conditions while EHT is defined as voltages above 33 kV under normal conditions subject to the percentage variation permissible under section 53 of the Electricity Act, 2003. Section 3 under UERC HT & EHT regulations mentioned above states:

1. All connections above 88 kVA shall be released on HT/EHT only with contracted load in kVA

9 Release of New HT & EHT connections, enhancements and reduction of loads, 2008

2. All loads more than 1 MVA shall be sanctioned with independent feeders emanating from the nearest 33/66/132/220 kV substation with metering arrangements at both ends.

3. Provided that if the right of way for the proposed independent feeder is not available, such loads above 1 MVA may be sanctioned either through underground cables or from the existing feeder provided more than 50% spare capacity is available on such feeder.

4. Voltage of supply should be as given in Table as under:

Load	Voltage
>88 kVA and up to 3 MVA	11 kV
>3 MVA and up to 10 MVA	33 kV
>10 MVA and up to 50 MVA	132 kV
>50 MVA	220 kV

Assessment of required infrastructure: Physical visits to the depots and their respective workshops have presented a brief overview of the land availability and power infrastructure availability at selected depots. Furthermore, the charging infrastructure requirements are highly localized in nature i.e. factors like the distance from the nearest sub-station (11/33/66 kV) and getting the 'right of way' constitutes the bulk of the length of wires to be considered and whether the connection will be given through underground cables or overhead lines. UERC has provided certain guidelines and estimates for obtaining the connection at different voltage levels which are tabulated below:

Table 20 Cost Estimates for Power Infrastructure

Description	Estimated Costs
11 kV Connection:	
1. Terminal equipment at consumer end including HT cables, Current Transformer (CT), Potential Transformer (PT), Meter Cubicle etc.	₹ 1,50,000
2. For independent feeder terminal equipment at sending end including switchgear, HT cables, CT/PT, meter cubicle etc.	₹ 4,00,000
3. Line Costs –	
a. Overhead line costs	₹ 4,00,000 per kilometer
b. Underground cabling costs	₹ 15,00,000 per kilometer
33 kV Connection:	
1. Terminal equipment including circuit breakers, isolators, lightening arrestors at sending end and EHT cables, CT, PT, Meter cuble etc. at both ends	₹ 10,00,000
2. Line Costs –	
a. Overhead line costs	₹ 7,50,000 per kilometre
b. Underground cabling costs	₹ 25,00,000 per kilometer

E.g. considering a depot that is 5 km from the nearest sub-station from which the connection is to be supplied. Considering the 'right of way', the wires required to be laid down come out as 10 km. Assuming that the depot stations 20 buses for overnight charging, requiring a total of 2000 kVA (100 kVA/80 kW chargers, no fast charging). This translates to obtaining the sanctioned load of roughly around 3 MVA that could be supplied with an 11 kV connection as per the UERC guidelines, but will not be feasible considering future expansions (if any). The cost of power infrastructure requirement (with independent feeder) along with EVSE can be calculated as follows:

Total Cost (₹)= Cost of Single EVSE (₹)* 20 + Cost of Power Infrastructure (₹)

Cost of EVSE = ~ ₹ 10,00,000 per unit

Cost of Power Infrastructure = ₹ 4,00,000 (terminal equipment and independent feeder) + ₹ 4,00,000*10 (overhead wires cost) = ~ ₹ 45,00,000

Therefore,

Total Cost (₹) = 10,00,000*20 + ₹ 45,00,000 = ~ ₹ 2,50,00,000

The above calculation is done for an 11 kV connection considering 100 % slow charging (80-100 kW). These costs are just estimates and the actual costs for network infrastructure can only be assessed by the UPCL when an application for obtaining the required sanctioned load is submitted[10].

Initial security amount required at ₹ 1000/kVA of contracted load. Both the registration fees and the security amount will be adjusted towards the final settlement after the process is over. The no. of days required to set up the connection can vary from 60 (without independent feeder) to 90 days (with independent feeder) for connections at 11 kV and 120 days for connections at 33 kV. In case the supply of power requires commissioning of new substation/bay, the distribution licensee is required to bear the expenses for augmentation of the substation on their own and complete the work with additional time specified as under –

Description	# Days
New 33/11 kV sub-station	180 days
Augmentation of existing 33/11 kV sub-station	120 days
Extension of bay ay 33/11 kV sub-station	45 days
132 kV and above sub-station	18 months
Extension of bay at 132 kV and above sub-station	90 days

6.4 Carbon Abatement Opportunity in Uttarakhand by 2030 through the deployment of Electric Buses (Fermi Estimations)

As per the Vahan portal, around 21447 buses are registered in Uttarakhand.[11] As for the year 2020, 669 buses were sold in the state. A study by UITP suggests that the bus fleet has to increase at least by 6% per annum to meet the transportation demand of the growing population.[12] Concurrently, the RMI- Niti Aayog study states that by 2030 the sale of electric buses must account for 40% of total bus sales in India.[13]

10 Additional amout in the form of Registration-cum-Processing fees required are as follows: i) Connection at 11 kV - ₹ 5,000; ii) Connection at 33 kV - ₹ 10,000

11 https://vahan.parivahan.gov.in/vahan4dashboard/

12 https://www.uitp.org/news/accelerating-e-bus-deployment-uitp-india-launches-two-reports-on-electric-buses/

13 https://rmi.org/insight/indias-electric-mobility-transformation/

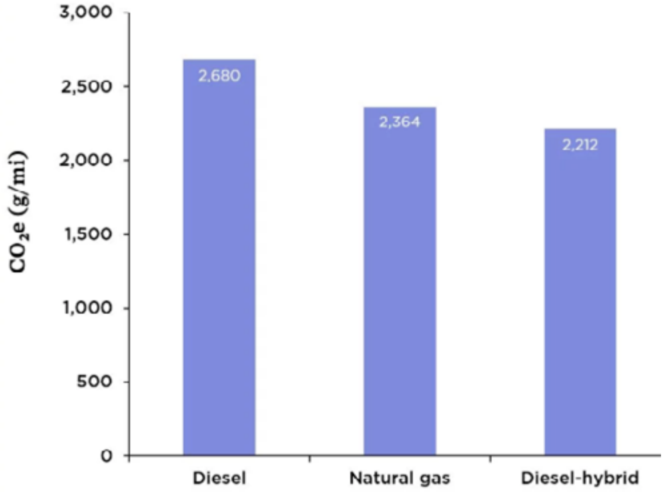

Figure 8 Life Cycle Global Warming Emissions from different types of transit buses 14 (Source: Study by Union of Concerned Scientists)

For this analysis, we have considered 10 years as the average service life of a bus. Figure 8 highlights the lifecycle emissions from buses of different fuel types. Table 21 captures the data points specific to diesel buses.

Table 21 Diesel bus-specific data points

Sr.No.	Parameter	Value	Unit
1	Life Cycle GHG emissions	2680	g-CO2e/mi
2	Daily Average Distance Travelled	90	Miles
3	Average service life of bus	10	Years
4	Annual GHG emissions	0.088	Mt-CO2e

Using the aforementioned data and the sales trajectory outlined by BNEF, Table 22 captures the absolute electric bus sales trajectory for Uttarakhand.[15]

Table 22 Sales trajectory for Electric buses in Uttarakhand

Year	Sales% (E-buses)	Absolute Sales Value (E-buses)	Absolute Sales Value (All Buses)
2020	0.25%	2	669
2021	5%	58	1287
2022	6%	82	1364
2023	8%	116	1446
2024	10%	153	1533
2025	13%	211	1625
2026	16%	276	1722
2027	20%	365	1825
2028	27%	522	1935
2029	34%	697	2051
2030	40%	870	2174

14 https://www.greentechmedia.com/articles/read/study-electric-buses-already-emit-less-carbon-than-diesel-buses-in-any-stat
15 https://about.bnef.com/electric-vehicle-outlook/

It is expected that Uttarakhand will have an electric bus fleet of ~3,352 by 2030. The calculation of the emissions from the electric buses based on the grid emissions factor is given in Annexure 1. Since the grid emissions factor for Uttarakhand is already half of the national average, we have retained the same for the assessment tenure. However, any improvement will only result in improving the prospect of deploying electric buses in the state.

07 Key takeaways and next steps

Uttarakhand as a state stands to accrue several benefits from the electrification of its bus fleets. One of the primary benefits is the emission savings for this pristine state. The state had experienced an increase in emissions from 3.6 MtCO2e to 19.8 MtCO2e during the period 2005 - 2013 at an estimated CAGR of 23.81%. It is important to note that in Uttarakhand, emissions arose only from Fuel Combustion, and transport and industries are the leading contributors.

The factor that distinguishes Uttarakhand from the rest of India is that the power sector emissions are very low. India's grid emission factor is 0.8 kg-CO2/ kWh, primarily due to the significant amount of coal-based power generation. However, as Uttarakhand has rich hydro resources, the grid emissions factor for the state is less than half of the national value i.e. 0.35 kg-CO2/ kWh. In Uttarakhand, an analysis of the power generation mix for the past 5 years shows that close to 46% of the electricity demand is met by hydro sources, and the grid emission factor is reducing with the increase in penetration of renewable energy in the state. This implies that emission reduction from the electrification of bus fleets will be twice the emission reduction at the national level.

For the proposed roadmap scenarios in Chapter 5, the electricity consumption and cumulative emission reduction are estimated. The details of the assessment are available in Annexure 1.

- Under scenario 1, which is 84% fleet electrification by 2030, through cumulative procurement of 1861 buses in 2022-30 will result in an increase in electricity consumption of 908 GWh, and an emission reduction of 382.7 million kg of CO2
- Under scenario 2, which is 90% fleet electrification by 2030, through cumulative procurement of 3361 buses in 2022-30 will result in an increase in electricity consumption of 1635 GWh, and an emission reduction of 689.3 million kg of CO2

Electrification of the bus fleet in Uttarakhand is critical for the decarbonization of transport in the state. It is expected that the mobility needs of people will increase with the increase in urbanization and improved infrastructure to boost tourism in the state. To map the following three future objectives, it becomes imperative to transform the public bus sector into an electric one:

1. Upgrading the bus services to fulfill the user's mobility needs,
2. Adhering to NITI Aayog mission of EV30@30.
3. Reducing air pollution from vehicular exhaust.

The continuous improvement of road infrastructure to various pilgrimage sites & tourist spots and being an electricity surplus state will facilitate the deployment of electric buses on various routes. There are multiple routes on which electric buses can be deployed initially to start the wheel of transition. The analysis of current operations and assessment of route feasibility indicates that the adoption of electric buses is not complicated. The electric bus operations under Dehradun Smart City Limited and the adjoining neighboring state of Himachal Pradesh proved the suitability of electric bus operations under hilly terrain. The first round of deployment i.e., the short-term plan will give the necessary experience and feedback to implement more efficiently next rounds of implementation. The successful deployment will put Uttarakhand state as one of the advanced states in electric mobility under public services.

It is recommended that UTC adopts a long-term outlook towards a fleetwide transition to electric buses and identify the solutions to meet their financial needs. The tools used for this analysis as well as the proposed approach are replicable across other urban and regional bus agencies-public and private.

However, there are multiple short-term challenges to overcome to complete the vision of green Uttarakhand. These are listed below:

1. **Capacity building of UTC:** At present, the majority of STUs need capacity building for procuring the services of electric buses. The tender conditions should be able to protect the interests of the public transport authority and be competitive enough to attract the maximum number of bidders. The risk and responsibilities should be clearly defined.

2. **Availability of HT infrastructure at every depot and terminal points:** The assessment should be done at each required location in the planning stages itself. The electrification of locations should be the responsibility of the authority and should be completed at the time of tendering.

3. **Selecting appropriate cleaner technology:** The GCC rate for 9m without air-conditioning is below ₹ 40/ km with the latest aggregation of buses under the grand challenge scheme. This rate is significantly lower than the rates received by UTC electric bus tender and is most likely to result in the operation of buses without viability gap funding. Presently, UTC is exploring CNG-propelled buses. The CNG filling stations are not prevalent in Uttarakhand and can be explored only after detailed cost comparison and emissions.

4. **Coordination between various stakeholders of the state:** The coordination between various stakeholders is critical for toll out of buses, be it UTC and UPCL or UTC with Urban Local Bodies (ULB) OR Department of Transport, Uttarakhand.

5. **Lack of consistent funding from the State Government:** UTC doesn't have access to consistent Government financial assistance as a result of which they're reliant on farebox for 97% of their revenues. This has led to financial losses over the past year as the revenue increase didn't match increasing staff and fuel cost needs. Therefore, UTC needs to be supported financially to attract investments in improving UTC service quality and quantity, through e-bus leverage.

The government of India is betting big on the electrification of buses, and through Convergence Energy Services Ltd. (CESL) initiatives, plans are being rolled out to tender 50,000 electric buses on behalf of states in the next five years. The first phase of the tender with a demand aggregation of 5000+ buses for Bengaluru, Delhi, Surat, Hyderabad, and Kolkata resulted in the lowest prices. Uttarakhand can benefit from aligning with the government plans and this is recommended as the near-term action for the state.

Annexure 1

Assumptions

Electricity consumption per km	0.84	kWh/km
Grid emissions factor for Uttarakhand (estimated)	0.35	kg-CO2/ kWh
Diesel bus consumption	0.24	liter/km
CO2 emissions from diesel	2.7	kg-CO2/liter
Average Annual Travel distance	105000	km/bus
UTC bus utilisation rate	308	km/bus/day

Scenario 1 estimation

Year	Cumulative electric buses (in numbers)	Electricity usage (in GWh)	Emissions from electricity usage (million kg of CO2)	Diesel usage if not electrified (million liters)	Diesel emissions (million kg of CO2)	Emissions abated (million kg of CO2)
2022	87	7.7	2.7	2.2	5.9	3.2
2023	181	16.0	5.6	4.6	12.3	6.7
2024	349	30.8	10.8	8.8	23.7	13.0
2025	429	37.8	13.2	10.8	29.2	15.9
2026	567	50.0	17.5	14.3	38.6	21.1
2027	1118	98.6	34.5	28.2	76.1	41.6
2028	1202	106.0	37.1	30.3	81.8	44.7
2029	1288	113.6	39.8	32.5	87.6	47.9
2030	1452	128.1	44.8	36.6	98.8	54.0
2031	1761	155.3	54.4	44.4	119.8	65.5
2032	1861	164.1	57.4	46.9	126.6	69.2

Scenario 2 estimation

Year	Cumulative electric buses (in numbers)	Electricity usage (in GWh)	Emissions from electricity usage (million kg of CO2)	Diesel usage if not electrified (million liters)	Diesel emissions (million kg of CO2)	Emissions abated (million kg of CO2)
2022	87	7.7	2.7	2.2	5.9	3.2
2023	331	29.2	10.2	8.3	22.5	12.3
2024	649	57.2	20.0	16.4	44.2	24.1
2025	879	77.5	27.1	22.2	59.8	32.7

Year	Cumulative electric buses (in numbers)	Electricity usage (in GWh)	Emissions from electricity usage (million kg of CO2)	Diesel usage if not electrified (million liters)	Diesel emissions (million kg of CO2)	Emissions abated (million kg of CO2)
2026	1167	102.9	36.0	29.4	79.4	43.4
2027	1868	164.8	57.7	47.1	127.1	69.4
2028	2102	185.4	64.9	53.0	143.0	78.1
2029	2338	206.2	72.2	58.9	159.1	86.9
2030	2652	233.9	81.9	66.8	180.4	98.6
2031	3111	274.4	96.0	78.4	211.7	115.6
2032	3361	296.4	103.8	84.7	228.7	124.9

Estimation of grid emission factor for Uttarakhand

Year	Power procurement (approved) in GWh						Grid emission factor calculation		
	Hydro (large and small)	Thermal	Nuclear	Renewables	Gas	Total	Coal emissions (thousand tonnes)	Gas emissions (thousand tonnes)	Grid emission factor
2018 - 19	6712	3841	306	848	2719	14426	3994	1169	0.36
2019 - 20	6630	3424	312	976	2330	13673	3561	1002	0.33
2020 - 21	6446	3760	282	1264	2330	14082	3910	1002	0.35
2021 - 22	6645	3925	300	1173	2330	14373	4082	1002	0.35

Specific CO2 emissions	Coal	Gas-CC
tCO2 /MWh	1.04	0.43

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