UITP CENTRE FOR TRANSPORT EXCELLENCE
MIDDLE EAST & NORTH AFRICA

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REPORT

DECARBONISING MOBILITY

THE RISE OF ELECTRIC BUSES IN THE MENA LANDSCAPE

MAY | 2025

ABOUT UITP MENA CTE

The MENA Centre for Transport Excellence (CTE) was launched in 2011 as a joint effort between Dubai's Roads & Transport Authority (RTA) and the International Association of Public Transport (UITP) to unify regional efforts to build sustainable transport systems in MENA countries. MENA CTE aims to create cutting-edge knowledge and develop innovative tools necessary for the development of effective transport policies, strategies, and solutions to public and private institutions in the MENA region. It contributes to unifying regional efforts to foster sustainable mobility and enhance the quality of life in all Middle Eastern and North African countries.

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EXECUTIVE SUMMARY

The electrification of public bus fleets has become a central focus for cities aiming to modernise their transport systems and align with global sustainability and climate goals. In particular, battery electric buses (BEBs) are gaining traction as a viable solution to reduce greenhouse gas (GHG) emissions, improve urban air quality, and support the transition to low-carbon mobility. This report focuses on the MENA region, where interest in electric public buses is accelerating, yet implementation remains nascent across many urban centres.

The report provides a comprehensive overview of the current landscape of BEB deployment in MENA, outlining the decarbonisation targets of regional cities and documenting the status of electric bus adoption. It identifies the key enablers and barriers influencing uptake ranging from infrastructure and financing to policy and operational readiness and draws on global case studies to contextualize findings. Additionally, it presents lessons learned from early adopters in the region and evaluates the economic, environmental, and social impacts of transitioning from diesel to electric buses, using total cost of ownership and economic net present value analyses.

A key finding emerging from the study is the importance of regional knowledge exchange, particularly among cities that share similar climatic, geographic, and institutional conditions. Such collaboration enables mutual learning, accelerates capacity building, and helps cities adapt global best practices to local contexts. The report further underscores the need for strategic infrastructure planning, including the co-utilisation of depot charging facilities and the adoption of interoperability standards to reduce capital expenditure, enable competitive procurement, and support long-term operational flexibility.

The development of skilled technical teams capable of maintaining electric propulsion systems, managing charging infrastructure, and ensuring safety is essential to the sustainable operation of BEB fleets. Moreover, as cities transition to cleaner fleets, it is important to reaffirm that prioritising and promoting public transport use itself remains a foundational pillar of sustainable urban mobility.

In sum, the report offers a roadmap for MENA cities to transition toward zero-emission bus fleets through evidence-based planning, cross-sectoral coordination, and locally tailored strategies. By combining regional cooperation with strategic investments and institutional readiness, cities can unlock the full environmental and economic benefits of electric bus deployment.

FOREWORD

As cities across the MENA region strive to build cleaner, more resilient, and sustainable urban mobility systems, the transition to zero emission buses (ZEBs) has emerged as a pivotal pathway toward decarbonising public transport. With growing environmental imperatives, technological advancements, and shifting policy priorities, electric buses offer a transformative opportunity to reduce emissions, enhance energy efficiency, and modernise fleet operations across the region.

This report is the product of extensive work by the UITP MENA Bus Working Group, a collaborative platform bringing together public transport authorities, operators, and industry stakeholders committed to advancing sustainable bus systems in the region. The insights presented in this report reflect the joint efforts, technical discussions, and policy dialogues that have collectively shaped a comprehensive understanding of the region's readiness for bus fleet electrification.

The report explores the landscape, enablers, barriers, cost structures, and policy mechanisms surrounding e-bus deployment in MENA. It also highlights lessons learned from early adopters and offers strategic recommendations to support evidence-based decision-making.

As MENA cities continue their journey toward sustainable mobility, UITP MENA remains steadfast in its mission to facilitate knowledge exchange, provide technical guidance, and empower stakeholders with tools and insights to accelerate the shift to zero-emission public transport.

The successful completion of this report would have not been possible without the dedication and expertise of our UITP CTE MENA team. Their commitment to thorough research, meticulous data analysis, and thoughtful synthesis of insights has been invaluable in shaping this publication.

I also extend my sincere appreciation to the Working Group and all participants for their valuable contributions, expertise, and commitment that made this work possible.

Mohamed Mezghani
Secretary General, UITP

INTRODUCTION

OVERVIEW

Many cities around the world are seeking to meet their greenhouse gas (GHG) reduction targets in their transportation activities. Several strategies have been proposed for transportation sector including electric mobility (e-mobility), which has become one of the fast-growing opportunities to contribute to nations' climate and sustainable development goals (SDGs). It is a key part of the sustainability mobility agenda towards alignment with the Paris agreement on climate change[1]*. E-mobility not only offers opportunities to decarbonise the transport sector, but also, brings a wide range of social and economic benefits on the long term. These include potential job creation which are driven by the development of new value chains and industries.*

Among the e-mobility initiatives is the electrification of bus fleets, which is expected to rise due to its environmental and social benefits. Recent advancements in battery technology have led to the establishment of affordable, lighter, and more efficient energy storage capabilities, playing a pivotal role in the rise of electric buses. Today, e-buses provide reliable technology and have access to a range of well-established charging solutions and strategies [1].

The MENA region is witnessing a significant uptake in the electrification of transport systems and related deployments. Governments and policy makers across the region are increasingly adopting e-mobility policies, setting ambitious targets, and launching various initiatives to transition towards decarbonising their public transport systems.

WHAT ARE THE OBJECTIVES OF THIS STUDY?

1. **Electric bus landscape in the MENA**

   Identify the decarbonisation targets of the MENA cities as well as status the electric buses in the MENA region

2. **Underpinning factors influencing electric bus deployment and adoption in MENA**

   Identify, list, and evaluate the significance of the factors influencing the adoption of electric buses in the MENA cities and other cities with advanced adoption of the technology to learn from their experience and highlight the discrepancies in the enablers and barriers across different adoption phases.

3. **Lessons learned from electric bus deployments in the MENA region**

   Highlight the lessons learned from the early adoption of electric buses in the MENA region from different perspectives including energy consumption, driver and passenger experience, and training requirements.

4. **Cost-benefit analysis framework**

   Assess the economic, environmental, and social impacts of the transition from diesel buses to electric buses through performing Total Cost of Ownership and Economic Net Present Value analyses.

GLOBAL CONTEXT: SUSTAINABILITY & DECARBONISATION

Urban population has dramatically increased over the years. In 2018, the UN (United Nations) reported that 55% of the world population reside in urban areas, which is estimated to be 4.2 billion people. By 2050, 68% of the world population is expected to be urban. The growth of the world's population and urbanisation mandate developing sustainable cities that provide opportunities for economic growth and social responsibility while reducing the adverse effects on the environment.

(1) UITP, Going Electric: A Pathway to Zero-Emission Buses, 2021. Available: https://www.uitp.org/publications/policy-paper-going-electric-a-pathway-to-zero-emission-buses/

The rise in global carbon emissions presents a formidable challenge, even to concerted international initiatives such as the Paris Climate Accord. This accord sets forth the ambitious goal of limiting the impact global warming to a rise of 1.5 degrees Celsius, compared to pre-industrial levels. Despite that, realising this target is intricate due to the significant contributions of certain sectors to the overall emissions profile. In a contemporary context, the transport sector is pivotal, functioning as both a cornerstone of economic vitality and as a major contributor to GHG emissions. In the United States, for example, transport accounted for 28% of the total GHG emissions [(2)]. On the global level, transport contributed to 21% of total GHG emissions in 2023, making transport the second-largest source of emissions worldwide. To be more specific, road transport is the largest contributor to the sector's emissions, followed by air and marine transport [(3)].

Initiatives aimed at curbing transport emissions are gaining a central focus, especially in light of commitments toward net zero emissions vision and the turbulent nature of oil prices. These dynamics are pushing policymakers towards considering alternative technologies to oil-dependent mobility.

Public transport is recognised as a crucial backbone for sustainable urban development as it enhances mobility by providing the infrastructure and services for safe and efficient movement of people. Bus transport is a critical component of public transport systems, significantly contributing to urban mobility and sustainability. Figure 1 illustrates the ridership per capita for different cities around the globe including the MENA region and others.

In the MENA region, the bus market is expected to continue expanding at an annual growth of 1.86%, as per the CAGR between 2025 and 2029. Currently, there are more than 32,000 buses operating in the MENA [(4)]. Figure 2 shows the bus fleet per 1 million inhabitants in several MENA cities.

Cities	Annual Ridership per Capita	Ridership	Population	Year
Singapore	209.0	1,263,265,000	6,039,577	2022
Hong Kong	204.0	1,560,727,000	7,643,256	2022
London	182.0	1,737,600,000	9,540,576	2022
Oslo	148.0	159,000,000	1,071,062	2022
Paris	103.0	1,148,000,000	11,142,303	2022
Beijing	81.0	1,725,580,000	21,333,331	2022
Barcelona	62.0	350,900,000	5,658,472	2022
Istanbul	59.0	924,078,480	15,636,243	2022
Sfax	49.0	49,000,000	1,000,000	2019
Brussels	48.0	101,800,000	2,109,631	2022
Dubai	43.5	159,000,000	3,655,000	2023
Makkah	36.9	87,924,770	2,385,509	2023
Amsterdam	35.0	40,700,000	1,165,898	2022
Agadir	33.6	48,000,000	1,430,000	2023
Rabat-Sale-Temara	33.1	77,900,000	2,350,071	2023
Tunis	30.0	85,600,000	2,900,000	2022
Toronto	27.0	170,853,254	6,312,974	2022
Abu Dhabi	21.2	80,400,000	3,789,860	2023
Los Angeles	18.0	223,276,000	12,487,737	2022
Alexandria	13.8	76,000,000	5,523,511	2020
Casablanca	12.6	97,000,000	7,700,000	2023
Marrakesh	11.2	55,000,000	4,900,000	2023
Jakarta	7.0	74,776,500	11,074,811	2022
Mexico City	5.9	129,200,000	22,085,139	2022
Isfahan	3.0	16,384,000	5,429,000	2019
Doha	2.5	2,952,576	1,186,000	2023
Amman	1.4	6,977,344	4,834,500	2023
Jeddah	1.3	4,842,954	3,712,917	2023
Dammam	1.1	1,540,869	1,386,166	2023
Tehran	0.9	12,982,000	14,425,000	2019
Madinah	0.8	1,092,339	1,411,599	2023
Ras Al Khaimah	0.8	302,366	394,000	2023
Kuwait	0.6	1,700,000	2,989,000	2023
Muscat	0.2	334,848	1,455,671	2023
Qassim	0.2	297,641	1,336,179	2024
Ajman	0.2	126,116	573,886	2023
Sharjah	0.2	333,556	1,800,000	2023
Taif	0.2	247,529	1,404,997	2024
Jazan	0.2	156,280	913,347	2023
Riyadh	0.1	1,245,547	8,591,748	2023
Salalah	0.1	51,100	417,891	2023

Figure 1. Bus annual ridership statistics [(4)]. Note: Dark bars represent MENA cities while the orange bars are for the non-MENA cities, where the data are taken originally from UITP GUMI Report [(5)].

(2) U.S. Environmental Protection Agency, Fast Facts on Transportation Greenhouse Gas Emissions, 2022, Available: https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions

(3) Statista, Carbon dioxide emissions from the transportation sector worldwide from 1970 to 2023, 2023. Available: https://www.statista.com/statistics/1291615/carbon-dioxide-emissions-transport-sector-worldwide/

(4) UITP MENA CTE, MENA Transport Report, 2025. Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=296031301421

(5) UITP, Global Urban Mobility Indicators Project, 2022. Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=295098001327

Cities	Bus Fleet/ 1 mn inhabitants	Fleet	Population	Year
Beirut	1,703.7	2,200	1,291,280	2021
Oran	1,565.2	3,316	2,118,603	2023
Doha	963.7	1,143	1,186,000	2020
Isfahan	469.3	2,548	5,429,000	2024
Tehran	419.4	6,050	14,425,000	2019
Dubai	346.1	1,265	3,655,000	2023
Cairo	319.8	8,333	26,054,128	2024
Abu Dhabi	210.3	797	3,789,860	2023
Makkah	167.7	400	2,385,509	2022
Tunis	151.4	439	2,900,000	2024
Rabat	148.9	350	2,350,071	2022
Agadir	140.6	201	1,430,000	2024
Kuwait	129.2	557	4,310,108	2023
Riyadh	98.0	842	8,591,748	2022
Ajman	95.8	55	573,886	2023
Casablanca	90.9	700	7,700,000	2024
Muscat	81.1	118	1,455,671	2023
Constantine	77.5	100	1,290,000	2021
Taif	63.5	58	913,347	2022
Dammam	61.3	85	1,386,166	2022
Sharjah	61.1	110	1,800,000	2022
Qassim	54.6	73	1,336,179	2022
Marrakesh	51.0	250	4,900,000	2024
Jazan	33.5	47	1,404,997	2022
Amman	28.1	136	4,834,500	2023
RAK	25.4	10	394,000	2023
Jeddah	21.8	81	3,712,917	2022
Salalah	21.5	9	417,891	2023
Madinah	21.3	30	1,411,599	2022

Figure 2. Bus Fleet in MENA region [4].

In recent years, many new policies have sought to decarbonise bus fleets and the wider public transport network. Electric powertrains are capable of nullifying harmful emissions from the tailpipe, using the energy provided by an electric battery or a fuel cell [6]. This makes e-buses an environmentally friendly alternative to diesel buses. In addition, e-buses are expected to have lower operational cost, improve air quality, and provide health benefits [7].

Bus fleet decarbonisation strategically aligns with different SDGs. The explicit inclusion of public transport expansion in SDG target 11.2 underscores its significance. In addition, the transition to ZEBs directly contributes to SDG13 by mitigating GHG and air pollution. It is worth mentioning that a ZEB can be referred to as a vehicle without an ICE or with an ICE but emitting less than 1 g CO_2/kWh or less than 1 g CO_2/km [8].

To know more about the linkage between public transport and SDGs, interested readers may refer to UITP knowledge reports [9] and [10].

UNDERSTAND THE TECHNOLOGY [8]

Battery-electric buses (BEBs)

BEBs are all-electric or purely electric vehicles with an electric propulsion system that uses chemical energy stored in rechargeable battery packs. Battery electric vehicles (BEVs) use electric motors and motor controllers for propulsion instead of internal combustion engines (ICEs). They have no ICE, fuel cell or fuel tank and derive all their power from their battery packs

Fuel cell-electric buses (FCEBs)

Fuel cell hydrogen buses use electric energy produced through an electro-chemical reaction both for the powertrain and for a support battery charging. Energy stored in the batteries adds additional power in demanding situations like a rapid acceleration or gradients. Only water and heat are emitted because of hydrogen consumption. The biggest advantage of this technology is the longer range, allowing normal daily public transport bus operations with no intermediate refuelling stops.

Plug-in electric buses

The main feature of plug-in hybrid buses is that motion is achieved through an electric motor using energy stored in rechargeable batteries, similar to BEVs. However, an internal combustion engine is used only as a backup. The main difference with conventional hybrid buses (not in the category of clean buses for this report) is that hybrid buses use the ICE to provide most of the power.

Battery trolleybuses

These are bus-type vehicles propelled by an electric motor, drawing power from overhead wires via connecting poles called trolleys. Power is supplied either from a central power source that is not onboard the vehicle or via on-board rechargeable batteries.

This enables the vehicles to run electrically while independent of the overhead wires for part of their route while maintaining full operational capability.

Battery trolleybuses are charged dynamically using the existing trolleybus catenary, or static with a device for connecting to the electrical grid. This combination of technologies allows cities with existing trolleybus infrastructure to expand the network without necessarily expanding the infrastructure. This is a direct substitute for trolleybuses that use a diesel

(6) Journal of Renewable and Sustainable Energy Reviews, Factors Influencing the Adoption of Zero-Emission Buses: A Review-Based Framework, 2024. DOI: https://doi.org/10.1016/j.rser.2024.114388

(7) Journal of Applied Energy, Charging Strategy Selection for Electric Bus Systems: A Multi-Criteria Decision-Making Approach, 2023. DOI: https://doi.org/10.1016/j.apenergy.2023.121415

(8) ASSURED, Clean Bus Report, 2022. Available: https://cms.uitp.org/wp/wp-content/uploads/2022/05/ASSURED-Clean-Bus-report_final2.pdf

(9) UITP, Linking Public Transport Activities and Organisations with The UN's Sustainable Goals, 2024. Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=295096801327

(10) UITP, Why Public Transport Is Key to Achieve the SDGs, 2023. Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=291818001909

range extender for extended trolley lines, or as a backup in case of disruption in the infrastructure.

Transitioning to BEBs necessitates substantial investments in charging infrastructure. Charging technologies are crucial to their operation, influencing fleet efficient, operational range, and infrastructure requirements. Charging requirements and implementation prospects are greatly affected by the conditions of the city where this technology is deployed as well as the required bus operations [11].

E-buses showed rapid scaling up, where cities in Europe, Latin America, Africa, and Asia, announced and executed plans to electrify their bus fleets. According to the International Energy Agency (IEA), in the European Union, BEBs accounted for 43% of urban bus sales in 2023, marking clear progress toward the target of making 100% of urban bus sales zero-emission [12]. Currently, there are growing trends in BEBs around the globe. Some of these trends worldwide are given below in Table 1.

Table 1. Decarbonisation/electrification targets in several global cities

Country	Cities	Existing fleet - BEBs	Decarbonisation/Electrification Target (2015–2040)
	Shenzhen	15,680	2017
	London	1,762	2034
	Paris	~2,400	2035
	Berlin	227	2030
	Amsterdam	159 (2023)	2025
	New York	60	2040
	Toronto	60	2040
	Bogotá	~1,500 (2022)	2035
	Santiago	2,497	2035
	Delhi	2,050	2030
	Singapore	480	2040
	Izmir	20	2053

Note: The number of BEBs represents the total number of BEBs in 2024, excluding those in Bogota and Amsterdam.

Charging technologies

There are two primary charging technologies for BEBs: conductive and inductive charging. Battery buses are charged statically using mechanical and electrical equipment. Different technologies for battery charging can be found on the market, all of them with similar functionalities but with specific advantages and drawbacks which are considered by cities or operators in their selection according to what fits better in their overall strategy. The most common charging technologies are conductive, via manual connectors (plug-in), roof-mounted pantograph, infrastructure-mounted pantograph, flash-charging. For trolleybuses technologies include catenary charging and In-Motion-Charging [8].

Conductive charging [13]

Conductive charging involves establishing a direct physical connection between the vehicle's battery and an external power source. This process necessitates metal-to-metal contact to enable the transfer of electric current from the charger to the electric vehicle.

Plug-in charging

In plug-in charging configurations, the electric vehicle is manually connected to the charging infrastructure using a plug and cable system. The rate of energy transfer is contingent upon the electrical capacity of both the cable and the connector, which collectively define the permissible power throughput from the charger to the vehicle.

Infrastructure-mounted pantograph charging (Panto-down)

This method employs an Automated Connection Device (ACD) affixed to a fixed structure, such as a pole or facility within the charging infrastructure. When the vehicle arrives at the designated charging point, the pantograph is deployed from the infrastructure to connect with the vehicle. The process is enabled by wireless communication systems that facilitate the vehicle's transmission of a "pantograph down" request to initiate physical contact.

(11) UITP MENA CTE, Electric Buses in MENA, 2020. Available: https://www.uitp.org/publications/electric-buses-in-mena/

(12) International Energy Agency, Global EV Outlook, 2024. Available: https://www.iea.org/reports/global-ev-outlook-2024

(13) ASSURED, Pre-normative Technology Roadmap and New Use Cases in Electric Bus and Truck Charging, 2022. Available: https://assured-project.eu/storage/files/public-pre-normative-technology-roadmap-and-new-use-cases-in-electric-bus-and-truck-charging-final.pdf

Roof-mounted pantograph charging (Panto-up)

In this configuration, the pantograph is integrated into the roof of the vehicle, allowing it to interface with a static connector located at the charging site. This setup reduces the complexity and cost of the charging station; however, it imposes additional weight, structural height, and system complexity on the vehicle itself due to the on-board equipment.

Flash charging

Flash charging involves rapid high-power charging at selected bus stops during passenger boarding and alighting. These systems typically operate at around 600 kW and utilize a precision-guided robotic arm, often controlled by laser systems, to establish contact with a fixed overhead charging point. Unlike conventional trolleybus infrastructure, this system eliminates the need for continuous overhead catenary lines by enabling opportunistic charging at predefined intervals.

Infrastructure for in motion charging (IMC)

IMC is based on proven trolleybus systems that are largely standardised and operating in almost 300 cities across the world. IMC trolleybuses are electric buses that charge dynamically through an overhead contact system and are capable of operating on battery power for up to half of their journey. This design allows IMC trolleybuses to have a smaller, lighter battery, while offering an essentially unlimited daily range. The reduced weight of the vehicles enhances their performance, minimises wear and tear, and lowers operational, environmental, and geopolitical expenses and risks [14].

Inductive charging

Wireless charging technologies are generally classified into two categories: capacitive power transfer and inductive power transfer. Capacitive charging, suited for low-power applications, relies on electric fields, whereas inductive charging is designed for higher power requirements and operates through magnetic fields. In the case of inductive charging, electrical energy is transmitted via electromagnetic induction, wherein an electromagnetic field facilitates energy transfer between a transmitter and receiver coil embedded respectively in the charging infrastructure and the vehicle.

This contactless system enables energy transfer without physical connectors and has achieved moderate to high efficiency levels, although its performance still lags slightly behind conductive (contact-based) systems. Inductive charging allows electric vehicles to be charged either while stationary (static inductive charging) or in motion (dynamic inductive charging), offering a seamless and rapid energy replenishment process. This approach can potentially reduce the need for oversized batteries or additional fleet vehicles, thereby improving operational flexibility and system efficiency.

▶ *Plug-in charging*

▶ *Infrastructure-mounted pantograph charging*

▶ *Roof-mounted pantograph charging*

▶ *Infrastructure for in motion charging*

▶ *Flash charging*

▶ *Inductive charging*

(14) UITP, Infrastructure for IMC Trolleybus Systems, 2021. Available: https://cms.uitp.org/wp/wp-content/uploads/2021/07/Knowledge-Brief-IMC.pdf

From traditional plug-in charging to the more advanced conductive (pantograph) and wireless charging systems, each charging mechanism presents its own set of advantages and potential challenges. While some provide faster charging, others focus on enhancing safety by reducing the risk of electric shock or increasing operational flexibility. In addition, key factors such as vandalism risk, weather-related damage, maintenance needs, and others are important to assess the practicality of each method.

Charging strategies

The charging infrastructure is conceived and installed based on the charging strategy selected by the operator, and considering parameters like energy consumption per bus, available time for charging (e.g. number of hours spent by a given bus at the depot during the night, or number of minutes spent at the terminal stop during operation) number of chargers needed, and location of the chargers [15].

There are two primary charging strategies for BEBs: **overnight charging**, typically conducted at depots, and **opportunity charging**, which occurs at various points during the bus's route or at the depot.

Overnight/depot charging, takes place at a depot or designated parking area over extended periods. BEBs are typically charged during off-service hours, most commonly at night, using plug-in or conductive systems with capacities ranging from 20 - 150 kW [11]. This is the primary charging strategy for most BEBs and is often supplemented by opportunity charging for additional flexibility during operation.

Opportunity charging, also referred to as fast charging, involves the installation of charging stations at various locations. BEBs are charged at various points along their routes, such as at stops or at the beginning/end of lines, using high-power inductive or conductive systems (300 – 600 kW) [11].

In sum, charging strategies are based on the vehicle battery size, the duty cycle and the power supply:

- Depot charging, fast/slow charging, during/off-operation, via either pantograph or plug-based solutions,
- Opportunity charging, fast charging, during operation, via pantograph-based solutions, at the depot or in public space, either end of the line or at intermediate stops,
- Combination of both, along the line and at the depot, combining fast and slow charging, and including slow overnight charging for battery balancing and preconditioning [15].

The primary goal of opportunity charging is to extend battery ranges beyond their typical limits. Further advancements in this technology may enable the use of smaller batteries, however, slow overnight charging is still necessary to balance battery cells and ensure optimal performance.

TECHNOLOGICAL ADVANCEMENTS FOR IMPROVING THE OPERATIONAL EFFICIENCY OF BEBS

BEB thermal management system “TMS”, importance, and benefits

What is the TMS?

A TMS uses combined technologies and control strategies to regulate the internal temperatures of a vehicle and its vital components (battery, motor, power electronics, passenger cabin, etc.), preventing both overheating and excessive cooling. This optimisation of temperature enhances efficiency, safety, and component longevity.

Why is it important?

In BEBs, especially in hot climates like the MENA region, climate control systems consume significant power. An effective TMS is crucial not only for maintaining optimal temperatures for the battery, motor, and power electronics, but also for ensuring passenger and driver comfort, thus improving overall vehicle efficiency and performance. This is particularly important in hot climates where cooling demands are high.

To know more about thermal comfort for electric buses, interested readers may refer to (16).

Smart charging management system

A smart charging management system is a sophisticated technology solution that optimises and automates the process of charging BEBs. By dynamically adjusting to operational requirements, grid conditions, and energy costs, smart charging systems ensure efficient, cost-effective, and reliable charging while supporting sustainable energy use.

In general, such smart charging mechanism optimises the energy usage by distributing charging loads during off-peak hours. In addition, the rapid electrification of bus fleets requires scalable and flexible infrastructure to meet the demands. With this system, fleets can be managed ensuring that the available charging stations are utilized effectively. Last but not least, dynamic scheduling and predictive maintenance ensure buses are charged only as needed, avoiding unnecessary energy costs.

(15) UITP, Depot Adaptation for Clean Bus Technologies, 2024. Available: https://cms.uitp.org/wp/wp-content/uploads/2024/07/5_UITP_template_Bus_Depot-Final.pdf

(16) UITP, Toolkit on Thermal Comfort and Energy Efficiency for Electric Buses, 2024. Available: https://mylibrary.uitp.org/GED_V14/293415701169/UITP_Report_Thermal_Comfort_and_Energy_Efficiency_for_Electric_Buses,_May_2024.pdf

Data-driven planning and scheduling optimisation

As cities across the MENA region shift toward electrified public transport systems, the need for innovative, data-driven approaches to planning and scheduling becomes paramount. Electrification introduces unique infrastructure and operational challenges. Limited charging infrastructure, grid constraints, range limitations, and electricity costs add complexity to planning and scheduling.

Advanced technological solutions that leverage big data and AI are now essential to addressing these challenges.

Key challenges in electrified bus operations

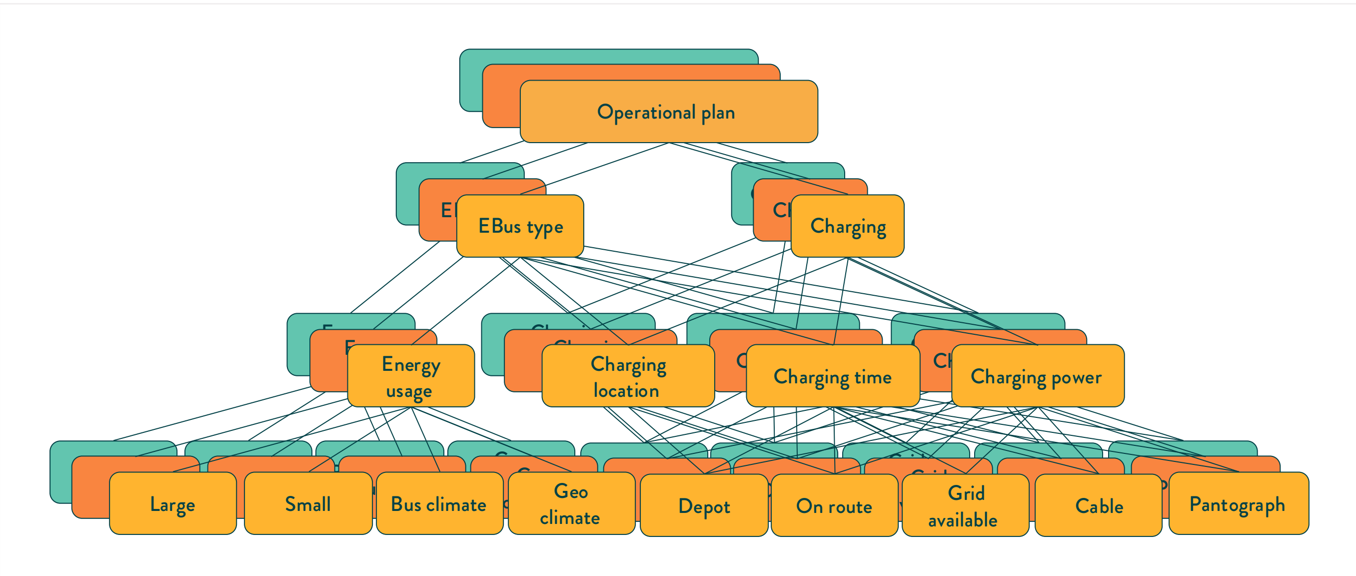
- Charging infrastructure integration
- Range limitations
- Mixed fleet management (BEB + diesel transition)
- Depot bottlenecks and charging congestion
- Data silos and operational complexity
- Dynamic energy pricing and grid constraints
- Battery performance and lifecycle management
- Driver scheduling and training for EV operations
- Real-time fleet monitoring and incident response
- Regulatory and compliance challenges

Optimising electric fleet operations: key considerations for success

Advanced optimisation technologies powered by AI, machine learning, and real-time analytics are transforming how authorities and operators plan, schedule, and manage electric fleets. By combining automation with predictive insights, these solutions provide the data-driven visibility and decision-making capabilities needed to improve service reliability, resource utilisation, and regulatory compliance.

The key to EV fleet success

The transition to electrified public transport systems requires **precise planning, real-time adaptability, and cost-effective operations.** A strategic, technology-driven approach is essential for winning tenders, maintaining contracts, and ensuring a scalable, future-ready electrification strategy.



Some of the parameters to be considered during the operational planning of an e-bus. [17]

(17) Optibus

E-BUSES IN MENA REGION

The electrification of bus fleets holds significant potential for the MENA region, bringing a range of positive impacts.

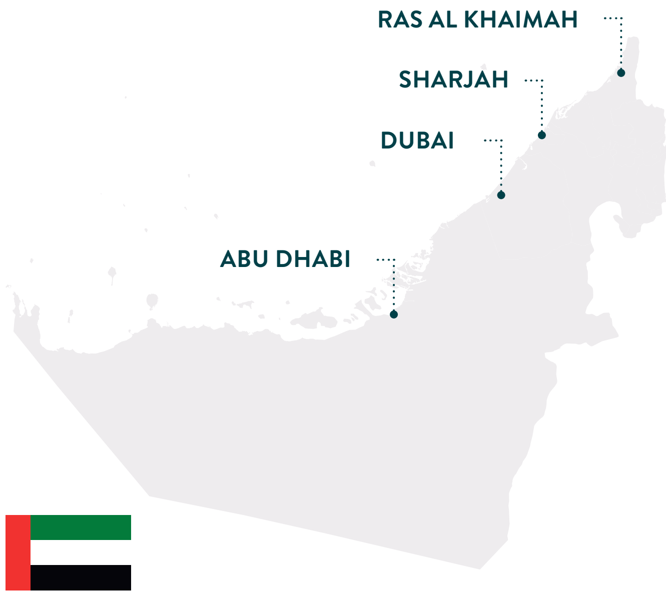
- Adopting e-buses can lead to considerable environmental benefits, reducing GHG and helping cities meet their sustainability goals. This aligns with the region's growing focus on decarbonisation and the transition to cleaner energy sources.
- The operational costs of BEBs are generally lower than those of conventional diesel buses, due to reduced fuel costs and fewer maintenance requirements. This presents an opportunity for PTAs and PTOs to achieve long-term cost savings, despite higher upfront investment.
- The shift to e-buses improves public health by lowering harmful pollutants in urban areas.

DECARBONISATION TARGETS AND CURRENT STATUS OF E-BUSES IN THE MENA

The demand for BEBs (in specific) in the MENA region is steadily increasing, as cities are setting specific targets to decarbonise their public transport networks.

The region is primarily advancing in the BEB technology, since it has achieved a higher level of technological maturity and lower costs compared to FCEBs, making them more tested, reliable, and scalable. This technological maturity enables MENA cities to benefit from established best practices and global experiences, fostering an easier integration of BEBs into their public transport systems as they navigate the transition to cleaner energy solutions.

Government policies in the MENA region are moving more toward BEBs, with many countries already running successful pilot programs for BEBs. While hydrogen is still being explored as a future fuel, its adoption in public transport remains limited due to the higher costs and challenges associated with infrastructure, supply and storage. **Therefore, this research will primarily focus on the adoption and evolution of BEBs in the MENA region.**



UNITED ARAB EMIRATES

DUBAI

Dubai has developed a comprehensive decarbonisation strategy, aligning with the United Arab Emirates' overarching goal of achieving net-zero carbon emissions by 2050. The Dubai Roads and Transport Authority (RTA) plays a pivotal role in this initiative, particularly through the electrification of its public transport fleet. The RTA has developed the 'Zero-Emissions Public Transport in Dubai 2050' strategy, marking it as the first entity in the MENA to establish a long-term plan for net-zero emission public transport. The strategy outlines specific targets for converting public transport vehicles to electric and hydrogen power [(1)].

- **Taxis and limousines:** Convert 30% to electric and hydrogen vehicles by 2030, 50% by 2035, and achieve 100% conversion by 2040.
- **Public transport buses:** Convert 10% to electric and hydrogen buses by 2030, increasing to 30% by 2035, 50% by 2040, 80% by 2045, and reaching 100% by 2050.
- **School buses:** Convert 10% of Dubai Taxi company's (DTC) school buses into electric and hydrogen buses by 2030, which will be raised to 30% in 2035, 50% in 2040, 80% in 2045, and 100% by 2050.

(1) Government of Dubai, RTA rolls out strategy to transition to zero-emissions operations by 2050, 2023. Available: https://mediaoffice.ae/en/news/2023/May/28-05/RTA-rolls-out-strategy-to-transition-to-zero

In terms of public buses, the RTA is being progressively moving toward trialling e-buses since 2015. It began with the introduction of the BEB (Design Line) in 2015. In 2019, the RTA trialled the Yutong BEB, followed by the dynamic electric vehicle wireless charging technology trials in 2019-2020. Between 2020 and 2021, RTA has tested Volvo BEB with opportunity charging technology, which allows buses to charge at key points along routes to extend their range. During COP28 summit, the RTA operated a fleet of 10 BEBs, including models from Volvo, Yutong, Higer, Mercedes, and BYD (2).

In 2024, RTA procured 40 Zhongtong BEBs, each 12 meters in length, with plans to commence operation in the coming years. The latest trial, involving the Volvo BZL BEB, will for the first time incorporate fare collection, an advancement from previous trials that were limited to passenger service without fare integration.

These efforts highlight Dubai's commitment to adopting cleaner, more sustainable transport solutions, aligned with global environmental goals. More details about their progress in given in Table 2.

Table 2. RTA trials of BEBs (2).

Trials	2019	2019 - 2021	2023 - 2024	2024 - 2025
Bus model	ZK6128BEVG (E12LF)	7900E	KLQ6126GEV	BZL
OEMs	Yutong	Volvo	Higer	Volvo
Bus length	12m	12m	12m	12m
Key	Trial operation of bus complies with GCC specifications	Introducing for the first time in the region the opportunity charging technology (concept) using Pantograph European specs. bus	Trial operation of a BEB designed for Dubai environment as per the main RTA requirements and support the opportunity charging using Pantograph	Trial operation of BEB designed for Dubai environment and as per RTA main requirements, will operate in actual (existing) route using depot charging
Key stakeholders	RTA, Yutong, Al Khoory	RTA, DEWA, FAMCO, Volvo, ABB, Al Naboodah	RTA, DEWA, KHF, HIGER, ABB	RTA, DEWA, FAMCO, Volvo, ABB
Trial duration	About 4 months	About 6 months	About 9 months	9 months in the program
Battery size (kWh)	422	200	423	470

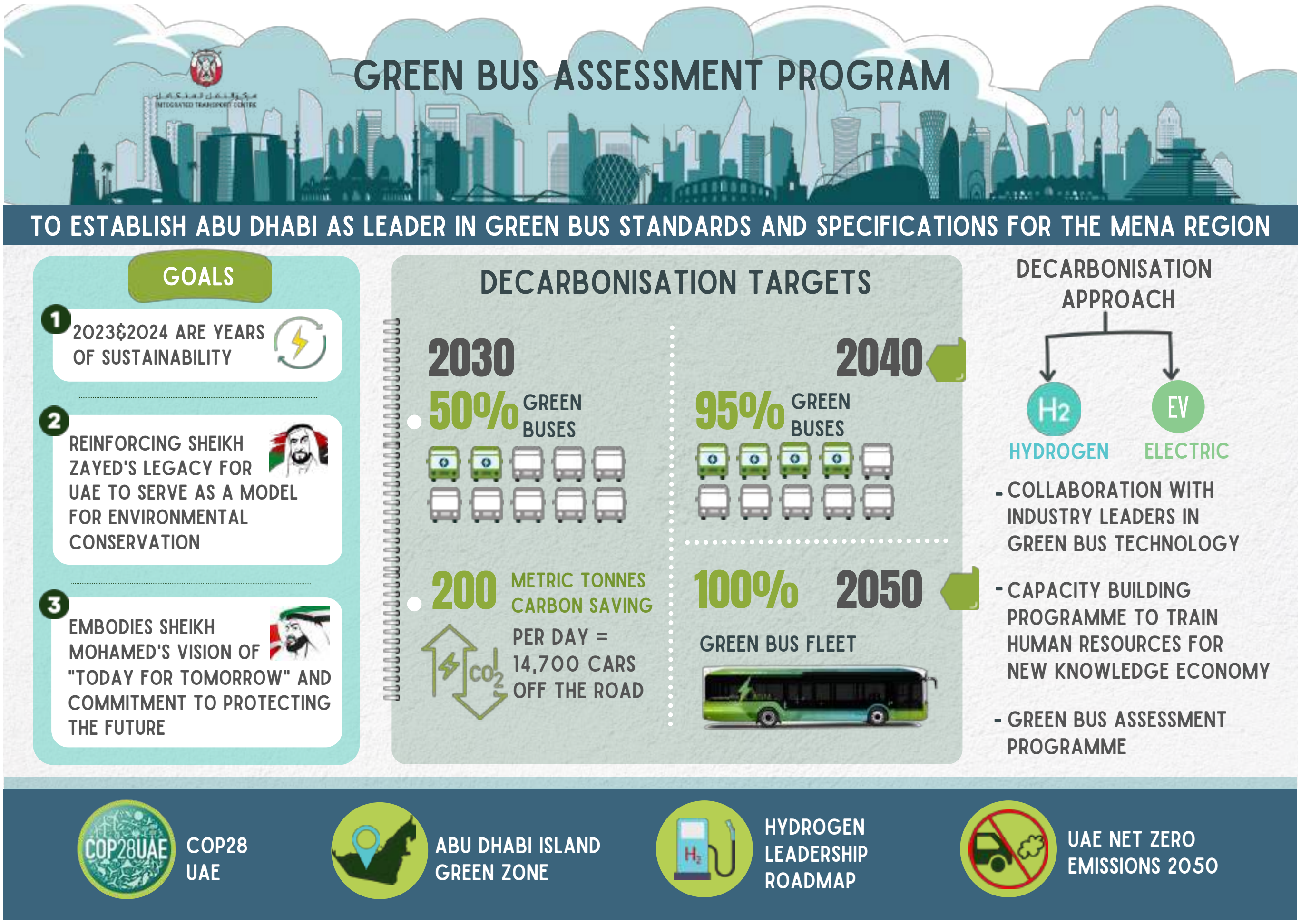
(2) Roads & Transport Authority in Dubai

ABU DHABI

Abu Dhabi aligns with the UAE's Net Zero by 2050 Strategic Initiative, which sets ambitious goals for reducing GHG emissions. The emirate is focusing on sustainable urban development, energy efficiency, and clean transport to achieve these objectives.

The Integrated Transport Centre - ITC (Abu Dhabi Mobility) is targeting to achieve a deployment of 50% green buses, including BEBs and hydrogen buses, by 2030, with a goal to increase this to 95% by 2040, and ultimately reaching a fully green bus fleet by 2050 [3].

The below figure demonstrates the green bus program that the authority in Abu Dhabi is taking forward to decarbonise their public bus fleet [3].



Urban Buses

ZEBs	Service launch	Buses	Length	Lines	Stops	Seat Capacity
BEBs	2024	23	30 km	4	54	36 - 42 *(pax/vehicle)*
Hydrogen buses	2024	5	30 km	2	49	37 - 70 *(pax/vehicle)*

(3) Abu Dhabi Mobility

Figure 3 represents Abu Dhabi's Decarbonisation Roadmap, a structured pathway aimed at achieving net-zero carbon emissions by 2050.

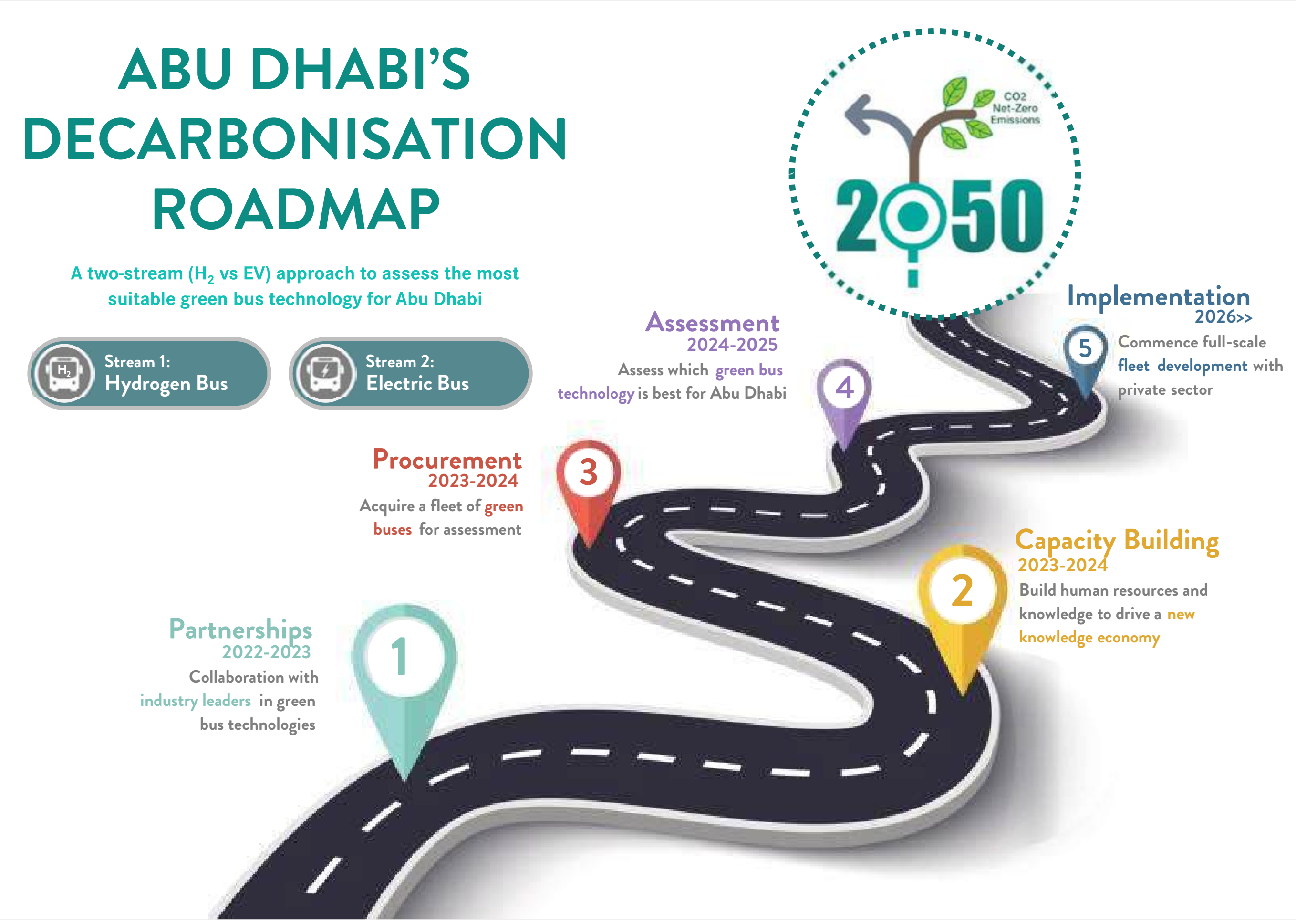


Figure 3. Abu Dhabi decarbonisation roadmap.

SHARJAH

Sharjah Roads and Transport Authority (SRTA) is taking significant steps toward a greener future for public transport, aligning with the national objectives outlined in the 2050 Climate Neutrality Strategic Initiative. Since 2022, SRTA has been operating two BEBs within the city, and in September 2024, they unveiled the first phase of its e-bus intercity services. This initial rollout includes ten BEBs of the King Long model, each measuring 9 meters in length. These buses are equipped with advanced safety features, having met international standards and obtained a European safety certificate. Additionally, they are air-conditioned and include a battery cooling system designed for the UAE's climate. This phase features the launch of three intercity routes connecting Dubai, Ajman, and the Hamriyah area, boosting public transport services and supporting the Authority's commitment to a gradual shift toward eco-friendly transit solutions [4].

(4) SRTA, The Launch of The First Phase of The Operation of Electric Buses in The Emirate of Sharjah, 2024. Available: https://www.srta.gov.ae/en-us/Media-Center/News/Detail/FirstLaunchElectricBuses.html

Urban Buses (Battery-electric buses)[5]

Launch	Length	Buses	Lines	Stops
2022	25 km	2	1	17

Operators	Seat Capacity	Avg. Trip Duration	Avg. Load	Annual Trips
SRTA	28 *(pax/vehicle)*	100 min	15 *(pax/vehicle)*	6,480 *(2023)*

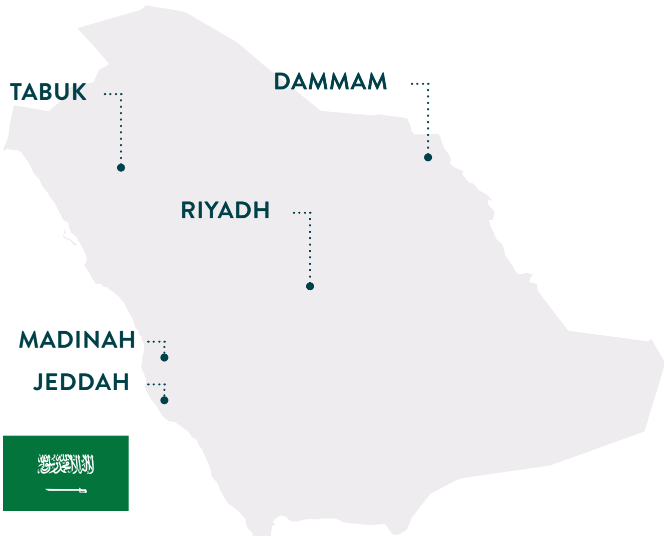
RAS AL KHAIMAH

Ras Al Khaimah has unveiled its Green Mobility Strategy 2040, a comprehensive roadmap aimed at achieving sustainable and eco-friendly transport across the Emirate.

A key component of this strategy is the transition of 50% of the public transport bus fleet to ZEBs by 2040. As of 2025, the Emirate is planning to deploy 10 BEBs for city services and one BEB for intercity services. Trials for these BEBs are scheduled to commence by June 2025, strategically timed to coincide with the region's peak summer temperatures. This period provides an optimal testing environment to evaluate the buses' performance under extreme climatic conditions, ensuring that the most effective operational strategies and technological adaptations are identified. These trials will offer critical insights into the feasibility of scaling BEB operations in similar environments, further solidifying the Emirate's commitment to sustainable urban mobility. In addition, RAK Transport Authority (RAKTA) has signed a cooperation agreement with the Federal Electricity and Water Authority to establish the necessary infrastructure for electric chargers [6].

(5) UITP MENA CTE, MENA Transport Report, 2025. Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=296031301421

(6) RAKTA



SAUDI ARABIA

Saudi Arabia outlines a target to convert 30% of all vehicles to electric by 2030, as part of its broader plan to cut emissions in the capital city by 50%. In light of that, many cities have taken steps to decarbonise their services.

JEDDAH

In 2023, SAPTCO (Saudi Public Transport Company) launched its first BEB from Yutong for public use in Jeddah. This trial bus boasts an impressive range of 350 km and a capacity to accommodate 72 passengers, marking a significant step in introducing eco-friendly transit options in the city [(7)].

MADINAH

SAPTCO expanded its electric public transport services to Madinah in 2023, demonstrating a strong commitment to embracing advanced, sustainable transport technologies. The BEB, manufactured by King Long, can travel approximately 250 km per charge and includes features such as high-efficiency air conditioning, interactive trip detail screens, and specially designed areas for passengers with disabilities [(8)].

DAMMAM

SAPTCO also initiated a BEB of TAM model in Dammam and Qatif Governorate. The vehicle features 37 passenger seats and a 420kWh battery capable of operating for up to 18 hours across 73 daily trips, covering up to 300 kilometres in operational range [(8)].

TABUK

has announced that 25% of its public transport will consist of BEBs, positioning the region as a forward-thinking adopter of sustainable transport initiatives [(9)].

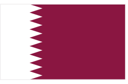
In December 2024, SAPTCO in collaboration with other stakeholders including Transport General Authority (TGA) have conduct a successful trial for the first hydrogen-power bus in the kingdom. The bus, manufactured by Hyundai, features the capability of to travel up to 635km on a single charge and accommodate up to 45 passengers. The bus will connect the city of Dammam with Al Ahsa Governorate covering a total distance of 358 km daily as part of the intercity transport service operated by SAPTCO.

▸ *BEBs and hydrogen bus in Saudi Arabia [(8)].*

(7) Argaam, Electric Bus Services Launches in Dammam, Al Qatif, 2023. Available: https://www.argaam.com/en/article/articledetail/id/1683319

(8) Saudi Public Transport Company. Available: https://saptco.com.sa/en/solutions-innovations

(9) Zawya, Electric buses constitute 25% of Tabuk public transport project, 2024. Available: https://www.zawya.com/en/business/transport-and-logistics/saudi-electric-buses-constitute-25-of-tabuk-public-transport-project-q7s2vrtc



QATAR

As of 2024, around 75% of the public bus fleet is electrified with 852 BEBs are in operation, with a target to achieve a fully e-bus fleet by 2030 [10].

Doha has been proactive in advancing its strategy for the electrification of public transport as part of its broader sustainability and environmental goals. The initiative aligns with Qatar's vision for sustainability, driven by the Qatar National Vision 2030. Qatar's Ministry of Transport is actively working to position the country as a regional hub for electric vehicles (EVs) by implementing strategies that include new EV testing and certification facilities. In addition, Doha has the world's largest e-bus depot, that covers an area of more than 400,000 square meters and is composed of 24 multi-functional buildings and has the capacity of 478 electric bus charging points.

Qatar has aspired a 25% electric public bus target by 2022 in preparation for hosting the FIFA World Cup. Around 741 BEBs manufactured by Yutong were deployed and operated by Mowasalat during the World Cup [11].

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Urban & Suburban Buses (Battery-electric buses) [5]

Launch	Length	Buses	Lines
2022	2,972 km	852	81

Operators	Seat Capacity	Ridership	Stops
Mowasalat	30 *(pax/vehicle)*	1,979,432 *(2023)*	3,160

(10) Ministry of Transport, Qatar

(11) Sustainable Bus, Largest E-Bus Depot Inaugurated In Qatar. There's Room For 478 Vehicles from Yutong, 2022. Available: https://www.sustainable-bus.com/infrastructure/world-largest-e-bus-depot-qatar-yutong/

EGYPT

ALEXANDRIA

Alexandria e-bus integration began in 2019 with the Alexandria Public Transport Authority (APTA) introducing 10 BEBs (12 meters, low-floor/low-entry) from BYD. This initial fleet marked Alexandria as an early adopter of electric public transport solutions in Egypt. The expansion continued in early 2023, when APTA added another 10 BEBs, this time from MCV with a Dong-Feng powertrain. These buses, featuring an elevated floor design, have been operating efficiently across three main routes in Alexandria, enhancing sustainable transit in the city and contributing to reduced emissions.

A landmark event for Egypt's e-bus push was COP27 in 2022, where 140 BEBs, involving contributions from APTA, Cairo Transport Authority (CTA), and Administrative Capital Transport Authority (ACTA), were deployed in Sharm El-Sheikh. These buses were later redistributed to designated urban areas to continue serving residents after the event.

Urban Buses (Battery-electric buses)

Launch	Length	Buses	Stops
2019[12]	2,741 km [13]	55[12]	..

Operators	Ridership	Seat Capacity
APTA	76.0 million / year [5]	90 *(pax/vehicle)* [12]

NEW ADMINISTRATIVE CAPITAL

New Administrative Capital (NAC) Gradual transitioning towards clean modes of transport, including electric and hydrogen powered vehicles by 2030 [14]. ACTA a joint venture between Mwasalat Misr and the Egyptian Ministry of Transport rolled out 30 Higer BEBs (12 m, low-floor/low-entry) dedicated to serving routes within the New Administrative Capital, showcasing the expansion of e-mobility beyond central Cairo.

Urban Buses (Battery-electric buses) [15]

Launch	Length	Buses	OEM	Stops
2022	28 km	30	Higer	26

Operators	BEB Length	Lines	Seat Capacity
ACTA	12m	2	1,230 *(total)*

Looking forward, Cairo plans to elevate its e-bus capabilities by deploying 100 BEBs built with Bus Rapid Transit (BRT) specifications. The total cost of these 100 buses, produced for the Egyptian Ministry of Transport, amounts to EGP 1 billion. The BRT system on the Ring Road will have a capacity of 70 passengers per vehicle, with designated seats for passengers with special needs. The Ministry of Transport considers the BRT project one of the most significant transportation arteries under development, aimed at connecting East Cairo with the West while integrating with the New Administrative Capital.

The project is designed to complement other modes of transport, including the high-speed train, the (Light Rail Transit), the monorail, and metro lines, to enhance mobility and facilitate seamless travel to the new capital through sustainable, eco-friendly transport. This project is expected to start the pilot phase in July 2025 [16].

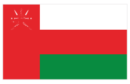
(12) Alexandria Public Transport Authority

(13) TUMI Data, Alexandria, 2024. Available: https://hub.tumidata.org/dataset/gtfs-alexandria

(14) Ministry of Planning and Economic Development, Vision of Egypt, 2023. Available: https://mped.gov.eg/Files/Egypt_Vision_2030_EnglishDigitalUse.pdf

(15) Mwasalat Misr

(16) Youm7, 2024. Available: https://www.youm7.com/story/2024/9/13/



OMAN

Oman has articulated a comprehensive strategy to achieve carbon neutrality by 2050. This commitment is supported by interim objectives, notably a 21% reduction in greenhouse gas emissions by 2030, relative to 2020 levels [17].

Oman has initiated steps toward electrifying its public bus fleet, though specific long-term targets have yet to be publicly disclosed. In July 2024, Mwasalat, the national transport company, introduced the country's first BEB. This bus, measuring 8.94 meters in length and equipped with a 211kWh lithium iron phosphate battery, is designed for urban operations with a capacity of 28 seated passengers and up to 35 standing passengers [18].

While these developments indicate a commitment to sustainable transportation, Oman has not yet announced specific electrification targets for its public bus fleet.

© Mwasalat

JORDAN

AMMAN

Amman is progressing towards public transport electrification by 2030, aiming for 20% of taxis to be electric and ensuring that all BRT buses are fully electrified. The transport sector is the second largest contributor to emissions in Amman, and traffic congestion is the top challenge facing the city. On-road vehicles contribute to the majority of transport emissions [19]. In light of that, Greater Amman Municipality (GAM) is setting clear plans in deploying electrifying their bus fleet, in which 15 BEBs will be launched in 2025 [20].

The buses will be allocated to enhance the BRT routes during the pilot operation phase. The objectives of the pilot phase are:

- Evaluate the operational performance of buses within the current transport environment.
- Test the supporting infrastructure such as charging stations and electricity feedback.
- Monitor user feedback and measure the efficiency of buses in improving the public transport experience.

Below (Table 3), a timeline outlines the progression of BEB technology across various MENA cities. The objective of this mapping is to highlight the advancements and growth of e-buses in the region over time, offering valuable insights into the development of this technology.

(17) Foreign Ministry of Oman, Oman Launches Net Zero 3 Initiative In Drive For Carbon Neutrality, 2024. Available: https://www.fm.gov.om/oman-launches-net-zero-3-initiative-in-drive-for-carbon-neutrality/

(18) Mwasalat

(19) Greater Amman Municipality, The Amman Climate Plan: A Vision for 2050 Amman, 2019. Available: https://documents1.worldbank.org/curated/en/816961617187012025/pdf/The-Amman-Climate-Plan-A-Vision-for-2050-Amman.pdf

(20) Alsaa, 2024. Available: https://alsaa.net/article/592127/

Table 3. Overview of e-bus rollout across MENA

Flag	City	PTO	2019	2020	2021	2022	2023	2024	2025
	Dubai	**RTA**	1 BEB, E12LF, Yutong,12m long *(trial)*	1 BEB, 7900E, Volvo, 12m long *(trial)*			1 BEB, KLQ6126GEV, Higer, 12m long *(trial)*		1 BEB, BZL, Volvo, 12m long *(trial)*
								40 BEBs, Zhongtong, 12m long *(procured)*	
	Abu Dhabi	**ITC**						23 BEBs and 5 Hydrogen buses *(in operation)*	
	Sharjah	**SRTA**	1 BEB, Changhan *(trial)*			2 BEBs *(in operation)*			
								10 BEBs, King Long, 9m long	
	Ras Al Khaimah	**RAKTA**							10 city BEBs 1 intercity BEB *(planned)*
	Doha	**Mowasalat**				852 BEBs, Yutong *(in operation)*			
	Saudi Arabia	**SAPTCO**				1 BEB, TAM, Dammam *(trial)*	1 BEB, Yutong E11 pro, 11m long, Jeddah *(trial)*	1 Hydrogen bus, Hyundai, 45 passenger capacity, Dammam and Al Ahsa *(trial)*	
							1 BEB, King Long, 9m long, Madinah *(trial)*		
	Amman	**GAM**							15 BEBs, Yutong, 12m long
	NAC	**ACTA**				30 BEBs, Higer, 12m long *(in operation)*			
	Alexandria	**APTA**	15 BEBs, BYD, 12m long *(in operation)*						
						40 BEBs, DongFeng / MCV SetiBus, 12m long *(in operation)*			
	Muscat	**Mwasalat**						1 BEB, Yutong, 8.94m long *(trial)*	

**The data represent number of e-buses, OEM, and bus length, and city (in case of Saudi Arabia)*

Battery-electric and hydrogen buses initiatives in the MENA

ALEXANDRIA

Alternative Fuel	Battery-Electric Bus
Status	Operational
Operational Stage	Moderate scale

RAS AL KHAIMAH

Alternative Fuel	Battery-Electric Bus
Status	Trial
Operational Stage	-

MUSCAT

Alternative Fuel	Battery-Electric Bus
Status	Trial
Operational Stage	-

SHARJAH

Alternative Fuel	Battery-Electric Bus
Status	Operational
Operational Stage	Small scale

KUWAIT

Alternative Fuel	Battery-Electric Bus
Status	Operational
Operational Stage	Small scale

AMMAN

Alternative Fuel	Battery-Electric Bus
Status	Trial
Operational Stage	-

DUBAI

Alternative Fuel	Battery-Electric Bus Hydrogen bus
Status	Trial
Operational Stage	-

SAUDI ARABIA

Alternative Fuel	Battery-Electric Bus Hydrogen bus
Status	Trial
Operational Stage	-

NEW ADMINISTRATIVE CAPITAL

Alternative Fuel	Battery-Electric Bus
Status	Operational
Operational Stage	Moderate scale

DOHA

Alternative Fuel	Battery-Electric Bus
Status	Operational
Operational Stage	Large scale

ABU DHABI

Alternative Fuel	Battery-Electric Bus Hydrogen bus
Status	Operational
Operational Stage	Moderate scale

UNDERPINNING FACTORS INFLUENCING BEBs DEPLOYMENT IN MENA

WHAT ARE THE FACTORS INFLUENCING THE DEPLOYMENT OF BEBs?

Why is it important to identify the attributes of BEBs adoption?

E-buses are influenced by different factors that can enable or hinder their adoption. Understanding these factors allows stakeholders to make well-informed decisions. By recognising enablers, such as government policies or technological advancements, decision makers can leverage these strengths to accelerate progress. Similarly, identifying barriers allows for the anticipation of challenges and the development of mitigation plans.

Hence, evaluating the extent of an enabler or a barrier ensure that resources are allocated effectively. Adding to that, the early identification of the barriers aids in developing contingency plans, reducing the risk of delays or failure. Further, distinguishing both enablers and barriers encourages open dialogue among stakeholders. This helps build consensus on the path forward, ensuring that all parties are aware of the challenges and opportunities and there is a clear understanding of what's at stake, which enable effective collaboration eventually.

The process of collecting the factors should be grounded in a contextual and critical understanding. In particular, some of the factors may function as both enablers and barriers depending on the stakeholder standpoint and local context. For instance, the well-to-wheel (WTW) emissions of BEBs were found to vary based on the electricity generation methods in a specific country. From a policy-making standpoint, regions with a higher proportion of renewable energy benefit from this factor as an enabler, while areas dependent on fossil fuels see it as a barrier to promoting BEBs [(1)]. Similarly, in regions with strong governmental support through subsidies and clear regulations for promoting EVs, policies can accelerate the transition to BEBs. On other hand, in countries with limited or ambiguous policies or continued support for fossil fuel industries, policy environments can hinder the adoption of e- buses.

Therefore, the framework can be effectively adapted to different local contexts by adjusting the influence (whether enabling or impeding) and the scale of impact of each factor, according to the unique characteristics of the case study.

DATA COLLECTION APPROACH

1. Collection of factors

Data was gathered by reviewing the literature to compile a list of factors influencing the adoption of BEBs. The identification and the assessment of the factors is conducted through a multi-step process involves key stakeholders, including PTAs and PTOs. The literature review involves several resources such as UITP literature, academic literature, and the publicly available reports. In this phase, the focus is on gathering relevant information and setting the foundation for subsequent analysis.

2. Validation and categorisation

The list was then validated by subject matter experts in the field to ensure comprehensiveness. This step involves the refinement of the collected factors, which may include adding, removing, or combining the factors. The collected factors are then categorised into groups for enhancing their representation.

3. Construction of open-ended questionnaire and selection of respondents

The evaluation is conducted through an open-ended questionnaire, which is divided into three elements:

1. **First part:** Level of e-bus deployment, drivers of adoption, e-bus fleet, and status of charging infrastructure.
2. **Second part:** Assessment of the collected factors, that is based on the extent to which each factor acts as an enabler or barrier in their context (dual assessment). In specific, the evaluation is performed through a qualitative scoring scheme where stakeholders rate the influence of each factor on a scale from 1 (very low influence) to 5 (very high influence).
3. **Third part:** Open-ended questions involving most critical factor, barrier, and entities' strategies for strengthening enablers and tackling barriers.

Finally, each factor is assessed by the involved stakeholders, which are provided in Table 4. From each entity, the targeted sample involves experts working in different departments that are directly or indirectly involved in buses electrification.

(1) Journal of Transportation Research Part D, Energy Performance Indicators As Policy Support for Public Bus Transport – The Case of Sweden, 2018. DOI: https://doi.org/10.1016/j.trd.2018.10.008

Table 4. List of participating cities and countries.

Region	City	PTA/PTO	Entity name
MENA	**Dubai**	PTA	RTA
	Abu Dhabi	PTA	ITC (Abu Dhabi Mobility)
	Ras Al Khaimah	PTA	RAKTA
	Saudi Arabia	PTA	TGA
	Muscat	PTO	Mwasalat
	Cairo	PTO	Mwasalat Misr
	Amman	PTA	GAM
International	**Toronto**	PTA	Toronto Transit Commission
	Shenzhen	PTO	Shenzhen Bus Group
	London	PTO	Arriva
	Kayseri	PTO	Kayseri Ulasim

Besides identifying the significance of enablers and barriers, it is important to examine the relationship between the level of deployment of BEB technology and how these attributes are perceived. By studying the above cities, which are at different stages of e-bus adoption, we can gain valuable insights into how the relative importance of these factors changes over time and adapt strategies to accelerate transitions in diverse contexts.

When examining cities with varying levels of transitioning to e-buses (emerging/early market as in MENA, middle deployment, advanced deployment), the significance of enablers and barriers changes with the stage of adoption. The participants are asked to self-assess their current phase in the transition to e-buses. Figure 4 highlights the four phases we are taken into consideration.

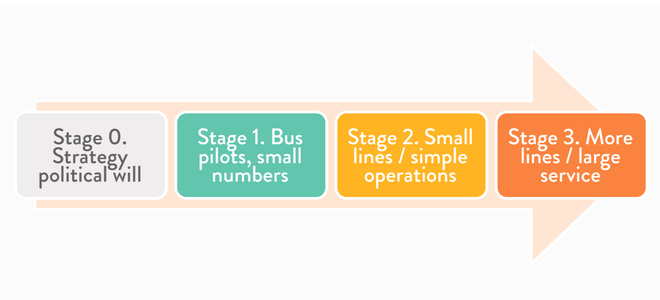


Figure 4. Phases of BEB deployment [2].

4. Evaluation and data analysis

Afterwards, the factors are weighted based on their relative importance, as determined by stakeholders. The results of the assessment are then visualised using radar charts, which provide a clear graphical representation of the strengths and weaknesses of each factor as an enabler or barrier. These visualisations allow stakeholders to easily compare the relative influence of various factors and identify areas needing attention.

The results were summarised in a detailed report that highlighted the key enablers and barriers across the MENA region and the international cities.

IDENTIFIED FRAMEWORK

After several refinements and mapping the factors, the framework, in Figure 5, is ended up with 21 factors that are mapped into four main clusters, namely, technological dimension, economic dimension, environmental dimension, and socio-institutional and policy dimension. Each of the dimensions is then detailed.

Technological dimension

This dimension encompasses various factors that directly impact the operational efficiency, sustainability, and long-term viability of BEB fleets.

(2) UITP, Coordinated EC Project ZeEUS (2014 – 2018)

Technological dimension (7 factors)

1		**Supporting infrastructure**
	Sub-factors	**Charging infrastructure** Availability charging points, changing technology, and grid capacity (all linked to the charging strategy defined to fulfil the operational requirements)
		Depot conversion / upgrade Compatibility of existing depots with BEB charging and infrastructure needs (depots upgrade for BEBs) Identification suitable areas/surface for new depots (need to increase depot surface as the charging infrastructure, and perhaps higher number of vehicles is to be expected)
		Grid capacity/energy supply Reliability, availability, and quality of energy grid to scale to support charging demand (dimensioning the depot energy needs based on worst case scenario and considering upscaling (if planned) in the future)
2		**Battery technology** Advances in battery capacity, durability, charging speed, and energy density
3		**Integration of renewable energy resources** Incorporation of energy generated from alternative resources, such as renewables into the energy systems
4		**Technological innovations and digital solutions of support systems** Level of development and implementation of various technologies such as IT intelligence to optimise fleet management as well as the operations and automation for depot operations and safety
5		**Operational and technical efficiency**
	Sub-factors	**Fleet management** Effective planning for routes and schedules to maximize the efficiency of BEBs
		Operational range The maximum range that can be covered by a single charging, considering the local operational context (this of course will differ from line/route/system system).
		Charging time Managing charging times and potential downtime during operation (Charging / refuelling time)
6		**Maintenance and safety**
	Sub-factors	**Repairs & spare parts** Availability of spare parts and specialised equipment for BEB repairs (e.g., battery packs, power electronics)
		Safety standards & monitoring Clear safety standards (e.g., charging infrastructure are installed and equipped with safety measurements) Staff training on battery bus technology and depot safety – certifications
		Routine & preventive maintenance Regular inspections to identify wear and tear (e.g., for regenerative braking system and thermal management systems) IT tools for predictive maintenance (potential of AI, to be checked)
7		**On-going safety and new skills trainings** Requirements for new profiles and skills and proper training to ensure smooth operations of vehicles

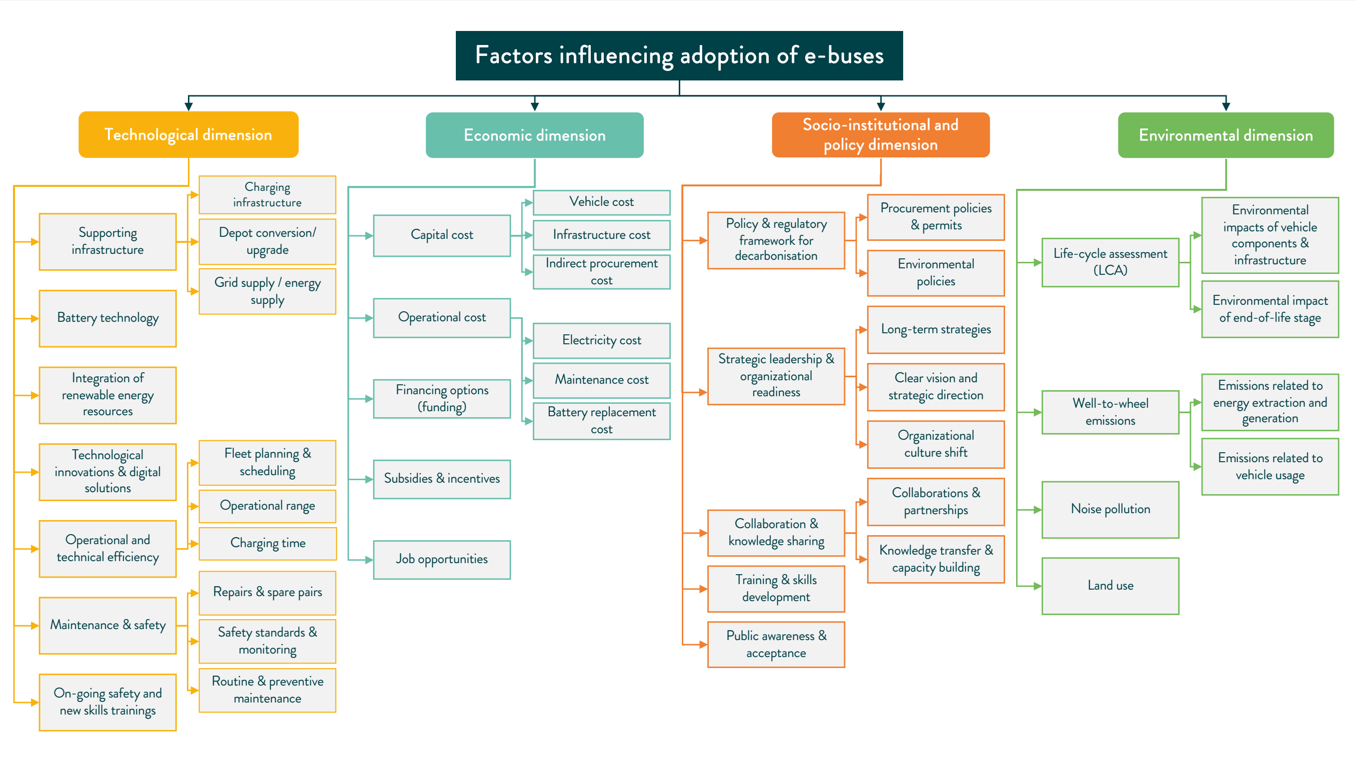


Figure 5. Identified framework for factors influencing adoption of BEBs

Economic dimension

The economic dimension is a critical consideration in the adoption of e-buses, as it directly affects financial viability, and long-term sustainability of BEB deployment.

Economic dimension (5 factors)

No.	Factor	Sub-factors
1	**Capital costs**	**Vehicle cost** Bus purchasing costs, midlife costs (e.g., battery replacement), and disposal costs **Infrastructure cost** Installing and running electric chargers and refuelling stations and modifying depots **Indirect procurement cost** Training and workforce development, fleet optimisation tools, etc.
2	**Operational costs**	**Energy cost** Fluctuating electricity prices and the cost-effectiveness of operating BEBs compared to diesel fuel **Maintenance cost** The cost required for maintaining the vehicles (e.g., battery maintenance, electric drivetrain, charging infrastructure, vehicle, electrical system, etc.) **Battery replacement cost** Expense of replacing or recycling batteries over vehicle lifetime
3	**Financing options (funding)** Financing mechanisms, such as green bonds, concessional loans, and public-private partnerships	
4	**Subsidies & incentives** Government grants, tax incentives, or subsidies for technology adoption	
5	**Job opportunities** Effects of the BEB transition on employment and job skills	

Environmental dimension

The environmental dimension is critical for ensuring that the adoption of electric buses aligns with broader sustainability objectives. The identified factors ensure that BEB deployment not only reduces tailpipe emissions but also addresses environmental trade-offs throughout their lifecycle.

Environmental dimension (4 factors)

1	**Life-cycle assessment (LCA)**	
	Sub-factors	**Environmental impacts of vehicle components & infrastructure** Resource extraction and processing (batteries: lithium, cobalt, nickel, etc.), manufacturing processes, and distribution
	Sub-factors	**Environmental impact of end-of-life stage** Waste management of vehicle components and end-of-life disposal or recycling of BEB including batteries
2	**WTW emissions**	
	Sub-factors	**Emissions related to energy extraction and generation** Emissions including GHG and other pollutants (CO_2, NOx, PMx) generated from extraction, production, and delivery
	Sub-factors	**Emissions related to vehicle usage** E-buses have zero direction emissions (tailpipe emissions), but emissions (CO_2, NOx, PMx) are tied with energy mix of grid distribution
3	**Noise pollution** Resulting noise levels due to BEBs operations including noise coming from charging points if located in public space (e.g., opportunity charging)	
4	**Land use and needs** Efficient utilisation of land and integration of charging infrastructure with existing networks	

Socio-institutional and policy dimension

The socio-institutional and policy dimension is crucial for the successful implementation of bus electrification as it provides the foundational framework needed to drive systemic change. This dimension addresses technical, operational, and societal barriers comprehensively, ensuring a holistic transition.

Socio-institutional and policy dimension (5 factors)

1	**Policy & regulatory framework for decarbonisation**	
	Sub-factors	**Procurement policies and permits** Government-led initiatives or tenders requiring the purchase of electric fleet
	Sub-factors	**Environmental policies** Policies aimed at reducing emissions and promoting sustainability, such as zero-emission mandates and carbon taxes
	Sub-factors	**Long term strategies** National or regional green transport strategies that define long-term electrification goals and targets
2	**Strategic leadership & organisational readiness**	
	Sub-factors	**Clear vision and strategic direction** Establish a clear vision and objectives for the transition, communicated effectively by leadership to all stakeholders
	Sub-factors	**Organizational culture shift** Encouragement of a culture that embraces new technologies and continuous improvement
3	**Collaboration & knowledge sharing**	
	Sub-factors	**Collaborations and partnerships** Involves joining global initiatives, trials, or partnerships aimed at testing, evaluating, and scaling electrification technologies
	Sub-factors	**Knowledge transfer and capacity building** Sharing expertise, best practices, and technical knowledge between countries, organisations, or industries to accelerate the adoption
4	**Training & skills development** Enforcement of trainings and workshops for drivers, maintenance staff, and planners to handle the new technology In other words, the need of engaging staff with the new technology, to ensure they are confident and comfortable with the new operational conditions, tasks, routines, e.g., drivers who need to be trained (eco-driving, vehicle features, etc.)	
5	**Public awareness & acceptance** Growing public demand for cleaner, more sustainable transport options	

ANALYSIS AND FINDINGS

Results of the first part - Where does each city stand in terms of e-bus deployment and adoption?

The first element of the survey involves identifying the implementation phase and the drivers that have triggered the transition to BEB in the surveyed cities. Table 5 summarises the results.

Table 5. E-bus development phases and adoption drivers.

Country	City	Service / Trial launch	No. buses	Phase	Drivers				
					Politically driven	Environmental benefits	Energy efficiency	Economic driven	Strategic approach
	Shenzhen	2011	15,680	Full deployment	✓	✓	✓		
	London	2013	1,782 ZEBs (1,762 BEBs and 20 hydrogen buses)	Stage 3	✓	✓	✓		✓
	Toronto	2019	60 in operation and 340 procured	Stage 3	✓	✓	✓	✓	✓
	Kayseri	2019	16 in operation	Stage 2		✓	✓	✓	✓
	Dubai	2018	40 procured Several trials	Stage 1	✓	✓			✓
	Abu Dhabi	2022	28 ZEBs (23 BEBs & 5 hydrogen buses) in operations	Stage 2	✓	✓			✓
	Ras Al Khaimah	2025	10 city BEBs & 1 intercity BEB to be procured	Stage 0/1	✓	✓	✓	✓	✓
	Cairo inc. NAC	2019	30 BEBs in operation	Stage 2		✓	✓	✓	✓
	Amman	2025	15 BEBs planned for BRT	Stage 0/1	✓		✓		✓
	Muscat	2024	1 BEB in trial phase	Stage 0/1		✓			✓
	Taif & Jazan	2024	In planning phase	Stage 0				✓	✓

**Note: The term Phase corresponds to the stages outlined in Figure 4.*

Results of the second part:

Key insights – Technological dimension

Supporting infrastructure is the most important enabler for all cities, while operational and technical efficiency remains a critical barrier for regions still in the early phases of deployment. Shenzhen has the strongest enabling technological framework and the fewest barriers, proving that early and sustained investment leads to success. London and Toronto are in the middle, while they benefit from moderate enabling factors, their barriers in renewable energy and cost structures require attention. MENA has an infrastructure potential (enabler) but faces barriers in operational efficiency as well as maintenance and safety, which is due to the fact that the region is still in early phases.

Factor analysis for most critical aspects: comparing enablers vs. barriers

Supporting infrastructure: Even in cities with high to moderate BEB adoption (Shenzhen and Toronto), infrastructure remains both an enabler and a barrier.

This suggests that continuous upgrades in charging infrastructure are required to meet growing demand.

Battery technology: Some cities are still investing in improving the utilised bus technology to overcome their severe weather conditions as in Toronto.

Integration of renewable energy resources: Renewable energy integration is still a lower priority across cities. This suggests a need for better alignment between BEBs and clean energy.

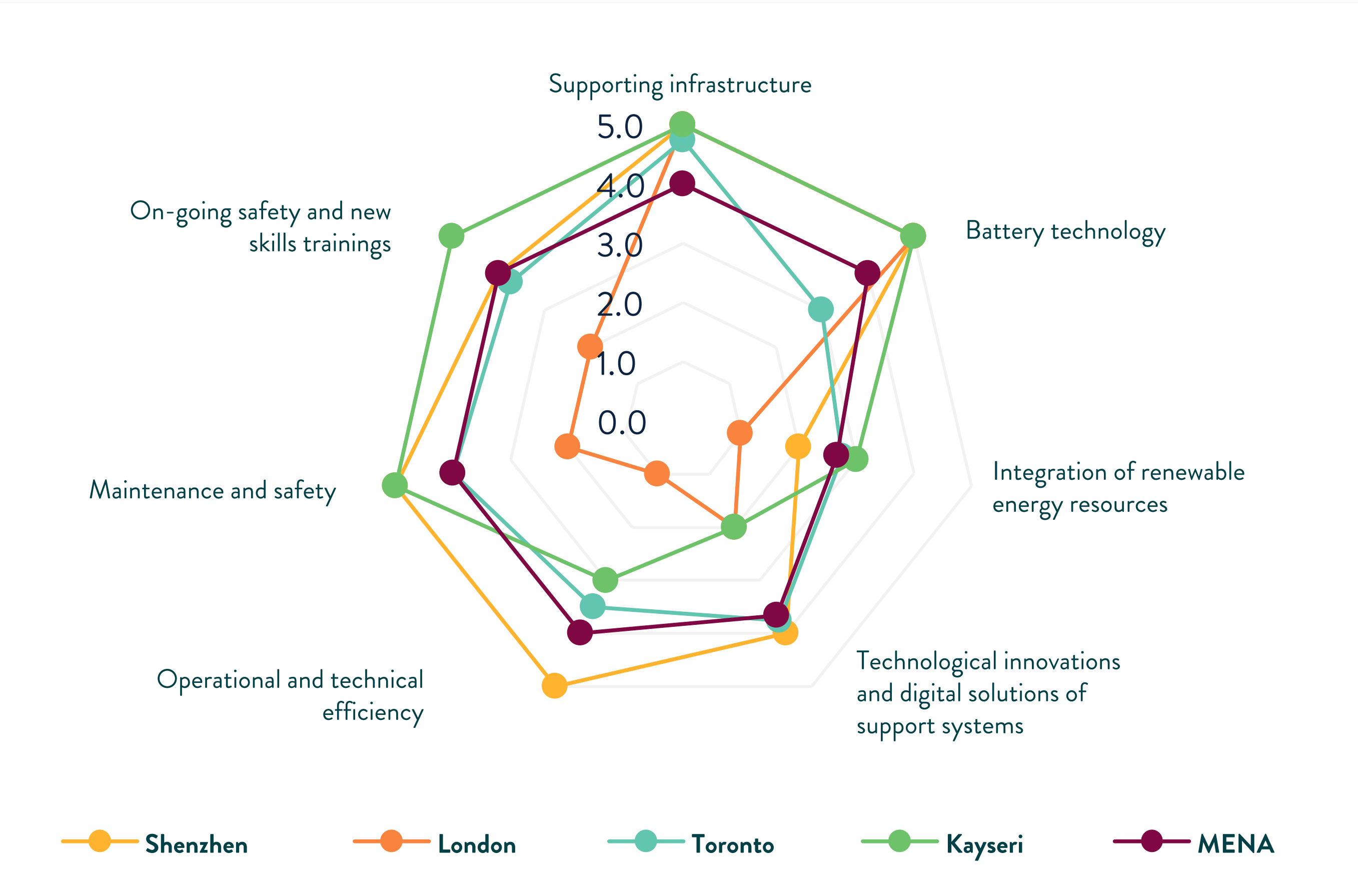
Operational and technical efficiency: Shenzhen has the most experience in optimising BEB operations, yet it remains both a priority and a challenge. On the other hand, performance optimisation is needed in the MENA region for BEB adoption and expansion.

Maintenance and safety: Cities in early adoption phases emphasise maintenance and safety to ensure fleet reliability, requiring workforce training.

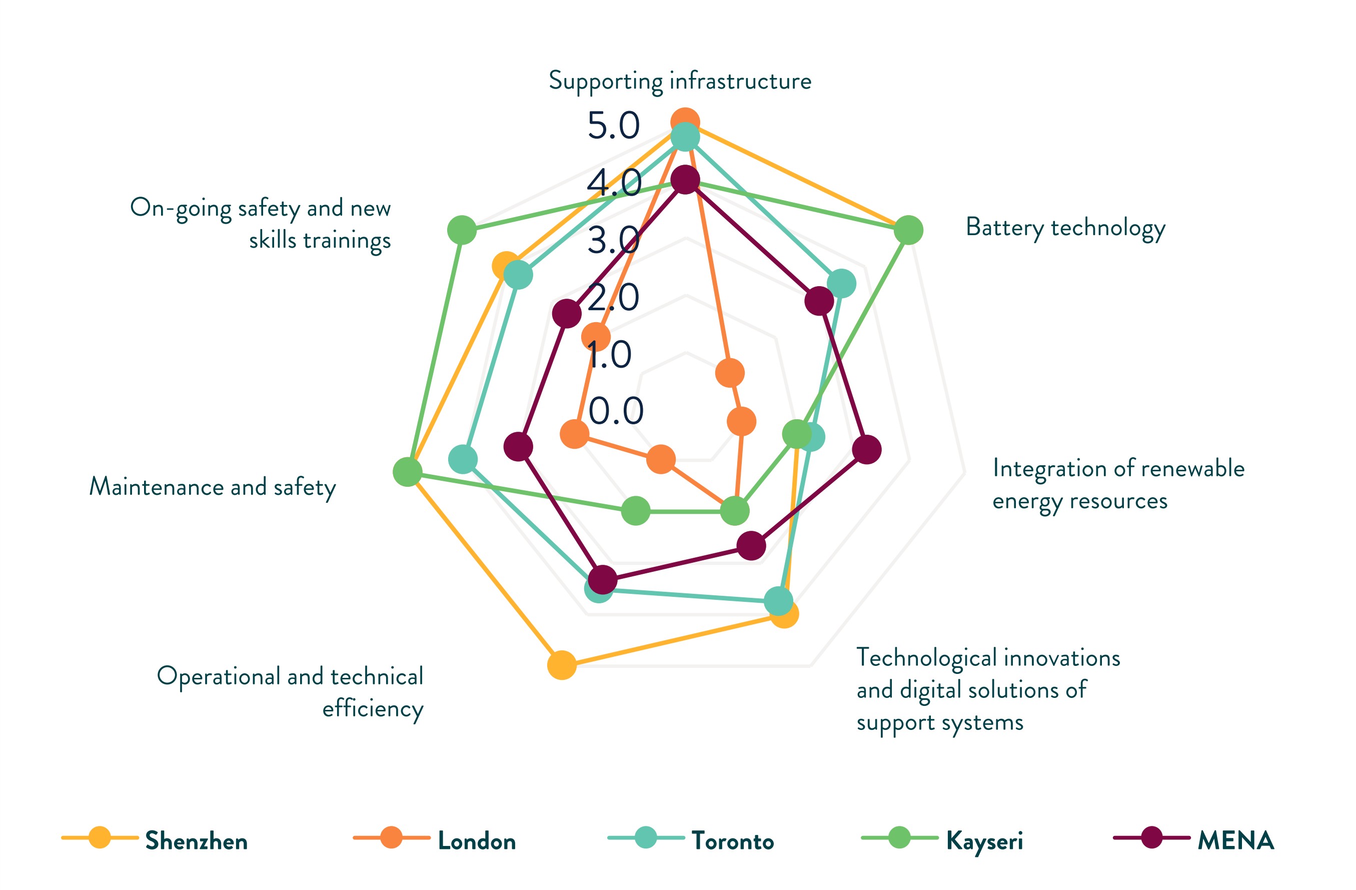
Lessons from the frontrunner cities in e-bus adoption

- Encourage private sector involvement in charging station deployment through PPPs.
- Work with global suppliers to develop regional battery manufacturing partnerships.
- Establish technical training programs to enhance maintenance and operational readiness.
- Collaborate with international leaders to adopt best practices in technological innovations.
- Promote knowledge transfer from regions with advanced BEB adoption.
- Collaborate with utility providers to optimize grid reliability and charging schedules.
- Align charging infrastructure with clean energy sources to ensure sustainability.

Technological dimension (Significance as Enabler)



Technological dimension (Significance as Barrier)



**Note: The significance of each factor for the MENA region is calculated using the median.*

Key insights – Economic dimension

Capital and operational costs remain the biggest barriers globally. Similarly to the technological dimension, Shenzhen's economic advantages outweigh its barriers, making it the global leader in cost-efficient BEB deployment. However, these two factors are still seen as barriers, indicating that financial management is critical. London is facing challenges with cost and availability of funds, needing reforms in financial policies and operational efficiencies. MENA sees financing options as a key enabler but faces challenges with capital cost, highlighting the need for more structured funding and financing mechanisms.

Factor analysis for most critical aspects: comparing enablers vs. barriers

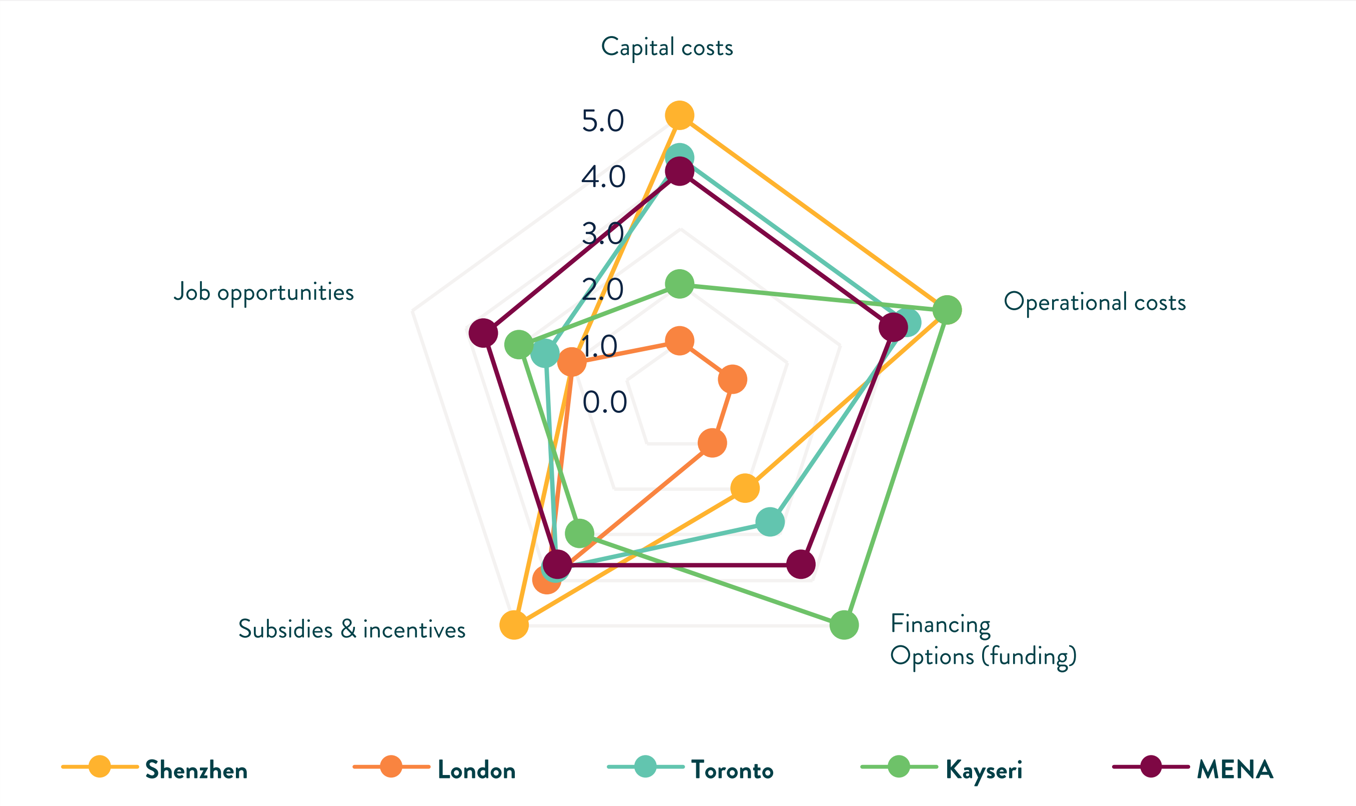
Capital costs: All cities experience financial strain due to high capital investment needed.

Operational costs: Operational costs can be manageable with the availability of cost-optimisation strategies such as route optimisation systems and smart energy management systems.

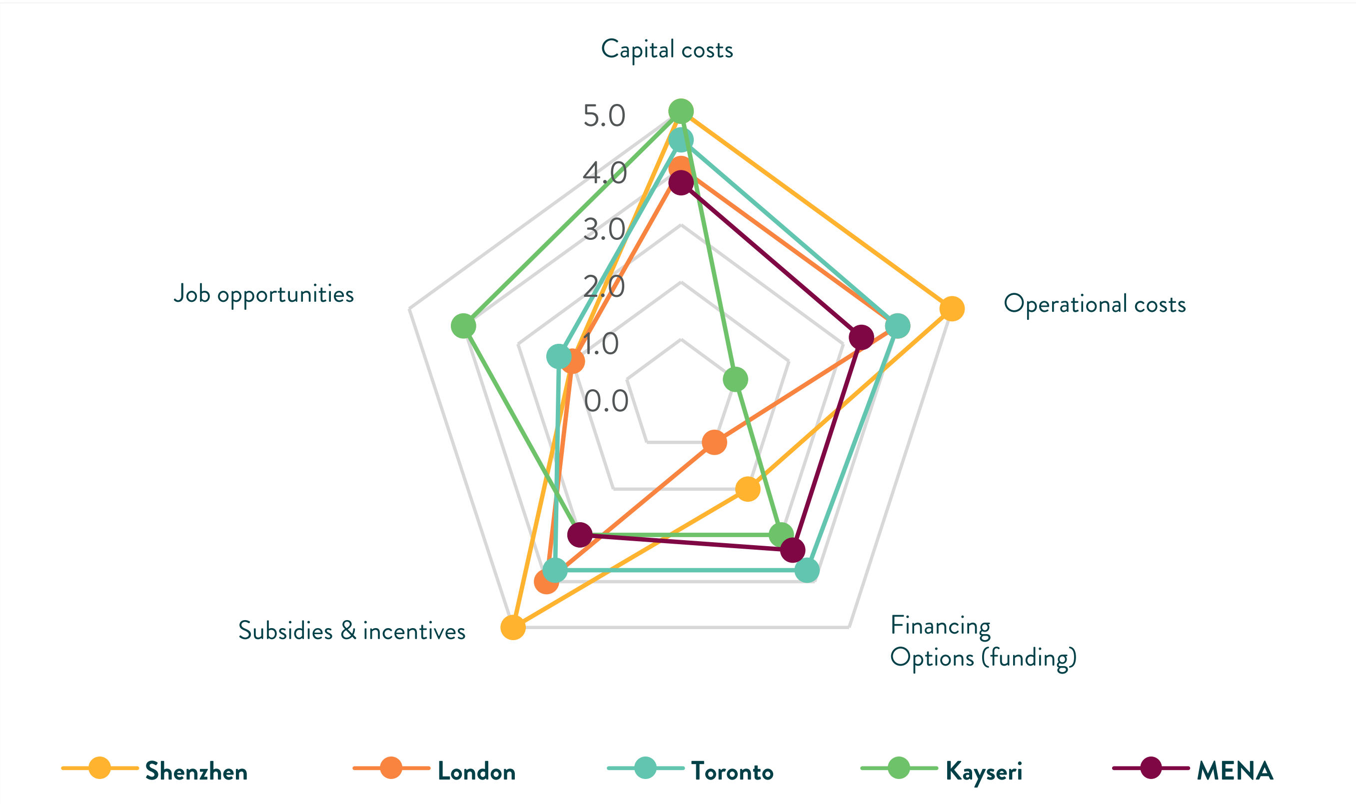
Financing options (funding): Financing and funding is a significant factor to advancing in BEB adoption in almost all of the cities.

Subsidies and incentives: The majority of the cities depends on the subsidies, along with other sources such as private investments as in Toronto. MENA perceives subsidies as an enabler but requires further improvement and better support in the region.

Economic dimension (Signifiance as Enabler)



Economic dimesion (Significance as Barrier)



**Note: The significance of each factor for the MENA region is calculated using the median.*

Lessons from the frontrunner cities in e-bus adoption

- Encourage PPPs and innovative business models such as leasing models.
- Explore green financing options as well as develop long-term financing modes for sustainable growth.
- Expand subsidies for BEB procurement and infrastructure beyond electricity prices (if exists).
- Optimise charging infrastructure to minimise energy expenses, as well as implement data-driven route planning for cost-effective fleet operations.

Key insights – Environmental dimension

The environmental consideration is a key driver of e-bus deployment and adoption.

Factor analysis for most critical aspects: comparing enablers vs. barriers

Life-cycle assessment: LCA is seen as key enabler but remains a challenge, as it requires strong sustainability frameworks.

WTW emissions: Emissions reduction is significant in majority of cities but requires evaluating the complete cycle from battery production to battery secondary life or disposal as well as renewable energy integration to reduce emissions generated from grid energy mix.

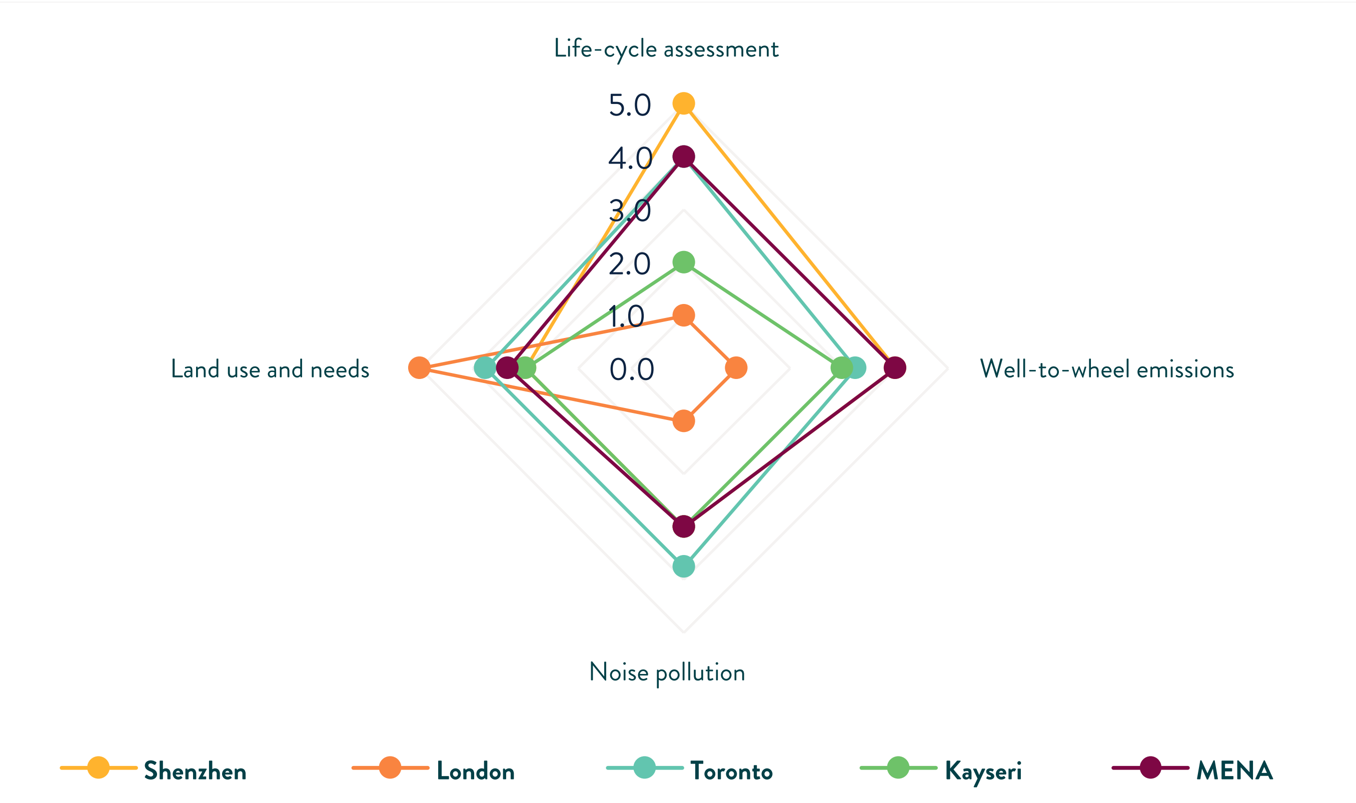
Land use and needs: The challenge of land utilisation varies from one city to another. For example, Kayseri does not see land use as a major issue, possibly due to less urban congestion. For the MENA, land use constraints are manageable (moderate enabler and slightly more seen as a barrier) but still need better planning.

Noise pollution: As BEBs are powered by batteries, noise pollution is not the most critical factor (moderate enabler) compared to others.

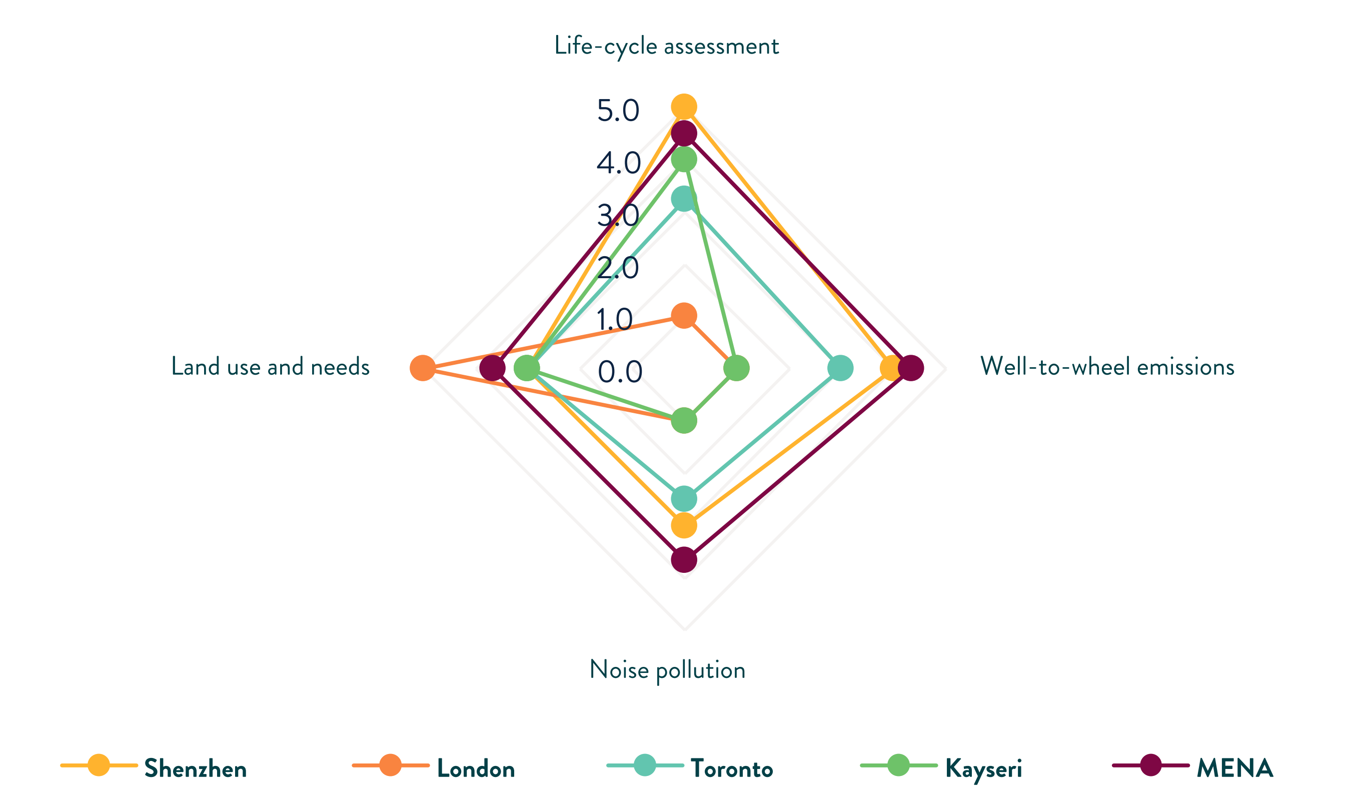
Lessons from the frontrunner cities in e-bus adoption

- Implement government policies that encourage LCA-based procurement models.
- Implement carbon tracking and circular economy policies for LCA.
- Utilise multi-modal transport strategies for efficient urban planning.
- Encourage renewable energy buses to complement battery electric fleets and thereby improve WTW emissions.

Environmental dimension (Significance as Enabler)



Environmental dimension (Significance as Barrier)



**Note: The significance of each factor for the MENA region is calculated using the median.*

Key insights – Socio-institutional and policy dimension

The socio-institutional and policy dimension is a critical enabler for BEB deployment. MENA has strong socio-institutional and policy enablers, which outweigh their significance as barriers.

Factor analysis for most critical aspects: comparing enablers vs. barriers

Policy and regulatory framework for decarbonisation: The majority of the MENA cities involved in this study have clear policies and decarbonisation mandates.

Strategic leadership and organisational readiness: This factor is a significant enabler to BEB deployment and adoption in all cities. On the other hand, some cities see it as a barrier, implying that more proactive approaches are needed.

Collaboration and knowledge sharing: Sharing of knowledge is critical both within cities and across cities. This requires better inter-agency cooperation, and regional partnerships.

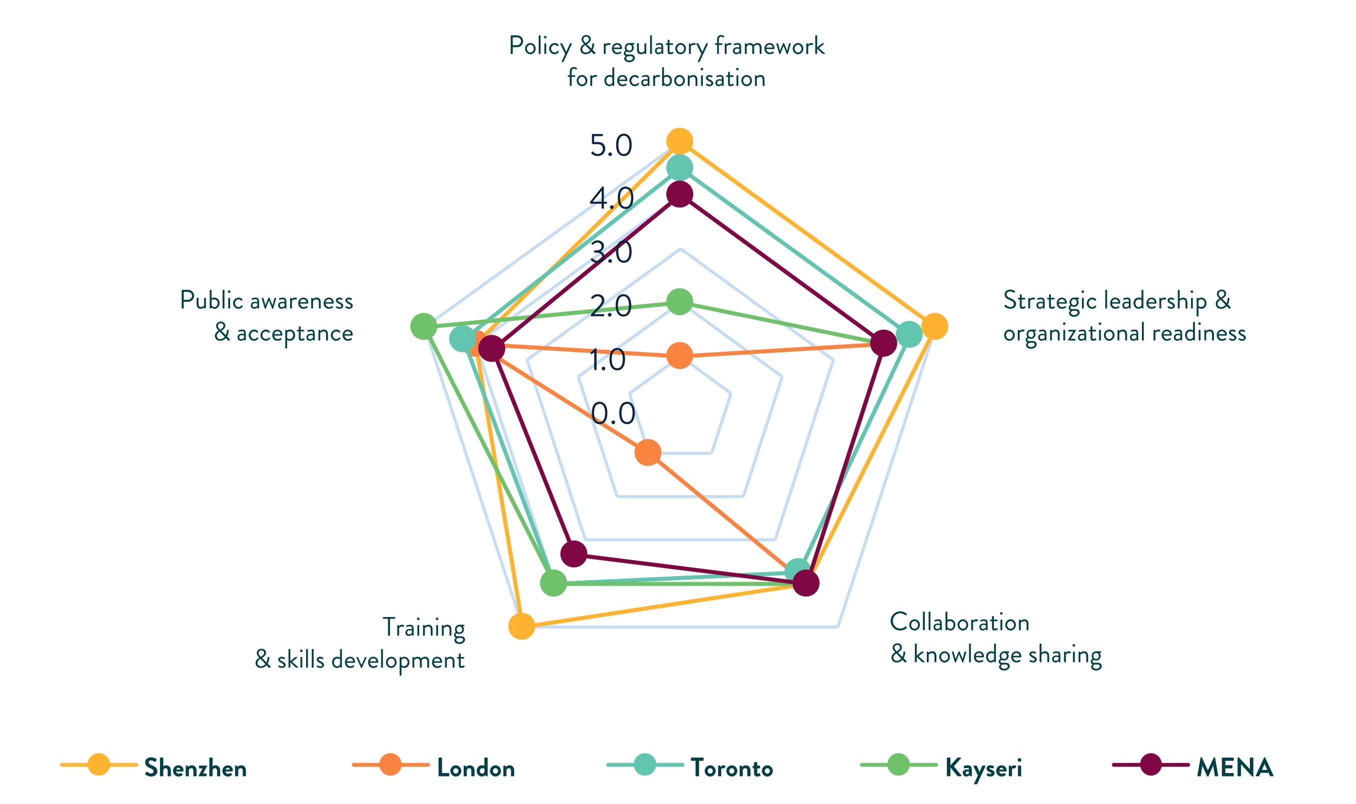
Training and skill development: It plays a critical role in ensuring operational efficiency of BEBs. Cities like Toronto and Kayseri see it more of an enabler than a challenge but still needs improvements. The MENA has moderate progress, but large-scale and continuously updated training programs are needed for advancing adoption.

Public awareness and acceptance: Public engagement influences the success of BEB adoption. Without strong public support, ridership may decline, and policies may face resistance. Kayseri has the strongest public support, allowing for easier policy implementation, while the MENA perceives it as both an enabler and a barrier, which means that the region is still working on the improving the operational efficiency to avoid concerns about charging times, range anxiety, and service reliability.

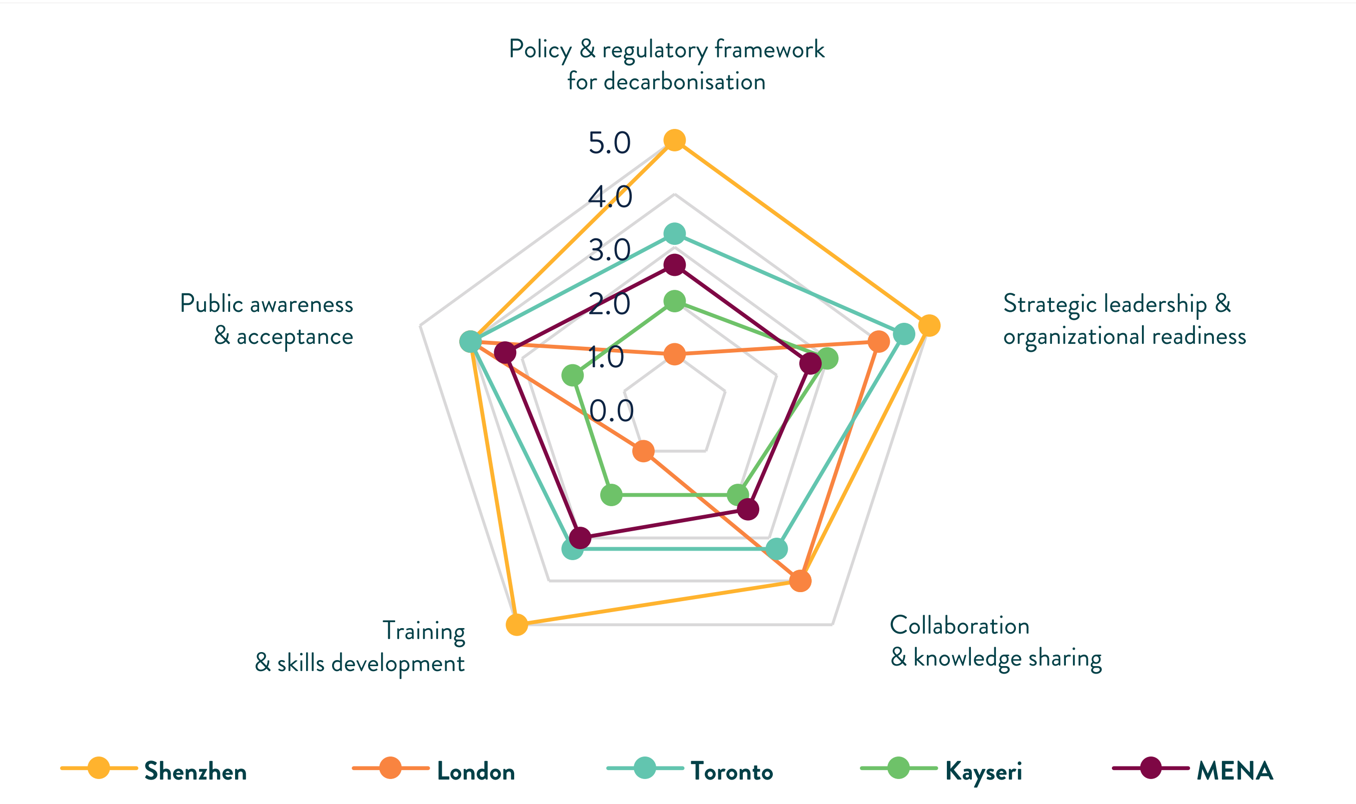
Lessons from the frontrunner cities in e-bus adoption

- Develop BEB policies and encourage PPP.
- Create a knowledge-sharing platform for policymakers, PTAs, PTOs, and industry players.
- Invest in driver and maintenance training academies.

Socio-Institutional and Policy Dimension (Significance as Enabler)



Socio-Institutional and Policy Dimension (Significance as Barrier)



**Note: The significance of each factor for the MENA region is calculated using the median.*

Key insights – Overall dimensions

The below figures illustrate the significance of the aggregated factors that fall under each dimension (technological, economic, environmental, socio-institutional and policy).

Shenzhen's leadership is driven by its technological superiority and strong policy support, making it a benchmark for other cities. The city's strong enablers across all dimensions explain its success with complete electric fleet.

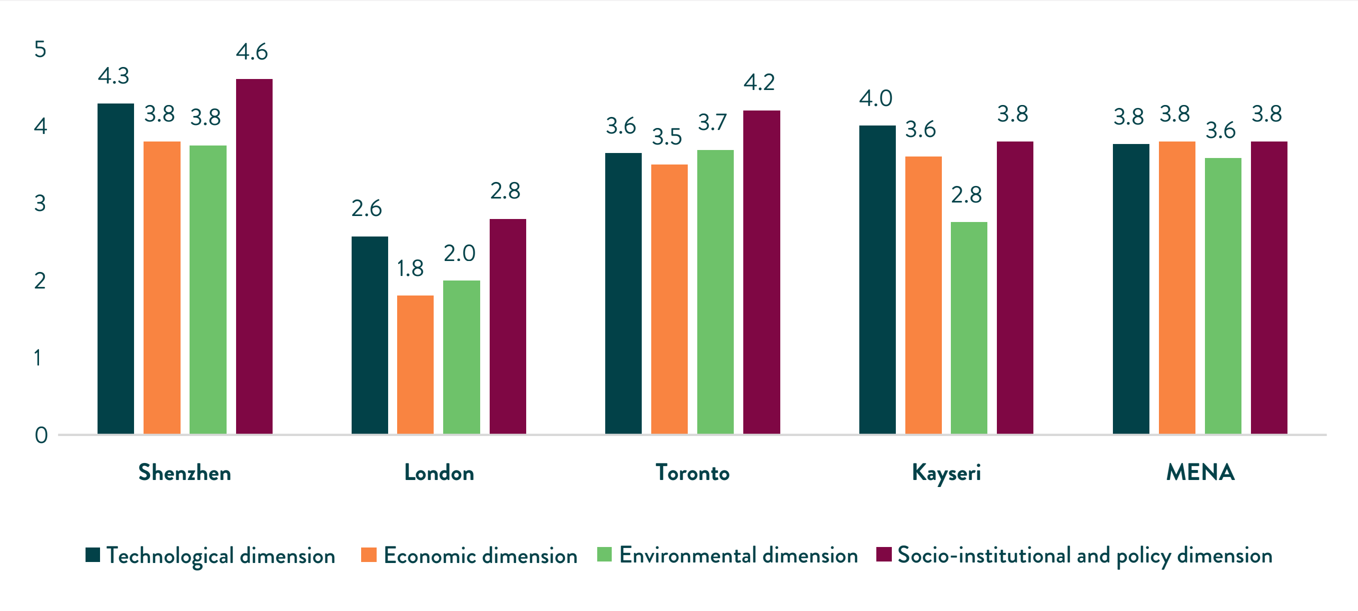
London prioritises policy and environmental sustainability, though economic and technological constraints present challenges.

Toronto is progressing in policy and technology but requires stronger economic support and renewable energy integration.

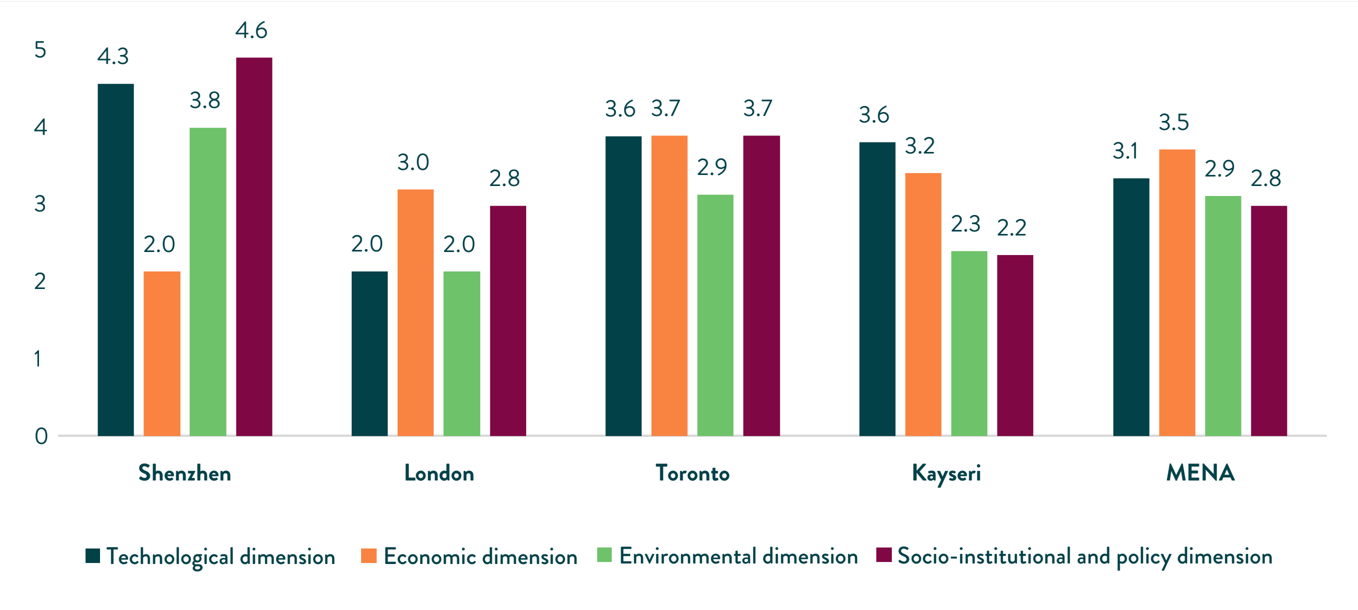
Kayseri's strategy is primarily environmentally driven, but technological and economic barriers impact its pace of adoption.

The MENA region has strong policy foundations and environmental potential but faces economic and technological challenges.

Level of significance (as enabler)



Level of significance (as barrier)



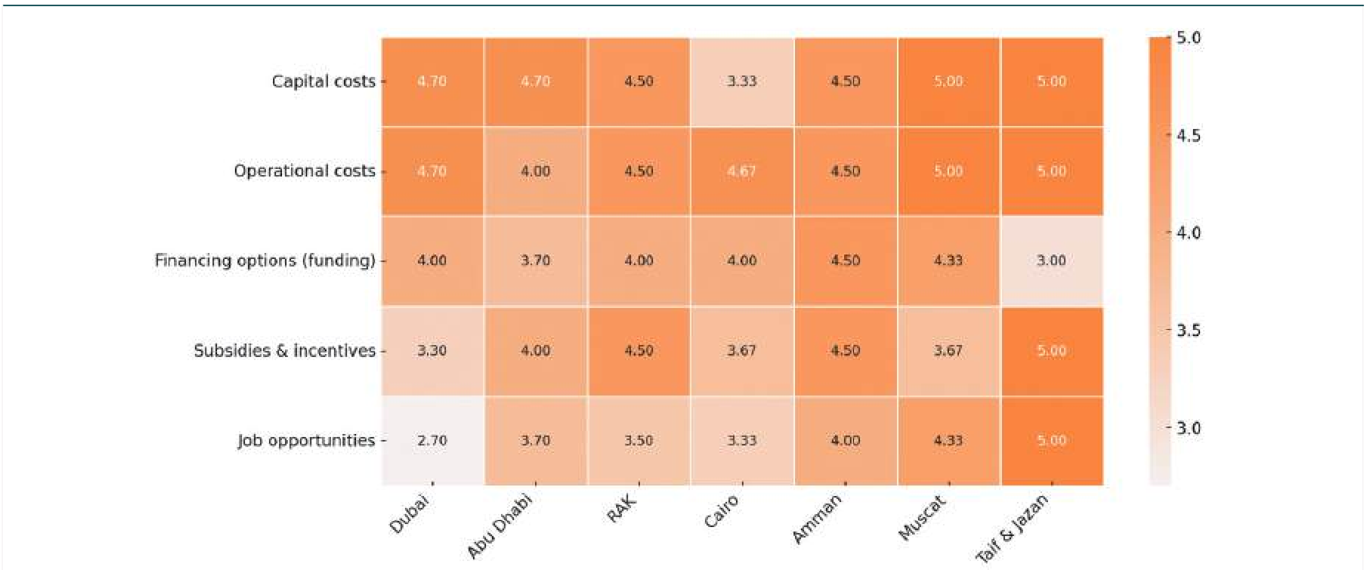
The overall significance of technology-related factors across MENA cities

Dubai and Abu Dhabi lead MENA's BEB transition, benefiting from strong policies and infrastructure investments.

Despite regional solar energy potential, cities have yet to fully align BEB deployment with renewable energy sources. Stronger grid integration is needed.

Advanced adopters emphasize workforce training, while emerging cities may need more skill development.

The overall significance of economy-related factors across MENA cities



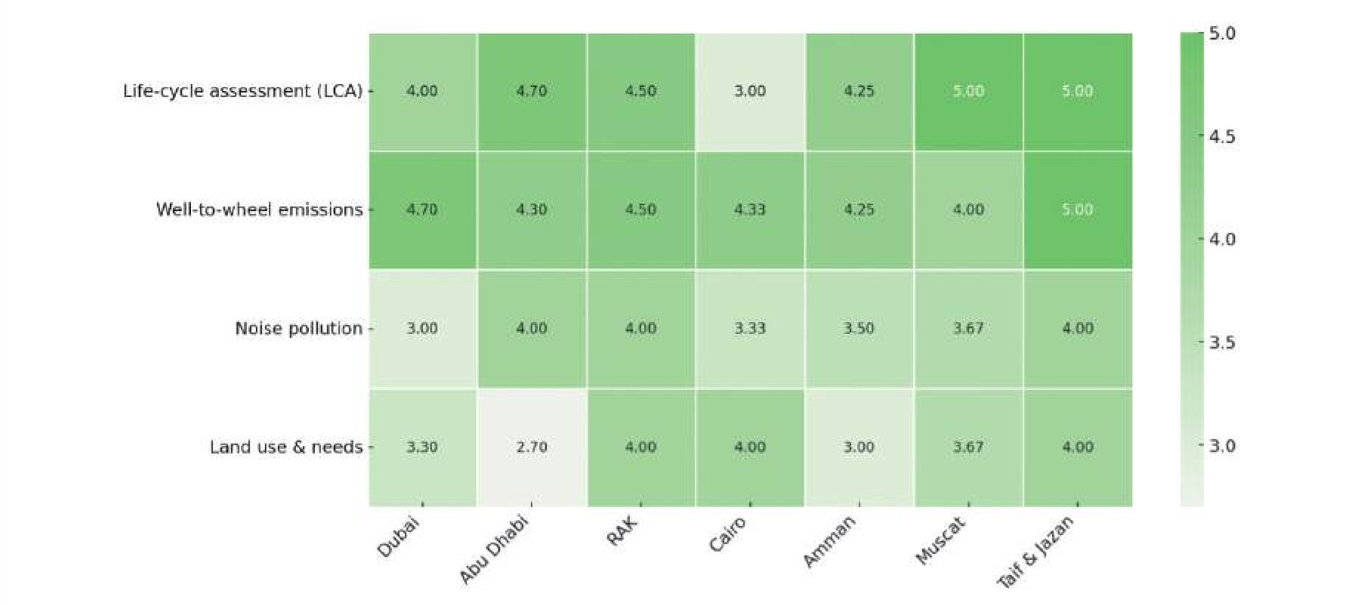
Capital costs remain a concern for all cities regardless of financial stability that some cities have.

Emerging BEB market requires better financing mechanisms to ensure large-scale deployment.

Ras Al Khaimah sees subsidies and incentives as the most important factor, suggesting reliance on government financial support.

Job opportunities are the least important factor across all cities, suggesting that workforce expansion is not currently a major economic driver for BEB adoption.

The overall significance of environmental factors in MENA cities

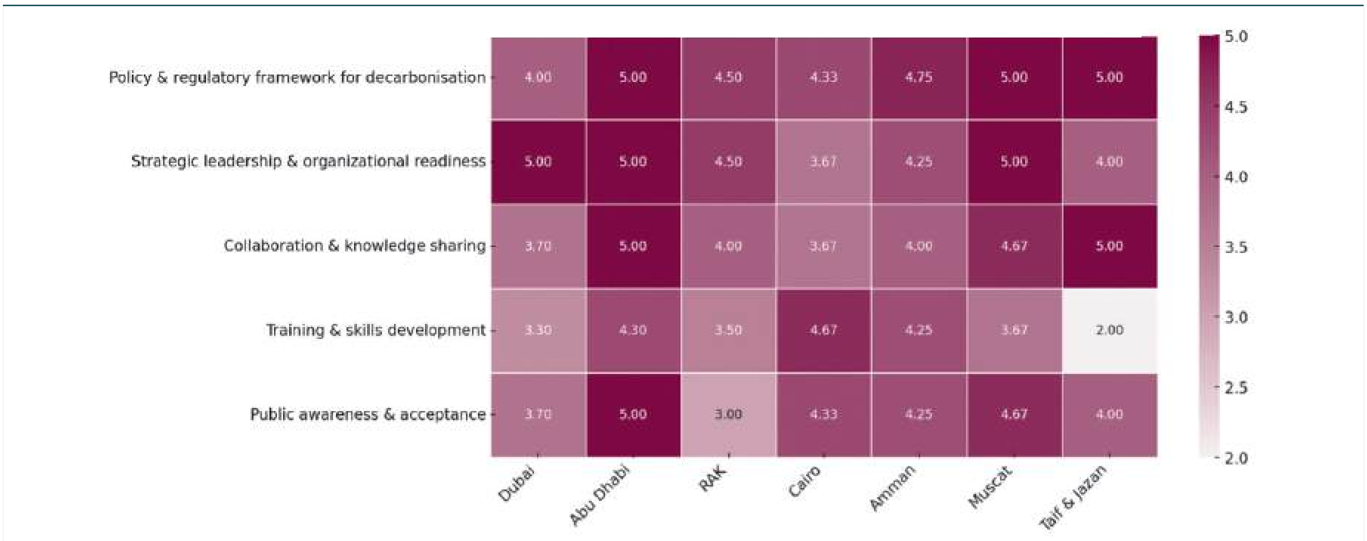


LCA receives the least importance by the majority of cities, which highlight the importance of understanding and implementing recycling programs for used batteries as they transition to further deployment.

Noise pollution is consistently the least important factor across cities, indicating that other environmental factors take precedence in decision-making, as well as the low pollution generated by BEBs compared to diesel buses.

Cities with high-density urban population emphasize land utilization, while cities with available space see it as a lower concern.

The overall significance of socio-institutional and policy factors across MENA cities



Dubai, Abu Dhabi, RAK, as well as Taif and Jazan prioritise strategic leadership, indicating strong government involvement in transport electrification.

Abu Dhabi, RAK, Cairo, and Amman emphasize policy frameworks, showing the importance of a clear regulatory structures for decarbonisation.

Strong leadership correlates with successful BEB deployment, while less leadership impact slows progress.

Leadership, workforce development, and policy clarity can enhance socio-institutional readiness for large-scale BEB deployment in the MENA.

Results of the third part:

Lastly, surveyed cities were asked to answer the following questions. The summary of their responses is depicted in the below tables.

1. What do you consider the most critical factor driving the adoption of e-buses in your city?
2. What do you see as the main barriers to adopting of e-buses in your city?
3. What measures/strategies could help overcome them?
4. What are your entity's strategies for strengthening the enablers of BEBs deployment in your city?

Critical success factor driving the adoption of BEBs

	Shenzhen	London	Toronto	Kayseri	Dubai	Abu Dhabi	Ras Al Khaimah	Muscat	Taif & Jazan	Cairo	Amman
Long-term policies & political will	✓	✓	✓		✓	✓	✓	✓			
Government subsidies & incentives	✓					✓		✓			
Cost efficiency (OPEX)					✓		✓			✓	✓
GHG reduction target commitment &			✓	✓	✓		✓	✓		✓	✓
Legislative requirements			✓								
Infrastructure readiness & technology					✓					✓	
Stakeholders' collaboration					✓	✓					
Funding					✓	✓					
Public heath					✓	✓	✓				

Main barrier to adopting BEBs

	Shenzhen	London	Toronto	Kayseri	Dubai	Abu Dhabi	Ras Al Khaimah	Muscat	Taif & Jazan	Cairo	Amman
Procurement (CAPEX)	✓				✓	✓	✓	✓	✓	✓	✓
Complexities in tendering process		✓									
Continuity of funding			✓								
Grid supply & reliability			✓		✓	✓					✓
Resistance to change			✓				✓				
Operational range				✓							
Infrastructure readiness			✓		✓	✓	✓				✓
Operational efficiency					✓	✓	✓	✓			✓
Lack of sufficient support & incentives							✓	✓		✓	
Maintenance & technical expertise							✓	✓		✓	✓

Strategies to overcome barriers of adopting BEBs

	Shenzhen	London	Toronto	Kayseri	Dubai	Abu Dhabi	Ras Al Khaimah	Muscat	Taif & Jazan	Cairo	Amman
Government subsidies	✓					✓	✓	✓		✓	✓
Planning ahead					✓						
Securement of long-term funding commitment			✓		✓			✓			✓
Low interest financing options								✓			✓
Smooth program rollout			✓				✓				
Availability of trained & skilled workforce				✓							✓
Stakeholder collaboration			Close cooperation with utility providers			✓	✓				✓
PPP						✓	✓				✓
Expansion of charging networks						✓	✓				
Others		Partnership with PTAs for contract length; Route optimisation			Coordination centralisation	Formulation of task force committee for monitoring work progress; Investment in R&D for climate adopted technology	Improve battery technology	Conduct additional testing and pilot programs; Governments should encourage OEMs to establish a presence and offices in the region	National Strategies	Government support	Implementation of pilot project for validation & calibration; Establishment of supportive policies & regulations

Strategies to strengthen enablers of adopting BEBs

	Shenzhen	London	Toronto	Kayseri	Dubai	Abu Dhabi	Ras Al Khaimah	Muscat	Taif & Jazan	Cairo	Amman
Provision of subsidies	✓										
Building partnerships with suppliers		✓									
Share of knowledge and best practice		✓	✓			✓					
Staged rollout to allow adaptation					✓	Thorough viability and adaptivity assessment of BEBs					
Stakeholders' collaborations			Close cooperation with financial partners			✓		✓			✓
Investments in renewables				✓		✓					
Run piloting programs					✓	✓	✓				✓
Others	Proper planning for chagrining facilities; Encourage investors to join the building of charging facilities		Regular communication of electrification benefits		Run a pilot, start small scale operation, document the pros and cons, address the cons and expand the operation	Integrate sustainable transport policies		Encouragement of capital expenditures approvals due to positive operational impact of BEBs	National Strategies	Build the culture & environment of smart urban transport	Establishment of e-charging strategies

OVERALL SUMMARY AND KEY TAKEAWAYS

Key enablers and barriers

City / region	Deployment status	Key enabler(s)	Key barrier(s)
Shenzhen	Complete deployment	Strong government support, low costs, high efficiency	Stringent regulatory compliance
London	Phased transition	Leadership, public support	High costs, land-use restrictions, policy gaps
Toronto	Growing adoption	Leadership, public backing	Financial barriers, infrastructure challenges
Kayseri	Early adoption	Environmental support, public awareness	Technological and economic limitations
MENA	Early adoption / emerging market	Infrastructure ongoing development, decarbonisation targets, relatively growing policy support	Financial hurdles

Key learnings from Shenzhen, London, Toronto, and Kayseri

Shenzhen

- Shenzhen exemplifies how strong government support and subsidies can overcome financial barriers, becoming a global leader in electrification. In addition, it leads in battery technology and charging infrastructure, ensuring high operational efficiency.

London

- London demonstrates the importance of policy consistency and stages transition for navigating complex operational frameworks. It also aligns electrification efforts with emissions reduction targets.

Toronto

- Toronto highlights the role of political will and legislative mandates in maintaining momentum despite funding challenges. The city also focuses on workforce training and operational readiness to optimise BEB operational performance.

Kayseri

- Kayseri focuses on operational range and workforce readiness, showing a practical approach to overcoming local challenges. In addition, it leverages public support for environmental benefits as a key driver for electrification.

The MENA region (Dubai, Abu Dhabi, Ras Al Khaimah, Cairo, Muscat, Amman, Taif, and Jazan) balances cost efficiency, infrastructure readiness, and strategic planning, showcasing a diverse set of priorities and solutions tailored to the region's unique context.

Leveraging experiences from more mature markets, MENA cities are recommended to focus on the following aspects to advance BEBs integration.

- Boost financial accessibility through introducing PPP, providing subsidies, and adopting green financing models.
- Expand infrastructure investment by strengthen charging infrastructure and grid readiness for large-scale deployment.
- Strengthen policy enforcement through introducing clear regulatory frameworks to guide e-bus adoption.
- Improve workforce training such as establishing vocational programs to develop skilled labour for e-bus maintenance.

SUMMARY

When examining cities with varying levels of transitioning to BEBs (emerging/early market as in MENA, middle deployment, advanced deployment), it becomes evident that the significance of enablers and barriers evolves with the stage of adoption.

In early stages, critical enablers include initial investment support, pilot projects to validate technologies, and incentives to encourage adoption by operators. Barriers at this stage involve high capital costs, limited infrastructure for charging, and resistance to change from conventional systems.

As cities progress into intermediate stages of transition, enablers such as technological advancements and policy alignment begin to play a more prominent role. Barriers may shift towards operational challenges like grid capacity, availability of skilled maintenance personnel, and integration of charging schedules with operations.

In advanced stages of electrification, the focus moves towards sustainability, long-term cost optimisation, and resilience of the electric fleet. Enablers like robust policy frameworks, advanced energy storage solutions, and successful PPP drive continued adoption. Barriers at this stage include ensuring supply chain resilience for batteries, addressing end-of-life vehicle recycling, and maintaining high levels of service reliability as the fleet scales up.

LESSONS LEARNED FROM THE EARLY DEPLOYMENT OF E-BUSES IN MENA

DUBAI – RTA EXPERIENCE [1]

In the last five years, RTA conducted conducted several BEBs trials to identify their needs according to Dubai climate and topography. In specific, between 2019 and 2021, RTA introduced the first opportunity changing technology in the region using pantograph. Following that, RTA performed trials of two Volvo BEBs and one Higer BEB, which are designed for Dubai environment. Both trials were conducted on route Eb1 which is from La Mer South to Al Sufouh Tram Station.

E-bus OEM	Volvo	Higer
Trial timeline	October 2021 – April 2022	July 2023 – January 2024
Model	7900E	KLQ6126GEV
Length	12m	12.2m
Battery capacity	200 kWh	423 kWh
Passengers' capacity	Seating capacity: 37 Total capacity: 89	Seating capacity: 36 Total capacity: 76
Changing infrastructure	Opportunity Charging (Pantograph) + Overnight Charging (Terra 54)	Opportunity Charging (Pantograph) + Overnight Charging (Terra 54)
Stakeholder(s)	RTA, DEWA, Volvo, FAMCO, ABB, Dubai Holding	RTA, DEWA, KHF, HIGER, ABB

Findings from trial (October 2021 to April 2022)

The purpose of trial was to measure the operational efficiency of the vehicles and assess their viability. The trial duration was 6 months and two buses were tested.

KPI	Value
Total mileage (two buses)	75,147 km
Average mileage per bus per day	250 – 280km
Total Savings in CO_2	64,100 kg compared to Euro VI diesel bus
Average speed	32 – 38 km/h
Idle ratio	45 – 58%
Average energy consumption	1.19 kWh/km Energy consumption increases significantly during higher temperatures, due to increased cooling requirements.
Efficiency of charging	Overnight depot charging (Terra 54): 1hr with 50 kWh Pantograph charging: 39 mins with 41 kWh
Passenger feedback	A total of 146 passengers took part in the electronic survey conducted during the trial. The findings revealed that 88% of respondents observed lower noise and vibration levels in the e-bus compared to diesel buses. Additionally, 85% of participants reported a positive experience with the BEB. Moreover, 118 participants (out of 146) shared their preferences regarding the proposed plan for dedicated electric bus routes within Dubai.

(1) Roads & Transport Authority in Dubai

Findings from trial (July 2023 to January 2024)

Building on the initial trial, the second phase was conducted during the summer to assess the average energy consumption of BEBs under seasonal operating conditions.

KPI	Value
Total mileage	49,098 km
Total Savings in CO_2	41,880 kg compared to Euro VI diesel bus
Average energy consumption	1.23 kWh/km (with 17 passengers on average) 1.45 kWh/km during extreme conditions
Efficiency of charging	Pantograph charging: 20 minutes for 37 km trip
Passenger feedback	89% of respondents indicated a preference for riding e-buses over diesel buses

The actual operational results of the bus in Dubai, along with the validation of the fast-charging method on-route, have contributed to defining the technical specifications for new buses and suitable electric chargers for the Emirate of Dubai.

Prerequisites for acceptance of the proposal to pilot e-buses in Dubai:

1. A company that has been qualified in RTA system
2. Availability of all related certificates. They must have at minimum:
   a. R107 – Vehicle construction based on M3 Clas ½
   b. R100 – Battery charging system
   c. R10 – Electro-magnetic and electrical conductivity safety
   d. R66 – Rollover test
   e. R46 – In case the bus comes with camera system instead of mirror
3. Air-conditioning settings suitable for Dubai climate (48°C ambient temperature and 24 °C thermal comfort)
4. Innovations that add to e-bus specifications knowledge and performance
5. BEBs should be equipped with telematics capability to monitor bus performance and collect vehicle and operations data.


Volvo BEB ©RTA


Higer BEB ©RTA

Lessons Learned:

Electrification of bus fleet is a fully integrated system based on complete solution covering the bus, charger, infrastructure, and power source connectivity.

Close cooperation across all stakeholders is the key to project success.

Continuous trialling contributes to identifying the specifications of BEBs that should be compatible with Dubai climate conditions.

Due to the unique climate characteristics of the MENA region, certain technical specifications need to be adjusted to enhance the performance of e-buses in Dubai's local environment. These modifications include expanding the charging inlet system, optimising battery size, and refining cooling system specifications. Additionally, the washing protocol has been updated to meet the specific needs of e-buses, ensuring more frequent cleaning of charging terminals for improved electrical connectivity.

Field inspection procedures and cleaning protocols for surfaces related to the main charger, the "pantograph," require adjustments to ensure efficient power transmission and minimise operational errors caused by environmental factors, such as high humidity and airborne particles, which can affect charging surfaces.

The necessity of integrating and defining the electric charger system from "ABB" within the Dubai Electricity and Water Authority (DEWA) system to enhance fault diagnosis and response speed.

ABU DHABI – ITC (ABU DHABI MOBILITY) EXPERIENCE [2]

Timeline of the green bus program (GBP) in Abu Dhabi and key activities between 2022 and 2024

1. Knowledge development (Late 2023)

This phase commenced in late 2023 and included a one-month theoretical training followed by a practical training month. The primary objective was to equip the Integrated Transport Centre (ITC) staff with the necessary knowledge and skills to manage a new energy vehicle (NEV) public transport fleet. To enrich the program, ITC engaged international industry leaders to provide insights on global best practices and technological advancements.

2. Bus and charger model & specification review

The project team, in collaboration with key partners, conducted a comprehensive review and revision of vehicle models and specifications. This review aimed to select and deploy buses with diverse configurations for comparative studies, allowing the assessment of different operational parameters, such as performance, energy efficiency, and passenger experience.

3. Bus delivery and charger installation

Following the specification finalization, the delivery of buses and the installation of charging stations commenced. The charging infrastructure was designed to support efficient fleet operation and meet the growing charging demands as more buses were introduced.

4. Operation and assessment (Since September 2024)

The operational assessment began in September 2024 with the deployment of the green buses. The roll-out was structured to gradually integrate additional buses over subsequent months. To ensure operational readiness and gather baseline data, the following step-by-step approach was implemented:

- Step 1: Two dummy runs (no stops, no passengers) – To allow drivers to familiarize themselves with the bus operation and to collect preliminary vehicle performance data.
- Step 2: Two dummy runs (with stops, no passengers) – Simulating actual service conditions to further enhance driver experience.
- Step 3: Three days of half-block operations (morning and afternoon shifts) – Partial service operation to test vehicle handling, charging requirements, and performance under real-time conditions.
- Step 4: Full-day operations – After reviewing the initial data and performance feedback, the buses commenced full-day operations.

Between Steps 3 and 4, the General Bus Assessment (GBA) team collaborated closely with the operations team and operator to refine and finalize a detailed execution plan for the fleet's transition to full service.

Hydrogen bus © ITC (AD Mobility)

BEB © ITC (AD Mobility)

(2) ITC (Abu Dhabi Mobility)

Key features of the program:

- Vehicle OEMs, models, and specifications: The assessment includes buses from multiple OEMs with varying lengths, battery capacities, and charging specifications to optimize fleet performance in Abu Dhabi's climate.
- Charger types: The installed charging infrastructure features both depot and fast chargers, designed to handle the operational demands of a growing NEV fleet.

Lessons Learned

1. Driving experience: Feedback from drivers indicates improved manoeuvrability and a smoother driving experience with BEBs. However, driver comfort varies depending on the design of the driver's cabin, highlighting the need for ergonomic improvements tailored to different bus models.

2. Passenger experience: More than 80% of passengers provided positive feedback, rating their experience as "Above Average" or "Good." Key aspects contributing to this satisfaction include effective in-bus temperature control and reduced noise levels both inside and outside the bus.

3. Energy efficiency: Current observations show that passenger ridership has minor impact on energy consumption. However, ambient temperature significantly influences energy efficiency. During winter, buses have demonstrated an energy consumption rate of approximately 1.0 kWh/km, reflecting enhanced performance during cooler conditions.

4. Digitalisation and smart fleet management: The use of e-buses enhances data collection accuracy through the CAN BUS system, which reads operational data directly from circuits rather than interpreting sensor data. This allows for more precise monitoring of key performance metrics, particularly battery degradation during the GBA phase. Access to this granular data enables the project team to closely monitor technical performance and address potential issues early. Additionally, the detailed insights assist the operations team in making minor service adjustments to mitigate the impact of mechanical or electrical degradation, ensuring service continuity.

5. Depot management and charging strategy: The charging infrastructure management is a critical focus area within the program. The current average charging time is approximately 2 hours. However, with enhanced infrastructure and vehicle-based charging management strategies, the efficiency of charging operations can be significantly improved, reducing downtime and optimizing fleet availability. Currently, the operator is still not too well adapted to the NEV operation, leading to multiple short overnight charging sessions for the same vehicle, which significantly reduced charging efficiency.

These insights emphasize the importance of ergonomic designs, environmental considerations, and robust digital and infrastructure management for the successful implementation and long-term sustainability of e-bus operations in Abu Dhabi. In addition, the GBP's phased approach highlights Abu Dhabi's commitment to a well-planned, data-driven integration of e-buses, ensuring that both operational teams and vehicles are prepared for seamless, long-term service expansion.

JEDDAH - JEDDAH TRANSPORT COMPANY (JEDTC) EXPERIENCE[3]

JEDTC conducted a BEB trial to evaluate performance, feasibility, and user satisfaction under real-world conditions, in alignment with Saudi Vision 2030's sustainability goals. The trial operated on Route 7A and covered both winter and summer seasons to account for temperature impacts from February 2023 to September 2023.

Key Technical Specifications	Route Operational Parameters
Bus: Yutong 11.2 m BEB	Route 7A
Battery capacity: 350 kWh	Full line length: 31 km
Cooling: Dynamic liquid cooling system	Circular trip time: 95 mins
Passenger capacity: 30 seats	Headway: 15 mins
HVAC: Roof mounted	Number of daily trips: 22 trips
Charging: Dual-side DC chargers (180 kW)	Operational time: 18 hrs daily

Performance Comparison	BEB	Diesel bus (King Long city bus)
Bus charging/refuelling time	2:37 hrs	0:15 hrs
Routine maintenance	Before/during/after operations	Before/during/after operations
Initial maintenance	5,000 km or 3 months	5,000 km or 1 month
Elementary maintenance	20,000 km or 2 months	Up to 40,000 km or 8 months
Complete maintenance	60,000 km or 6 months	80,000 km or 12 months
Maintenance complexity	Simpler and less frequent maintenance	More frequent maintenance
Emissions	Total 71,860.05 kg CO2 reduced, which equals 30 trees planting, for a total mileage of 78,000 km	

Challenges

- **Battery capacity:** Larger batteries are needed to improve operational duration and avoid trip scheduling disruptions.
- **Charging time:** The BEB requires around 3 hours for charging, compared to 15 minutes for diesel refuelling.

User Feedback

- **Comfort:** Soundless operation and advanced seat ergonomics.
- **Safety:** Robust safety features.
- **Public satisfaction:** High levels of approval due to smooth rides and environmental benefits.

(3) Jeddah Transport Company

© JEDTC

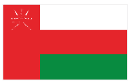
Lessons Learned

- **Climate resilience:** The BEB performed reliably in Jeddah's extreme weather conditions, proving the adaptability of modern battery cooling systems.
- **Economic feasibility:** Lower energy and maintenance costs make BEBs more economical over time.
- **Environmental benefits:** Significant reduction in carbon emissions aligns with national sustainability objectives.
- **Operational adjustments:** Battery upgrades and optimised charging infrastructure are crucial for minimising operational interruptions.

Recommendations

- Gradual fleet transition to BEBs across the Kingdom's public transport network.
- Investment in larger battery systems and improved charging facilities to enhance operational efficiency.
- Ongoing public engagement to ensure widespread acceptance and understanding of the benefits of e-mobility.

This trial demonstrates the feasibility of adopting BEBs as a sustainable transport solution in Saudi Arabia's urban areas.



OMAN – MWASALAT EXPERIENCE [4]

Oman has taken initial steps toward electrifying its public bus fleet, although long-term goals have not yet been announced. In July 2024, Mwasalat launched the country's first BEB, marking a significant move toward sustainable urban mobility.

BEB Characteristics

OEM	Yutong
Length (m)	Length: 8.94 m, Height: 3.3 m
Battery capacity (kWh)	211
Operational range (km)	Up to 350 km
Passengers' capacity	28 seated passengers and up to 35 standing passengers
Charging Technology	Fast Charging (~ 3 hours), Portable Charging (8 hours)
Others	Equipped with a Permanent Magnet Synchronous Motor (PMSM)

Important Note:

No formal operational trials conducted. The BEB has primarily been showcased in various cities and event venues across Oman in 2024 and 2025. Mwasalat has utilised the BEB for awareness campaigns, exhibitions, and roadshows to promote sustainable mobility and public transport electrification. The focus has been on engaging the public, stakeholders, and industry experts rather than gathering operational data.

Findings

Since no operational deployment has taken place, Mwasalat does not have real-world data on energy consumption, emissions reduction, or actual performance in a revenue service. However, the roadshows and events have provided some key insights:

Public awareness and perception: The events have helped in raising awareness about e-mobility and have generated interest among stakeholders.

Operational readiness: Infrastructure requirements such as charging stations, maintenance capabilities, and power supply considerations remain critical for future deployment.

Technology considerations: The demonstrations have allowed us to assess available e-bus models, charging technologies, and their suitability for Oman's climate and urban transport needs.

Stakeholder engagement: The participation of government agencies, private sector partners, and transport planners has highlighted the necessity of multi-stakeholder collaboration for successful adoption.

Conclusion

Mwasalat's experience with BEBs has been primarily through roadshows and awareness events rather than operational deployment. While no direct operational data is available, these activities have provided valuable insights into public perception, stakeholder engagement, and infrastructure readiness. Future steps should focus on conducting structured operational trials to collect performance data and guide large-scale e-bus integration in Oman's public transport system.

© Mwasalat

(4) Mwasalat

COST-BENEFIT ANALYSIS FRAMEWORK FOR THE TRANSITION FROM DIESEL BUSES TO BEBS

The cost benefit analysis (CBA) is a systematic process for identifying, quantifying, and comparing expected costs and benefits of a potential infrastructure project over a specified period of time.

WHAT ARE THE OBJECTIVES OF THE CBA ANALYSIS?

- Outlines the essential components for evaluating the transition from diesel buses to BEBs
- Estimate the costs and benefits associated with the transition to the extent possible in the context of Gulf Cooperation Council (GCC) countries.
- Formulate an illustrative example to calculate the Total Cost of Ownership (TCO) and the Economic Net Present Value (E-NPV) for both diesel and BEBs.
- Conduct a comparison that offers decision-makers insights about the viability and long-term impacts of this transition, aiding in better understanding the current economic, environmental, and social implications, under certain conditions.

DATA AVAILABILITY AND KEY PARAMETERS

Conducting a CBA for diesel and BEBs requires comprehensive data on operational, economic, environmental, and social parameters. These data components form the foundation for accurate and actionable insights.

Challenges in data availability

Data for diesel buses is often well-documents, given their long-standing presence in public transport systems. However, regional variations in fuel prices, maintenance practices, and traffic conditions require localised data collection. On the other hand, BEBs, being relatively new, may lack historical operational data. Specific parameters, such as battery performance, real-life energy consumption under carrying climatic conditions, and charging infrastructure may not be readily available. Thus, conducting trials is essential to collecting the needed data.

Importance of passenger data

Passenger data plays a pivotal role in assessing the operational efficiency, economic viability, and overall success of transitioning to e-buses. Why are they important?

- To understand passenger expectations regarding comfort, noise levels, and ride quality. Transitioning to e-buses often enhances the passenger experience (e.g., quieter rides, reduced vibrations, etc.), where including qualitative improvements in the analysis can justify higher initial costs.
- To estimate fare revenue based on ridership trends, as revenue directly impacts the payback period of e-bus investments.

KEY ELEMENTS OF COST RELATED DATA

The transition to e-buses involves a range of initial capital and ongoing operational costs. BEBs have additional investments (compared to diesel buses) in charging infrastructure, grid upgrades, and staff retraining. There are also expenses associated with phasing out diesel buses, including resale or disposal. However, these costs associated with scrapping diesel buses are inevitable and will be incurred regardless of whether a fleet transitions to BEBs or continues with diesel buses. Hence, they can be excluded from the analysis.

On the operational side, BEBs generally offer lower maintenance costs due to fewer moving parts, though energy costs and battery replacements must be factored in.

Indirect costs include environmental impacts from battery production and the carbon footprint of the power supply, which depends on the grid's energy mix.

Initial capital costs

BEB purchase costs: BEBs have higher upfront costs than diesel buses.

Charging infrastructure: Cost depends on charging strategy and number of buses per charger. The cost must also account for land acquisition or lease costs (in case of building new depots) and the construction and installation costs, including terminal adjustments like setting up electrical panels and wiring.

The capital costs for BEB depots vary significantly depending on whether a new depot is built specifically for them or an existing depot is retrofitted to support them.

Each approach has unique cost factors and implications:

Building new depots offer long-term operational savings and optimised layout and design for electric fleets but involve higher upfront costs. On the other hand, **retrofitting existing depots** can reduce initial expenses but may face increased costs for ongoing maintenance and capacity constraints as the fleet grows.

Grid upgrades can be done, if necessary, to meet increased electricity demand for bus charging. In the context of the GCC, grid upgrades costs should be considered, accounting for the current grid configuration, which is highly likely to be insufficient for EV charging scenarios. Grid upgrades may require the following:

- New power-substations might be necessary to cater to the increased electricity demand.
- Battery storage systems can be added to manage peak loads and optimise energy costs.
- Particularly for retrofits, accommodating the space and weight needs of chargers and high-capacity power connections might require layout reconfigurations.
- Advanced software for charging management and fleet coordination can streamline operations, though it represents an added cost.

Training and operational transition: Costs for retraining drivers and maintenance staff, as BEBs differ significantly from diesel buses in operation and servicing.

- **For training:** this may include driver training, maintenance staff training, charging infrastructure training, safety training.
- **For operational transition:** this may cover fleet scheduling changes, telematics and data analytics, and fleet adjustments (e.g., mix of BEBs and diesel buses).

Operational costs

Energy (electricity) prices: it's important to evaluate the local energy prices and grid stability.

Maintenance costs: BEBs typically have fewer moving parts and lower long-term maintenance costs. These costs may include corrective and preventive maintenance.

Battery replacement: This element involves costs related to battery life cycle, disposal, and replacement after degradation (typically 5-8 years). It is a significant factor in CBA analysis, as it impacts both operational budgets and environmental considerations. Battery replacement depends strongly on the context (e.g., topography, climate) and annual mileage.

It is worth noting that transferring part of the cost associated with second-life battery usage can be considered, as it offers economic and environmental benefits. When EV batteries reach the end of their life for automotive applications (typically when their capacity drops to around 70-80%), they can still be repurposed for other applications, such as energy storage.

Context-dependent factors impacting battery longevity

- **Mileage and usage patterns:** Annual mileage plays a crucial role in battery wear. In the GCC countries, buses frequently cover greater distances. For instance, Abu Dhabi's city bus fleet records an average of approximately 100,000 kilometres per year. Such intensive usage accelerates battery wear, which in turn has substantial implications for the total cost of ownership and lifecycle planning. Under these conditions, it is plausible that one or even two battery replacements may be required over the vehicle's operational lifespan, necessitating careful consideration in procurement strategies, warranty negotiations, and financial modelling.
- **Operating conditions and climate:** Heat is a significant factor in battery degradation. In hot climates, like those in the GCC, battery efficiency declines more rapidly due to thermal stress. In addition, high temperature climate often necessitates constant air conditioning use, placing additional strain on the battery. Cities in the GCC are providing innovative solutions to tackle climate conditions. For example, the use of a water-cooling mechanism for battery management system (BMS) in Abu Dhabi's BEBs is a strategic choice, especially given the extreme climate conditions in the region. The water-cooling mechanism can control the battery temperature to around 30°C in operation and no more than 40°C in charging sessions.

Other costs: This may include the **cost of insurance** and **drivers' salaries**.

One of the less obvious costs of transitioning to BEBs is the potential increase in staffing requirements, particularly drivers. This is influenced by several factors directly and indirectly.

- BEBs typically have a shorter operational range compared to diesel buses, and this range is even shorter in several MENA cities due to high temperatures. For example, while a diesel bus might run continuously for a full day on one tank of fuel, a BEB may need to return to the depot or visit a charging station multiple time or take breaks for fast opportunity charging a terminal location of the bus line.
- To maintain the same level of service with BEBs, additional buses might be required, especially if a 1:1 replacement of diesel buses is not feasible. For instance, if a transit route requires eight diesel buses but would need 10 BEBs to maintain the same frequency due to charging needs (buses have to return to the depot for recharging or take breaks for fast opportunity charging a terminal location of the bus line), this implies more drivers must be employed to operate the additional buses. Driver shifts may also need to be adjusted, potentially incurring additional costs. For instance, to accommodate charging times or maintain service frequency during peak hours, PTOs may need to stagger shifts or employ part-time drivers, which could add complexity to scheduling and increase labour costs.

Indirect costs

Indirect costs include **environmental externalities** from battery production and disposal as well as the carbon footprint of the power supply, depending on the grid's energy mix.

In most cases, the production of batteries is performed outside the country that is procuring or operating the buses. Hence, the indirect cost related to that can be assumed to be eliminated from the analysis, which is on the national level.

Further, while BEBs do not emit tailpipe emissions, the carbon intensity of the grid (e.g., reliance on fossil fuel electricity generation) needs to be considered.

Types of grid energy:

- Coal dominated grid -> High emissions
- Natural gas-dominated grid -> Moderate emissions
- Renewable-dominated grid -> Low emissions
- Mixed energy grid -> Moderate emissions depending on the mix of energy sources

Table 6. The 2022 electricity generation mix of different MENA countries [(1)].

	Source of electricity				
Country	Oil	Natural gas	Nuclear	Renewables	Energy -related emissions
UAE	0.6%	81.0%	13.3%	4.8% (*Solar PV*)	174 Mt CO_2
Saudi Arabia	41.2%	58.2%	-	0.4% (*Wind*)	533 Mt CO_2
Qatar	-	98.9%	-	1.1% (*Solar PV*)	91 Mt CO_2
Oman	2.8%	94.7%	-	2.5% (*Solar PV*)	75 Mt CO_2
Kuwait	47.7%	52.1%	-	0.1% (*Solar PV*)	94 Mt CO_2
Bahrain	-	99.9%	-	0.1% (*Solar PV*)	34 Mt CO_2
Egypt	8.6%	79.2%	-	7.0% (*Hydro*) 2.8% (*Wind*) 2.3% (*Solar PV*)	218 Mt CO_2
Jordan	3.8%	73.1%	-	15.3% (*Solar PV*)	21 Mt CO_2

As shown in Table 6, fossil fuels clearly have the highest share in today's electricity generation in the GCC countries and are therefore associated with a high GHG footprint. However, most GCC countries have announced plans to significantly reduce their overall GHG emissions with one pillar being an increase of renewables in their energy mix as well as deploying carbon capture technologies.

Given these targets, we can assume that with each future year of BEBs operations, the associated emissions from electricity generation will go down making them even more competitive with respect to their overall emission footprint.

(1) International Energy Association, Energy System of Middle East. Available: https://www.iea.org/regions/middle-east

KEY ELEMENTS OF BENEFITS RELATED DATA

Switching to BEBs brings numerous environmental, economic, and social advantages.

- **Environmentally,** it reduces GHG, improves air quality by cutting pollutants like nitrogen oxides (NOx) and lowers noise pollution.
- **Economically,** it offers significant savings on fuel and maintenance while potentially creating new jobs in the EV industry. It will also help with talent development in the automotive industry, as more technicians will be equipped with electrical knowledge as opposed to only focusing on mechanical with ICE vehicles.
- **Socially,** the shift enhances public health by improving air quality and elevates the passenger experience.

Economic benefits

Operational cost savings: The operating cost mainly includes vehicles' maintenance. E-buses have fewer worn-out components, reducing preventive and corrective maintenance costs.

Job creation: Potential for new jobs in the EV industry, including manufacturing, charging infrastructure, and energy services. In general, the expansion of EVs is transforming the job market worldwide. According to the Environmental Defence Fund, the EV and battery OEMs could generate up to 931,000 indirect/secondary jobs [(2)]. Moving to local manufacturing in MENA could promote the job creation, generating positive implications of BEBs deployment.

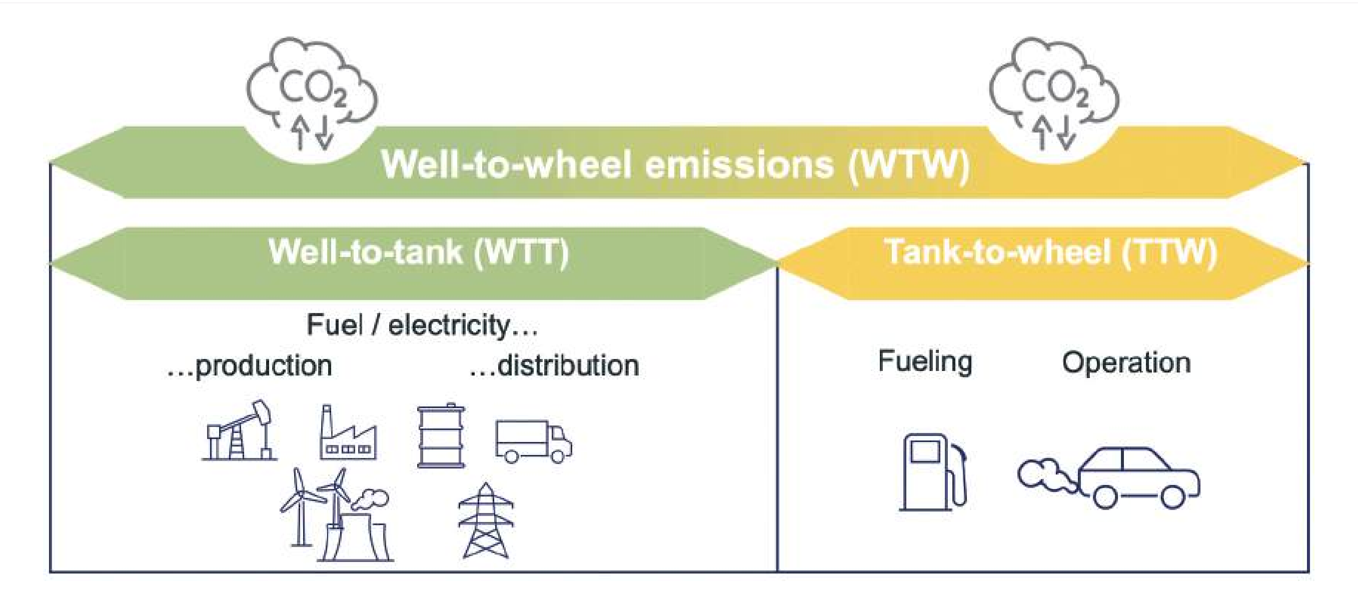
Environmental benefits

Reduction in emissions: When BEBs are compared to diesel buses, the emissions of GHG from BEBs are shifted from operation or use phase to nonoperation stages, that is vehicle production and electricity generation phases. A typical LCA includes (1) bus production, (2) battery production, (3) electricity generation, (4) operation, and (5) end of life phase [(3)]. An important type of emissions from the combustion of transport fuels is GHG, specifically CO_2.

Social (health) benefits

When the impact of health benefits is included in a CBA, they can significantly reinforce the economic justification for BEBs. Reduced healthcare spending, productivity gains, and enhanced public health translate to quantifiable financial benefits, making air quality improvement a powerful factor in the CBA framework for BEBs implementation. The U.S. Department of Transportation recommends measuring NOx, sulfur oxides (SOx), and particulate matter PM 2.5 for CBAs in transport. Based on consumption data, these could be measured and improvements in air quality can be monetised [(4)]. BEBs produce zero tailpipe emissions, which specifically helps improve air quality in urban areas.

Reduction in noise pollution: BEBs are significantly quieter than diesel buses, especially at idle or low speeds. This is primarily because they lack the internal combustion engine and complex mechanical systems that produce much of the noise associated with diesel buses. At a speed of around 50 km/h the difference between BEBs and ICE buses does not exist anymore. With the high average speeds in GCC cities this might therefore be neglectable.



▶ *Source: Dornier*

(2) Blink Charging, What Are the Economic Benefits of Electrifying Transportation, 2024. Available: https://blinkcharging.com/blog/what-are-the-economic-benefits-of-electrifying-transportation

(3) UITP, Bus Tender Structure, 2023. Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=180704690898

(4) U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, 2024.

Emissions quantification

The estimation of the emissions derived from electricity is complex and mainly depends on the mix of energy sources from the grid. To be accurate, each step of the energy generation must be considered and assessed for its GHG emission footprint. This is called the Well-to-Tank (WTT) part of transport emissions. Most countries use more than one source of energy for electricity. Therefore, all the relevant sources need to be investigated and after this an average can be computed according to the country's share of each of these primary energy sources. Also, the upstream part of Diesel production needs to be considered to have a full comparison. The figure below illustrates the components of different WTW pathways.

The exact values will differ from country to country as even in the GCC oil drilled in the UAE will have a different GHG content than oil drilled in KSA, for instance. Luckily, several energy companies have started to issue regular sustainability reports in which they assess the carbon intensity of electricity. If done correct, this will mirror the steps outlined above and can be used for calculating the WTW emissions.

Emissions monetisation

GHG appraisal value: One way of translating emissions into financial values is through a central appraisal value for GHG emissions. It is a standardised GHG value used in government appraisals to evaluate the GHG impacts of public projects, policies, or investments. One of the ways that the United States use to monetise GHG emissions is through the social cost [5]. Social cost of GHG represents the estimated monetary value (expressed in dollars per metric ton) of the damages caused by emitting an additional unit of GHG into the atmosphere, including damage to infrastructure (e.g., from extreme weather events). Currently, the carbon value defined by the Environmental Protection Agency (EPA) is set at $190 per ton [6].

For extensive calculations of environmental and health implications of buses, interested readers are advised to refer to UITP work on bus (3).

Other indirect benefits

Passenger experience: BEBs generally offer a smoother ride, less vibration due to the absence of combustion engine and less mechanical complexity, and reduced noise, providing better passenger experience.

> It is worth mentioning that quantifying and monetising these indirect benefits might be challenging in the meantime, but it essential to include in such analyses in the future.
>
> These benefits require the identification of measurable indicators (e.g., ridership) that define them.

TOTAL COST OF OWNERSHIP

Electrifying urban mobility not only requires changing the fleet and urban infrastructure but also has important implications for operators' business models. One of the primary methodologies for the comparison and choice of technology is TCO. The TCO is a comprehensive calculation of all costs associated with owning and operating a BEB over its entire lifespan. The TCO methodology allows for comparing the costs of different technologies operating the same services. For instance, it helps decision-makers evaluate the long-term financial implications of investing in BEBs compared to diesel buses.

Simplified TCO Formula

$$TCO = C_{capital} + C_{operation} + C_{insurance} - R$$

$$C_{capital} = C_{bus} + C\_infrastructure$$

$$C_{operation} = C_{energy} + C_{labor} + C_{maintenance} + C_{training}$$

C_{bus} = Bus purchase cost
$C_{infrastructure}$ = Charging infrastructure costs (installing charging stations, grid upgrades, ...)
$C_{operation}$ = Operating costs
C_{labor} = labour cost
$C_{insurance}$ = Insurance
C_{energy} = Energy prices (e.g., electricity / fuel)
$C_{training}$ = Training cost
$C_{maintenance}$ = Maintenance costs (corrective & preventive maintenance costs, overhaul)
R = Residual value

(5) U.S. Department of Transportation, Cost benefit analysis for: Targeting net zero - Next steps for the Renewable Transport Fuels Obligation, 2021.
(6) Environmental Protection Agency, 2023.

ECONOMIC NET PRESENT VALUE (E-NPV)

E-NPV is a financial metric that calculates the value of an investment or project over its entire lifetime, adjusted to today's monetary value. A financial NPV is calculated from the perspective of the project itself and focuses on the incremental cash flows generated by the project. It uses market prices that are actually paid or received by the project and is used in the private sector and business decision making focusing purely on its financial viability.

For a CBA, an economic NPV can be used which is calculated from the perspective of the entire economy and assesses the overall impact of a project on the welfare of all citizens in a country. This includes the monetisation of e.g., emission savings, and evaluates the project from a public/ society point of view. The E-NPV is usually calculated in real terms without inflation and uses a social discount rate which is lower than the financial discount rate to better account for intergenerational equity and long-term societal benefits.

Simplified NPV Formula

$$E\text{-}NPV = \text{Initial investment} + \left(\frac{B_1 - C_1}{1 + r}\right) + \left(\frac{B_2 - C_2}{(1 + r)^2}\right) + \dots + \left(\frac{B_t - C_t}{(1 + r)^t}\right)$$

B_t = Benefits in year t (including the residual value in year T)

C_t = Costs in year t

r = Discount rate (expressed as a %)

T = Total number of years

A positive E-NPV means the project is worth it (benefits exceed costs), while a negative E-NPV means it may not be a good investment

PRACTICAL EXAMPLE

Parameters and input values for the base scenario

To achieve this, we have constructed a baseline scenario using anonymised data to demonstrate how this method should be carried out.

General information	Value
Average annual traveling distance per bus	90,000 km
Replacement ratio	1:1.15

CAPEX cost element	Diesel Bus	BEB
Vehicle purchase cost including warranty	€ 300,000	€ 550,000
Battery replacement	N/A	30% of bus procurement
Battery lifetime	N/A	600,000 or 70% of battery state of health (SoH)
Diesel engine / transmission overhaul	10% of bus procurement	N/A
Diesel engine lifetime	300,000 km	N/A
Residual value of vehicle	5% of bus procurement	5% of bus procurement
Residual value of battery	N/A	50% of € per kWh capacity at time of bus procurement
Diesel fuelling station (shadow price)	100,000 (€/fuelling station)	N/A
Electric charger 150kw (for depot) - 4 charging points per cabinet	N/A	150,000 (€/charger)
Depot charging gantry and canopy	N/A	50,000 (€/bay)
Transformer	N/A	33,300 (€/MVA)
Installation cost	N/A	30% of charging infrastructure
Air conditioning	N/A	1,000 (€/AC unit)
Peripheral utility infrastructure	N/A	10% of charging infrastructure
Further CAPEX cost		
Start up and training cost	N/A	1,500 (€/driver)
Bus planning and charging management software	N/A	1,500 (€/bus)
Upgrade of workshop facilities	N/A	2,500 (€/ workshop bay)
OPEX		
Annual service days	365	365
Annual driver salary	€ 14,400	€ 14,400
Average yearly working hours bus driver	2,145	2,145
Electricity consumption of air conditioning	N/A	5% of electricity consumption
Diesel price / electricity price	0.7 (€/L)	0.07 (€/kWh)
Maintenance cost of vehicles	0.32 (€/bus-km)	0.22 (€/bus-km)
Maintenance cost of charging infrastructure	3% of initial infrastructure investment	2% of initial infrastructure investment
Insurance cost	1.8% of bus procurement	1.8% of bus procurement
Emissions		
Average fuel consumption	0.4 (L/km)	1.5 (kWh/km)
TTW carbon emissions per fuel consumption	2,731 (g/L)	0
WTT carbon emissions per fuel/energy consumption (2026)	529 (g/L)	226 (g/kWh)
WTT carbon emissions per fuel/energy consumption (2035)	529 (g/L)	126 (g/kWh)
Nox emissions	1.2148 (g/km)	0
SOx emissions	0.0043 (g/km)	0
PM2.5 emissions	0.0208 (g/km)	0

***Note: This is a dummy example, and the numerical values do not reflect any city or a country. Values are collected based on the expertise of the group members.**

Assumptions and considerations

- The operational lifetime of a BEB is assumed to match that of a diesel bus, set at 10 years. As the BEB technology is still emerging in most of the GCC cities, it is currently considered an identical operational lifetime for both vehicles when evaluating and comparing these two vehicles.
- Battery replacement is assumed to account for 30% of the vehicle procurement cost.
- Diesel fuelling station costs are included in the calculations to ensure a fair comparison between both buses.
- The cost of depot charging gantries and protective canopies is factored in as a best practice for safeguarding BEBs.
- The cost of adding electricity transformers is included to ensure that charging stations can supply adequate power for BEB.
- Installation costs, including connections and commissioning, are accounted for.
- The cost of upgrading the utility grid is included to enable fast and reliable electricity connectivity for charging the BEBs.
- Drivers' training is considered essential to monitor and improve driving behaviour, which significantly impacts battery efficiency and range. This cost includes initial training sessions and potential reassessments.
- The cost of implementing basic bus planning and charging management software for managing EV operations is considered.
- Costs related to upgrading workshops to accommodate the tools and equipment necessary for maintaining the BEBs are included.
- It is assumed that one diesel pump can support up to 10 diesel buses, while one charging cabinet provides four charging points for the electric buses.
- The CBA focuses on the emissions generated during the vehicles' operational phase, specifically emissions associated with bus usage.
- The underlying carbon footprint for electricity generation drops by 44% over the timeframe, representing the region's energy transition.
- Given the GCC context, it is assumed that the business model followed here is direct (outright) purchase. Also, subsidies or incentives are not considered in the base scenario.
- Farebox revenues and non-farebox revenues are not taken into consideration, due to the challenges in obtaining these values.

Important: The value of electric energy consumption is not fixed and is assumed to vary depending on seasonal factors. The value used here for the calculations represents the annual average consumption.

TCO results and discussion

A TCO assessment covers everything from asset acquisition, its operation and maintenance, to any other expenses incurred that one may wish to consider based on the conditions of the evaluation. From the results depicted in Figure 6, we can imply the following.

- **Higher initial costs for BEBs:** The most significant cost component for BEBs is the vehicle purchase cost, which is considerably higher than for diesel buses. BEBs also require additional battery replacements/overhauls over their lifecycle, contributing to further capital expenditures. Infrastructure costs (charging infrastructure, depot modifications) and further CAPEX costs are additional financial burdens for BEBs.
- **Operational cost advantages of BEBs:** BEBs exhibit savings on energy compared to diesel fuel costs. In addition, diesel buses have higher vehicle maintenance costs, indicating that BEBs require fewer repairs and replacements. On the other hand, BEBs tend to retain higher residual value at the end of their lifespan compared to diesel buses.
- BEBs have higher costs related to insurance costs, drivers' salaries and infrastructure maintenance, compared to diesel buses.

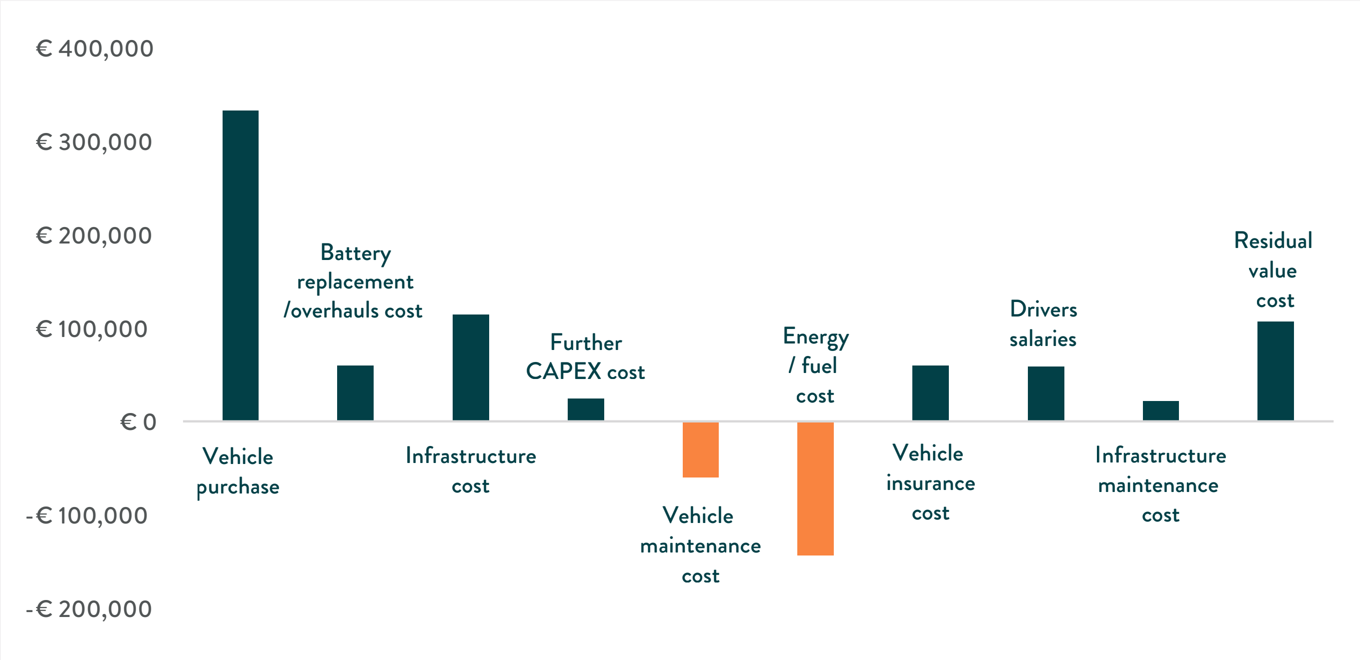


Figure 6. The cost difference between BEB and diesel bus using a 1:1.15 replacement ratio.

In summary, BEBs have significantly higher CAPEX due to vehicle purchase costs and charging infrastructure investments. In contrast, diesel buses exhibit higher OPEX, likely driven by greater fuel costs and maintenance expenses. Despite OPEX savings, the **overall TCO for BEBs remains higher than diesel buses,** mainly due to elevated CAPEX.

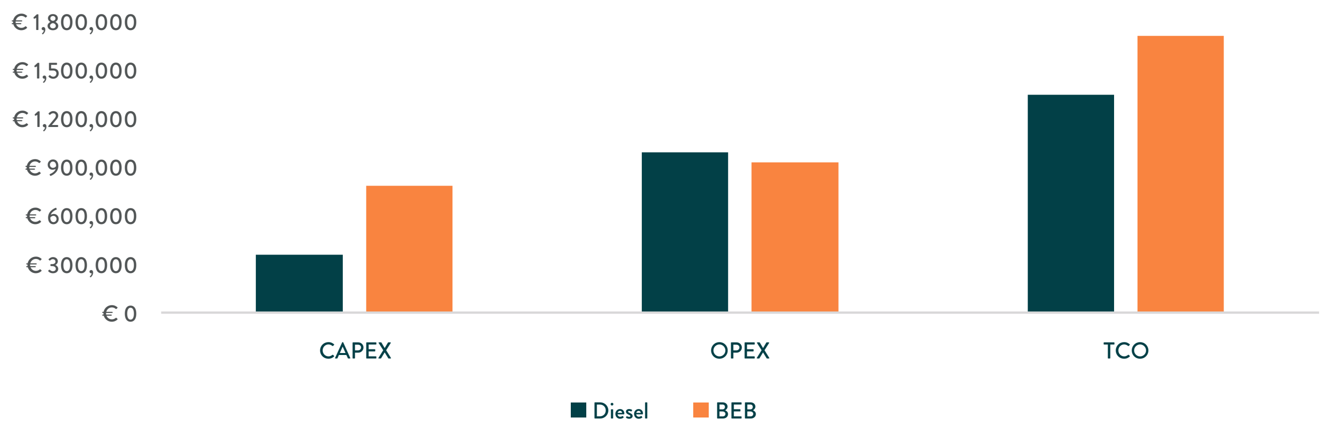


Figure 7. Aggregated costs for CAPEX and OPEX as well as the TCO for both diesel bus and BEB using a 1:1.15 replacement ratio.

E-NPV results and discussion

To assess the economic viability of BEBs and diesel buses over their lifecycle, we perform a comparative assessment of both buses through cash flow analysis and E-NPV. The E-NPV captures the time value of money by discounting future cash inflows and outflows, thus offering a comprehensive metric for comparing investment alternatives.

Alongside, a detailed cash flow analysis over a 10-year horizon illustrates the CAPEX, OPEX, overhaul costs, and residual values associated with each bus type. This enables a robust evaluation of the long-term fiscal impacts of adopting BEBs versus conventional diesel buses.

Cashflow Trend in Figure 8:

- The cashflow line shows a steep drop in 2025, driven by the upfront CAPEX (vehicle and infrastructure).
- From 2026 onwards, the cashflow is relatively stable but exhibits cyclical increases and dips, aligned with the periodic overhauls.
- In 2035, a final drop in cashflow is noted, due to the bus residual value at the end of the 10th year.

The diesel bus presents lower initial investment and a reasonable positive end-of-life cashflow but suffers from cost volatility due to recurring overhauls and higher OPEX levels. While it may appear more economically feasible in this limited 10-year window, this comes at the cost of less financial predictability and higher cumulative environmental externalities.

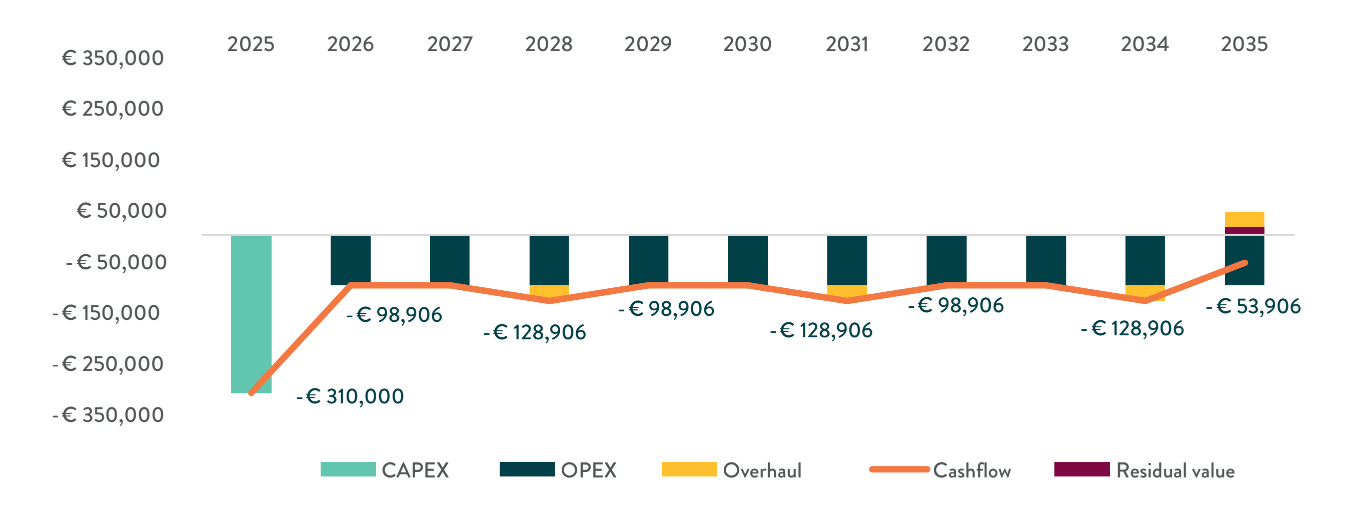


Figure 8. 10 years cashflow for a diesel bus.

Cashflow Trend in Figure 9:

- The cashflow trajectory shows a sharp decline in 2025 due to the high initial CAPEX (vehicle and charging infrastructure costs).
- From 2026 to 2029, the cashflows remain steady, only affected by OPEX.
- In 2030, the cashflow falls sharply again due to the combined effect of OPEX and overhaul cost (battery replacement).
- After 2030, the cashflow stabilises again until 2034, and finally, in 2035, a positive cashflow is observed, representing a residual value adjustment.

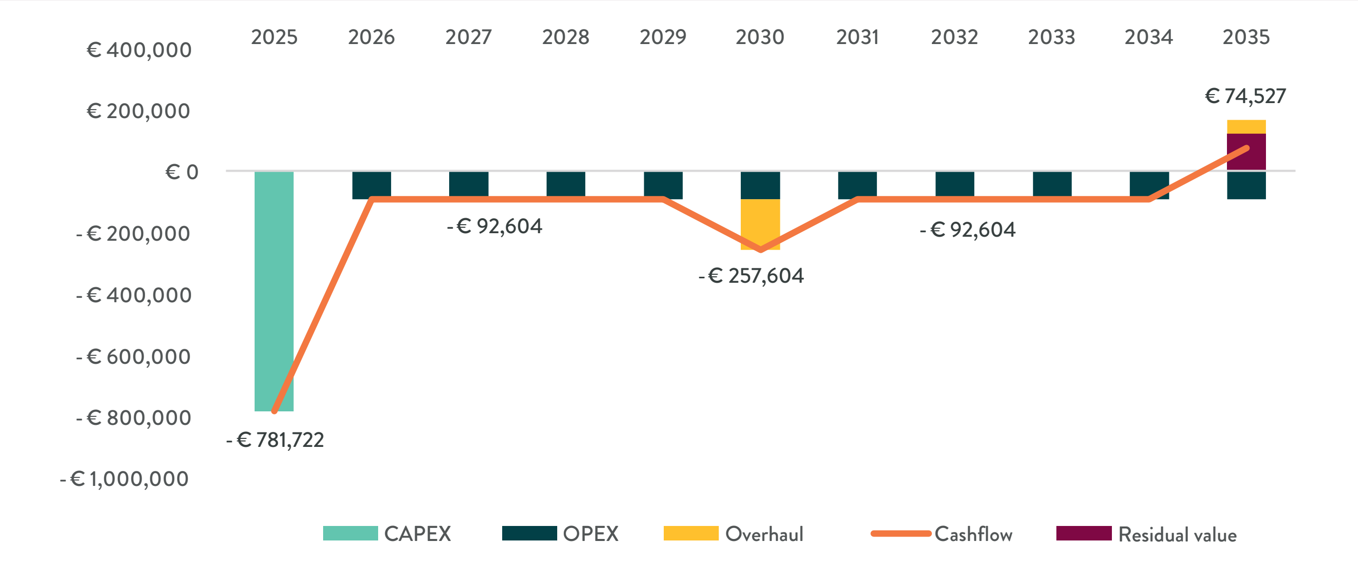


Figure 9. 10 years cashflow for a BEB with a 1:1.15 replacement ratio.

***Note:** Cashflow is calculated based on the sum of CAPEX, OPEX, and overhaul.

In sum, the BEB can generate greater long-term cost regularity, especially when extended beyond the 10-year period or coupled with incentive schemes.

Given the following values, the E-NPV for transitioning from a diesel to BEB is depicted below

- Discount ratio r of 3%.
- Replacement ratio is considered 1:1.15.
- Carbon prices ranging from €60 to €300 per ton.
- Pollutants prices are assumed to be as follows NOx: €6,041 per ton, SOx: €55,364 per ton, and PM2.5: €291,505 per ton). These prices are 30% of the U.S Department of Transport pricing to account for lower healthcare costs.

The results presented in Figure 10 indicate that, under the base scenario conditions, the transition to BEBs yields a negative E-NPV, reflecting unfavourable economic implications at current cost and business model. However, the magnitude of this negative value decreases progressively with higher carbon pricing, demonstrating that carbon price is a key determinant of E-NPV outcomes. This trend underscores the significant influence of environmental cost internalisation on the economic feasibility of BEB adoption. Nonetheless, it is important to note that E-NPV is shaped by a range of interrelated factors, which will be further explored in the subsequent sensitivity analysis to better understand their respective contributions and implications for large-scale deployment.

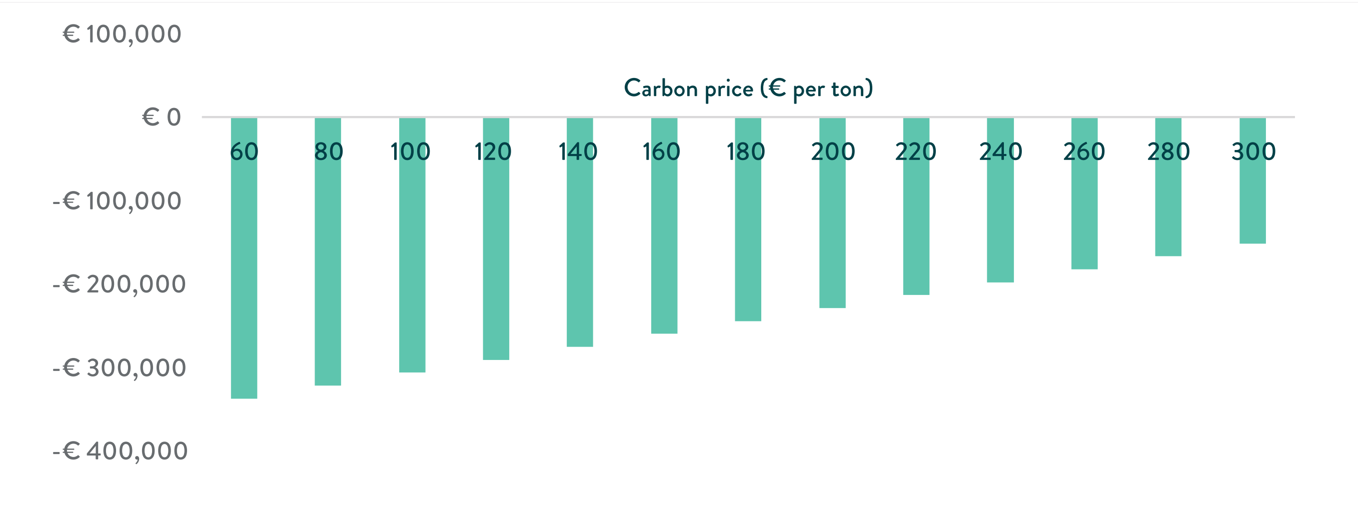


Figure 10. E-NPV results considering economic, environmental, and social impacts under a 1:1.15 replacement ratio.

Key takeaways from TCO and E-NPV

BEBs are capital-intensive but operationally cost-efficient.

- While they save on fuel and maintenance costs, their high upfront investment remains a barrier to adoption.

A long-term perspective is needed to justify BEB adoption.

- The higher TCO suggests that benefits like reduced emissions and long-term financial savings need to be factored in.

Policy interventions and incentives are required.

- The negative E-NPV implies that to make BEBs more competitive, financial incentives, infrastructure subsidies, and optimised procurement strategies, should be considered.

GHG generation

Following the calculations of the cash flow for both buses, the E-NPV is computed where environmental (GHG emissions) and social (NOx, SOx, and PM2.5) impacts of both vehicles are considered and calculated as the following. To quantify the emissions and other pollutants:

$$\textit{Amount of GHG in tons (diesel bus)} = \frac{(TTW+WTT)\,.mileage\,.fuel\ consumption}{1\ mn}$$

$$\textit{Amount of NOx in tons (diesel bus)} = \frac{mileage\,.\ NO_x\ emissions}{1\ mn}$$

*Note: Same formula applies for the other pollutants (SO_x and $PM_{2.5}$).

$$\textit{Amount of GHG in tons (BEB)} = \frac{WTT\,.\ mileage\,.energy\ consumption}{1\ mn}$$

The generated GHG emissions (in tons) for both diesel bus and BEB as well as the reduction in GHG, given a 1:1.15 replacement ratio is shown in Figure 11.

As it can be seen, there is a consistent high GHG emissions from diesel buses across all years. Hence, diesel buses contribute significantly to atmospheric carbon emissions, which is typical due to combustion-based fuel usage (diesel). On the other hand, BEBs exhibit substantially lower GHG emissions, consistently around 20–35 tons annually, across the entire period. These emissions reflect indirect emissions from electricity generation rather than tailpipe emissions (which are zero). The BEB emissions are dropping over time reflecting the anticipated energy transition in the next decade which indicates a clear environmental advantage, especially if powered by renewable energy sources.

The results clearly demonstrate that transitioning from diesel to BEBs results in substantial and increasing GHG reductions over time. While diesel buses contribute heavily to emissions, BEBs offer a cleaner alternative, even when accounting for upstream electricity emissions. The growing GHG reduction trend strengthens the case for electrification from a climate mitigation perspective.

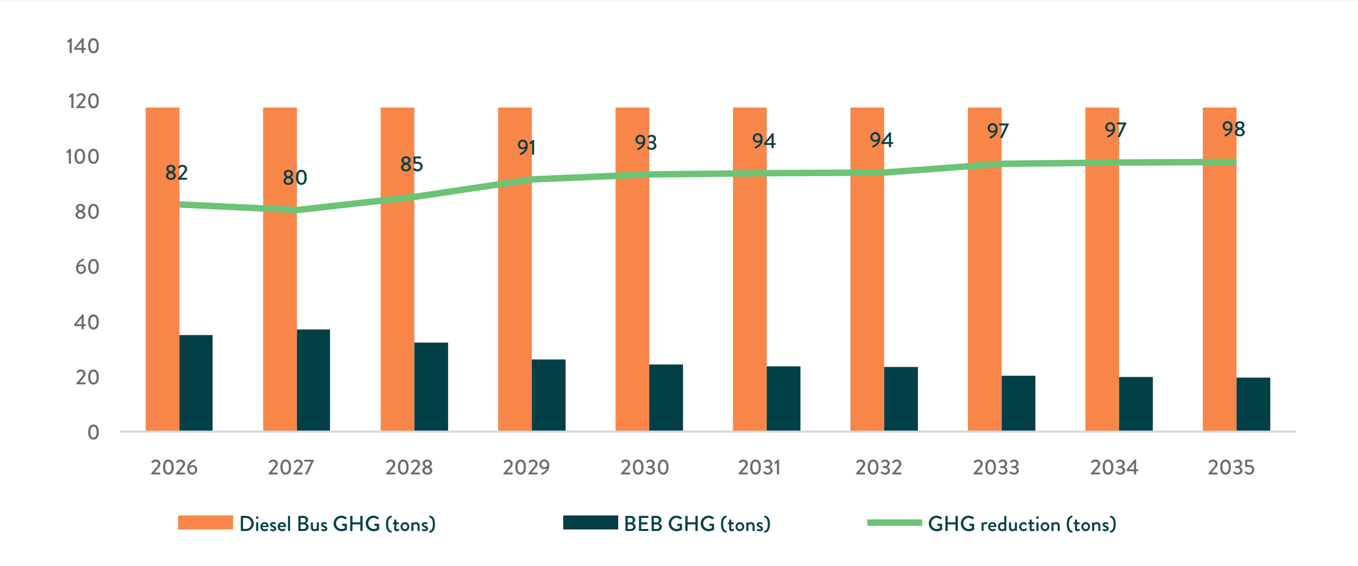


Figure 11. GHG emissions for both buses.

Sensitivity analysis for TCO and E-NPV

In this part, a sensitivity analysis of the TCO and E-NPV is conducted to identify key cost drivers influencing the economic feasibility of transitioning from diesel buses to BEBs.

The analysis examines the percentage change in TCO and E-NPV when critical input parameters are varied within realistic ranges. This approach allows a better understanding of which parameters have the most significant impact on the TCO and E-NPV differential and helps inform procurement strategies and risk mitigation measures for PTAs and PTOs.

The following variables are considered in the sensitivity analysis:

- Electricity costs and fuel prices (± 10%)
- Battery cost (-20% to -10%)
- Diesel bus and BEB purchase prices (± 10%)
- Replacement ratio (1:1 to 1:1.30)
- GHG price (€60 per ton to €300 per ton)

TCO sensitivity findings:

Replacement ratio has the strongest impact on TCO

- The replacement ratio, which compares the number of BEBs needed to substitute a diesel bus on a 1:1 basis has the most pronounced effect on TCO. A shift from 1:1 to 1:1.30 increases the TCO differential by up to 45%, while a more favourable ratio (e.g., 1:1 or lower) reduces the TCO gap to 8.8%.

This highlights the operational efficiency and range limitations of BEBs as a critical determinant of cost competitiveness.

CAPEX for BEBs and diesel buses significantly influence TCO

- A ±10% variation in BEB CAPEX results in a TCO change from 21.4% to 32.4%, indicating that initial vehicle costs remain a major sensitivity driver.
- Similarly, Diesel CAPEX variation leads to a TCO fluctuation from 23.2% to 30.8%, though its impact is slightly less severe than for BEBs.

These findings underscore the importance of cost reduction strategies in procurement and the potential role of capital subsidies or financing mechanisms.

Battery and electricity prices also have notable effects

- Battery cost variations (–20% to -10%) influence the TCO by approximately 26.5% to 26.7%.

This narrow range indicates that the TCO insensitive to the reduction in battery price solely, given the prices taken for the vehicles, infrastructure, and other elements. Hence, it may generate better reductions when the prices of the other elements are also improved.

Diesel fuel price sensitivity

- The TCO impact ranges from 24.6% to 29.3% under ±10% changes in diesel fuel prices.

While still important, the diesel price sensitivity is less dominant compared to the replacement ratio and CAPEX of BEBs, indicating that fuel cost volatility alone is insufficient to drive economic justification for electrification.

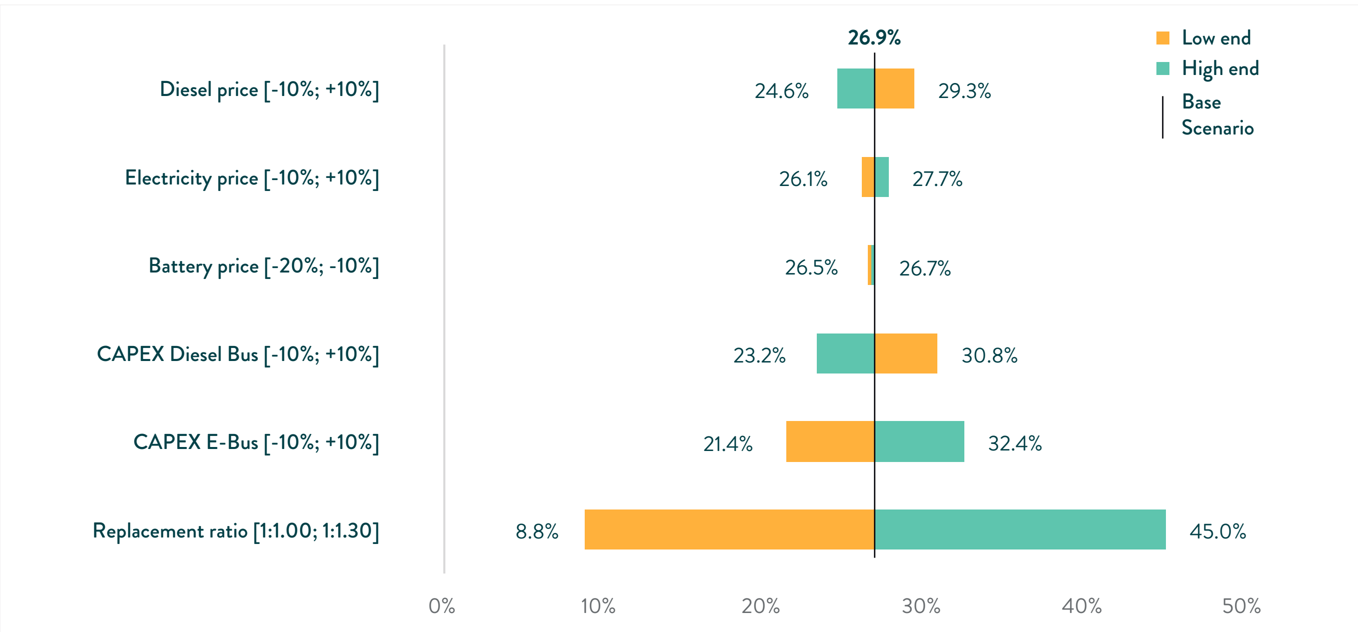


Figure 12. Sensitivity Analysis: % TCO increase (for transitioning from diesel bus to BEB) with a replacement ratio of 1:1.15 as base scenario.

E-NPV sensitivity findings:

Replacement ratio as a primary cost driver

The analysis identifies the replacement ratio as the most critical determinant of E-NPV. A decrease from 1.15 to a 1:1 replacement scenario substantially improves the economic case, whereas an increase to 1.30 significantly reduces E-NPV. This finding underscores the need to optimise operational planning and duty cycles to minimise fleet expansion requirements for BEB deployment.

High sensitivity to BEB capital costs

Variations in BEB CAPEX result in E-NPV fluctuations, aligning with TCO findings that capital investment remains a key barrier to adoption. Hence, cost mitigation strategies such as capital subsidies, low-interest financing, and aggregated procurement are critical to improve economic attractiveness.

Moderate sensitivity to energy prices

Changes in electricity and diesel prices yield relatively moderate E-NPV shifts. Although these factors influence operating costs, they are less decisive than replacement ratios or vehicle acquisition costs.

Impact of carbon pricing and environmental externalities

The E-NPV increases significantly with higher carbon prices. This highlights the economic value of internalising externalities such as GHG emissions through carbon pricing or emission-based policy instruments.

Given that the replacement ratio is one of the most influential variables in the economic viability of BEBs, it is particularly insightful to examine the E-NPV under a 1:1 replacement scenario.

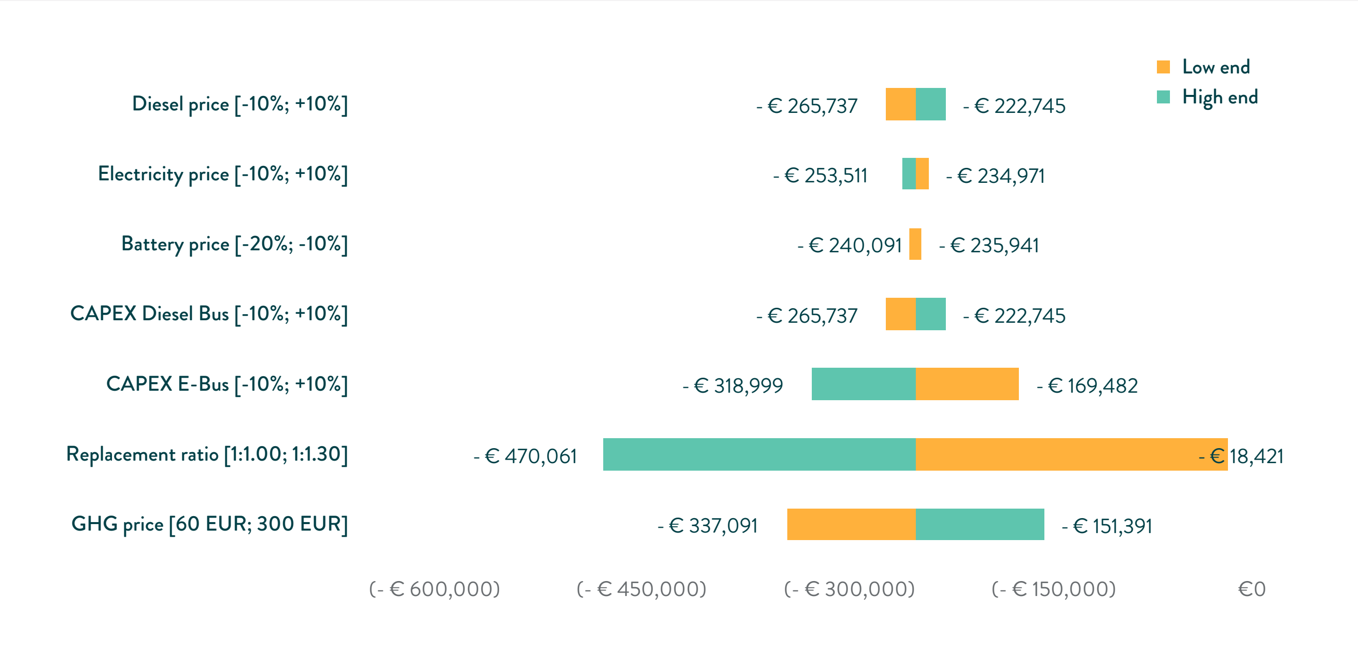


Figure 13. Sensitivity Analysis: E-NPV value with a replacement ratio of 1:1.15 as base scenario and a carbon price of €180 per ton.

As illustrated in Figure 14, the results indicate that the transition to BEBs becomes economically justifiable at a carbon price of approximately €220 per ton or higher, at which point the E-NPV turns positive. This highlights the economic challenge of BEB adoption under current conditions, where diesel buses remain more financially attractive due to their lower CAPEX and the absence of additional infrastructure costs typically required for BEB deployment. Moreover, the internalisation of externalities through mechanisms such as carbon pricing and pollution charges plays a critical role in improving the economic case for BEBs.

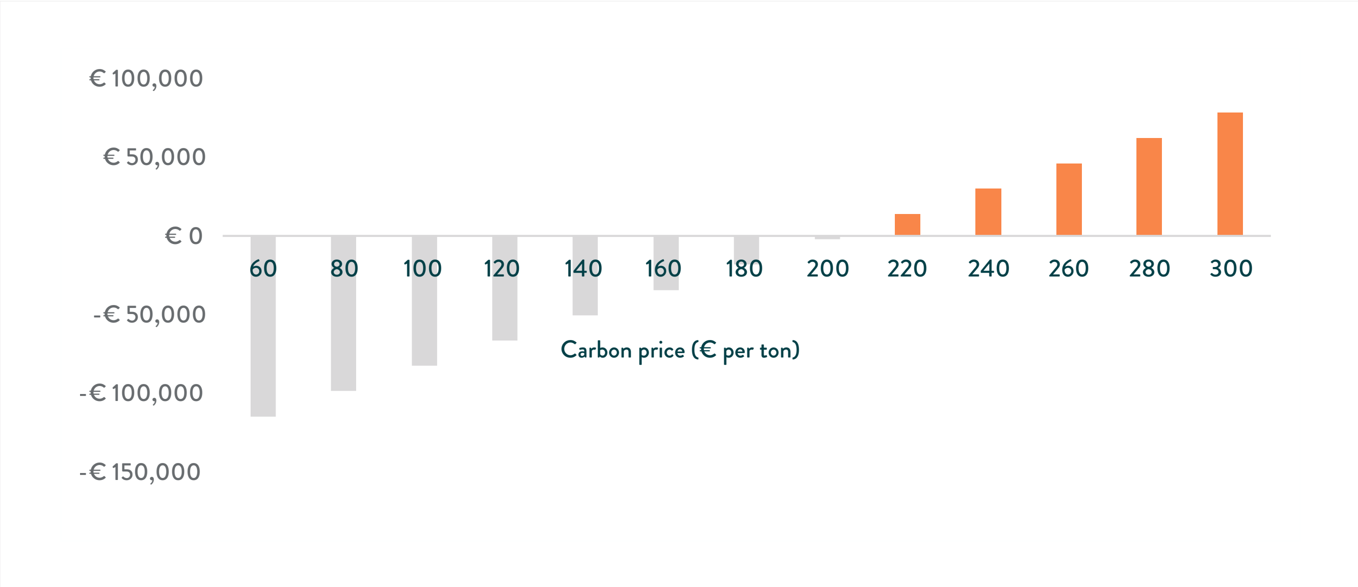


Figure 14. E-NPV results considering economic, environmental, and social impacts under a 1:1 replacement ratio.

It is important to note that the E-NPV outcome is shaped by a constellation of interacting factors, including initial CAPEX, carbon pricing mechanisms, subsidy structures, regulatory incentives, and environmental cost accounting. These variables must be strategically addressed to enable the large-scale adoption of battery electric buses and to ensure that their long-term economic and environmental benefits are fully realised.

The sensitivity analysis shows that while BEB adoption can yield positive economic outcomes under certain conditions, its feasibility is most sensitive to fleet sizing assumptions and capital cost structures. Policymakers and PTAs should focus on reducing CAPEX, promoting operational efficiency (e.g., low replacement ratio, improving battery capacity, etc.), and implementing carbon pricing mechanisms to improve investment returns and accelerate the transition toward sustainable public transport.

FINDINGS AND FORWARD THINKING: RECOMMENDATIONS FOR THE MENA REGION

This section provides a synthesis of the key insights presented in the preceding chapters, consolidating findings across technical, economic, and policy dimensions. It also outlines forward-looking recommendations to guide the strategic transition toward BEBs in the MENA region.

SUMMARY OF KEY FINDINGS

Technical challenges in harsh climatic conditions

While the range of BEBs is getting improved due to advancements in battery capacities, challenging climate conditions, particularly the high temperatures common in MENA, can reduce battery efficiency and range. This remains a challenge for heavy-duty operations (high daily kilometres) and can complicate the scheduling of longer routes or high-demand services.

Although BEBs may not be economically optimal in the short term within the MENA context, the reduction of GHG emissions remains a priority. Aligning with the Paris Agreement goals necessitates placing long-term environmental benefits over immediate financial considerations. Furthermore, the MENA region presents distinct challenges that amplify the complexity of transitioning to BEBs. These include harsh climate conditions, significantly higher average mileage compared to other regions, and the ease and low cost of fossil fuel energy production, which further complicate the shift toward sustainable transport solutions.

High upfront and infrastructure costs

The upfront cost of purchasing BEBs and installing charging infrastructure is significantly higher than conventional diesel buses. The purchase price of BEBs is typically 1.5 to 2 times higher than that of diesel counterparts, largely due to the cost of battery systems and associated electrical components.

Capital-intensive investments are required for charging infrastructure, grid reinforcement, and depot retrofitting. This elevated CAPEX profile strains municipal and operator budgets, especially in cities lacking dedicated clean transport financing mechanisms, and acts as a deterrent to early adoption unless offset by subsidies or concessional funding.

Limited cost advantage due to low diesel costs

Many cities in the MENA region benefit from low fuel prices, making the operational costs of conventional diesel buses relatively inexpensive. As a result, transitioning to BEBs can be financially challenging, as the upfront costs for BEBs and the necessary charging infrastructure are significantly higher. Additionally, the cost savings typically associated with reduced fuel expenses are less pronounced in regions with subsidised fuel, which can impact the overall economic feasibility of BEB adoption in the short term.

Policy and institutional gaps

Unlike several advanced markets where BEB deployment is driven by targeted policy incentives and subsidies, many MENA cities have insufficient frameworks to support zero-emission public transport. The absence of structured incentive schemes, such as purchase subsidies, carbon pricing mechanisms, or reduced electricity tariffs for public transport operators, limits the financial attractiveness of BEB investments. Furthermore, policy uncertainty and fragmented institutional mandates inhibit long-term planning and private sector confidence in electrification programs.

Economic viability and infrastructure considerations

One of the factors contributing to the current economic viability of diesel buses is the pre-existing depot infrastructure, which supports fleet operations without requiring significant new capital investment. In contrast, the deployment of BEBs in the region necessitates the construction of new depots or retrofitting of existing facilities, leading to additional upfront capital expenditures. However, these infrastructure costs are primarily incurred during the initial phase of implementation. Once established, the focus shifts toward operational expenditures primarily infrastructure maintenance which, over time, contributes to an improved E-NPV and strengthens the long-term economic case for BEB adoption.

SUMMARY OF KEY RECOMMENDATIONS FOR ACCELERATING THE TRANSITION TO ELECTRIC BUSES

- Environmental rationale for BEB adoption
- Establishing carbon pricing frameworks
- Technological advancements and battery economics
- Phased approach and piloting strategy
- Decarbonising the electricity grid
- Enabling policy and regulatory environment
- Emerging business models for BEB deployment
- Stakeholder collaboration and governance structures
- Regional knowledge exchange and mutual learning
- Depot optimisation for shared charging infrastructure
- Charging interoperability to avoid vendor lock-in
- Battery and infrastructure management
- Data-driven decision making
- Battery second life and recycling planning

KEY RECOMMENDATIONS FOR ACCELERATING THE TRANSITION TO BEBS

Environmental rationale for BEB adoption

Transitioning to BEBs generates significant GHG reductions and positive health impacts, and therefore, MENA cities should capitalise on these positive implications which align with their decarbonisation targets.

Establishing carbon pricing frameworks

To make it more effective, the MENA region should intensify its efforts to develop their own carbon or GHG pricing frameworks (carbon pricing mechanisms). As highlighted previously, transitioning to BEBs is economically improved when environmental and social externalities are internalised. Global schemes can be localised to align with specific national conditions. For instance, countries can use global benchmarks like the U.S. SCC or the UK shadow price for carbon as baselines, then adjust them based on local economic and environmental conditions. Additionally, regional collaboration could be pursued, with neighbouring countries establishing region-specific frameworks to address shared environmental concerns effectively.

Technological advancements and battery economics

Over time, advancements in battery technology are expected to lead to significant improvements in battery capacity (e.g., increased energy density), resulting in lower replacement rates, extended battery lifespans, and reduced capital expenditures, particularly through declining battery prices. These developments will collectively enhance the economic viability of BEBs by lowering total lifecycle costs and improving operational reliability.

Phased approach and piloting strategy

While procuring BEBs may not be the most financially viable investment in the short term in the MENA region, the long-term potential is significant. In other words, the immediate replacement of entire fleets may not be practical, but gradual adoption (phased approach) allows for necessary experience to be gained.

Hence, it is essential for PTAs and PTOs to conduct trials to get the experience, building the learning curve, and identify their requirements. Further, having the initial investment of procuring BEBs for conducting technical tests and building the incremental learning curve is essential to encourage cities to initiate trials. The availability of subsidies and incentives could further encourage PTAs and PTOs to take the first step towards investing in this technology.

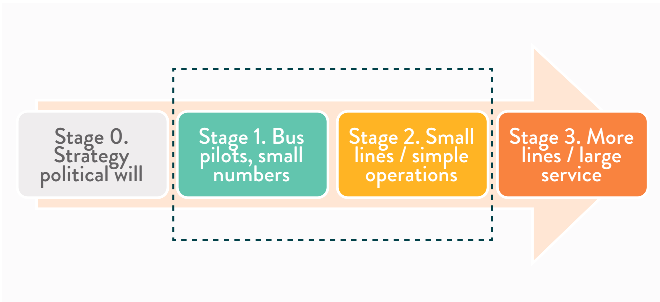


Figure 15. Recommended deployment stages for e-buses in MENA region in the short term.

Open opportunities for OEMs and technology providers to test and pilot innovative BEB technologies under local operating conditions. Data collected from such trials can inform procurement decisions, enhance product suitability, and encourage market-driven solutions tailored to MENA-specific climatic, topographic, and operational challenges.

Cities aiming to convert an entire bus line to BEBs must undertake thorough and forward-looking planning to ensure operational reliability and service continuity. Unlike conventional diesel buses, BEBs are subject to range limitations, charging time requirements, and potential variability in performance under different climatic and topographical conditions. These factors often necessitate additional vehicles to maintain the same service frequency and coverage, especially during peak hours or on long routes. If not accurately forecasted, this could result in fleet shortages, leading to disruptions in service delivery and failure to meet passenger demand after procurement.

Decarbonising the electricity grid

Increasing the share of renewable energy in the grid mix is a critical enabler for enhancing the environmental benefits of BEBs. As the electricity grid becomes cleaner through greater integration of solar, wind, and other renewable sources, the indirect emissions associated with BEB charging are significantly reduced, thereby amplifying their advantage over diesel buses, which continue to emit GHG at the tailpipe. Over time, this shift not only strengthens the climate impact of BEB adoption but also affects the comparative economic outlook. As carbon pricing mechanisms and environmental externalities become increasingly internalised, diesel buses dependent on fossil fuels will incur higher operating costs, rendering them less financially viable in the long run.

Enabling policy and regulatory environment

Policy makers in the MENA region should introduce supportive regulations, fiscal incentives, and subvention schemes to offset high upfront costs and ensure long-term cost parity with conventional buses. This includes facilitating access to concessional finance and adjusting procurement frameworks.

Introduction of carbon taxes, subsidies for BEBs, and renewable energy mandates that could either increase the benefits or mitigate the costs are some of the things that should be considered in the future policy changes.

Emerging business models for BEB deployment

The growing adoption of BEBs has encouraged the development of various innovative business models. One key difference with BEBs is that buses and batteries have different lifecycles, and this leads to the need for flexible ownership and contract models. Another critical component of BEBs deployment is the charging infrastructure, which can either be bundled with bus procurement or handled as a separate service. The unbundling assets ownership and operations is another approach being evolved, which refers to the separation of the roles between those who own BEBs assets and those is responsible for daily operations.

To know more about how business models is transformed for bus electrification, interested readers can refer to (1).

Stakeholder collaboration and governance structures

Electrification involves multiple stakeholders with a joint objective towards achieving a sustainable transformation in the transportation sector, making it a complex interaction between the players. Several stakeholders are involved in this transformation including governments, city councils, PTAs, PTOs, energy providers, OEMs, and passengers, among others. To achieve sustainable electrification, every participating entity should have a sustainability mindset and consider the collaboration with other stakeholders as a key enabler for efficient and sustainable bus systems. In essence, establishing consortiums or joint implementation frameworks with clearly defined roles and responsibilities will ensure coordinated execution and shared accountability.

▶ *Figure 16. Stakeholders involved in e-buses deployment* (2).

Regional knowledge exchange and mutual learning

Regional knowledge sharing and mutual learning are vital for accelerating BEB adoption in the MENA region. Cities with similar climate and topography can benefit from each other's experiences, enabling context-specific planning, avoiding common pitfalls, and aligning technologies and operational models with local conditions. Such collaboration also supports informed decision-making and capacity building across the region.

Depot optimisation for shared charging infrastructure

Given the substantial capital investment required for charging infrastructure, optimising existing depots for multi-use charging applications offers an opportunity to

(1) UITP, Business Model Canvas: Transforming Business Models for Large Scale Bus Electrification, 2019. Available: https://mylibrary.uitp.org/GED_V14/182265790044/Business_model_c.pdf

(2) UITP, Depot Adaptions for Clean Bus Technologies, 2023. Available: https://www.uitp.org/publications/depot-adaptions-for-clean-bus-technologies/

improve asset utilisation and generate additional revenue streams. One effective strategy is to leverage depot-based charging infrastructure to serve other electric vehicle segments, such as electric taxis, which are increasingly prevalent in the MENA region. Facilitating shared use of charging facilities through inter-operator collaboration among PTOs can maximise land use efficiency, enhance infrastructure returns, and support broader e-mobility integration. Strategic planning and policy coordination are essential to enable such synergies and foster a more integrated urban electric mobility ecosystem.

Charging interoperability to avoid vendor lock-in

One of the key elements when building the needed infrastructure for BEBs is ensuring the interoperability. Charging interoperability refers to the ability of electric vehicles to work with different charging infrastructure seamlessly, irrespective of brand and without any limitations or technical restrictions. However, full interoperability is achieved not only through robust standardisation. It also requires conformance and interoperability testing to ensure that the standards are properly understood and correctly followed by vehicle and charger suppliers. The standardisation of electric bus charging solutions covers numerous aspects, such as the mechanical implementation, parking tolerances, electrical interfaces, electrical and functional safety and communication requirements.

Agreed standards stimulate innovation, boost confidence and create suitable market conditions for further technological advances while reducing deployment barriers and encouraging competition. A standards-based and interoperable charging system that includes both technical capabilities and contractual rights provides an invaluable basis for wider market penetration and enables the flexibility and optimisation of bus operations, as well as higher rest value of the equipment.

Furthermore, by not binding the product choice to a single solution or supplier, this approach contributes to reducing the cost of charging infrastructure by ensuring functionality, compatibility and interoperability [3]. Therefore, cities should mandate interoperability in the procurement of BEB charging infrastructure to avoid long-term dependence on a single bus manufacturer. It is essential to adopt standardised, open interface charging systems that allow future procurement from multiple OEMs without requiring costly retrofits or new infrastructure.

Proprietary charging technologies pose significant financial, operational, and technological risks, as they lock operators into exclusive vendor relationships and limit competitive tendering. To mitigate this risk, cities should explicitly include interoperability requirements in all technical specifications and procurement documents. An interesting report on interoperability is referred to (4) for further information on this topic.

Battery and infrastructure management

Maintaining optimal battery performance requires an effective TMS to regulate battery temperatures and prevent thermal degradation. Simultaneously, an advanced BMS is essential for real-time monitoring of key parameters such as state of charge, state of health, and temperature ensuring safety, operational efficiency, and extended battery life. Together, TMS and BMS are critical for enhancing reliability and optimizing the lifecycle performance of electric bus fleets.

Storing BEBs in shaded areas and ensuring chargers are within their designed operating temperature ranges can minimise HVAC energy use and maintain battery temperatures. Parking the electric fleet in shaded or indoor areas reduces HVAC energy use during preconditioning. Implementing canopies, possibly with photovoltaic panels, can provide shade and additional energy. In addition, preheating or precooling BEBs before service or charging can improve performance, though it requires additional energy and may extend charge times.

Data-driven decision making

To enhance the operational performance of electric bus systems, it is recommended to implement AI-driven fleet management solutions that enable intelligent scheduling, route optimisation, and energy-efficient operations. Additionally, integrating predictive maintenance technologies will allow for real-time monitoring of vehicle and battery health, enabling timely interventions and reducing unplanned downtime.

(3) ASSURED, A real driver for the electrification of urban bus fleets, 2022. Available: https://cms.uitp.org/wp/wp-content/uploads/2022/12/ASSURED-Project-Brief-_-Final..pdf

(4) ASSURED, Interoperability Reference 1.1, 2021. Available: https://assured-project.eu/storage/files/d44-assured-11-interoperability-reference-pdf.pdf

Battery second life and recycling planning

It is recommended to incorporate second-life applications for batteries from BEBs as part of the overall asset management strategy. Repurposing retired batteries for other applications can generate additional value and offset initial capital investments. This approach not only enhances the economic return on battery assets but also contributes to circular economy practices and supports the development of sustainable energy ecosystems.

Important message:

It is essential to underscore that the transition to public transport and the enhancement of bus ridership are fundamental steps toward achieving sustainable mobility. Therefore, promoting and prioritising public transport should remain a foundational pillar of any sustainable transport strategy.

CONCLUSION

The deployment of BEBs across the MENA region presents a pivotal opportunity to advance environmental sustainability, improve public health, and enhance the efficiency of urban mobility systems. While the benefits are clear, the transition is impeded by economic constraints, extreme climatic conditions, and insufficient regulatory frameworks.

To navigate these complexities, MENA cities must adopt a phased and data-driven approach that aligns with local operational realities. Regional collaboration, technical standards interoperability, and localised carbon pricing mechanisms are critical to enabling cost-effective deployment and ensuring long-term deployment. Strengthening institutional capacity, investing in workforce development, and integrating BEBs into broader public transport strategies will be essential for ensuring a just and resilient shift toward zero-emission mobility across the region.

UITP MENA WORKING GROUP ON ZERO EMISSION BUSES

The UITP MENA Working Group on Zero Emission Buses serves as a platform to advancing the deployment, integration, and policy development of zero-emission buses across the MENA region. Established under the umbrella of the UITP MENA Bus Platform, this Working Group brings together public transport authorities, operators, manufacturers, technology providers, and consultants to facilitate knowledge exchange, technical dialogue, and collaborative research on zero-emission mobility solutions. The Working Group is chaired by Anan Al Amri, Section Head – Alternative and Sustainable Mobility at Integrated Transport Centre (Abu Dhabi Mobility). The MENA Bus Platform is chaired by Badar, Chief Executive Officer at Mwasalat in Oman.

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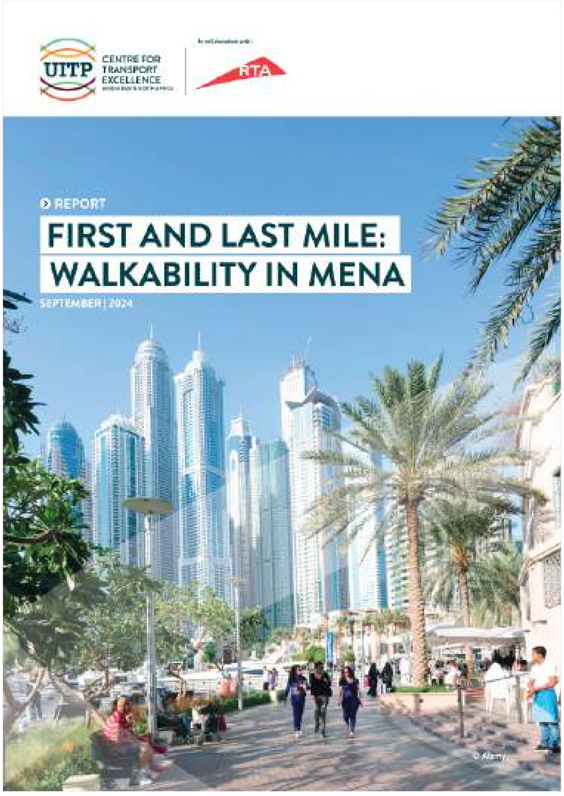
TO KNOW MORE ABOUT UITP PUBLICATIONS ON ELECTRIC BUSES

- UITP, SORT Cycles for Electric Buses, 2017.
  Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=168325798650
- UITP, Transforming Cities with Bus Rapid Transit (BRT) Systems, 2019.
  Available: https://cms.uitp.org/wp/wpcontent/uploads/2020/07/BRT_ENG_Web.pdf
- UITP MENA CTE, Electric Buses in MENA, 2020.
  Available: https://mylibrary.uitp.org/GED_V14/181437990961/UITP_-_Electric_Bus_in_MENA_-_V5.pdf
- UITP, Bus Fleet Renewal Checklist, 2020.
  Available: https://www.uitp.org/publications/bus-fleet-renewal-checklist/
- UITP, Electric Bus Procurement under FAME-II: Lessons Learnt and Recommendations for Phase-II, 2020.
  Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=182159190033
- UITP, Strategies for Deploying Zero-emission Bus Fleets: Route-Level Energy Consumption and Driving Range Analysis, 2021.
  Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=183161390134
- ASSURED, Interoperability Reference 1.1, 2021.
  Available: https://assured-project.eu/storage/files/d44-assured-11-interoperability-reference-pdf.pdf
- ASSURED, Pre-Normative Technology Roadmap and New Use Cases in Electric Bus and Truck Charging, 2022.
  Available: https://assured-project.eu/storage/files/public-pre-normative-technology-roadmap-and-new-use-casesin-electric-bus-and-truck-charging-final.pdf
- ASSURED, Guidelines on Fleet Upscale with E-buses, 2022.
  Available: https://assured-project.eu/storage/files/assured-guidelines-on-fleet-upscale-with-electric-buses.pdf
- ASSURED, Innovation in E-bus Rapid Transit, 2022.
  Available: https://assured-project.eu/storage/files/assuredinnovation-for-bus-rapid-transit-public-version.pdf
- UITP, Large-scale Bus Electrification: New Challenges for IT Systems, 2022.
  Available: https://mylibrary.uitp.org/PermaLinkRecord.htm?archive=187196890537
- UITP, Financial Planning for the Electric Bus Transition, 2022.
  Available: https://www.uitp.org/publications/financialplanning-for-the-electric-bus-transition/
- UITP, Performance Evaluation of Electric Bus from Six Indian Cities, 2022.
  Available: https://www.uitp.org/publications/performance-evaluation-of-electric-bus-from-six-indian-cities/
- UITP, Planning for Electrification of Rural and Intercity Buses, 2022.
  Available: https://www.uitp.org/publications/planning-for-electrification-of-rural-and-intercity-buses/
- ASSURED, Clean Bus Report, 2022.
  Available: https://cms.uitp.org/wp/wp-content/uploads/2022/05/ASSUREDClean-Bus-report_final2.pdf
- UITP, Depot Adaptations for Clean Bus Technologies: Factsheet Battery Electric Technology, 2023.
  Available: https://mylibrary.uitp.org/GED_V14/188721390690/UITP_template_Bus_Depot-Final.pdf
- UITP, Tender Structure Report, 2023.
  Available: https://www.uitp.org/publications/bus-tender-structureupdate-2023/
- UITP, Fleet Wide Transition to Zero Emission Buses – A roadmap for the city of Bengaluru, 2023.
  Available: https://cms.uitp.org/wp/wp-content/uploads/2023/08/Working-Paper_Fleet-Wide-Transition.pdf
- UITP, Series of Webinars on Clean Buses.
  Available: https://cleanbusplatform.eu/news-and-events/events/past

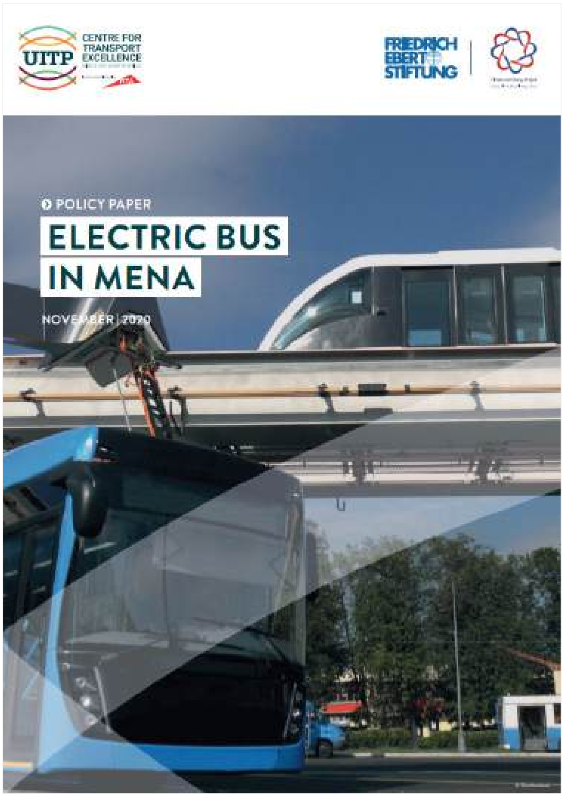
TO KNOW MORE ABOUT UITP MENA CTE RESEARCH CONTRIBUTIONS

▶ *MENA Transport Report (2025)*



▶ *First and Last Mile: Walkability in MENA (2024)*

▶ *First and Last Mile: Navigating Shared Micromobility in MENA (2024)*



▶ *Electric Bus in MENA (2020)*

LOOKING AHEAD: INSIGHTS FROM AROUND THE WORLD ABOUT ELECTRIC BUSES

Building on our ongoing efforts to generate evidence-based insights into electric bus deployment, the upcoming research project will deliver a comprehensive synthesis of global experiences and best practices.

This report will broaden the analytical lens by drawing on international case studies to understand the diverse pathways, performance metrics, and enabling conditions associated with electric bus adoption across varied urban contexts.

Which cities are covered ?

The study will feature an in-depth benchmarking analysis of twelve strategically selected cities: London, Berlin, Gothenburg, Toronto, San Francisco, Shenzhen, New Delhi, Ahmedabad, Kayseri, Doha, Alexandria, and Santiago. These cities represent a rich spectrum of geographies, development stages, governance models, and levels of electrification maturity ranging from early adopters to emerging implementers.

Which indicators are considered?

The benchmarking framework is structured around a set of **key indicators** to enable robust cross-city comparisons and knowledge transfer. These include:

- City Characteristics
- Bus Network and Fleet Characteristics
- Technical Characteristics
- Cost Attributes
- Environmental Metrics

What to expect?

The anticipated outcomes of the upcoming report include:

- Identification of best practices and innovative solutions in planning, procuring, and operating electric bus fleets.
- Analysis of the primary drivers and transition triggers including regulatory mandates, climate action plans, financial incentives, and institutional commitments that have catalysed the shift toward e-buses in the selected cities.
- Comparative analysis to inform decision-making pathways for cities in the MENA region and beyond considering large-scale electrification.

By examining these global experiences through a structured and comparative lens, the upcoming report aims to contribute not only to knowledge dissemination but also to policy translation and implementation planning for public transport authorities and stakeholders worldwide.

Stay tuned for the launch of this research project, as we continue to build the empirical foundation for a sustainable and decarbonised future in public transportation.

This is an official Report of UITP, the International Association of Public Transport. UITP has members all throughout the world and represents the interests of key players in this sector. Its membership includes transport authorities, operators, both private and public, in all modes of collective passenger transport, and the industry. UITP addresses the economic, technical, organisation and management aspects of passenger transport, as well as the development of policy for mobility and public transport worldwide.

This Report was prepared by the UITP MENA Centre for Transport Excellence.

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