UITP CENTRE FOR TRANSPORT EXCELLENCE
MIDDLE EAST & NORTH AFRICA
IN COLLABORATION WITH RTA

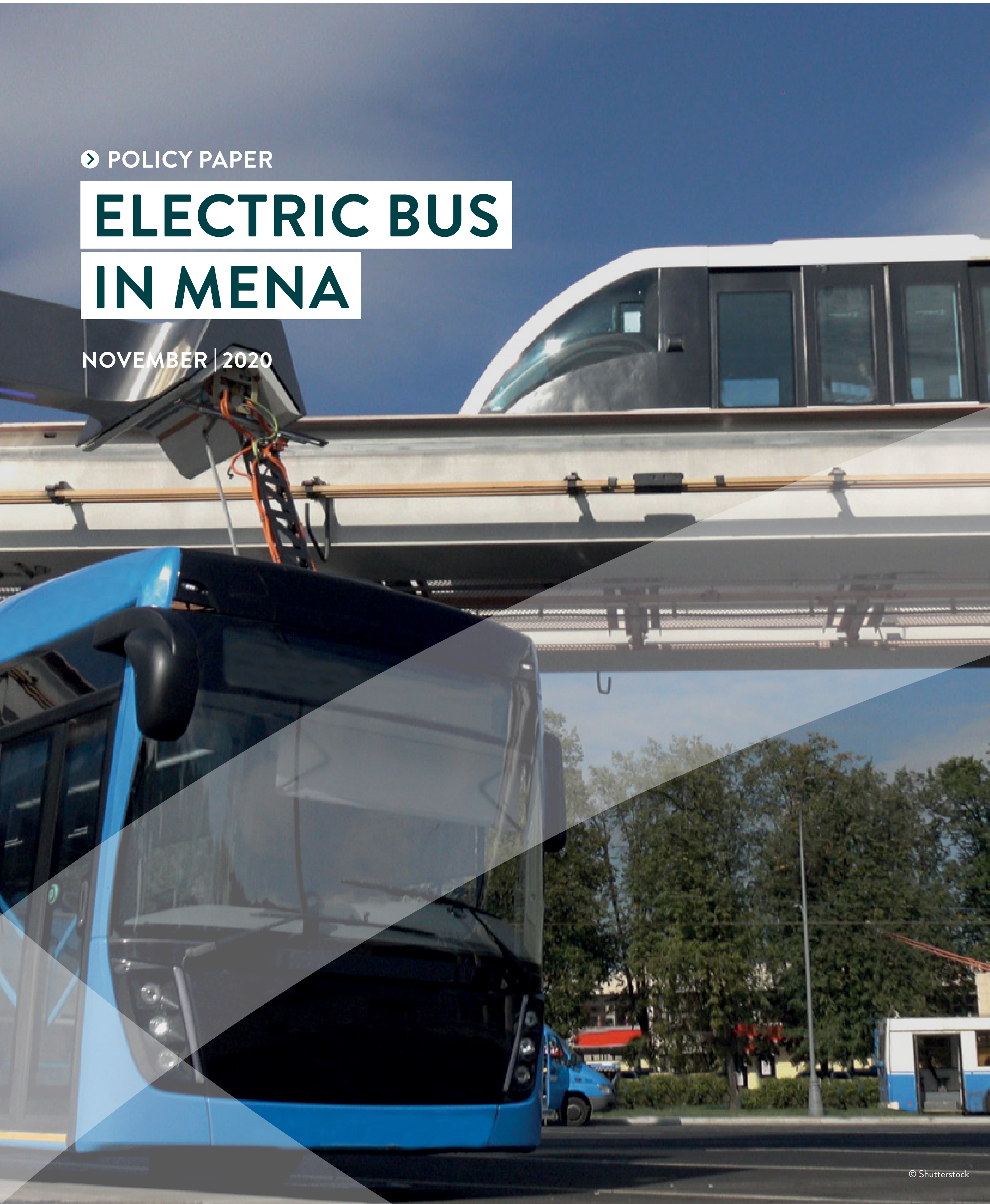
FRIEDRICH EBERT STIFTUNG

Climate and Energy Project
مشروع الطاقة والمناخ

POLICY PAPER

ELECTRIC BUS IN MENA

NOVEMBER | 2020



About Friedrich-Ebert-Stiftung

The Regional Climate and Energy Project MENA advocates for an energy transition into renewable energy and energy efficiency. It continues to search for solutions for a just transition in the energy sector ensuring both, the protection of the planet and the people.

As the MENA region is one of the most affected areas by climate change, FES contributes to policy advising, research, and advocacy in the areas of climate change policy, energy transition, and urban sustainability, with the support of research institutions, civil society organizations, and other partners in the region and in Europe.

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

This policy paper aims to highlight the need for a "systems approach" regarding the deployment of electric buses. The objective is to support decision makers in MENA with the necessary knowledge, tools and frameworks to implement necessary policies to ensure successful electric bus deployment.

In line with global climate and emission objectives, electric buses must be part of a broader low or zero emission mobility strategy with public transport at its core, also including non-motorized transport components such as walking and cycling. Authorities and operators must adopt a systems approach prior to e-bus deployment to understand the new technology and its components as well as the role of new stakeholders to ensure its success.

ABBREVIATIONS

BEB	Battery Electric Bus
BRT	Bus Rapid Transit
CNG	Compressed Natural Gas
FCB	Fuel Cell Bus
GEF	Global Environment Facility
GHG	Greenhouse Gas Emissions
HB	Hybrid Bus
HCPV	High concentration photovoltaics
HVO	Hydrotreated Vegetable Oil (Biofuel)
ICE	Internal Combustion Engine
NOx	Nitrogen Oxides
OEM	Original Equipment Manufacturer
PHB	Plug-in Hybrid Bus
PM	Particulate Matter
PTA	Public Transport Authority
PTO	Public Transport Operator
RNG	Renewable Natural Gas (Biomethane)
SDG(s)	Sustainable Development Goal(s)
TB	Trolleybus
TCO	Total Cost of Ownership
TTW	Tank-to-Wheel
WTT	Well-to-Tank
WTW	Well-to-Wheel

INTRODUCTION

With mounting concerns over climate change and the increased levels of urban air pollution, e-mobility has been on the rise globally. Several governments have opted to rapidly deploy electric buses as well as put electric bus fleet targets as means to achieve their emission targets and climate objectives.

Although electric buses have clear environmental benefits, their implementation requires careful analysis in consideration of local conditions, including operational and infrastructure characteristics as well as availability of resources. The relative novelty of e-buses presents additional challenges as some of their technologies, especially battery and charging, are changing rapidly thus emphasizing the need of this analysis in order to ensure successful implementation.

The aim of this paper is to provide guidance on the implementation of e-buses in the Middle East and North Africa region taking into consideration its unique characteristics. The methodology for developing this guidance utilizes as a foundation the extensive UITP e-bus knowledge base and customizes and adapts this information based on stakeholder interviews, case studies and data collected from the MENA region.

The paper shows the link between international climate objectives and electric bus deployment and provides a basic overview of electric bus technologies, along with a comparative analysis of other fuels, highlighting benefits and challenges as well as components of electric bus systems and finally providing policy recommendations to MENA decision makers.

BACK TO THE FUTURE – A GLIMPSE OF HISTORY

An early version of an electric trolleybus was introduced in Berlin, Germany, in the early 1880s. Dr. Siemen's Elektromote paved the way for the mass adoption of such technology in several European cities decades later. With the success of Henry Ford's Model T and the extensive spread of gas stations amidst the commercialization of fossil fuels, it was evident that the gasoline powered combustion engine would be the prevailing technology for centuries to come.

However, the focus on climate change and development of battery technologies have renewed interest in electric mobility and with it the "new" electric bus.

Fig. 1: Werner Von Siemens' Elektromote, 1882

WHY ELECTRIC BUS?

With more than 450 billion journeys per year worldwide, buses constitute the main mode of transport for most public transport systems.[1] With increased levels of traffic congestions, low air quality remains the most important motivation for the electrification of public transport. World Bank data also shows the MENA region struggling with high air pollution values (PM 2.5), hindering its economies' sustainable growth potential.[2]

The UN Sustainable Development Goals lay out 17 goals and 169 detailed targets for the journey of human development. To achieve SDG Goal 11, Sustainable cities and communities, sustainable mobility, and transport (11.2) constitute the "connective tissue" for the new world we imagine by 2030.[3]

11. Make cities and human settlements inclusive, safe, resilient, and sustainable

11.2. By 2030, provide access to ***safe, affordable, accessible and sustainable, transport systems*** *for all, improving road safety, notably by* ***expanding public transport****, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.*

Sustainable mobility at the forefront of integrated mobility plans is a cornerstone of tomorrow's green cities that we advocate for today. It is important for policymakers in MENA also to acknowledge the important role of other sustainable modes of transport, such as walking, cycling, and car-sharing. Mentioned policies are prerequisites for the success and sustainability of emission lowering strategies in the transport sector.

The traditional approach to solving increased transport demand by building additional roads must be abandoned. This is essential to achieve sustainable mobility in MENA. This "old school" approach has not delivered sought results, on the contrary, it has contributed to increased car traffic, and therefore aggravating road congestion and increasing GHG emissions. An alternative demand-side approach, A-S-I, (Avoid/Reduce, Shift/Maintain, Improve) has been adopted worldwide by policymakers as a more holistic and effective approach in the fight against congestion and air pollution.[4]

Avoid/ Reduce	Reduce need for energy – improve system efficiency (integrated land-use planning, travel demand management)
Shift/ Maintain	Shift to clean and alternative energy sources – improve trip efficiency (walking, cycling, public transport)
Improve	Improve energy efficiency and vehicle technology – improve vehicle efficiency (electric bus)

Table 1: A-S-I approach[5]

1 UITP, 2019. Global Bus Survey. Report. https://www.uitp.org/publications/global-bus-survey/
2 World Bank, World Development Indicators Database
3 UITP & UCLG, 2019. Mobility & SDGs. Report.
4 UITP, 2017. Decarbonsation: Public Transport Contribution. Report.
5 Adapted from Sustainable Urban Transport Program. www.sutp.org

UNDERSTANDING EMISSIONS

While reductions in vehicle emissions are often measured from Tank-To-Wheel (TTW), total emissions measured Well-To-Tank (WTT), which include upstream emissions such as extraction and refinery, usually caused by fossil fuel energy production, are more accurate (see fig. 2 below). In power plants, fuel is burnt more efficiently than in internal combustion engines (ICEs), and, therefore, the overall fuel efficiency is higher in an electric bus than a diesel bus.

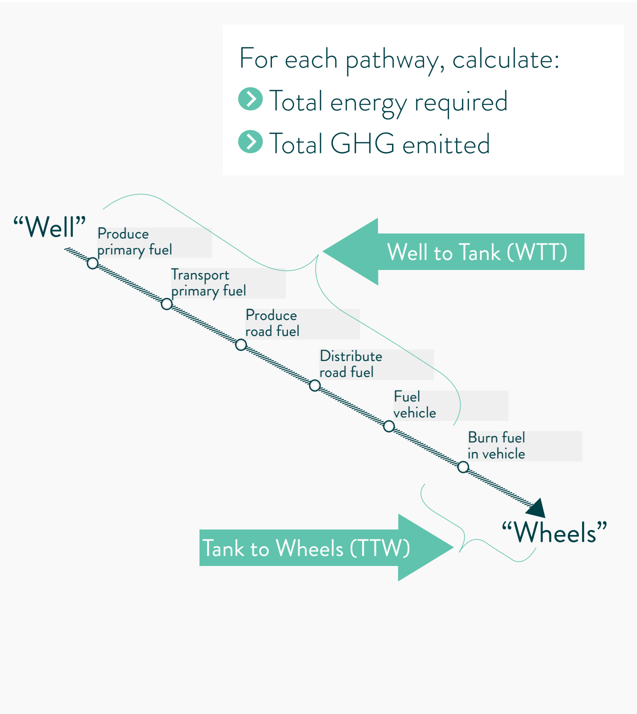


Fig. 2: Well-to-Wheels analysis: WTT + TTW = WTW (Well-to-Wheels)[6]

EUROPEAN EMISSION STANDARDS (EURO I - VI)

Throughout the past decades, fuel emission standards have been improving drastically. The European emission standards have been widely adopted as a global benchmark for acceptable exhaust emission limits for new vehicles entering the market. For buses specifically, which are categorized under heavy duty vehicles, the marginal improvements have been substantial (see fig. 3 below), exceeding 90% from Euro I until today's Euro VI on acceptable NOx and PM values.

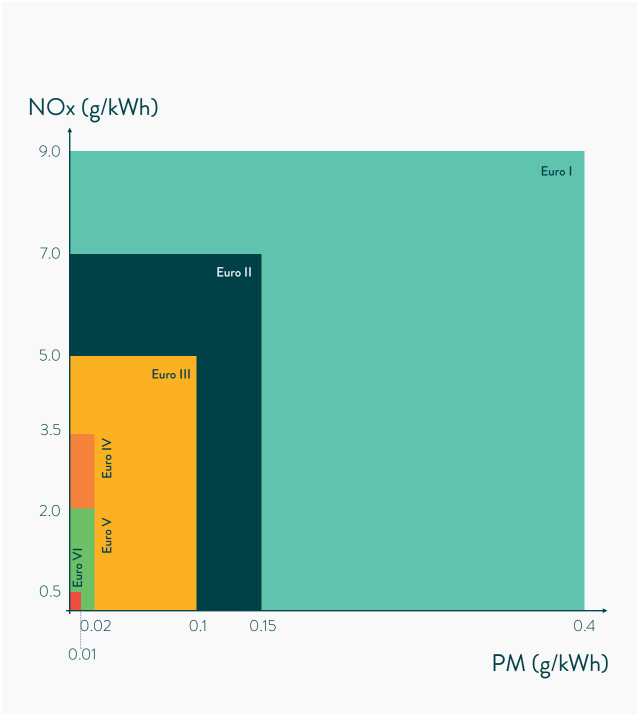


Fig. 3: EU Emission Standards for Heavy Duty Vehicles (Diesel Engines)[7]

Similarly, e-mobility can be efficient, but the overall energy use and GHG emissions depend on the energy source used to produce electricity. A shift to renewable energy is an ultimate prerequisite for mass adoption of electric vehicles to maximize energy efficiency and decrease global emissions.

For the MENA region, which is a significant global producer and exporter of fossil fuels, energy diversification remains an important policy priority. With abundance in solar energy and an attractive renewable energy market, hopes remain high in reducing the dependence on fossil fuels.

In many of MENA's areas, Euro III is still quite dominant with even Euro II for older fleets. This clearly indicates the need for a gradual fleet replacement strategy combined with upgrading Euro standard compliance. Such an approach for the short to medium term in MENA could prove effective in reducing emissions together while exploring e-buses.

6 EU Commission, 2016. EU Science Hub: JEC. https://ec.europa.eu/jrc/en/jec/activities/wtw
7 Land Transport Guru, 2017. European Emission Standards. https://landtransportguru.net/european-emission-standards/

ALTERNATIVE FUELS – EMISSIONS COMPARISON

In the framework of approaching e-bus implementation, it is also important to understand the relative environmental characteristics of various fuel technologies. The table below (Table 2) shows selected emission measures for various fuel types.

	Diesel (Euro VI)	Natural Gas (CNG)	Biofuel (HVO)	Diesel Plug-in hybrid (PHB)	**Battery Electric (BEB)**	Hydrogen (FCB)
Local emissions (NOx PM)	Baseline	Euro VI compliance		↓	Zero	Zero
Global emissions (CO_2) WTT	Baseline	↑	↓	↑	↑	↑
Global emissions (CO_2) TTW	Baseline	→	→	↓	Zero	Zero
Global emissions (CO_2) WTW	Baseline	→	↓	↓	↓	↘

↓	Much lower emissions vs Diesel
↘	Lower emissions vs Diesel
→	Same/similar emissions vs Diesel
↑	Much higher emissions vs Diesel

WTW: Depending on Electricity Source

(Arrows equal to average EU electricity 295g CO2/kWh - *source: EEA*)

Table 2: Alternative Fuels – Emissions Comparison[8]

GOVERNMENT COMMITMENTS

Having the commitment of the governments is critical for ensuring other needed support mechanisms are in place: regulations, incentives, standards, etc. Various governments have developed climate action plans including targets for electric mobility and a gradual phase-out of ICE technology. Individual and collective initiatives and declarations among governments, cities as well as vehicle manufacturers are essential in driving market and industry maturity. The table below (Table 3) shows examples of ICE phase-out targets across the world (such as the C40 fossil fuel free streets declaration).

To ensure the success of such commitments they must be translated into public procurement quotas, such as the EU Clean Vehicle Directive, which clearly determines mandatory and progressive calendar-based quotas for the gradual uptake of clean and zero-emission vehicles.[9]

In MENA, Qatar has aspired a 25% electric public transit bus target by 2022 in preparation for hosting the FIFA World Cup, while RTA is leading Dubai's Green mobility efforts in procuring Euro VI compliant buses as well as increasing the share of hybrid and electric taxis to 50% by 2021.[10 12] Jordan, which has more than 18,000 electric vehicles on the street, is also looking to electrify its entire public vehicle fleet.[12]

While many international authorities have developed clear targets for electric buses, similar commitments and incentives are needed in the MENA region to encourage electric bus supply chain development and gradual market adoption.

8 All comparisons based on SORT 2, adapted from UITP, 2020. Bus Tender Structure (update). Originally from Clean Bus Deployment Initiative (Expert Group on Clean Bus Deployment, D.1 Technology/Trends)
9 EU Clean Vehicles Directive. https://ec.europa.eu/transport/themes/urban/clean-vehicles-directive_en
10 Ministry of Transport & Communications, Qatar.
11 Road and Transport Authority Dubai
12 FES, 2019. Recommendations on E-mobility in Jordan. http://library.fes.de/pdf-files/bueros/amman/15635.pdf

Targets	All new vehicles should be zero emission by 2025	No new ICE vehicles sold after 2030	All buses electric by 2037
City/ Country	Norway	Ireland	London

Targets	Only electric buses bought after 2025 (C40 Green and Healthy Streets and Clean Bus Declaration)							
City/ Country	Liverpool	Paris	Los Angeles	Copenhagen	Barcelona	Quito	Vancouver	Mexico City
	Milan	Seattle	Auckland	Cape Town	Amsterdam	Austin	Berlin	Jakarta

Table 3: Selection of Government commitments to phase-out ICE technologies[13]

HIGHLIGHT: COVID-19 AND PUBLIC TRANSPORT

The global economy has been severely affected by the COVID-19 pandemic, but there was a silver lining. As countries imposed lockdowns and movement restrictions, emissions dropped significantly, allowing people to see firsthand and perhaps for the first time in decades what it means to have clean air.

Therefore, post-pandemic recovery plans need to be and remain green and sustainable, with public transport as the backbone of urban mobility. Electric buses can be a great tool to achieve this.[14]

13 Adapted from UITP & World Bank, 2018. Electric Mobility & Development.
14 For more information, visit http://bettermobility.uitp.org/

DECARBONISATION OF PUBLIC TRANSPORT IN MENA ?

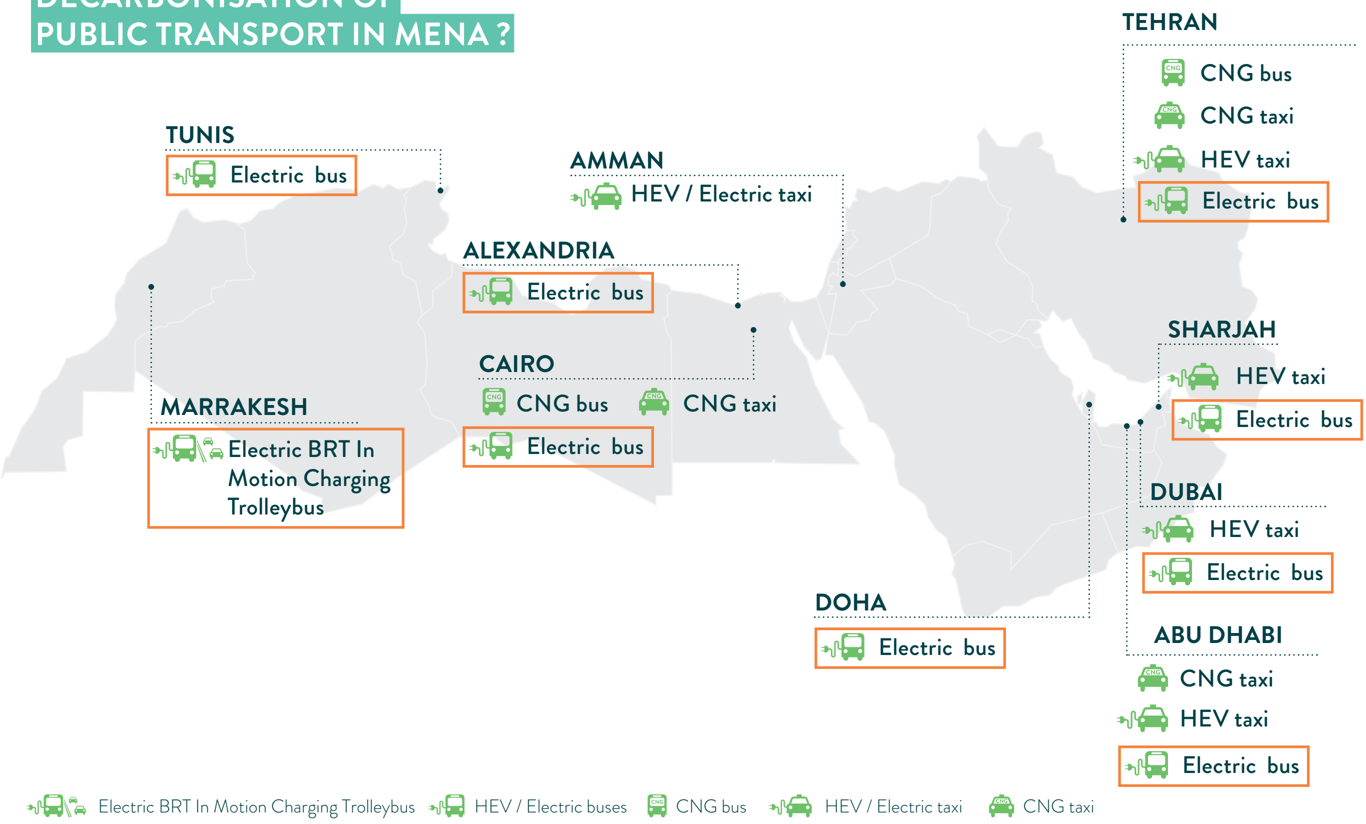


Fig.4: Alternative fuels & e-mobility in MENA[15]

As depicted in fig.4, there is considerable and growing interest in the region towards clean fuels for public transport fleets.

Below are some of the most recent developments related to E-Bus deployment in MENA. Many of them are still in the pilot phase, nonetheless, they offer some interesting insights.

EGYPT

Alexandria

The Alexandria Public Transport Authority (APTA) has commenced the operations of 15 BYD K9 BEBs in May 2020 along 3 routes after successful completion of a three-month pilot. The USD 40 million contract awarded in 2018 includes the charging infrastructure (18 charging stations) and maintenance.[16]

BYD E-Bus depot in Alexandria

15 Adapted from UITP, 2019. MENA Transport Report.
16 'APTA prepares for new electric bus line in Mahmoudeya Axis', AlMasry Alyoum.16 April 2019.

Cairo

Mwasalat Misr, public transport operator in Cairo, has commenced a pilot of a Shanghai Wanxiang BEB in February 2020. An MoU with the Arab Organization for Industrialization, an Egyptian state-owned industrial enterprise, highlights future joint-venture plans for local production in Egypt.[17]

Shanghai Wanxiang E-Bus operated by Mwasalat Misr in Cairo

Cairo Transport Authority (CTA), Cairo's public transport operator, has commenced pilot operations for two Foton BEBs in October 2019, as part of a larger batch of 50 buses. An ambitious agreement was signed between Foton and the Ministry of Military Production to start local manufacturing of 2,000 electric buses starting in November 2020 and over a period of four years with 45% local components.[18]

Foton E-Bus at demo in Cairo

MOROCCO

Marrakech

Hosting COP22 in 2016 in Marrakech has inspired the city to initiate an ambitious electric BRT showcase project, which is powered by an integrated 750 kW HCPV solar energy plant. The project, supported by GEF and UNDP, currently deploys 10 (+5 backup) Dongfeng & Yutong IMC TBs in line with plans to expand the project to include 3 new lines and 48 additional buses by 2030.

The e-BRT is managed and supervised by TLDC, which also owns the solar plant and the IMC TBs, while ALSA is responsible for bus operations.[19] A stronghold for automotive manufacturing industry, Morocco is keen to set up a local manufacturing plant for electric buses.[20]

Marrakech electric BRT with In Motion Charging Trolleybus

QATAR

Doha

Qatar has aspired a 25% electric public transit bus target by 2022 in preparation for hosting the FIFA World Cup. The Ministry of Transport and Communications along with Mowasalat (Karwa), the public transport operator in Doha, have started piloting a North BEB in September 2018.[21]

E-Bus pilot in Doha

17 'Mwasalat Misr operates first electric bus in Cairo', Daily News Egypt, 5 February 2020.
18 'Military Factory 200 unveils date of electric bus manufacturing', Akhbar El Yom, 15 March 2020.
19 For more information, UITP Knowledge Brief on In Motion Charging Trolleybus: https://www.uitp.org/publications/in-motion-charging-innovative-trolleybus/
20 UNDP& GEF, 2019. Renewable Energy for the City of Marrakech's Bus Rapid Transit System – Terminal Evaluation Report. https://erc.undp.org/evaluation/documents/download/14951
21 Qatar Government Portal

TUNISIA

Tunis

The city of Tunis completed a 6-month pilot using a BYD K9 BEB in November 2018, with local manufacturing in future plans.[22]

BYD E-Bus in Tunis

UAE

Abu Dhabi

Masdar in cooperation with the Department of Transport (DOT) launched the Hafilat Industry BEB in December 2018. The "Eco-Bus" was jointly developed by Masdar, Hafilat and Siemens and was free of charge for customers along its 6-stop route in Abu Dhabi until March 2019. The bus has been tested and evaluated for about 2 years, ensuring performance and durability in GCC summer weather conditions; 50 °C and 105% humidity.[23]

"Eco-Bus" in Abu Dhabi

Dubai

Dubai Road and Transport Authority (RTA) has been testing wireless dynamic charging for electric buses in preparation for future deployment of electric buses. The Shaped Magnetic Field In Resonance (SMFIR) technology allows the bus to be charged while on the move, drawing power from a 60-meter road-embedded coil. Electric bus pilots have been on-going since 2015.[24]

Trials for a Yutong BEB have been concluded successfully in 2019 while trials for a Volvo BEB(s) will start in 2020 and are planned to use opportunity charging.

RTA testing SMFIR charging technology in Dubai Silicon Oasis

Sharjah

Sharjah Road & Transport Authority (SRTA) has commenced a 6-month pilot operation of a Changhan BEB in December 2019 on Sharjah – Ajman route.[25]

Changhan E-Bus pilot in Sharjah

22 'Tunis welcomes first electric bus provided by BYD', Afrik21. 21 November 2018.
23 'Abu Dhabi launches first all-electric bus in region', Gulf News, 8 January 2019.
24 RTA, 2017. Highlighting green economy achievements in WETEX 2017 starred by Tesla. Press Release
25 'SRTA launches first electric bus in Sharjah', Gulf Today, 17 December 2019.

UNDERSTANDING THE TECHNOLOGY

OVERVIEW OF POWERTRAIN TECHNOLOGIES FOR E-BUS[26]

Battery Electric Bus (BEB)

Instead of internal combustion engines, battery electric buses use electric motors for propulsion. The energy is provided and stored in rechargeable batteries that can be charged through several charging options; overnight at the depot or on-route (opportunity charging) through pantographs(pantograph up/ pantograph down) (or induction). They are the most popular solution in the electric bus market globally today. HVAC and range extenders in some applications can be powered by Diesel or alternative fuels (e.g. Hydrogen).[27]

Plug-in Hybrid Bus (PHB)

Plug-in hybrid buses are hybrid electric vehicles that, through rechargeable batteries, operate an electric motor in combination with an internal combustion engine, if support is needed. The majority of such buses can run more than 2/3 of their average expected range on the electric motor. Yet, as the expected range increases, so does the upfront cost.

Hybrid buses (HB) are not rechargeable and rely mostly on their internal combustion engine for power, with the electric motor for extra support. They are not considered in the electric powertrain technologies.

Fuel Cell Bus (FCB)

Fuel Cell buses use energy provided by Hydrogen stored on board to operate the bus as well as recharge the batteries (or supercapacitors). Although they produce no tailpipe emissions and have a longer range due to the high energy density, they currently still have a higher TCO than Euro VI diesel buses as well as BEBs. There are also supplychain challenges regarding handling hydrogen. Once these issues are solved they can become a strong contender with BEB for future mass adoption.[28]

FCBs produce no tailpipe emissions and have a longer range due to hydrogen's high energy density compared to other technologies.

Commercialization projects are currently helping for large scale roll-out, reducing high CAPEX costs and making the technology a complementary solution with BEBs for future full zero tailpipe bus networks.

Trolleybus (TB)

Electric Trolleybuses use overhead wires to draw power and can be considered as the Godfathers of the Electric bus. New applications, In-Motion Charging (IMC) Battery Trolleybus, are charged in-motion through overhead lines or statically (see graph below). On-board batteries also can function as power supply, enabling the trolleybus to operate (partially) independent without need of contact with overhead lines.[29]

26 Buses that are powered by electric powertrains and are zero emission (exception Plug-in hybrid, which is low emission).
27 Adapted from UITP & World Bank, 2018. Electric Mobility & Development.
28 For more information, visit JIVE & JIVE 2 as well as UITP Knowledge Brief on Fuel Cell Bus: https://www.uitp.org/publications/fuel-cell-buses-best-practices-and-commercialisation-approaches/.
29 UITP, Knowledge Brief: https://www.uitp.org/publications/in-motion-charging-innovative-trolleybus/

GLOBAL E-BUS MARKET OVERVIEW

The global electric bus market size today is around 500,000 electric buses. China has 98% of the market largely due to a strong policy promoting electric buses through subsidies and incentives. Although the number of new electric bus registrations in China have been slowly decreasing after 2016 as a result of the gradual subsidy phase-out, the Chinese e-Bus market is expected to triple by 2025.[30]

The Netherlands is leading EU efforts in electric bus deployments and new orders. Market forecasts predict that 75% of all new bus sales to be electric in 2030, which will put electric buses at about 50% of total bus market.[31] With joint-ventures and factories set up globally, localizing manufacturing remains a national priority for some countries, such as India and its ambitious FAME II policy.[32] Taking advantage of falling battery production costs, BEBs are expected to lead the electric bus market with approx. one million units in 2030.

ALTERNATIVE FUELS – PERFORMANCE COMPARISON

	Diesel (Euro VI)	Natural Gas (CNG)	Biomethane (RNG)	Biofuel (HVO)	**Battery Electric (BEB)**	Hydrogen (FCB)	Plug-in hybrid (PHB)
Energy consumption	benchmark	-	-	=	+++	++	+
TCO Euro/km	benchmark	++	+	-	--	---	-
TCO trends	benchmark	++	++	-	+++	+++	+
Noise (standing by)	benchmark	+	+	=	+++	+++	++
Noise (passing by)	benchmark	+	+	=	+	+	+
Energy security	benchmark	++	++	+	++	++	n.a.
Range	benchmark	=	=	=	--	=	=
Zero emission range	n.a.	n.a.	n.a.	n.a.	+++	+++	+
Route flexibility	benchmark	=	=	=	-	=	=
Recharging/ refueling time	benchmark	=	=	=	--	=	-
Service lifetime	benchmark	=	=	=	8-15*	=	=

* Technology still in early stage, limited verifiable data, will mostly depend on manufacturer TCO trends

+	Slightly better	-	Slightly worse
++	Better	--	Worse
+++	Significantly better	---	Significantly worse
=	Almost the same	n.a.	Not available

Table 4: Alternative Fuels – Performance comparison (Euro VI as benchmark)[33]

30 IEA, 2020. Global Electric Vehicle Outlook.
31 UITP, 2017. ZeEus Report #2.
32 UITP India, 2020. FAME scheme for Electric Buses.
33 Adapted from UITP & World Bank, 2018. Electric Mobility & Development. - originally from European Commission Clean Bus Expert Group, STF (Sustainable Transport Forum), DG MOVE

Table 4 summarizes low emission bus options (including Euro VI as baseline, and other alternative fuels such as CNG, Biomethane and Biofuel) and provides a basic framework for comparing key characteristics such as range, energy consumption and other factors. Euro VI is the minimum legal requirement for new buses in the EU in respect to emission limits, thus used as baseline. It is clear that the BEB outperforms its competitors in energy consumption, noise, zero emission range and TCO trends, suggesting that it can improve its current TCO Euro/km with the expected fall of battery manufacturing costs in the future.[34]

Technology improvements in battery capacity and charging power have already shown that it is a matter of time for the electric powertrain to catch up with its competitors in regards to range and recharging time.

Several Governments (Egypt, UAE and Iran amongst others) have been active in using CNG as an alternative to diesel mainly in public transport fleets.[35] The abundance and market supply of CNG in MENA illustrates a potentially suitable "policy transition" given its economic and environmental advantage (as per fig.3) prior and parallel to an eventual mass electrification in the future. This could assist authorities in emerging economies in gathering data and creating regulatory frameworks that are able to govern and implement policy reforms, similar to CNG scrapping programs in Egypt.[36]

TOTAL COST OF OWNERSHIP (TCO)

The TCO approach provides a comprehensive methodology to calculate all relevant costs over a period of time (usually related to the life span of the product). Such a framework provides the basis for decision makers to choose the most cost-saving product.

Fuel cost ($/km)
Maintenance cost ($/km)
Battery lease/ Battery replacement ($/km)
Insurance cost ($/km)
Tax cost($/km)
Subsidies
OPEX 10 years (Operating Expenses) ($/km)[37]
CAPEX vehicle (Capital Expenses)
Infrastructure[38]
TCO 10 years ($/km)

Table 5: Example of TCO parameters for e-bus[39]

The current TCO for electric buses can indicate an advantage over other powertrains if health (air quality) and climate (GHG emissions) external costs are included, given a certain set of requirements and depending on various operational contexts.

Research estimates that an electric bus with daily duty cycles of up to 200km/day can on average be competitive with a diesel bus on a TCO basis, but this will depend on local settings as some costs could be more significant.[40 41 42] Optimizing the battery capacity and charging strategy to the route requirements is a first step to achieving TCO advantage.

While purchasing prices of electric buses are higher than diesel buses, they generally offer a significant reduction in operating costs due to lower fuel and maintenance cost.

Therefore, lower diesel prices can harm the economics of e-buses, while higher prices could improve their operating cost competitiveness. Removing fossil fuel subsidies and re-directing them to the electric bus industry can also tilt TCO in favor of e-bus such as the case of China. This indeed presents an illustration of how policy interventions can have significant impacts on the implementation of electric buses.

34 2023 according to McKinsey.
35 UITP, 2019. MENA Transport Report.
36 CEDARE & FES, 2020. Mainstreaming Electric Mobility in Egypt (update).
37 Includes vehicle and infrastructure depreciation.
38 Includes maintenance.
39 Hooftman, N. et. al. (2019). 'Analysis of the Potential for Electric Buses'. European Copper Institute.
40 UITP & World Bank, 2018. Electric Mobility & Development.
41 https://www.kearney.in/article/?/a/electric-mobility-2-0-tracking-the-next-wave-in-india
42 UITP, 2017. ZeEus Report #2.

BENEFITS

Deploying electric buses can provide great environmental, societal and technological benefits.

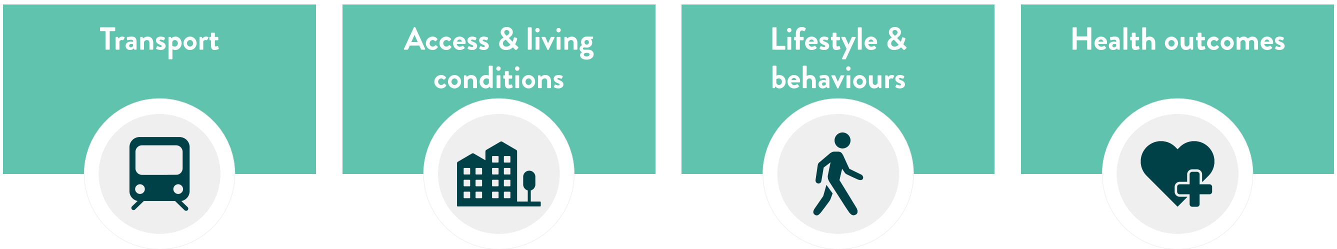


Fig. 5: Relationship between Transport & Health[43]

Operational savings

Although electric buses have a high upfront cost, they have lower maintenance and energy costs. On a large scale, 1,000 electric buses can save 500 barrels of diesel a day, while saving up to half of the maintenance cost of diesel buses.[44] However, these savings must be considered in context of a TCO approach as there are additional costs related to e-bus deployment.[45]

No (local) air pollution[46]

With zero (local) emissions (no tailpipe emission) electric buses can greatly contribute to improving urban air quality. They can be especially helpful in implementing low-emission zones (LEZ) in city centers and other congested areas that suffer from high levels of air pollution. This is very relevant for many MENA cities where traffic congestion and its associated pollution negatively impact city centers. Decarbonisation of public transport will lead to cleaner cities for its residents and eventually less health problems caused by high levels of air pollution.

Lower noise pollution

Transport is the main cause of environmental noise, which ultimately may lead to the increase in hearing loss and cause other issues. WHO data ranks Cairo and Dubai as 2nd and 23rd noisiest cities respectively globally, citing a strong correlation between noise and pollution and hearing loss.[47] Electric buses can save up to 33% of total yearly socio-economic cost of road noise. They can be up to almost 20% (12dBA) quieter than a diesel bus for exterior noise at low speeds and up to 32% (15dBA) quieter for interior noise. For bus users, this also means a better and more comfortable ride and user experience, potentially increasing ridership.[48]

Energy security & diversification

Mainstreaming electric buses would gradually encourage energy diversification. Electric buses require less energy than diesel buses, improving the energy security of the city or country if deployed on a large-scale replacing diesel. For MENA, eventually, if mass electrification in mobility is achieved, smart charging EVs could increase system flexibility, thus reducing investments required to balance the grid and taking advantage of the lower price volatility of electricity. By enabling vehicle-to-grid (V2G) and other vehicle-to-x applications, electric buses can evolve from moving batteries to power suppliers, feeding the grid with electricity if not in use.

Innovation: City, economy & industry

Electric buses are a paradigm shift to urban transport that creates an opportunity to innovate public transport systems, making it more attractive for residents. These improvements would eventually lead to an increase in ridership and revenues for bus operators. Eventually, the smarter electric buses can speed up the technological transition towards autonomous mobility.

43 UITP, 2018. Integrating Mobility Health Impacts in Decision making. Policy Brief.
44 Aber, 2016. Electric Bus Analysis for New York City Transit. Report.
45 'How much oil is displaced by electric vehicles? Not much, so far', Bloomberg. 19 March 2019.
46 Not considering energy generation.
47 'Cairo ranked second nosiest city in the world', Egypt Independent. 14 March 2018.
48 Volvo, 2014. Electric Buses and Noise. Report.

KEY CONSIDERATIONS

Regulatory framework & procurement

Although political will is an important factor in facilitating the deployment of electric buses, it must be translated correctly into policies and regulations. Governments are bound to implement policy reform and change long-withstanding regulations mostly in public procurement. The deployment of electric buses can also achieve industrial policy targets, encouraging the transfer of technology and setting up local production plants and partnerships with global suppliers, a move which has been popular with some emerging economies such as in India and Egypt.[49]

Traditional procurement and tendering mechanisms may not be suitable for the deployment of electric buses. The relatively complex framework for implementing electric buses requires non-traditional relationships among various stakeholders, including vehicle manufacturers, charging entities, power providers, etc). It is important therefore, to clarify roles and responsibilities regarding ownership, contract extensions, warranty and other factors.

Higher upfront costs

Although battery costs are dropping, the average cost of an electric bus remains almost double that of a diesel bus. Despite financial savings and a lower TCO, the initial high upfront cost is still the biggest barrier for large scale fleet electrification. Innovations in the business model such as battery leasing have been effective in alleviating the Capex pressure.

Today, international development and financing organizations have increased their services geared towards e-bus financing such as green bonds and grants, supporting governments in enabling the industry.

Operational requirements

Electric buses have yet to achieve parity with diesel buses on range (in km). This indicates that for longer routes, electric buses might also face costlier TCO. It is therefore important to highlight that electric and diesel bus do not have a 1:1 relationship. Dynamic optimization models that take into account battery capacity, route characteristics, timetables and charging strategies are key to overcoming such obstacles.

On the other hand, electrifying public transport fleets would require operational data (timetable, frequency, waiting time, travel demand, etc.), which might, in some cases, be inaccurate in the MENA region. Infrastructure challenges such as providing space and land allocation for charging stations as well as grid instability can also hamper the adoption of electric buses.

Interoperability & standardization

The development of charging technology is offering a variety of charging solutions and standards. Depending on several factors, countries adopt various approaches to achieve standardization. This can mean promoting a specific technology (e.g. China) which can be a risk, given that new technologies may phase-out the present ones.

PTOs and PTAs are faced with different charging protocols and plug interfaces that can constitute a major challenge when upscaling fleets and may lead to technology lock-ins. To ensure interoperability, the deployment of charging infrastructure that can accommodate multiple plug interfaces and charging technologies is necessary but comes at an additional cost.

Cooperation between OEMs and procuring interoperable solutions with open standards is therefore essential for market adoption of electric buses.[50]

New technology

The technology transition set in motion by electric mobility will still need some time to reach mainstream adoption. With uncertainties in service lifetime, new technologies are always risky in implementation, occasionally discouraging decision makers to abandon conventional and traditional solutions. Given the necessary prerequisites for successful electric bus deployment, there might be some innovation gaps to overcome. Therefore, it currently might not necessarily be suitable technology for all cities (e.g. Extreme climate, mountainous topography, absence of energy infrastructure, absence of necessary procurement mechanisms etc.)

49 'Foton to begin electric bus production in Egypt in November', Sustainable Bus. 24 February 2020.
50 For more information, visit https://assured-project.eu/

HIGHLIGHT: SHENZHEN E-BUS FLEET

In 2017, Shenzhen, China, has achieved the world's first and largest full public transport fleet electrification (electric bus and taxi) operated by Shenzhen Bus Group (SZBG), Shenzen Eastern Bus and Shenzen Western Bus..

The Chinese Government mandate to shift to clean bus entailed generous subsidies from local and national government to decrease the high up-front cost meaning that TCO (with subsidy) constituted 36% less than that of diesel bus.

Shenzhen outsourced the charging infrastructure and services, therefore, SZBG does not own or operate charging infrastructure. Instead, a fee is paid to the provider who is also responsible for construction and charging services, including hiring technical staff. The Government facilitated the land allocation process and provided financial support (subsidies) for constructing charging stations, which made the business model viable, breaking even after 5-6 years.

The bus manufacturer provided 8-year warranty (average expected battery lifetime), as well as maintenance support and staff training. All 17,000 buses use the same powertrain technology: battery electric buses, enabling a faster scale-up and efficient optimization in operations.

SZBG also introduced a financial leasing model, where a financial leasing company is responsible for purchasing the vehicles and then leasing them to the operator for a period of 8 years.

The partnerships and synergies created between various stakeholders has highlighted the importance of an open and cooperative environment in which challenges were collectively beaten, turning Shenzhen into a test-bed for novel technologies (such as autonomous vehicles) in the e-mobility sector.[51]

51 IEA, 2020. Global Electric Vehicle Outlook. Shenzhen Case Study.

ELECTRIC BUS - SYSTEM APPROACH

Fig. 6: Electric Bus system approach components[52]

Electric bus implementation is more than buying a bus. It is a complex system that entails several components and requires careful analysis before deployment. Due to this outset, electric bus systems are case sensitive, meaning that not all systems would succeed in all places. Fig. 6 illustrates some of the building blocks that must be addressed in order to ensure successful deployment of electric buses.

Electric bus deployment requires a systems-approach that looks beyond bus procurement and includes a multitude of components and stakeholders. The decision to implement electric buses involves careful planning and considerations related to operations, infrastructure, business model, and finances.

52 UITP Bus

1. Strategy

Strategy is the driving force for considering electric bus deployment. This is often an outcome of transportation plans and/or climate mitigation plans that focus on the mobility ecosystem. Linking national climate objectives and local emission targets with e-bus deployment will also provide access to financing. Translating such objectives into a vehicle replacement and fleet upgrade strategy is essential before large e-bus deployment. The desired business model must have clear definition of roles and responsibilities as well as risk allocation while promoting cooperation among stakeholders.

Adopting a phased approach (Fig. 7 below) will facilitate the process of understanding e-bus system pre-requisites.

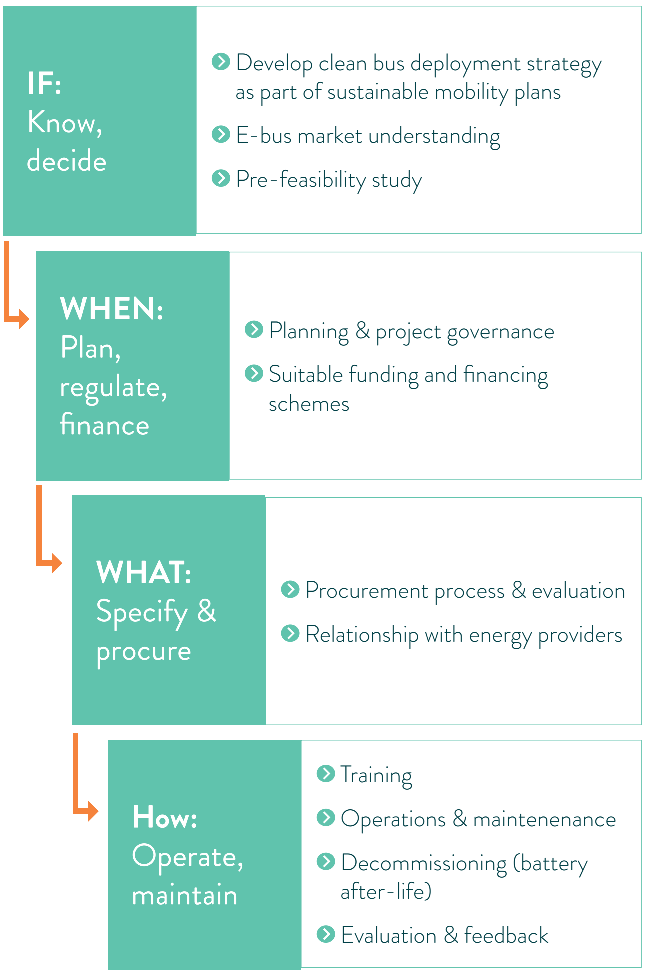


Fig. 7: 4-phase approach for E-bus deployment[53]

2. Charging Infrastructure

The charging infrastructure is one of the most important factors that, if not handled correctly, can be detrimental to the project. This is due to its complexity, novelty and stakeholders' intertwined roles and responsibilities.

Technological developments are a major driver for e-bus technologies, both in the battery and charging technology. Recent advances have led to faster charging times and easier charging procedures while batteries are getting smaller and more energy dense.

Charging Technologies

- low power
  - through cable & plug-in
  - overnight at the depot
- high power
  - conductive charging with physical connections, mostly through pantographs connecting with an overhead power supply or vice versa (inverted pantograph).
  - at selected bus stops
- fast charging
  - inductive charging through coils installed under the road transfer energy to matching coils installed under the bus floor, stationary and dynamic

Charging Strategies

- Overnight/Depot Charging
  - Charging the batteries in the depot at night using plug in or conductive systems (15-22kw/22-50kw/50-120kw). This is the main strategy for most electric bus systems and is often supplemented by opportunity charging.
- Opportunity Charging
  - Charging the bus along the line at stops or head/end of lines using inductive or conductive charging using high power (150-300kw). The main aim of opportunity charging is to extend the batter ranges beyond the standard charge. Further development in opportunity charging may allow for the use of smaller batteries, but there is still a need for batteries to be slow charged at night to balance battery cells.

53 UITP, 2020. Bus Tender Structure (update).

Overnight and opportunity combination (low/high power) both low power charging over night at the depot and high power opportunity charging at head/end stations or at the depot, which allows smaller battery sizes.

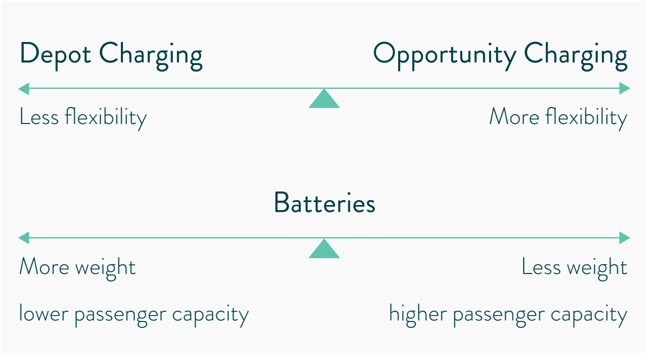


Fig. 8: Interconnection between charging strategy, batteries and passenger capacity[54]

The charging strategy and chosen technology need to be adapted to local conditions as well as the required bus operations. Stakeholders need to clearly address important considerations when implementing charging infrastructure:[55]

- Land acquisition
- Integration with other energy dependent PT (Tram & Metro) and shared mobility modes (e.g. e-bikes, e-scooters, EV shared mobility, etc.)
- Cable routing in public spaces (roads & pavements) and necessary approvals
- Bus stop design
- Charging equipment design (& immediate surroundings)

Charging management systems (software) for optimizing electric bus charging are fundamental to solving planning and scheduling issues. With the help of advanced algorithms, it is possible to optimize across several parameters such as cost and operational efficiency for larger electric bus fleets.

Training the staff (drivers and maintenance) is also an integral yet challenging component of electric bus deployment. Several operators opt to rely on manufacturers for driver training not only for effective bus operation but also on how to deal with high voltage components and battery technology specifics. Understanding new safety aspects along with new maintenance requirements is crucial to ensure safe operations.

3. Operations

One of the key considerations in the electric bus decision process relates to operations. This includes not only route lengths, but also various configurations of the network, load factor, schedule, distribution of bus stops, and location and characteristics of the depots. Operators need to consider operational requirements based on the route characteristics and vehicle specifications before deciding appropriate charging infrastructure. Some of the key design considerations include:[53]

- Average and maximum vehicle kilometers per day
- Line route and topography
- Service scheduling (frequency, stopping time, charging time in depot and/or at fast charging stations)
- Location of the bus depots
- Position of the opportunity charging equipment
- Availability of power supply for charging equipment
- Climate conditions (AC or heating needs)

For MENA, it is evident that some countries (especially GCC) must resolve challenges presented by predominantly hot climate, which will directly impact practical range as well as other battery related issues.

Experimentation and a phased approach as mentioned before are essential in achieving operational success. Piloting 1-2 busses is strongly advised to get acquainted with e-bus operations basics and explore potential challenges. The more e-buses are deployed, the more complex operational requirements become (See table 5 and fig. 9 below).

It is therefore critical to conduct a comprehensive feasibility analysis based on local conditions prior to any large-scale implementation of electric buses in any locality. Figure 9 below provides a framework for the feasibility analysis.

54 Adapted from UITP Bus presentation
55 UITP, 2019. Impact of E-bus on Urban Life. Policy Brief.

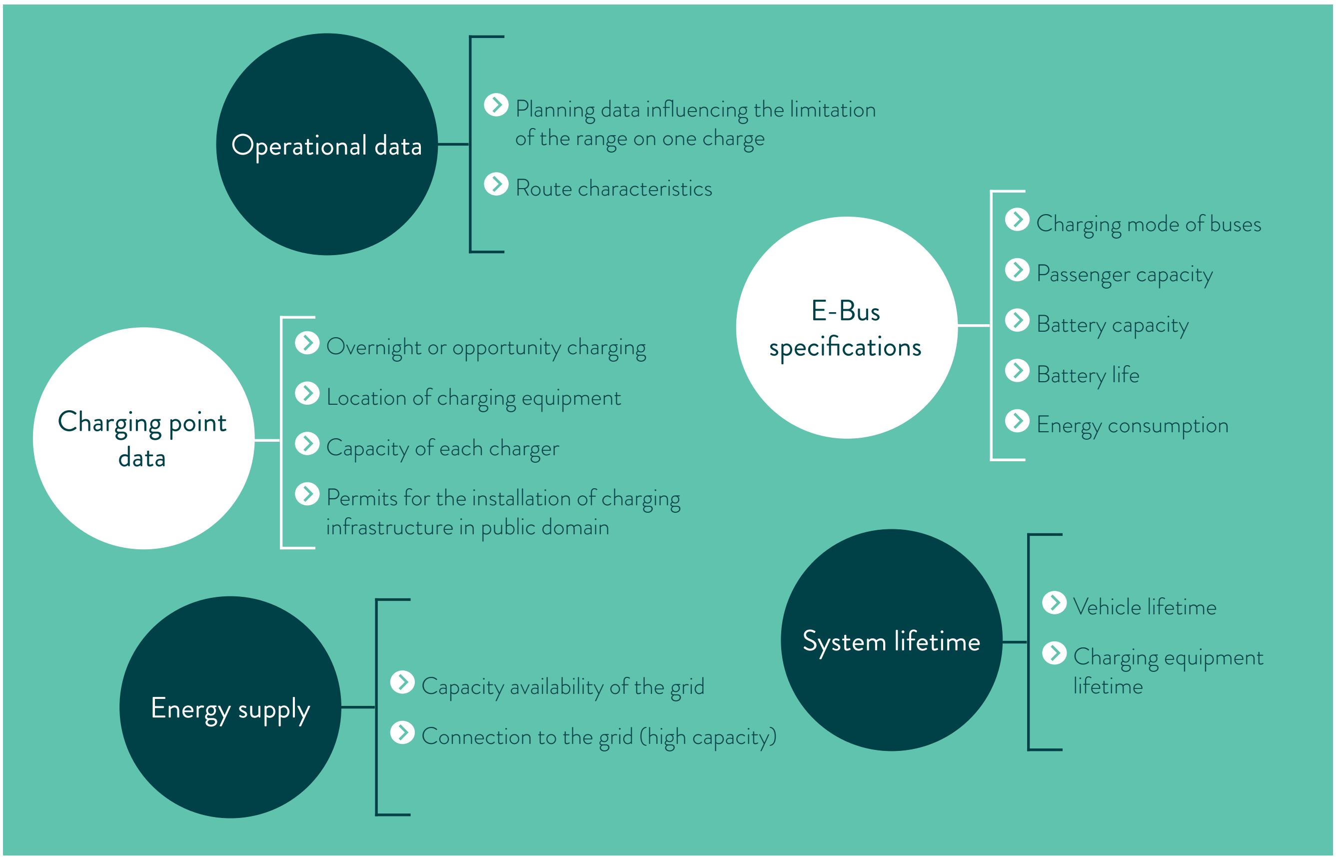


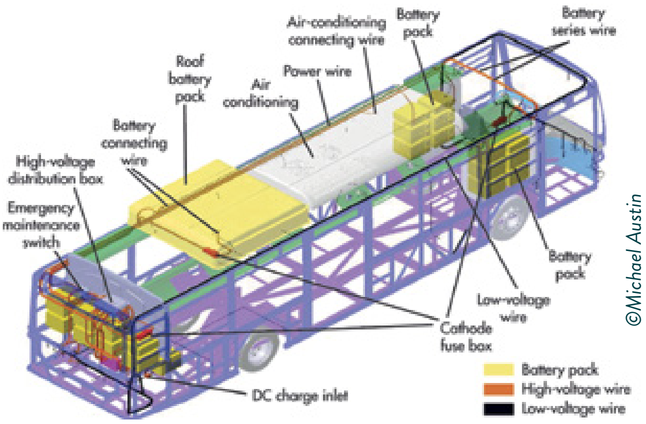
Fig.9: Feasibility study components[56]

Small fleet of E-bus	Large fleet of E-bus
daily distance less than 200km, passenger demand and energy consumption optimally moderate, enough time to charge batteries, back up with conventional buses adopt vehicle replacement philosophy instead of system approach	daily distance more than 300km (or 20hrs/day), high passenger demand, not enough time to charge batteries (slow charging overnight), replacing conventional buses (no back up)

Table 5: E-Bus fleet characteristics[57]

56 UITP, 2020. Bus Tender Structure (update). Report.
57 Adapted from UITP Tender Document.

4. Vehicle



E-Bus vehicle components

The electric bus most important and decisive component is the battery, which also constitutes almost half the vehicle cost.[58] The vehicle performance is crystalized by its energy consumption, which strongly depends on a range of factors from local conditions to style of driving.

Fig. 10: Impact of factors on energy use (kWh/km) [59]

To understand e-bus performance, UITP has developed E-SORT protocol (Standardised On-Road Test cycles for E-bus) providing access to comparative data regarding energy consumption.

Battery capacity size may differ with charging technology, the smaller the battery, the shorter the range.

- 50 – 250kWh short range
- 250 – 660 kWh long range[60]

BATTERIES: WHAT DO WE NEED TO KNOW?[61]

- Most important component in the vehicle and most expensive
- Commercialization of higher energy density materials and technology improvements are decreasing production costs eventually making battery prices more competitive
- Liquid-electrolyte (esp. Lithium –ion) batteries dominate today's market, with trials for solid-state batteries signalling an upcoming paradigm shift
    - Upcoming solid-state batteries charge faster, are none flammable thus safer, perform better due to higher energy density and have a longer life cycle
- Battery Management Systems (BMS) are key to ensure safety through battery thermal management (cooling)
    - Thermal management systems are improving in energy efficiency, scalability and weight (lighter)
- Recycling and second-life utilization of batteries must be included in the procurement plan to maximize utility and increase efficiency and sustainability

The vehicle range will be impacted by the battery degradation over time. The higher the batter capacity, the bigger its daily discharge, the greater is its degradation. Battery warranties usually guarantee 70 – 80% of the nameplate capacity for 6 – 12 years.[62]

Vehicle depreciation will largely depend on the battery, whereas its mid-life replacement can be included in warranty and contract with OEMs. OEMs must provide PTOs with best practices for battery management and maintenance procedures.

As electric buses reach the end of their lifetime, so does the battery. The re-use of batteries (second life) can be made possible in stationary storage yet causing a potential feasibility clash with decreasing costs of new batteries. Eventually, recycling Li-on batteries must be taken into consideration, to avoid a potential shortage of cobalt and other metals in the future.

58 Up to 45% of e-bus price (depot charging) according to ABB.
59 Adapted from Volvo Buses.
60 Transport Research Board, 2020. Guidebook for Deploying Zero-Emission Transit Buses.
61 Noshin Omar, 2020. Next Generation Battery Technologies, & Thermal Management for BEVs.
62 Transport Research Board, 2020. Guidebook for Deploying Zero-Emission Transit Buses.

5. Funding

Electric buses have a high upfront cost, sometimes double the price of a diesel bus. This may create a market barrier especially when taking into consideration cost of replacing a larger fleet. A TCO-focused approach enables the move from traditional upfront payments to lease or loan payments along the lifetime of the asset. This would in return lower operating costs.

Some popular financing mechanisms include leasing, where the local authority can lease the bus with the option to own at the end of the lease term. A battery lease entails purchasing the electric bus for roughly the same price as a diesel bus and then leasing the battery. This enables lower operating risks as the performance of the battery has to be preserved through its life and is therefore the responsibility of the OEM.

In Barcelona, TMB decided to go with a financial leasing model, where the bus is viewed as fixed asset and financial lease liability. The operator bears all risks, depreciation and maintenance, making the financial cost cheaper and eventually ownership is transferred automatically at maturity (12 years).[63] Other leasing options include an operating lease, which is shorter and more suitable for pilots and tests, as it entails a rental payment for operation and use of vehicles.

As most traditional financing mechanisms may not be suited for new technologies, it is imperative to seek and encourage new financing mechanisms. Green bonds and low-interest loan options from the European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD), and other international development organizations as well EU grant options (Connecting Europe Facility (CEF), European Regional Development Fund (ERDF) and Cohesion Fund) provide a great example.[64] Governments have been active in funding electric bus ventures around the world. In Germany, the Government introduced a fund to cover 80% of the incremental cost of electric buses through grants, aiming to fuel a sharp market uptake. The largest five German cities are now preparing large orders of electric bus fleets. Other facilitations can include no-cost lease for required land for charging stations, joint procurement and bus sharing

6. Synergies

Strong partnerships with energy providers are essential for the success of electric bus deployment. Early coordination and communication of infrastructure needs (e.g. land allocation) with city authorities. Off-peak smart charging (V1G) at night for buses at the depot as well as Vehicle-to-Grid (V2G) applications will require more closeness with the energy provider over time. Anticipating increasing vehicles in deployment may unlock opportunities in on-site energy generation and storage (solar or wind) as well as new contractual agreements such as Power Purchase Agreements (PPAs).

During the tendering process, PTAs/PTOs and OEMs need to work closely together to adjust technical specifications if needed, and in regards of maintenance and optimizing operations. Stronger involvement from city authorities will be needed when thinking of charging infrastructure and its required land allocation and as well as other infrastructure related requirements.

63 Transports Metropolitans de Barcelona. Innovation: How will we finance. Case study
64 Transport & Environment, 2018. Electric Buses arrive on time.

RECOMMENDATIONS

The policy recommendations are herewith geared towards policymakers in MENA with focus on building a long-term vision and plan prior to acquisition and deployment of electric buses.

- Development of National Urban Mobility Policies (NUMPs) and Integrated Mobility Plans (IMPs), which creates a collaborative framework and vertical policy making supporting local level implementation electric buses as a sustainable mobility solution with a long-term vision.
    - Adopt A-S-I Approach in sustainable mobility planning and abandon "old-school" approach of building more roads, causing induced traffic.
    - Encourage electric bus supply chain development and gradual market adoption by presenting objectives and targets of using alternative fuels in bus fleets that includes electric mobility as part of post-Covid-19 recovery plans.
- Link and support energy diversification efforts, decreasing reliance on fossil fuels and encouraging investments in renewable energy as pre-requisite of mainstreaming electric mobility.
- Adopt systems approach when planning for electric bus deployment to identify new stakeholders and further develop required novel procurement frameworks.
    - Utilize and engage with UITP resources and working groups to further understand available technologies, market updates and business models in tailoring needed policy interventions.
    - Develop a strategy for electric bus deployment with wider participatory approach including new stakeholders (e.g. Energy providers, etc.)
    - Long-term plans must rely on infrastructure integration as well as inclusion of de-commissioning and recycling of batteries
    - Current electric bus framework does not support a 1:1 vehicle replacement philosophy with diesel buses, avoid using it.
    - Understand and develop a TCO-focused approach including environmental costs as intangible costs in the tendering process to essentially better understand e-bus cost impact structure.
- Experiment preferably at small-scale to understand the limitations, potential challenges, and alternative solutions related to electric bus utilization. This is especially true in MENA to have a good understanding of needed changes and potential level of investments. Specifically, climate factors and AC performance specifications and how they impact battery range as well as availability of electric power infrastructure for charging.

- Continuous evaluation and learning are key as well as sharing experiences across the region and beyond. There are already several interesting pilots across MENA which may offer some insights to other organizations looking at electric buses.

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UITP, Fuel Cell Bus, 2020, Knowledge Brief

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