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WORKING PAPER

FINANCING ELECTRIC AND HYBRID-ELECTRIC BUSES: 10 QUESTIONS CITY DECISION-MAKERS SHOULD ASK

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EXECUTIVE SUMMARY

Highlights

- Electric and hybrid-electric buses offer cities environmental and health benefits, such as helping to lower emissions that contribute to poor air quality and global climate change, as well as economic benefits, such as potential cost savings.
- Although capital costs are often higher than conventional diesel buses, electric buses often have a competitive and sometimes lower total cost of ownership (TCO) due to savings from reduced energy costs per mile and maintenance.
- Cities are adapting to how buses and bus services are procured, allowing third parties to assume an important share of the risk. More flexible procurement enables bus manufacturers to offer operators the option to lease both buses and batteries, reducing technological and financial risks.
- Stakeholders not traditionally involved in transport, such as utility companies, have also recently been entering the market to purchase vehicles or batteries and lease them to the operators of the public fleets.
- Some governments are helping cities to afford both direct and indirect costs of bus electrification. A variety of grants are helping cover direct costs, including for both capital and operational expenditures on buses and research and development. Tax incentives, such as value-added, import, and corporate profit tax breaks, are used to reduce the cost burden on operators and manufacturers.
- Operators can reduce the financing costs by accessing available credit guarantees or concessional debt, for example, by public sector financial institutions.

CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues. Working papers may eventually be published in another form and their content may be revised.

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Box ES-1 | **About This Working Paper**

The overarching goal of this publication is to provide a practical, easy-to-navigate reference document to help practitioners decide if or how to adopt electric and hybrid-electric bus fleets for public transport in their cities. Designed for an action-oriented policy audience looking to learn from experiences of other cities, this publication provides evidence-based answers to questions about recent developments in the electric and hybrid-electric bus space. It is not designed to be a comprehensive guide to electric bus adoption, and it does not make prescriptive recommendations. For those purposes, the two WRI reports cited in the next column are better suited.

In addition, this paper touches on both electric and hybrid-electric buses because we see the challenges in terms of finance applying to both technologies, which require higher up-front capital costs to incorporate into transit systems compared to traditional internal-combustion-engine (ICE) buses. As such, the terms *electric* and *hybrid-electric* will be used throughout the paper to differentiate the types of technologies.

The questions have been selected by the authors based on literature reviews, extensive desktop research into specific case studies, and interviews with stakeholders and global experts in the field. Thus, the responses are not meant to be prescriptive but instead represent the findings of the research. Brief summaries of the questions that will be touched upon in this publication are included in this Executive Summary. These are intended to provide context to the relevance of each topic rather than offer direct answers to the questions posed, which will be elaborated later in the paper in separate sections.

Context

As electric and hybrid-electric buses gradually become a reality worldwide (see Figure ES-1), achieving a better understanding of the mechanisms supporting investments in these new technologies as well as their assets is more important than ever. The global electric bus fleet grew about 32 percent in 2018 (BNEF 2019), and it represents the fastest-growing part of the electric vehicle market (Heid et al. 2018). Nevertheless, capital costs for fully electric buses may be double or triple that of conventional internal combustion engine (ICE) buses (Lajunen and Lipman 2016), and batteries may need to be replaced after six to eight years (Guerrero 2017), highlighting the importance of finding sustainable financial plans and business models.

Studies show that, compared to ICE transit buses, hybrid-electric buses have 11.8 percent higher fuel efficiency, 24–40 percent lower carbon dioxide (CO_2) emissions, 18–90 percent lower nitrogen oxide (NO_x) emissions, 37–98 percent lower carbon monoxide (CO) emissions, and 17–78 percent lower hydrocarbon emissions, with the ranges dependent on different road test types and drive cycles (Hallmark et al. 2013). Our focus is on "public" electric or hybrid-electric buses used in public transit fleets, regardless of whether these are under public ownership or are privately owned and operated through a public service contract.

Since discourse on this topic is still relatively nascent, existing literature on electric bus adoption in public fleets is sparse and has mainly focused on technical components such as battery capacity and storage (Lajunen and Lipman 2016), performance uncertainties in cold and hot weather (Bullis 2013; Prohaska et al. 2016), or route and charging conditions (Perrotta et al. 2014; Li 2016). In addition, the few relevant publications are either a decade old (van der Straten et al. 2007) or concentrate solely on large-scale market dynamics (BNEF 2018) rather than providing case studies and lessons learned on individual cities' attempts at implementing clean buses into their public fleets. However, the World Resources Institute (WRI) has published two reports on electric buses: *Barriers to Adopting Electric Buses* (Sclar et al. 2019) and *How to Enable Electric Bus Adoption in Cities Worldwide* (Li et al. 2019). These sister reports explore the lessons learned from the experience of 16 cities that were early adopters of electric buses. Our paper seeks to build on guidance provided by those reports and dive deeper into some of the financial issues cities face.

Question 1: What are the benefits, costs, and reported impacts of electric and hybrid-electric buses?

Electric and hybrid-electric buses generally deliver local and global emission reductions, improved service quality, and lower per-mile operational costs compared to ICE buses. Cities have reported multifaceted benefits in using electric and hybrid-electric buses, including reduced air and noise pollution; lower operational and maintenance costs; and lower CO_2, CO, particulate matter, and other emissions. In terms of monetary costs, research demonstrates that, in their current (2019) state of maturity, electric buses may offer a lower TCO over their useful lifetime. Nonetheless, they do have higher up-front costs—due to expensive batteries and the need for additional charging facilities—as well as costs related to disposal and recycling of the assets. However, these expenses vary according to the local electricity, fuel, and labor costs as well as the local bus market.

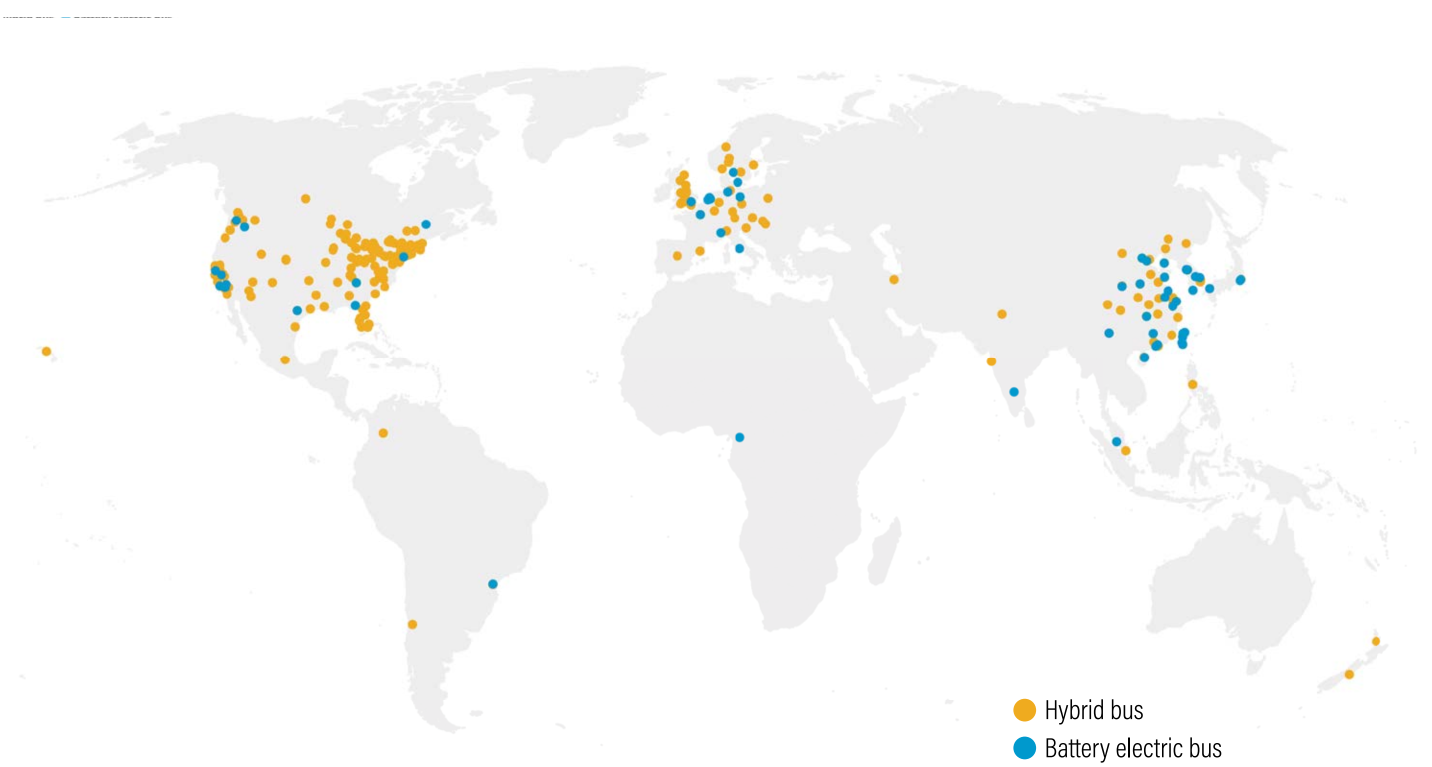
Question 2: What are the physical assets needed for the adoption of electric and hybrid-electric buses?

Electric and hybrid-electric bus adoption can have different combinations of technical components depending on the objectives pursued. A combination of several types of physical assets usually needs to be considered, including buses (which can be fully or partially electric), batteries, land, charging stations, power supply, and possible upgrades to transformers or distribution lines, along with other supporting infrastructure, such as adaptations to existing bus depots.

Question 3: How are cities procuring electric and hybrid-electric bus services?

In general, urban bus services can be provided along a spectrum of public to private provision. Along this continuum, the public and private sectors bear variable costs with different contracts or structures. Although cities have not typically made substantial changes in modes of contracting when introducing electric or hybrid-electric buses, a new model of delivery is emerging as third-party actors (mainly manufacturers and leasing companies) take on greater roles. In all provision types, social goals, performance metrics, and financial sustainability are important features to consider.

Figure ES-1 | **Cities That Have Adopted Electric and Hybrid-Electric Bus Fleets, 2016**



Source: Li et al. 2018.

Box ES-2 | **Methodology**

To answer these common questions, we examined 26 implementation experiences located in 22 cities (see the summary information of cases in Table A1 in the appendix). To identify implementation experiences, we first cataloged over 200 examples of electric and hybrid-electric bus adoption around the world. Then we selected specific experiences for deeper examination based on consultation with experts and practitioners in transit agencies, bus operating companies, manufacturing companies, and research institutes around the world. The criteria for selection of case studies included geographic distribution, electric bus and charging technologies (such as hybrid-electric or battery-electric technologies and plug-in, off-vehicle, or opportunity charging), a minimum operating time of at least six months, and diversity in contractual and financial characteristics; it excluded city-to-city buses or coaches and minibuses.

Data collection consisted of literature reviews and desktop research, guided by expert consultation and complemented by practitioner interviews. Each case was assessed in terms of the following four categories:

- Technical components. What types of technology and infrastructure needs arose during implementation?
- Funding. What revenues, incentives, and other budgetary allocations were used to cover expenses?
- Financing. What sources of capital, types of investors, and/or credit-enhancement options were used to mobilize investment capital?
- Legal arrangements and policy dimensions. What policy frameworks, ownership structures, and contracts shaped implementation?

These questions aim to capture the implementation experience from technical, financial, legal, and policy dimensions.

It should be noted that each implementation experience we examined is a unique result of local conditions. As such, each has advantages and disadvantages in the way it was implemented. We did not seek to identify exemplary systems or evaluate the success or failure of cases according to a set of criteria. Rather, throughout the paper we present diverse adoption experiences to illustrate how cities around the globe have tackled the transition in different ways. Our aim is to help cities take the first step in understanding what others have already done.

Question 4: What is the role of energy utility companies and manufacturers?

New players are entering the value chain around public bus service provision. The way in which local governments and transit agencies work with different private sector players varies somewhat according to which system of bus service provision is in place. In general, though, nontraditional third-party actors—battery and charging infrastructure manufacturers as well as energy companies—are becoming more involved in the transport business, which offers an acceptable mix of commercial risks and returns.

Question 5: What are possible ways to fund and finance electric and hybrid-electric bus services?

Our research finds that public and private operators have three options for paying for electric and hybrid-electric buses: up-front purchasing from public budgets, debt financing, and leasing buses (rather than owning them). In practice, approaches may be blended. For instance, operators may purchase buses and lease batteries. Although most public electric and hybrid-electric buses are still paid for by public budgets (including public transport system revenues), there is a growing need for affordable finance to help tackle the up-front investment gap and achieve scale. There is also a growing sophistication in leasing models, including for buses and batteries.

Question 6: What incentives exist for investments in electric and hybrid-electric buses?

Electric and hybrid-electric bus acquisitions typically involve some form of investment incentive to reduce the up-front cost. Investment incentives are often nonreimbursable resources given by one party (often a public entity) to make an investment more attractive to another party. On top of government subsidies, three broad types of investment incentives have been used to support electric and hybrid-electric bus investments: grants, preferential pricing, and in-kind incentives.

Question 7: What institutional and regulatory frameworks are guiding the adoption of electric and hybrid-electric buses?

Besides the contracting of the public electric or hybrid-electric service itself, institutional and regulatory frameworks are instrumental in shaping the conditions of the investments. Strategic plans are used for signaling political commitments and targets. Official guidelines help steer activities toward a common goal, and regulations and requirements impose accountabilities on public or private entities.

Question 8: What financial challenges have cities encountered when introducing electric and hybrid-electric buses?

From a city's perspective, financial and implementation challenges vary somewhat depending on whether the city is purchasing buses or outsourcing bus services. As with past experiences of improving bus services (e.g., setting up bus rapid transit and system-wide reforms), a city encounters a number of financial and procurement-related challenges when introducing electric bus services, including high capital costs, ensuring financial sustainability past pilot demonstrations, rigid procurement frameworks, and macroeconomic and business risk perceptions.

Question 9: What technical and institutional challenges have cities encountered when introducing electric and hybrid-electric buses?

Technical and institutional challenges are particularly pronounced in electric and hybrid-electric bus adoption. The availability of charging infrastructure and the stability of the grid can greatly impact the performance of the transition to electric. When it comes to fully electric buses, technical and operational challenges include the need to optimize technology to existing routes, difficulties installing charging technology and retrofitting bus depots, inexperience with battery ranges and charging procedures, repair and maintenance, and driving techniques. Institutional constraints include a lack of enabling legislation and policies, stakeholder coordination, and long-term planning to ensure proper disposal of batteries.

Question 10: What are key steps cities have taken to ensure greater success when adopting electric and hybrid-electric buses?

A few common elements are beginning to emerge across cities' early electric and hybrid-electric bus implementation experiences, many of which help address the investment risks described in question 9. Some factors that are emerging as important include performing cost-benefit analyses and basing investment decisions on a TCO basis, formalizing flexible procurement plans and optimizing the risk allocation, and investing in human capital (alongside physical assets) by training operators and fostering local innovation clusters.

ABBREVIATIONS

ATAC	Azienda per i Trasporti Autoferrotranviari del Comune di Roma (Rail and Road Transport Company for the Municipality of Rome)
BNDES	Banco Nacional do Desenvolvimento (Brazilian National Development Bank)
BRT	bus rapid transit
BTU	British thermal units
CIF	Climate Investment Funds
CO	carbon monoxide
CO_2	carbon dioxide
EDF	Électricité de France (Electricity of France)
ICE	internal combustion engine
NO_x	nitrogen oxide
PBoC	People's Bank of China
RATP	Régie Autonome des Transports Parisiens (Autonomous Operator of Parisian Transportation)
SEPTA	Southeastern Pennsylvania Transportation Authority
SPDB	Shanghai Pudong Development Bank
TCO	total cost of ownership
VAT	value-added tax
WRI	World Resources Institute
ZeEUS	Zero Emission Urban Bus System

QUESTION 1: WHAT ARE THE BENEFITS, COSTS, AND REPORTED IMPACTS OF ELECTRIC AND HYBRID-ELECTRIC BUSES?

Q1.1 Reduced Local and Global Emissions

Lower social and environmental impacts are some of the main benefits of introducing electric and hybrid-electric buses in cities. In many developing cities, buses are a dominant mode of transport for large parts of the population. What's more, internal combustion engine (ICE) buses also generate an important part of the negative externalities from the transport sector, such as noise and air pollution. Low- and zero-emission buses have either zero tailpipe emissions (if fully electric) or may be less carbon intensive (if hybrid-electric) than ICE buses. Studies show that hybrid-electric buses have moderately lower carbon dioxide (CO_2) emissions during service life than diesel buses, and fully electric buses have the potential to reduce CO_2 emissions by up to 75 percent, which is a significant reduction (Lajunen and Lipman 2016).

Although electric and hybrid-electric buses have the potential to improve local air quality and lower CO_2 emissions, the degree of abatement depends on the fuel used to produce grid electricity and its associated emission factors (Mulley et al. 2017). Other factors, such as temperature and topography, also affect the extent to which cities are able to achieve the potential climate benefits associated with electric and hybrid-electric buses.

Q1.2 Improved Service Quality

Cities invest in electric and hybrid-electric buses to improve the bus services they provide to residents. Although there are currently no accepted methodologies that would help account for their social benefits (Quarles and Kockelman 2018), anecdotal evidence shows that electric buses make for a more pleasant journey for passengers and drivers because they reduce vibrations from motors, allow for smoother pickups, and are quieter than diesel buses (Anderson and Pejcic 2019). The noise reductions improve livability for residents along transit routes, which can lead to improved sleep patterns, cognitive development in children, and mental health (Basner et al. 2014; Stansfeld et al. 2005). Since the reduction in noise and air pollution can strengthen proposals for general bus system improvements, transitioning to electric may be part of a broader suite of measures that improve bus services, such as the introduction of segregated busways and higher-capacity buses (often using bus rapid transit, or BRT, reforms), and more discreet measures that may be part of a larger service overhaul, such as centralized fare collection, intelligent fleet control, reorganized services, and changes in contracting structures.

Q1.3 Monetary Savings and Costs

This paper does not provide specific cost estimates because these vary greatly depending on the country or region, the type of technology or battery used, government or manufacturer incentives, and procurement costs. Our intent is to discuss the key cost factors that must be considered when deciding to adopt electric and hybrid-electric buses.

Total cost of ownership (TCO) is a common variable used by bus operators to determine the cost of owning and operating buses over a certain time period. Typically, it is presented in the form of present value, considering the time value of investment, and it includes capital expenditures, which include the up-front procurement of buses and related financial costs, as well as operational expenditures, which mainly include labor, fuel, and other costs related to operating and maintaining buses.

Fully electric buses cost more up front; however, there is a growing body of work showing that they have a lower TCO compared with ICE buses (BNEF 2018). According to Bloomberg New Energy Finance, electric buses are cost competitive with certain battery content and operational conditions, and the competitiveness improves in larger cities with longer annual distances traveled. The higher up-front costs of this new technology are associated with the more expensive battery prices and the need for charging facilities, along with costs related to disposal and recycling. The lower operating costs are associated with savings from more efficient energy consumption and reduced maintenance. Depending on whether buses are fully or partially electric, expenses associated with fuel and maintenance are lower because they require less (or no) fossil fuel, and electricity generally offers a lower cost per mile than fossil fuels, electric engines are more operationally efficient than combustion engines, and electric buses have fewer moving parts, making maintenance simpler and typically less costly.

Although the case for cost savings looks positive, it is still quite unclear because electric bus purchases represent such a small percentage of total purchases, with a majority of these occurring in China. In fact, there are still conditions where TCO analysis would be favorable toward ICE buses, such as in regions where fossil fuels are subsidized, import tariffs are high, or where electricity pricing is too expensive.

QUESTION 2: WHAT ARE THE PHYSICAL ASSETS NEEDED FOR THE ADOPTION OF ELECTRIC AND HYBRID-ELECTRIC BUSES?

Q2.1 Hybrid-Electric Buses

Hybrid-electric buses have both an ICE and an electric motor. In practice, several cities—including London, Shenzhen, and Singapore—began experimenting with hybrid-electric bus fleets and have since focused more on battery-electric buses and have scaled up their electric bus fleet sizes. Typically, hybrid-electric buses use the ICE at higher speeds and the electric motor at lower speeds. Regenerative braking is the most significant source of fuel economy for hybrid-electric buses, which recovers energy from the friction brake system to power the electric motor (Mashadi and Crolla 2011). Plug-in hybrids have additional storage capacity in the form of a battery and can receive charges from external power sources as well as regenerative braking.

Q2.2 Electric Buses and Batteries

In contrast to hybrid-electric buses, fully electric buses are powered solely by electricity. They vary in terms of their charging modes, including on-route charging and depot-based charging (see Table 1 below). The repair and upkeep of fully electric buses requires specific tools and replacement parts for unique components, such as an electric motor, electronic control system, and batteries that may need to be replaced two to three times during a typical bus life cyle (15–20 years). However, when city regulations mandate that operators follow the battery manufacturer's technical guidelines, this risk can be prevented and batteries could last 10-12 years before needing to be replaced. In addition, as electric vehicles are commonly higher quality, they require less frequent maintenance than ICE buses.

Q2.3 Charging Stations and Power Supply

In general, charging technologies include plug-in charging (dominant), battery swapping, and inductive charging technologies. Based on the charging speed and capacity, chargers are normally categorized into three levels of fast and slow charging and are applied to different operational mechanisms. The definitions of fast and slow charging may differ by country, but the speed can be measured by C-rates, or the rate of charge and discharge as compared to the capacity of the battery (Battery University 2017).

Charging can occur at the depot/terminal or on the route, which is also called opportunity charging. Depot charging usually occurs overnight for hours or during the day for around an hour during bus shift. Terminal charging usually occurs after the bus finishes one trip and normally takes only minutes to partially recharge. Plug-in charging is most commonly used for depot/terminal charging. On-route or opportunity charging can be plug-in or inductive. Plug-in chargers use an automatic connection that may link buses to high-capacity overhead chargers (used in Berlin, Germany). Inductive chargers are wireless and use specially equipped pads on the road and underbelly of the bus to transfer electricity (used in Gumi, South Korea, and in Turin, Italy). Opportunity charging allows buses to remain in use without returning to an off-route service center for battery charging throughout the day; however, it also presents issues for timetables and driver rest periods.

In addition, because charging stations need electricity to operate, grid stability and access are crucial for charging infrastructure. Thus, electric power supply company/utility engagement is important. Power is supplied via underground electric cables in trenches for on-route charging and through depot refurbishment for overnight charging. Additional electricity transformers and distributors may also be needed if the existing power facilities are not enough. Connecting electricity to charging stations and bus depots is an essential part of an investment in electric buses and may require major upgrades to be completed, especially for inductive charging mechanisms, which depend on new infrastructure.

Q2.4 Other Supporting Infrastructure

In moving to electric buses, cities also invest in supporting infrastructure, including bus depots and land.

Q2.4.1 Bus depots

Bus depots are structures that house the buses and other equipment, functioning both as in-house repair and storage facilities. This is where buses are recharged overnight and batteries are replaced. In order to keep up with the higher electrical demand required to charge electric bus fleets, upgrades to the electricity distribution infrastructure are sometimes required by the managing party.

Depending on the city, the transit authority or operators will be responsible for building and maintaining the bus depot. With greater emphasis being placed on renewable power generation, some depots are being fitted with wind or solar power.

Q2.4.2 Land

Public or private space is required for a range of elements, including charging stations, bus depots, and other supporting activities. Different charging methods require different amounts of space. For example, inductive charging stations require less visible space than overhead charging structures. Existing roadways, stops, and bus depots may need to be adjusted and retrofitted for electric fleets.

Table 1 | **Advantages and Disadvantages of Different Electric and Hybrid-Electric Bus Types**

TECHNOLOGY	KEY FEATURES	POTENTIAL ADVANTAGES[a]	POTENTIAL DISADVANTAGES	CITY EXAMPLES[b]
Hybrid-electric: regenerative braking and plug- in	Electric during stop-and-go traffic and combustion engine used at higher speeds Regenerative braking recovers energy from the friction brake system to power the electric motor	Reliable and relatively well-established technology makes transition easier Government funding programs are often well established Regenerative breaking is well adapted to urban stop-and-go traffic conditions Plug-in hybrids have additional energy storage capacity and recharge from an external power supply	Not 100% free of tailpipe emissions Driver training is essential to realize fuel economy savings	Auckland, New Zealand; Bogotá, Colombia; Curitiba, Brazil; London, England; Paris, France; Philadelphia and Seattle, United States; Toronto, Canada
Electric: plug-in charging	Plug-in charging uses an automatic connection that links buses to high-capacity chargers	Can be in a depot or on the route (opportunity charging) On-route charging leaves buses in operation without needing to return to off-route depots for recharging Using fast-charge technology increases operational capacity	Requires careful route optimization Requires investment in embedding on-road charging technology or in overhead chargers May affect grid reliability	Auckland, New Zealand; Bogotá, Colombia; Colombo, Sri Lanka; Curitiba, Brazil; Gothenburg, Sweden; London and Milton Keynes, England; Nanjing, Shenzhen, Tianjin, and Zhuhai, China; Paris, France; Philadelphia, Pomona Valley, and Seattle, United States; Rome, Italy; Stockholm, Sweden
Electric: inductive charging	Buried underground and connects wirelessly to special coils underneath the buses. This is a developmental technology that is generally unproven and not commercially available on a large scale as of yet	Less obtrusive and exposed to damage or vandalism than other charging technologies Operators can employ battery top-off techniques that keep buses near full charge for the entire route and extends their range	Requires careful route optimization Reduces flexibility of route design Relatively expensive	Berlin, Germany; Gumi, South Korea; London and Milton Keynes, England; Pomona Valley and Seattle, United States; Turin, Italy

Notes:
[a] The advantages and disadvantages in this table refer to the technologies themselves, not the city examples.
[b] Some cities have multiple types of technologies within their bus fleets.
Source: Based on case study research.

QUESTION 3: HOW ARE CITIES PROCURING ELECTRIC AND HYBRID-ELECTRIC BUS SERVICES?

Q3.1 A City or Transit Authority Purchases Buses and Operates Service

Public provision is a model in which the infrastructure is publicly owned and the bus service is provided by a public entity, such as a public transit agency or a subsidiary of the public administration. It is the major public transit provision mechanisms in countries like the United States and China. For pure public sector provision, the transit agency procures and operates buses and bears the costs for bus procurement, operation, and maintenance, which are often subsidized by the government in different ways (Gwilliam 2007; Cox and Love 1991).

For example, Philadelphia's Southeastern Pennsylvania Transportation Authority (SEPTA) owns and operates the buses that it purchases from private manufacturers. In 2002 SEPTA purchased its first hybrid-electric buses to increase fleet fuel efficiency (Hirano 2001; Lovaas 2012). In 2007 a major hybrid scale-up began, with the SEPTA board approving the purchase of 400 hybrid-electric buses for US$212 million from New Flyer of America. In 2016 more than half of SEPTA's bus fleet consisted of hybrid-electric buses; when the current contract with New Flyer ends, hybrids will make up approximately 95 percent of the fleet (New Flyer of America 2018; SEPTA 2018). SEPTA also has received $2.6 million through the U.S. Federal Transit Administration under the Low or No Emission Vehicle Program to purchase 25 fully electric buses from the American automotive and energy storage company Proterra (Li et al. 2019).

In practice, ownership of the transit operations may be mixed but under public control. In Shenzhen, China, for instance, three bus operators (Shenzhen Bus Company, Western Bus Company, and Eastern Bus Company) are technically under mixed ownership but are often considered to be state owned because the city is the largest shareholder and the companies receive financial support from the public budget.

Q3.2 Private Operators Purchase Buses and Operate Service on Behalf of the City

In this variation of service provision, a public entity, such as a local government or transit agency, owns and manages the bus system, but bus services are contracted out to private operators who are responsible for investing in the vehicles. This kind of private sector provision predominates in Europe, Latin America, and Oceania (Hensher and Stanley 2010). The transport authority can contract private entities to service specific areas of the system, including operating bus routes and installing and maintaining charging stations.

The city of Bogotá, Colombia, illustrates how buses are introduced in this provisional mode. When the city adopted its Technology Upgrade Plan (Plan de Ascenso Tecnológico) using a mayoral decree in 2013, the city's entire rolling stock started to be replaced by buses with at least Euro 5 equivalent emissions technology or with other cleaner technologies, such as hybrid-electric buses (Alcaldía de Bogotá 2013). Two private operators of Bogotá's Integrated Public Transport System bought 300 hybrid-electric buses from Volvo. The terms of the procurements were agreed upon by the operators and TransMilenio, the public transit agency in charge of contracting bus operations in the city.

Q3.3 A Third Party Owns (Manufactures or Purchases) Buses and Leases Them to Operators (Public or Private)

A third mode of contracting the provision of electric and hybrid-electric services emerged more recently, where third parties are assuming a more prominent role. Here, manufacturers and other asset owners provide options for operators (public and private) to lease buses rather than buying them. The leasing of assets is based on the third party's ability and willingness to take on some of the risks related to new technologies. Increasingly, this mode is widely used and may take various forms. Leases may encompass buses, batteries, and charging facilities; may be provided by existing manufacturers or financial companies; and may involve simple leases or more complex lease-to-buy and purchase-leaseback contracting, which will be explained in more depth in question 5.

It should be noted that in many developing cities, bus services provided through private operators may be largely "disorganized"—that is, they lack enforced route structures and vehicle standards and are characterized by inefficient competition between small-scale informal operators. As a result, these informal services are often of lower quality despite their ability to fill gaps where formal transit services do not meet the mobility needs of residents or where there are no formal systems (Gómez-Lobo and Briones 2013). There are no known experiences of electric buses being successfully introduced in situations where bus systems are not yet organized. Different cities' experiences of introducing BRT systems and other means of formalizing and reorganizing their bus systems are discussed by Pai (2010) and Rodriguez Hernandez and Mehndiratta (2017), among others.

QUESTION 4: WHAT IS THE ROLE OF ENERGY UTILITY COMPANIES AND MANUFACTURERS?

Q4.1 Energy Utilities

Energy utilities are increasingly seeing the electrification of the transport sector as a growing business opportunity. To position themselves in this emerging market, they may provide favorable pricing and invest in charging infrastructure. As seen more recently in Latin America, they may even purchase buses to lease them to the operators.

For example, in Gothenburg, Sweden, the utility company Gothenburg Energy invested in an electric substation adaptation and fast-charging stations during the Hyperbus project in order to participate in the European Union's Life+ program alongside key regional players from the public and private sectors. In Paris, France, the power generator Electricity of France (Électricité de France; EDF) signed a three-year partnership with the transit agency Île-de-France Mobilities (Île-de-France Mobilités) and the Autonomous Operator of Parisian Transportation (Régie Autonome des Transports Parisiens; RATP) to conduct the trials and tests of alternative electric power trains, batteries, and their charging systems to evaluate their impact on the electric grid. There are several instances in the United States of energy utilities waiving demand tariffs for transit companies operating electric buses, which can represent up to or more than 30 percent of an energy consumer's bill (Salisbury and Toor 2016). In Santiago, Chile, the country's largest utility company, Enel Chile, developed the city's electric bus business model in conjunction with a bus operator. By December 2018, two of the city's utility companies had purchased 200 electric buses from Chinese vehicle manufacturers and had leased them to the operators. These purchases were partially paid for by user fares and existing public transport subsidies (Fernández 2018; Enel X 2018).

Q4.2 Electric Bus Manufacturers

Manufacturers take a number of measures that are designed to make their electric and hybrid-electric buses successful alternatives to conventional buses. These include the provision of training schemes, bus and battery leasing options, and packages that include charging infrastructure and demonstration pilots.

Q4.2.1 Training for operators and longer maintenance contracts

In Bogotá's experience of deploying hybrid-electric buses, the manufacturer (Volvo) became more involved in the operation and maintenance of the fleet by providing training to the operator's technicians, who were previously working with diesel technology, and by securing a five-year maintenance contract, which is a longer period than would have been typical for diesel buses (Automotive World 2013). The operator's personnel were expected to be fully capable after five years; therefore, the training and maintenance contracts would no longer be needed. The all-inclusive contract included training for operators in proper driving techniques to achieve the fuel economy benefits of hybrid-electric buses. Similarly, in Shenzhen, China, the manufacturer provides lifetime warranties for batteries, motors, and electronic control systems so that service-related risks for bus operators are minimized (Lu et al. 2018).

Q4.2.2 Bus and battery leasing

Recognizing the reluctance of operators to bear the risk of transitioning to a new technology, manufacturers are providing options for operators to lease buses rather than buy them. In Bogotá, for example, Volvo excluded the batteries from the bus purchase price; instead, it allowed batteries to be leased for up to 12 years. Leasing has also been used in a number of Chinese cities in different forms, including in Shenzhen, where the Shenzhen Bus Company leased buses and then purchased them at a designated price (also called a lease-to-buy contract). Leasing can take a number of forms, including bus leases, battery leases, and lease-to-buy and purchase-leaseback contracting (which is further explored in question 5); these contracts are potentially one of the most important innovations of recent years (Li et al. 2018).

Q4.2.3 Pilots and solution packages

Manufacturers invest heavily in new bus technology and often partner with other private sector players and local governments in pilot programs. In 2016, for example, Volvo partnered with Siemens and local authorities in Curitiba, Brazil, on a pilot project for a new hybrid-electric bus capable of running on 100 percent electric power and thus substantially improving on the previous hybrid technology in terms of fuel consumed and CO_2, nitrogen oxide, and particulate matter emissions (URBS 2016). In Stockholm, Siemens and Volvo partnered together to provide a complete package of buses and fast-charging stations, including station installation and maintenance services, and a supply of electricity from the local utility company.

QUESTION 5: WHAT ARE POSSIBLE WAYS TO FUND AND FINANCE ELECTRIC AND HYBRID-ELECTRIC BUS SERVICES?

Q5.1 Up-Front Purchases from Public Budgets

In many cities in Europe and the United States, electric and hybrid-electric buses are paid for up front from existing public budgets (BNEF 2018). Worldwide, even where private operators purchase buses, public investment incentives reduce the up-front costs. Different types of investment incentives are discussed in detail in the next section, question 6. Besides incentives, the principal sources of up-front capital that have been used come from public budgets. Operational expenditures are also covered by revenues from the bus or wider transit system.

A common source is the public transportation budget, which covers the capital or operational costs of the transit system, including bus services. It is made up of operating revenues—including farebox revenues and potential revenues from other operations, such as property leasing and advertising—and taxes, which are sometimes transferred from the central government and other parts of the administration. In Philadelphia, for example, SEPTA raised revenues from advertisements on the rear of its buses, which are specifically designed to have rooftop air conditioners and route-number signs mounted close to the roof (SEPTA, n.d.b). Where states and cities have tax-raising powers (as in the United States), revenues from local sales taxes are a major source of funding for transport agencies. Similarly, in France, cities can use a type of payroll tax called the *versement transport* (transport payment) to fund improvements and expansion of the public transport system. It is collected by local authorities and is paid by employers above a certain size (Allen 2013).

Q5.2 Debt Financing

Debt financing is still not widely used for electric buses, but cases of concessional loans and green bonds do exist. These instruments, as well as commercial loans (loan to a business), may become more common as confidence in the technology and viability of the investment grow.

Q5.2.1 Concessional loans

Concessional loans are provided by a financier at flexible lending conditions, such as lower interest rates and/or longer repayment schedules. In the case of Curitiba, private operators purchased HibriBuses from Volvo using a concessional loan from the Brazilian Development Bank (Banco Nacional do Desenvolvimento; BNDES) to be used for buses that had been produced inside the country (Volvo has a factory in Curitiba). Similarly, in Bogotá bus service operators accessed concessional loans for several hundreds of hybrid-electric buses. In this case, the concession was made possible through on-lending by Colombia's entrepreneurial development and export-import bank (Bancóldex) to local financial intermediaries. The bank used financial resources (US$40M) that were made available through the Clean Technology Fund and the Inter-American Development Bank (BASE, n.d.) as well as financing from BNDES and the Swedish Export Credit Agency.

Q5.2.2 Green bonds

Green bonds share all the same financial features as other bonds, but 95 percent of their proceeds must finance projects with positive environmental and climate change impact (Climate Bonds Initiative 2019). In China, the Tianjin Public Transportation Group purchased more than 500 electric buses partly using a loan at preferential rates.

The source of finance was a capital pool that the Shanghai Pudong Development Bank (SPDB) created from the issuance of green bonds (Deng 2016). In the case of Tianjin, the bond issuance was aligned with the green bond guidelines issues by China's central bank, the People's Bank of China (PBoC).

In practice, however, using pure debt financing to purchase buses is rare; a blend of cash funding and debt finance is more common. In Tianjin, for example, low-cost financing (through bonds and a loan, which together totaled US$72.46 million) was blended with national budgets (worth $38.63 million).

Q5.3 Leasing

A third approach to dealing with up-front capital costs is to lease rather than purchase buses, batteries, and infrastructure. When leasing, a third party (who is not the operator) legally owns some or all of the assets and assumes some of the risks associated with the investment. This third party could be a technology manufacturer or a service provider. It could also be a specialized financial company, which is the case in Sweden, where a high percentage of all buses are leased. In recent years, leasing has emerged as an important model for managing the investment costs and risks involved with electric and hybrid-electric bus investments for both public and private operators. This is because leasing reduces the financial burden for the operator and transfers technology and/or credit risk onto the third party, although it works best where the risk of contract curtailment is low. There are several types of leasing options that have been used, with different levels of risk transfer.

Q5.3.1 Component leases (battery leases)

Some manufacturers offer operators the option to lease batteries separately from either leasing or owning the buses. The manufacturer (or third party) owns the battery during the lease term and replaces it as required. Several manufacturers offer this option, including Volvo in Bogotá and Proterra in the United States.

Proterra is pioneering a new type of contract in which the company sells a battery-electric bus at the price of a diesel bus (leveling the up-front costs) and recuperates the discount by converting the capital cost of the batteries into an operating cost for the operator. The contract, called an electric bus battery service agreement, is based on the idea that the operator can use the operational savings that accrue over the life of the electric bus (compared to a diesel bus) to cover the battery lease. It has won support by a green business accelerator, the Climate Finance Lab, for helping operators transition to electric buses without incurring the risk of the battery (Climate Finance Lab, n.d.). The model was used in Park City, Utah, where it increased the number of buses that could be purchased (Proterra 2017).

Q5.3.2 Operating leases

An operating lease is a contract that allows for the use of the bus but does not transfer ownership of the vehicle. Manufacturers or specialized companies offer the option to retain legal ownership of the asset while the operator pays for the use of the bus on a timely basis and takes on responsibility for taxes and insurance. Maintenance is often covered separately in a different service contract with the manufacturer or another provider. Operating leases are sometimes offered as lease-to-buy schemes in which the operator has the option to purchase the assets at the end of the lease period to benefit from their residual value. However, recent changes in accounting practices for operating leases make this model much more difficult to execute because assets are no longer left off of the balance sheet for the operator.

Q5.3.3 Capital (or financial) leases

Unlike the other types of leases, capital leases are much more like loans and typically require the lessee to have a strong balance sheet. The duration of the lease is close to the useful life of the asset (that is, typically much longer than operating leases), and it includes a residual value and repurchase agreement that applies at the end of the lease term. For example, the Shenzhen Bus Company used 100 percent financial leasing to purchase 1,000 new battery-electric buses, leasing the buses over the course of the agreed upon period and then purchasing them at a designated price. Other operators in Shenzhen (the Eastern Bus Company and the Western Bus Company) used mixed leasing arrangements, including operating and capital leases (Lu et al. 2018).

Table 2 summarizes the different ways cities are funding and financing electric and hybrid-electric buses.

Table 2 | **Examples of Different Payment or Acquisition Types**

TYPE OF ACQUISITION	SOURCE	FEATURES
Cash purchases	Investment incentive[a]	Grants often cover up-front costs but are time limited and irregular Preferential pricing sets prices at rates lower than otherwise available in the market In-kind incentives provide support in the form of goods, services, training, and transactions that do not involve money
	Operating budgets and budget transfer	Often used to cover operational or capital expenditures Includes farebox revenue and revenue from other operations, such as property leasing and advertising or taxes
Debt financing	Concessional loan	Provided by financier at flexible lending conditions Can encourage higher lending rates among local banks for environmentally beneficial investments
	Green bond	Created to fund projects that have positive environmental or climate benefits Backed by issuer's entire balance sheet
Leasing	Lease-to-buy contract	Between operator and bus manufacturer Operator pays rent over the course of the agreed upon lease period and then purchases the bus at a designated price at the end of the contract Allows operators to purchase buses without tying up their cash
	Purchase-leaseback contract	After selling an asset to a buyer, the seller then contracts with the buyer to lease the same asset Often used in cities where third-party leasing companies are not allowed to purchase vehicles directly Details of arrangement are made immediately after sale of the asset
	Battery lease	Manufacturer owns the battery during the lease term and replaces it when needed
	Operating lease	No residual value risks Predictable cash flow and cash flow benefits due to fixed monthly cost Monthly payment paid out of operating income and offset against taxable profits
	Financial lease	Only pay interest on the outstanding value Potential tax and value-added tax benefits Trade-in value: potential to profit from careful maintenance and use Vehicle appears as an asset on the balance sheet

Note: [a] See question 6 for more details on investment incentives.

Sources: Based on SCANIA, n.d.; Climate Bonds Initiative, n.d.; Climate Finance Lab 2018; and Proterra, n.d.

QUESTION 6: WHAT INCENTIVES EXIST FOR INVESTMENTS IN ELECTRIC AND HYBRID-ELECTRIC BUSES?

Q6.1 Grants

Most public electric and hybrid-electric bus investments use a form of grant to cover the up-front costs of electric buses. Grants are typically time limited and irregular and will not cover large-scale fleet investments. They often come from federal, state, and local initiatives based on public budgets, which can include general taxation as well as other specific sources of public funds. Several types of grants have been used to incentivize electric and hybrid-electric bus adoption.

Q6.1.1 Capital expenditure grants

Capital expenditure grants, or "grants for purchase," are used to overcome the higher up-front costs of buses and their accompanying infrastructure. They are used to acquire physical assets such as buses, batteries, and charging stations, and they can be provided by both public and private sources. In the case of electric buses, the greatest cost to operators occurs at the beginning of the project, so securing this kind of funding is especially important for projects to be successful.

Transport for London received over £22 million to purchase 338 hybrid-electric buses with regenerative breaking between 2009 and 2013 from the Green Bus Fund (Department for Transport 2013). The fund supported bus companies and local authorities in England to help them buy hybrid-electric buses by covering up to 50 percent of the cost difference between a hybrid-electric bus and an ICE bus and up to 80 percent of the cost difference between an electric bus and an ICE bus. It awarded over £89 million (around US$100 million) in grant funding and put more than 1,200 hybrid-electric buses into service on England's roads. It has since been replaced by a follow-up grant program, the ultra-low-emission bus scheme, through which the city has procured battery-electric buses with on-route inductive charging (OLEV 2015).

Q6.1.2 Research, development, and demonstration grants

Manufacturers invest heavily in new bus technology, and research and development are often supported by public or private grants that can be used for improving and testing new buses, batteries, electrical motors, and charging infrastructure. They help advance the technologies used in electric buses and ultimately lower technology costs. Often these funds will go directly to manufacturers, but sometimes transit authorities may benefit, too, if they are involved in piloting and deploying new bus models.

A flagship example of a major research, development, and demonstration project is the European Union's Zero Emission Urban Bus System (ZeEUS). It ran between 2013 and 2017 with a budget of €22.5 million, 50 percent cofunded from the European Union, with the aim of testing electrification solutions at the heart of the urban bus system networks through live demonstrations to facilitate the market uptake of electric buses in Europe (ZeEUS 2014). As the most important European project focusing on electric buses, it involved core demonstrations in 8 cities, reported on trends across an additional 40 European cities, and involved over 40 consortium participants across the private and public sectors, including manufacturers, utilities, research institutes, and industry associations (ZeEUS 2016).

Q6.2 Preferential Pricing

Preferential pricing is the setting of prices at rates lower than otherwise available in the market. There are a range of rates and services where concessions can be provided, including tariffs, taxes, and finance. In general, when operators are able to secure competitive pricing on fuel, taxes, and financing, they will be more inclined to transition to electric buses.

Q6.2.1 Electricity tariff rebates

Some energy companies offer electricity prices at discounted rates, either voluntarily or because of regulations. For example, state regulations helped Foothill Transit in California reduce its per-kilowatt-hour charge from 40 cents to 15 cents. Likewise, the transit agency has been exempted from the monthly demand charge levied by the energy company, following the regulator (the California Public Utilities Commission) granting a three-year reprieve on transit agencies using battery-electric buses (Salisbury and Toor 2016). Regardless of whether they are voluntary or mandatory, lower electricity rates could effectively incentivize operators to use electric buses over diesel buses because of reduced fuel costs; however, due to the volatility of fuel prices (whether diesel or compressed natural gas), lower electricity prices by themselves are not a guarantee of lower operating costs for electric buses.

Q6.2.3 Concessional and blended financing

Financing provided on preferential terms can include below-market interest rates, longer terms, and longer grace periods. If "blended," it may also include strategically used nonreimbursable elements (often capital expenditure grants) to mobilize commercial-grade financing (OECD 2018). It is usually provided by national and international development banks and agencies, including trust funds such as the Climate Investment Funds (CIF) and the Green Climate Fund. Debt financing is not yet commonplace for electric buses. In the case of Bogotá's hybrid-electric bus investment, US$40 million from the Clean Technology Fund (part of the CIF) was used to unlock an additional US$40 million from Colombian banks to be loaned to private operators for the acquisition of the buses. This sort of blended financing had special terms and conditions designed to make it attractive to operators (IDB 2012).

Q6.2.4 Tax incentives

Tax incentives are used by governments to encourage desirable private activities and discourage undesirable ones. In the case of electric buses, three main types of tax incentives have been observed to help reduce acquisition costs: import duty exemptions, value-added tax (VAT) reductions or exemptions, and corporate tax reductions. Import duty exemptions help in places where an import duty (tax or tariff) exists on electric buses and their components. In Brazil, for example, import tariffs designed to protect local production of diesel buses make electric buses relatively less attractive by adding costs to the investment (ISSRC 2013). VAT reductions or exemptions affect the taxes placed on products whenever value is added at a stage of production and at final sale. Finally, corporate tax reductions affect the tax on a company's profits. Tax breaks can be given to private entities to incentivize the purchasing of buses or materials by lowering the overall costs to companies.

In Bogotá, Colombia's national government introduced all three of these types of tax breaks to facilitate the purchase of electric buses by operators (IDB n.d.; BASE n.d.). An import duty tax reduction from 38 percent to 5 percent helped imports of hybrid-electric buses as well as parts for maintenance and repair. VATs, usually charged at 16 percent, were completely waived. Corporate tax deductions of up to 20 percent of the operator's profit were introduced as part of wider tax incentives for energy efficiency targeting the private sector at large. Yet given low profit margins and losses by the bus operating companies, these did not translate into substantial incentives in practice.

Q6.3 In-Kind Incentives

In-kind incentives are nonmonetary support provided in the form of goods, services, training, and other transactions not involving money or not measured in monetary terms. There are several types of in-kind incentives that have been used to incentivize electric and hybrid-electric bus investments across different cities.

Q6.3.1 Public land

Public entities can make parcels of public space available to save an operator costs and thereby make the investment more attractive. In Los Angeles, for example, Foothill Transit secured a no-cost 40-year land lease from the city of Pomona Valley to build and install its opportunity charging station, which was conveniently located by the Pomona Transit Center near an existing transformer (Eudy et al. 2016). Since leasing or purchasing land can be expensive and a lengthy process, this kind of incentive can reduce capital, operating, and transaction costs.

Q6.3.2 Regulatory exemption

In some cases, public entities may choose to exempt private operators from regulations that limit their commercial activities to incentivize them to invest in electric and hybrid-electric buses. An example is Bogotá, where the public entity that coordinates the city's public transportation system (TransMilenio) allows electric bus owners to sell advertising space on their buses, but ICE bus owners are not allowed to profit commercially from bus advertising space. The Clean Technology Fund and the Inter-American Development Bank negotiated this exemption as part of their funding and financing package for the city (IDB, n.d.).

Table 3 provides an overview of the incentives available, including their advantages and disadvantages.

Table 3 | **Summary of Investment Incentives in Electric and Hybrid-Electric Buses**

INVESTMENT INCENTIVE	ADVANTAGES	DISADVANTAGES	CITY EXAMPLES
Capital expenditure grant	Eligibility to receive a grant Proven ability to utilize funding	Could be limited in size and used only for specific aspects (e.g., capital expenditures) Eligibility may be restricted (in terms of who can access the grant and what it can be used for) Diverts public funds	Auckland, New Zealand; Berlin, Germany; Bogotá, Colombia; Colombo, Sri Lanka; Gothenburg, Sweden; Gumi, South Korea; London and Milton Keynes, England; Nanjing, Tianjin, Shenzhen, and Zhuhai, China; Philadelphia, Pomona Valley, and Seattle, United States; Rome, Italy; Singapore; Stockholm, Sweden; Toronto, Canada
Operational expenditure grant	Eligibility to receive a grant Proven ability to utilize funding	Could be limited in size and used only for specific aspects (e.g., capital expenditures) Eligibility may be restricted (in terms of who can access the grant and what it can be used for) Use up public funds	Berlin, Germany; Colombo, Sri Lanka
Land grant	City benefits are clearly articulated Coordination with different stakeholder groups	Difficulties reaching consensus regarding station locations	Pomona Valley, United States
Preferential pricing	Stable electrical grid exists Coordination between utility company, operators, and transit authority	Difficulties reaching consensus in deciding pricing scheme, especially as the electric grid and power generation are undergoing major changes	Pomona Valley, United States
Duty tax breaks	Clearly defined uses and regulations of tax breaks exist	Lack of enforcement or regulation resulting in improper use of tax reduction	Bogotá, Colombia
Value-added tax reduction	Clearly defined uses and regulations of tax breaks exist	Lack of enforcement or regulation resulting in improper use of tax reduction	Bogotá, Colombia
Reduced tax on corporate profit	Clearly defined uses and regulations of tax breaks exist	Lack of enforcement or regulation resulting in improper use of tax reduction	Bogotá, Colombia; Curitiba, Brazil; Shenzhen, China

Source: Based on case study research.

QUESTION 7: WHAT INSTITUTIONAL AND REGULATORY FRAMEWORKS ARE GUIDING THE ADOPTION OF ELECTRIC AND HYBRID-ELECTRIC BUSES?

Q7.1 Strategic Plans and Commitments

Strategic plans are expressions of short- and long-term goals, and they may help ensure that ambitions transcend political periods. They can be observed in multiple forms, including climate action plans, urban mobility plans, and other transport and energy action plans. In recent years, numerous cities have introduced such plans to reduce air pollution and global greenhouse gas emissions, overall carbon footprint, and dependence on fossil fuels. In some cases, electric and hybrid-electric buses are being implemented under such plans. For example, one of the central aspects of Stockholm's Vision 2030 is clean transportation. The public transit authority, Stockholm Public Transport (Storstockholms Lokaltrafik), set a target for buses to be 100 percent free of fossil fuels by 2025. Similarly, in the United States, Philadelphia's transport authority, SEPTA, seeks to reduce the diesel vehicle composition of its bus fleet to less than 5 percent of by 2021. SEPTA's sustainability program, SEP-TAINABLE, outlines 18 discrete initiatives that promise to reduce SEPTA's energy consumption by 126.2 million British thermal units (BTUs) per year, avoid 122.4 million pounds of CO_2 equivalents, and save more than US$2.2 million per year (SEPTA 2012).

More than 25 cities have signed the Clean Bus Declaration of Intent (which has since been superseded by the Fossil Fuel Free Streets Declaration), committing to invest in a combined total of 45,000 electric and hybrid-electric buses by 2020 (C40 Cities Climate Leadership Group 2016). Beyond political statements, declarations such as these can send market signals that demand for these technologies exists. Some cities make public commitments driven by specific situations (e.g., Paris launched its first electric buses during the twenty-first session of the Conference of Parties, COP 21), or they position their city from a specific angle (e.g., in 2007 Stockholm's city council announced the Vision 2030 goal of becoming the "green capital of the world") (City of Stockholm 2007). Strategic plans, along with regulations, requirements and enabling legislation, are part of the institutional framework that we see is shaping the introduction of electric and hybrid-electric buses in cities.

Q7.2 Official Government Guidelines

Besides strategic plans and terms of services, cities have drawn on official guidelines as institutional frameworks to help with their electric and hybrid-electric bus investments. For instance, the green bond guidelines issued by China's central bank, the PBoC, in 2015 are associated with an increase in the issuance of green bonds for infrastructure projects, including for electric buses (Dai et al. 2016). In Tianjin, over 500 electric buses were purchased partly using a loan at preferential rates from the SPDB, which came from a capital pool created by issuing green bonds for investments eligible under the PBoC's green bond guidelines (Deng 2016). The PBoC's guidelines adapted the Climate Bonds Standard and Certification scheme, which was important for creating a permissive environment for using bonds for sustainable investments (Climate Bonds Initiative, n.d.).

Q7.3 Regulations and Requirements

Some cities require a percentage of the public bus fleet to operate electric or hybrid-electric buses and restrict new tenders for ICE buses. Regulations and requirements such as these signal a long-term shift. As a result, manufacturers are rewarded for research and technology development, and operators see these buses as the future of their fleet. Cities tend to phase in requirements gradually because overly strict requirements shrink the pool of proposals to be submitted, reducing competition.

Low-emission zones (LEZs), which are a relatively recent regulatory approach, encourage the use of cleaner fleets and vehicles. The most prominent example of this approach is in London, where an LEZ encompasses most of greater London and requires vehicles entering the zone to pay a fee if they do not meet minimum emission requirements (at least Euro 3 and 4, depending on vehicle type) (Transport for London, n.d.a). Building on this experience, an ultra-low-emission zone was put in place, whereby a light-duty vehicle driving in a 13-square-mile area of London's downtown must meet strict emission standards or pay an additional £12.50 (US$16.27) on top of the normal congestion charge. Heavy-duty vehicles that do not meet the new emission standards must pay an additional £100.00 (US$130.00) (Transport for London, n.d.b). This approach is a clear requirement for London's bus operators to move toward zero-emission vehicles if they want to continue to operate bus services on London's roads.

QUESTION 8: WHAT FINANCIAL CHALLENGES HAVE CITIES ENCOUNTERED WHEN INTRODUCING ELECTRIC AND HYBRID-ELECTRIC BUSES?

The next two questions (8 and 9) will go through the financial, technical, and institutional challenges that cities have faced as they introduce electric and hybrid-electric buses in public fleets. For more details regarding technical and institutional barriers, please refer to the WRI report *Barriers to Adopting Electric Buses* (Sclar et al. 2019).

Q8.1 High Capital Costs for Vehicle Acquisition and Charging Infrastructure

Whether public or private, operators may struggle to mobilize enough capital for the up-front expenses associated with vehicle acquisition and the additional infrastructure investment for charging facilities. Operators (especially private ones) often have limited cash flow and low profit margins, and they may not be deemed creditworthy, especially in emerging markets. Although cost competitive with fossil-fueled buses in terms of TCO under certain conditions (see Q1.3), a big implementation challenge is often the need to cover higher up-front capital costs, especially compared to fossil-fueled bus alternatives. Up-front costs include the direct capital costs—buses, supporting infrastructure, and grid reinforcement—and the indirect costs. Also, charging facilities are an extra investment for electric buses (compared to ICE buses) and may exacerbate the financial situation of bus operators.

Funding fluctuations and restrictions can also impact the ability of cities and operators to reduce up-front costs, and the discontinuity of funding or subsidies will also raise concerns about the procurement of electric and hybrid-electric buses. In China, when the subsidy was announced to be decreasing over time, the sales of electric buses in the month of a reduced subsidy decreased by 97.3 percent compared to the same month in the previous year (National Information Center 2018). However, it is worth noting that the longer-term impact of the reduced subsidy is still yet to be seen; the national-level and city-level adoption targets for electric buses remain, and the price is decreasing constantly.

Q8.2 Rigid Procurement Frameworks

When cities procure bus services from private operators, existing procurement frameworks may bias decision-making against electric or hybrid-electric buses. This happens because bids in response to public tenders are often evaluated on a value-for-money basis that tends to favor technology options with the lowest purchase price. However, despite higher up-front costs, electric buses are cost competitive with fossil fuel alternatives in terms of TCO because of their low fuel costs and maintenance requirements and their environmental and social benefits. In the absence of the inclusion of TCO concepts—or additional tender guidance and specifications that bids need to meet minimum environmental standards—electric buses may come in at a higher cost to the public sector than fossil-fueled buses and therefore be disadvantaged in tender evaluations.

In Santiago, the public transport system (Transantiago) is operated under a concession contract mechanism whereby private bus operators receive certain payments from the government to procure and operate buses. The previous payment mechanism included incentives for bus operators to provide passengers with better service and the ability to travel longer distances. However, it did not have any environmental requirements, and the absence of the consideration of the up-front procurement costs of different technologies (operators need to procure their own buses and get a certain payment based on performance) indicates that electric buses were not encouraged under the previous mechanism (Gómez-Lobo and Briones 2013). In the latest tender process, operators were required to procure and operate a minimum of 15 electric buses in order to win the bid (MTT 2017). As of 2019, Santiago will be operating a fleet of more than 200 electric buses (BNamericas 2018).

In the absence of supporting measures, the financing challenges are exacerbated in contexts where operators have limited cash flow and low profit margins or where investment incentives are low or nonexistent and there is a history of operator bankruptcy (Miller et al. 2017). Challenging investment climates also add to this, including exchange rate fluctuation, which is a common factor in emerging markets. Finally, a risk that overshadows the entire investment over the vehicle's lifetime is the uncertainty around the residual value of assets, including potentially the bus, batteries, and other infrastructure. If the depreciation value is different than expected, this can have significant repercussions on an operator's business model.

Q8.3 Difficulty Scaling Up from Pilot Demonstrations

There is still limited long-term experience at the commercial scale, which means key actors are still uncertain about the long-term performance of electric buses and ancillary technologies. For operators and financiers, this makes it a relatively riskier investment than ICE alternatives (Mohamed et al. 2017). Operators may need to evolve fundamental aspects of their business model and way of working to maintain the same level of service. For instance, the residual value of buses at their end of life and battery disposal are key concerns for operators who rely on the resale of old buses as a revenue stream for fleet renewal (Nordelöf et al. 2014). Routes may need to be optimized to accommodate battery charging and storage, as bus technology is still being fine-tuned to accommodate different climatic and topographic conditions (Bullis 2013; Prohaska et al. 2016; Perrotta et al. 2014; Li 2016; Lajunen and Lipman 2016). There is even less long-term experience in terms of the financial performance of electric buses, which makes commercial investors reluctant to provide finance at affordable rates. In Singapore, officials have been testing electric and hybrid-electric buses since 2010, but they have yet to permanently electrify the entire bus fleet due to the technical uncertainty and immature market. In 2019 the Land Transport Authority of Singapore plans to spend more than US$94 million to trial 60 battery-electric buses and 50 hybrid-electric buses to prepare for a clean energy source target by 2040 (Tan 2019).

Q8.4 Macroeconomic and Business Risks

The risks deriving from the broader economic environment can be considerable depending on the context. In the development phase, a lack of confidence in the market may result in low interest from operators as well as investors. Under a private mode of provision, there is a risk that operators will not respond to requests for proposals for delivering electric bus services; as a result, only a few bids will be received, and there will be insufficient competition. Investors may be unwilling to finance if they believe the risk is too high. In the operational phase, electric bus services face similar business risks as standard bus services—namely, those related to lower-than-anticipated passenger numbers and, therefore, lower farebox revenues. If operators take on debt, they may compromise their ability to repay creditors.

QUESTION 9: WHAT TECHNICAL AND INSTITUTIONAL CHALLENGES HAVE CITIES ENCOUNTERED WHEN INTRODUCING ELECTRIC AND HYBRID-ELECTRIC BUSES?

Q9.1 Technical Challenges

As with any new technology, its adoption comes with unknown risks associated to performance. In the early stages of project preparation, uncertainties relate to the possibility of optimizing the technology with regard to existing route configurations. Routes were often set before the introduction of electric buses and therefore have not been designed with the specific battery range, charging requirements, and engine features in mind (Perrotta et al. 2014). During the installation phase, there may be technical challenges related to the installation of the charging technology and the retrofitting of bus depots, which also were typically not designed for electric buses.

Operational challenges can also emerge because operators face a learning curve with respect to battery ranges and charging procedures, repair and maintenance, and driving techniques. Unexpected breakdowns can fundamentally compromise a city's adoption of electric and hybrid-electric buses, and it may be difficult to recover from these setbacks. For instance, in Rome, Italy, the electric bus fleet was suspended in spring 2018 due to a lack of replacement of batteries, attributed partly to disagreements between the Rail and Road Transport Company for the Municipality of Rome (Azienda per i Trasporti Autoferrotranviari del Comune di Roma; ATAC), the city's transport agency, and Tecnobus, the operator of the vehicles (Hampel 2018).

Q9.2 Institutional Constraints

When new technologies, such as electric or hybrid-electric buses, are introduced in a city, institutional constraints may emerge because the existing system is unable to react to changes quickly and adequately enough.

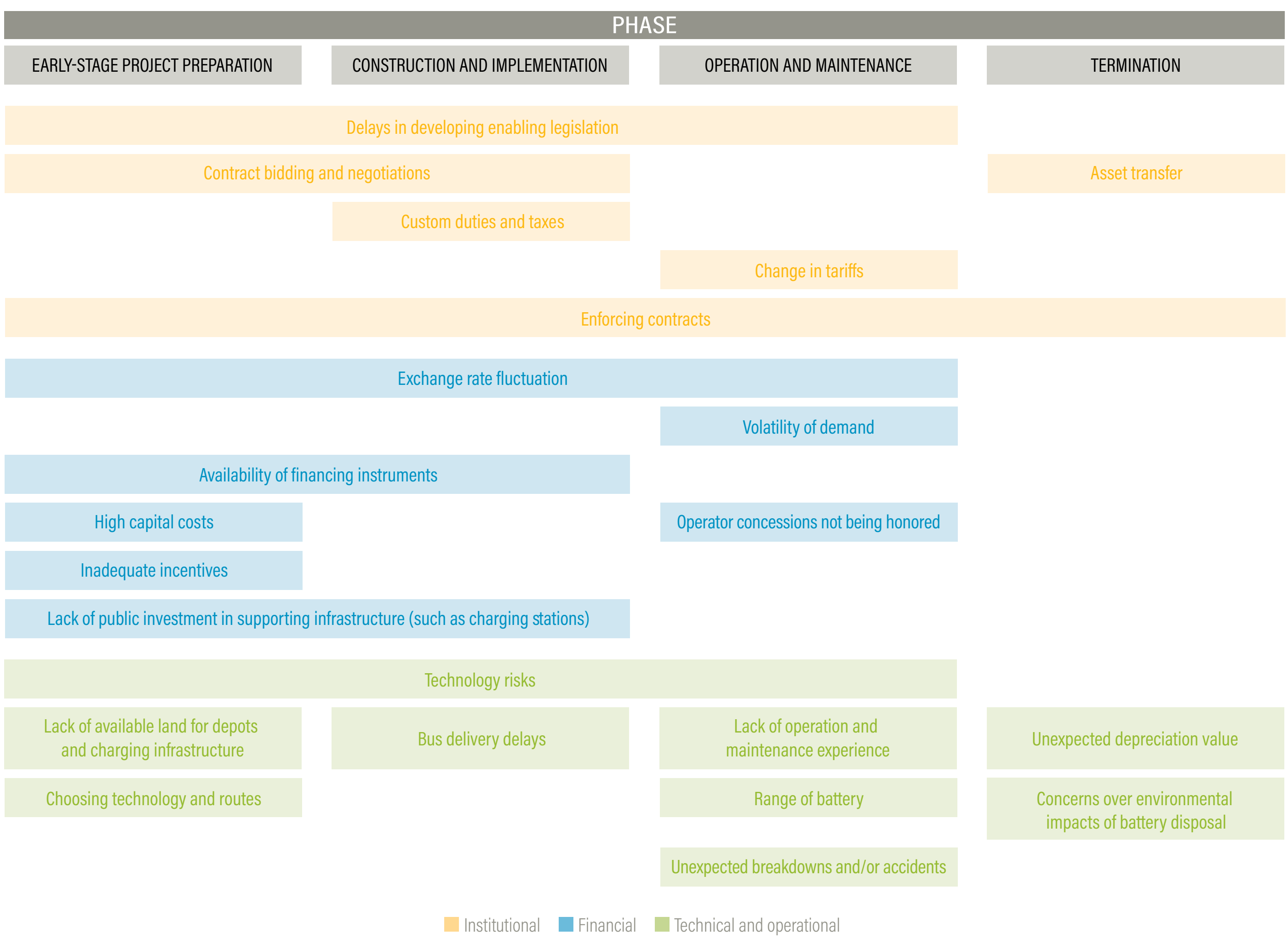
Q9.2.1 Enabling legislation and policy

In the early stages, there may be delays in developing enabling legislation and preparing public procurement and tender documents (in the case of private operation). These risks are higher if the city is introducing significant changes in its procurement or contracting system, and this could also provoke operator opposition, especially if operators are neither consulted nor included along the way. As a new technology that still relies significantly on public support programs, electric buses can be significantly affected if policies and regulations are reversed. For example, if the regulatory ruling of the California Public Utilities Commission were reversed, this would result in unanticipated cost increases for Foothill Transit, which secured a three-year reprieve on the daytime electricity rates it pays to the energy company, Southern California Edison (CPUC 2012).

Q9.2.2 Stakeholder coordination

Stakeholder coordination is another constraint, as new stakeholders, such as bus and charging infrastructure manufacturers, and utility companies are now involved with bus operating entities and transit agencies. Manufacturers often have difficulty engaging with cities, and it may

Figure 1 | **Summary of Investment Incentives in Electric and Hybrid-Electric Buses**



Source: Based on case study research.

be difficult to coordinate duties throughout the life span of a bus. It is similar within policymaking entities. More sectors—such as transport, environment, energy, and technology-related sectors in national, regional, and city governments—need to coordinate and make supporting policies to adopt electric buses.

Q9.2.3 Long-term planning

In addition, a lack of long-term planning may also impact the adoption of electric buses. For instance, there is not yet substantial experience with the termination phase. Bus batteries have an average expected life of around seven years, but the eventual disposal of used batteries is a question that still needs to be addressed on a large scale. In the future, guidelines and legislation may emerge that set responsibilities for different parties, such as battery manufacturers and operators.

Figure 1 summarizes the risks and challenges cities face over the different stages of the project development cycle.

QUESTION 10: WHAT ARE KEY STEPS CITIES HAVE TAKEN TO ENSURE GREATER SUCCESS WHEN ADOPTING ELECTRIC AND HYBRID-ELECTRIC BUSES?

This section outlines some of the emerging success factors from the financial perspective. For more details about enabling conditions from the technical and institutional points of view, please refer to the WRI report *How to Enable Electric Bus Adoption in Cities Worldwide* (Li et al. 2019), which identifies key actions that can help cities at different development stages to adopt electric buses.

Q10.1 Perform Cost-Benefit Analyses

As discussed in question 1, TCO is the key metric that tips the financial decision in favor of investing in electric buses. It is a comprehensive measure of the capital and operational expenditures over a specified ownership period. According to some estimates, electric buses can be cost competitive on a TCO basis with both diesel and compressed natural gas buses (BNEF 2018). Therefore, it is important to get a full picture of the potential costs and benefits over the lifetime of an electric bus before making the decision to procure them. The cost-benefit analysis can be revisited with real operational inputs from pilot and testing projects to help make more suitable procurement, operation, and financing decisions.

In addition, financial planning is another key factor to ensure a sustainable long-term adoption of electric buses given the financial needs and uncertainty, especially for large-scale adoption. The presence of a local innovation ecosystem and culture of cross-sector collaboration enables a diverse set of actors and resources. In cities such as Bogotá, Gothenburg, and Pomona Valley, partnerships with utility companies and bus manufacturers have been particularly important. These stakeholders have an interest in expanding electric mobility and therefore might be willing to take on additional risks or costs to help secure long-term resources for large-scale adoption.

Q10.2 Formalize a Flexible Procurement Plan and Optimize Risk Allocation

To embed the total cost of ownership and social benefits in bus operations, some cities are switching contracting practices from a capital acquisition model to a TCO model. This removes the bias that can exist against technologies like electric buses, which have higher up-front costs but lower maintenance expenses and higher environmental benefits (Miller et al. 2017). In practice, this involves changes in contracting practices, such as allowing operators to keep the same bus on the road for a longer period, which, in turn, provide ways to repay the additional up-front costs. In addition, making procurement more flexible can also allow operators to choose between purchasing and leasing buses and components, depending on their ability to take on debt and technical risks.

The need for a balanced distribution of investment risks between actors holds true regardless of the mode of bus provision. Many cities recognize the importance of finding ways to allocate credit and technical risks so that the operator (public or private) can focus on the principal task of bus service delivery. With typically low profit margins and limited cash flow, operators are oftentimes not the strongest party in the investment, financially speaking. In getting public electric buses on the road, operators already have a steep technical learning curve, but training provided by manufacturers and service contracts can help smooth the transition by providing a sort of safety net. However, expecting operators to simultaneously take on additional new financial responsibilities may overburden them.

Thus, flexible procurement and contracting plans are needed to optimize risk allocation. Greater flexibility in procurement and contracting can also create states of exception in which experimentation is possible outside of the norm. This was the case in Stockholm's 2013 pilot of eight biodiesel–electric hybrid buses and two fast-charging stations. According to normal contracting, private operators are responsible for owning, maintaining, and operating buses. In the pilot, however, responsibility was shared among the different stakeholders: the buses were supplied and maintained by Volvo and were cofunded by the European Union; the transit authority (Stockholm Public Transport) provided the bus depot; Siemens supplied the fast-charging stations, which were built and maintained by Vattenfall; and Keolis was selected to operate the buses (Volvo Buses 2014). In China, many cities used a financial leasing mechanism during the bus procurement stages; this gave bus operators more flexibility and reduced their financial risk and burden. This is another highlight that encouraged the electric bus increase in China after governmental subsidies.

Q10.3 Train Bus Operators and Invest in Human Capital

To reap the full benefits of electric and hybrid-electric buses, cities have been building up capacity and know-how around them as a new technology of public service provision. The need for expertise on up-to-date knowledge of available technology, equipment, and materials applies to several dimensions of the service. For transit agencies and local governments, for instance, it has been important to develop in-house technical capacity or to hire experts to help with the technical aspects of route planning, charging station siting, and the administrative procedures of designing, tendering, and managing public service and concession contracts. This includes drafting clear specifications for the requirements, compliance standards, and contract terms as well as holding transparent bidding and approval processes.

Similarly, on the operational side, it is essential to train drivers and maintenance staff in driving techniques, routine maintenance tasks, and daily upkeep and repairs. For example, optimal route selection can increase the success of hybrid-electric buses due to the fact that stop-and-go conditions increase the benefits of the regenerative braking, whereas ICE buses would be more polluting in these circumstances. As in the case of Bogotá's hybrid-electric buses, the manufacturer (Volvo) became more involved in the operation and maintenance of the fleet by providing training to the operator's technicians, who had previously worked with diesel technology. In the English town of Milton Keynes, over 30 drivers received training with a special focus on awareness in areas with high pedestrian traffic (since the buses are less noisy) as well as bus troubleshooting. When capacity building is included as a key component, the technology risk decreases.

CONCLUSION

In today's rapidly urbanizing world, with poor local air quality and issues related to global climate change negatively impacting the lives of millions, transitioning public bus fleets to cleaner technologies, such as electric and hybrid-electric buses, should be considered an important part of mobility and transport plans.

This publication sought to shed light on some of the more important questions and considerations that decision-makers encounter before, during, and after they commit to electric or hybrid-electric buses. An awareness of these considerations will help cities successfully improve the quality of their public bus fleets through informed decisions about the different technologies, plans, operations, procurement strategies, regulations, and financing opportunities. A clearer understanding of the real-world benefits and risks of investments in electric and hybrid-electric buses will also help to demystify some common misconceptions related to the topic.

It is important to remember that there is no one-size-fits-all solution to urban mobility, particularly when it comes to public bus provision in cities. Any city looking to transition its public fleet to electric and hybrid-electric buses will have to uniquely adapt its plans and strategies to local conditions. It is crucial to perform a robust assessment and evaluation of the nature and status of the city's existing public transport network before making any investment decisions in electric or hybrid-electric buses. This will allow decision-makers to make decisions about the types of technology, procurement strategies, and ownership structures, among others. Finally, from the financing point of view, a city should consider these key questions before investing in electric and hybrid-electric buses: How will the city pay for the buses? What incentives exist to help reduce costs and risks? And what institutional frameworks are in place or are needed to ensure the completion and financial feasibility of the project?

As the landscape of electric and hybrid-electric buses continues to rapidly evolve, there are a range of questions and considerations that would be interesting to explore with further research. Some of these emerging topics include the role of public authorities in supporting the operators in overcoming the technological risks of change; the responsibilities and risks that should be taken on by vehicle suppliers to allow these technologies to scale up; the importance of collaboration and partnership between transport, energy, and planning authorities; and the importance of creating standard methodologies to better assess the social benefits of electric buses.

APPENDIX A: CASE STUDIES

Table A1 lists the 26 case studies relating to the electric and hybrid-electric bus fleets that were selected from 200 cataloged examples around the globe. The selection was based on geographic distribution, the availability of system performance data, and consultation with experts.

Table A1 | **Case Studies of Electric and Hybrid-Electric Bus Adoption, June 2017**

NO.	CITY	NAME	TYPE	OWNERSHIP, MANAGEMENT, AND OPERATION	FUNDING SOURCES	INCENTIVES	FINANCE
1	Auckland, New Zealand	City Circuit	Hybrid-electric	Public/private		▪ Capital expenditure grant	
2	Berlin, Germany	E-Bus Berlin	Battery-electric	Public		▪ Capital expenditure grant ▪ Operational expenditure grant ▪ Research, development, and demonstration grant	
3	Bogotá, Colombia	Bogotá Hybrid Bus	Hybrid-electric	Public/private	▪ Public transportation budget	▪ Capital expenditure grant ▪ Private grant ▪ Import duty tax ▪ Value-added tax reduction ▪ Corporate tax break	Concessional loan
4	Colombo, Sri Lanka	e-BRT	Battery-electric	Public/private		▪ Public grant ▪ Capital expenditure grant ▪ Operational expenditure grant ▪ Private grant	
5	Curitiba, Brazil	HibriBus	Hybrid-electric	Public/private	▪ Farebox revenue ▪ Public transportation budget		Concessional loan
6	Gothenburg, Sweden	Gothenburg Hyperbus	Hybrid-electric	Public/private		▪ Public grant ▪ Capital expenditure grant ▪ Private grant	
7	Gothenburg, Sweden	Gothenburg ElectriCity	Battery-Electric	Public/private		▪ Public grant ▪ Capital expenditure grant ▪ Private grant	

Table A1 | **Case Studies of Electric and Hybrid-Electric Bus Adoption, June 2017 (Cont'd)**

NO.	CITY	NAME	TYPE	OWNERSHIP, MANAGEMENT, AND OPERATION	FUNDING SOURCES	INCENTIVES	FINANCE
8	Gumi, South Korea	Gumi OLEV	Battery-electric	Public		▪ Public grant ▪ Capital expenditure grant ▪ Private grant ▪ Research, development, and demonstration grant	
9	London, England	London Hybrid Bus	Hybrid-electric	Public/ private	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure grant ▪ Environmental impact tax	
10	London, England	London Electric Bus	Battery-electric	Public/ private	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure Grant ▪ Environmental impact tax	
11	Milton Keynes, England	Electric Bus Demonstration	Battery-electric	Public/ private		▪ Public grant ▪ Capital expenditure grant ▪ Private grant	
12	Nanjing, China	Nanjing Electric Bus	Battery-electric	Public		▪ Public grant ▪ Capital expenditure grant	
13	Paris, France	Paris Electric Bus	Battery-electric	Public/ private	▪ Farebox revenue ▪ Public transportation budget	▪ Private grant ▪ Payroll tax	
14	Philadelphia, Pennsylvania	Philadelphia Hybrid Bus	Hybrid-electric	Public	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure grant	
15	Philadelphia, Pennsylvania	Philadelphia Electric Bus	Battery-electric	Public	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure grant	
16	Pomona Valley, California	Foothill Transit	Battery-electric	Public/ private		▪ Public grant ▪ Capital expenditure grant ▪ Land grant ▪ Sales tax ▪ Electricity tariff rebate	
17	Rome, Italy	MIRACLES Project	Battery-electric	Public		▪ Public grant ▪ Capital expenditure grant ▪ Environmental impact tax	

Table A1 | **Case Studies of Electric and Hybrid-Electric Bus Adoption, June 2017 (Cont'd)**

NO.	CITY	NAME	TYPE	OWNERSHIP, MANAGEMENT, AND OPERATION	FUNDING SOURCES	INCENTIVES	FINANCE
18	Seattle, Washington	Seattle Hybrid Bus	Hybrid-electric	Public	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure grant ▪ Sales tax	
19	Seattle, Washington	Seattle Electric Bus	Battery-electric	Public	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure grant ▪ Sales tax	
20	Shenzhen, China	Shenzhen Electric Bus	Battery-electric	Public	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure grant ▪ Corporate tax break	
21	Singapore	Singapore Hybrid Bus	Hybrid-electric[a]	Public/ private	▪ Public transportation budget	▪ Public grant ▪ Capital expenditure grant ▪ Private grant	
22	Stockholm, Sweden	Stockholm Hybrid Bus	Hybrid-electric[a]	Public/ private		▪ Public grant ▪ Capital expenditure grant	
23	Tianjin, China	Tianjin Electric Bus	Battery-electric	Public		▪ Public grant ▪ Capital expenditure grant	Green bond
24	Toronto, Canada	Toronto Hybrid Bus	Hybrid-electric	Public	▪ Farebox revenue	▪ Public grant	
25	Turin, Italy	Turin STAR	Battery-electric	Public	▪ Public transportation budget	▪ Capital expenditure grant ▪ Sales tax	
26	Zhuhai, China	Zhuhai Electric Bus	Battery-electric	Public		▪ Public grant ▪ Capital expenditure grant ▪ Corporate tax break	

Notes: Some cities may have more than one project or procurement package, but because the general structures are similar, detailed information is not shown here.
[a] These cities have since tested or implemented electric buses.

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ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

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