



# E-BUS SOLUTION BOOKLET

Smart Cities Marketplace 2023

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ENERGY

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The Smart Cities Marketplace is an initiative supported by the European Commission bringing together **cities, industry, SMEs, investors, banks, research and other climate-neutral and smart city actors**. The Smart Cities Marketplace Investor Network is a growing group of investors and financial service providers who are actively looking for Climate-neutral and smart city projects.

The Smart Cities Marketplace has thousands of followers from all over Europe and beyond, many of which have signed up as a member. Their common aims are to **improve citizens' quality of life, increase the competitiveness of European cities and industry** as well as to **reach European energy and climate targets**.

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## WHAT & WHY

# WHAT AND WHY

## The need for e-buses

Transport emissions are on the rise – between 1990 and 2020, global CO<sub>2</sub>-emissions from transport grew by 58%.<sup>\*,\*\*</sup>

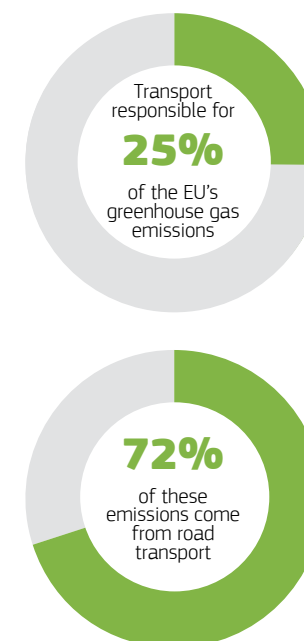
Currently, transport is responsible for 25% of the EU's greenhouse gas emissions, and 72% of these emissions come from road transport.<sup>\*\*\*</sup>

Traffic congestion remains an issue in urban areas, as pollutants such as PM2.5, PM10, and nitric oxides that are emitted by road transport have severe impacts on the environment and human health.

Additionally, noise pollution from vehicles also carries negative impacts; noise pollution is associated with poorer health outcomes and lower overall well-being and quality of life. 18 million people in the EU are suffering from long-term annoyance due to transport noise.<sup>\*\*\*\*</sup>

European cities recognise the issue road transport presents in urban areas and are seeking to address this. The sales of e-buses in Europe [increased six-fold from 2016 to 2021](#).

Alongside this, initiatives such as the Clean Bus Deployment Initiative<sup>\*\*\*\*\*</sup> are helping to promote the sale of clean buses and move towards a decarbonised transport system. Urban solutions such as the e-bus reduce emissions, improve quality of life and strengthen the economy by reducing susceptibility to fossil fuel price spikes.



\* Crippa, M., Guizzardi, D., Solazzo, E., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Banja, M., Olivier, J.G.J., Grassi, G., Rossi, S., Vignati, E., GHG emissions of all world countries – 2021 Report, EUR 30831 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-41547-3, doi:10.2760/173513, JRC126363

\*\* Transport includes road transport, non-road transport, domestic aviation and inland waterways for each country. International shipping and aviation also belong to this sector.

\*\*\* European Environment Agency (2021): [Decarbonising road transport — the role of vehicles, fuels and transport demand](#)

\*\*\*\* European Environment Agency (2022): [Outlook to 2030 — Can the number of people affected by transport noise be cut by 30%?](#)

\*\*\*\*\* [European Clean Bus Deployment Initiative](#)





# E-BUSES CITY CONTEXT

## E-bus market

E-buses currently represent [6.1% of the sales](#) of new buses in Europe.

The decarbonisation of public transport systems will be crucial as European countries and cities move towards a net zero economy, and as such, the e-bus market will continue to expand.

Cities in Europe that have different topographies, demographics, climates, electricity grids, and urban planning styles will face different challenges in the implementation of e-buses.

Projects must be tailored to the needs of individual cities.



## Case studies

Project name, city, country	E-bus solution
<a href="#">SmartEnCity</a> , Vitoria-Gasteiz, Spain	13 electric buses were introduced into the public mobility system, transforming the circular bus line around the city with the highest number of passengers into a clean electric bus line.
<a href="#">mySMARTLife</a> , Hamburg, Germany	The e-bus fleet of 105 vehicles uses 124 charging points spread over three locations. E-buses are charged overnight to help address the <a href="#">challenge of storing renewable energy</a> .
<a href="#">mySMARTLife</a> , Nantes, France	E-bus charging takes place at fast charging stations.* This helps <a href="#">avoid peaks in electricity consumption</a> and also avoids impacting the operation of the line that transports up to 55,000 passengers per day as e-buses are charged en route. The implementation of the 22 e-bus lines in Nantes has reduced energy consumption by 30% compared to fossil-fuelled buses.
<a href="#">REPLICATE</a> , San Sebastian, Spain	This project procured three electric buses and three hybrid buses for a bus route travelling between a district and the city centre. Two charging stations were also installed.

\* Fast charging stations charge the e-bus while passengers board and exit the bus.





**SOCIETAL AND USER  
ASPECTS**



## SOCIETAL AND USER ASPECTS

### Stakeholder Benefits

The implementation of e-buses benefits a range of stakeholders; citizens, public transport authorities, industry, bus drivers and users of the bus services.

For citizens, the benefits include:

- ☑ Less noise pollution;
- ☑ Better air quality;
- ☑ Less greenhouse gas emissions.

For public transport authorities, the benefits are:

- ☑ Achieve low emission targets;
- ☑ Improve air quality;
- ☑ Reduce societal cost on public health due to better air quality;
- ☑ Improve public perception of the city;
- ☑ Reduce fuel costs by transitioning to renewable energy and providing flexibility in energy demand.

I like the reduced noise, allowing me to enjoy my walks more.

This bus line received positive feedback during its journey. People were relaxed and enjoying their trip.

I love the new electric buses a lot and would like to see more in the future.

The new electric bus has such soft and nice benches. Good for my back pain! Also so quiet! Almost too quiet.

**For industries they:**

- ☑ Stimulate the domestic e-bus industry;
- ☑ Advance to a circular economy by opening opportunities such as second-life batteries;
- ☑ Improve the corporate public image.

**For bus drivers and users, the benefits are:**

- ☑ Less vibration;
- ☑ Comfortable and easy to drive;
- ☑ Less noise;
- ☑ Improved passenger comfort and better customer experience.

Extreme cold and hot weather [decrease the efficiency of e-buses](#): a decrease in temperature from an ambient temperature of 10 - 16°C down to -6 - 0°C will [decrease fuel efficiency by 32%](#)<sup>\*</sup>.

**Implementation challenges**

Despite the benefits of e-buses, challenges arise with their implementation.

- Getting permits for constructing the charging infrastructure can be time-consuming, particularly in regions with many historical sites,
- Identifying locations for charging infrastructures, considering the impact on electricity grids, other road users, and overall urban planning. Local topography and climate can impact e-bus driving ranges, especially in hilly and cold environments.<sup>\*\*</sup>

<sup>\*</sup> Henning, M., Thomas, A., & Smyth, A. (2019). An Analysis of the Association between Changes in Ambient Temperature, Fuel Economy, and Vehicle Range for Battery Electric and Fuel Cell Electric Buses. Urban Publications. 0 1 2 3 1630.

<sup>\*\*</sup> Henning, M., Thomas, A., & Smyth, A. (2019). An Analysis of the Association between Changes in Ambient Temperature, Fuel Economy, and Vehicle Range for Battery Electric and Fuel Cell Electric Buses. Urban Publications. 0 1 2 3 1630



## Lessons learnt

Barriers		Suggested actions
<b>Range anxiety/fear</b>	Bus drivers might be psychologically concerned on e-bus and battery reliability, mainly due to the concerns on the driving range (range anxiety). They also need to adapt their driving habits.	Provide information and training (eco-driving, energy monitoring training). Fast charging stations (en route, when passengers are boarding or exiting the bus) could also help negate this.
<b>Maintenance</b>	While maintenance needs are substantially lower with e-buses compared to conventional buses, practical experience in the maintenance and repair of e-buses is limited.	Offer training to the workforce around electrical equipment, high-voltage technology, and maintenance procedures. The available experience and existing expertise from trams and metros can be beneficial.
<b>Safety on road</b>	Buses are running silently, therefore, some safety measures might need to be taken in order to avoid that other drivers or pedestrians don't notice the buses	Increase awareness via polite warning bells for pedestrians, similar to trams, colourful designs of the buses.
<b>Battery safety</b>	Battery safety remains an issue in case of fire and unexpected accidents.	Inform different stakeholders (drivers, maintenance staff, firefighting department) in advance and avoid misconceptions related to battery safety.
<b>Change route and time table</b>	Public transportation authorities and operators might refuse to alter the bus route and timetable for electric buses, which might further lead to changes on all the other transportation timetables.	Be open to adapting routes or timetables to better match the e-bus use profile. Analyse and optimise the route and timetable, which will also bring economic savings.



## TECHNICAL SPECIFICATIONS



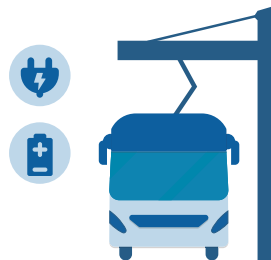


# TECHNICAL SPECIFICATIONS

## Overview of technologies

### Different types of electric buses

E-buses are vehicles with zero in-use emissions propelled by an electric powertrain and powered by a storage device (e.g. batteries, fuel cell). Current technologies available on the market are:



Battery Electric Vehicles (BEV)



Plug-in Hybrid Vehicles (PHEV)



Trolleybus with batteries



Fuel cell bus

### Battery Electric Vehicles (BEV)

A battery electric bus is an all-electric vehicle with an electric propulsion system powered by rechargeable onboard battery packs, using an electric motor and motor controllers for propulsion instead of an internal combustion engine.

### Plug-in Hybrid Vehicles (PHEV)

Similarly to BEVs, plug-in hybrid buses achieve motion through an electric motor using rechargeable batteries, with the difference of having an additional internal combustion engine powered by conventional fuel (e.g., diesel). The batteries are rechargeable by plugging into the electrical grid.

### Trolleybus with batteries

These are bus-type vehicles propelled by an electric motor, drawing power from either overhead wires via connecting poles called trolleys, from ground contact, or onboard rechargeable batteries. This enables the vehicles to run electrically while independent of the charging infrastructure for part of their route while maintaining full operational capability.

### Fuel cell bus

Fuel cell hydrogen buses use electric energy produced through an electrochemical reaction both for the powertrain and for support battery charging. Energy stored in the batteries adds additional power in demanding situations like rapid acceleration or slopes. Only water and heat are emitted because of the use of hydrogen as a fuel. However, using hydrogen as a fuel for buses is neither efficient nor sustainable.

This solution guide is mainly focused on the full battery electric bus.

## Charging options and infrastructures\*\*

The most typical charging options for fully electric battery buses are **opportunity and destination charging** (typically called overnight charging).

Destination charging occurs when the bus finishes its shift at the depot and is linked to longer charging times, where smart infrastructure can reduce costs due to dynamic tariffs, self-consumption, or peak power reduction.

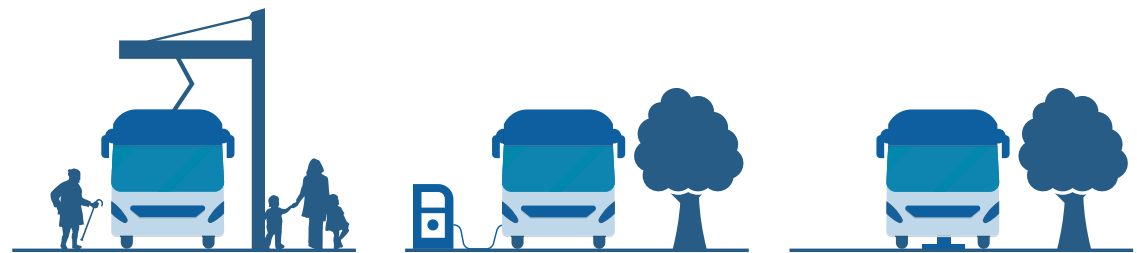
Alternatively, opportunity charging takes place at bus stops along the bus route, with the possibility of being combined with destination charging.

Both charging options can be combined for a specific bus, allowing the bus to leave the depot fully charged and charge small amounts during its route to maximise the length of its route.

There are two main types of infrastructure for charging electric buses: pantograph overhead charging and plug-in systems.

**While the plug-in is mostly used for destination charging, pantograph charging is used for both opportunity and destination charging.**

Recent technological and business developments enable road charging through retrofitting onboard charging elements and implementing a smart power road strip. The ongoing charging mechanism makes this full battery a trolleybus solution as the electric road charges the onboard rechargeable batteries, extending the bus' driving range. Even though this technology is not currently widely used, a broader implementation is expected.



Opportunity charging (often combined with destination charging)	Destination charging	Road charging (emerging)
<p>Small battery size;</p> <p>Short free range: &lt;100 km;</p> <p>Limited route operational flexibility;</p> <p>Recharging needed multiple times a day, and at the end of each day (overnight)</p> <p>Short charging time: seconds to minutes, with longer charging times overnight;</p> <p>Charging infrastructure en-route, and at the terminal;</p> <p>Expensive.</p>	<p>Large battery size;</p> <p>Medium free range: up to 550 km;</p> <p>Higher route operational flexibility;</p> <p>Recharging at the end of each day (overnight);</p> <p>Long charging time: usually measured in hours (2 up to 10 hours);</p> <p>Charging infrastructure only at the bus terminal;</p> <p>Cheaper.</p>	<p>Small battery size;</p> <p>Short free range: &lt;100 km;</p> <p>Limited route to operational flexibility;</p> <p>No stopping needed to charge;</p> <p>Charging infrastructure en-route;</p> <p>Technology not widely used</p> <p>Expensive.</p>

\* Transport& Environment, electric buses arrive on time

\*\* CIVITAS, Smart choices for cities - Clean buses for your city



These charging technologies have pros and cons. Much depends on the routes that the bus is going to serve:

- Opportunity charging aims to minimise the weight of the onboard battery pack by recharging the e-bus along the route at passenger stopping points. It uses roof-mounted pantograph equipment to connect the bus and the overhead power supply systems, and charging begins after the bus has arrived at the charging site and the pantograph is extended and made contact with the charger.
- Opportunity charging only requires a short period (less than 1 min).
- Opportunity charging is becoming increasingly popular for new e-bus fleets in European countries. However, issues such as visual intrusion, urban landscape impact, and local power connection restrictions of the charging points and their complex operational planning must be considered.
- Destination charging needs the electric bus to carry a larger battery (typically above 600 kWh for ranges of 500 km and more). This method requires lower power at the depot level (50-150 kW). Currently, destination charging with plug-in systems at the depot is significantly cheaper and more popular compared to the opportunity charging with a pantograph.
- Combining destination and opportunity charging allows for limiting the charging stations along the route while extending the range of the bus.



The charging time largely depends on the power of the charging station and battery technology. High-power charging infrastructure and en-route charging options can lower the number of required electric buses.



Cities and municipalities should choose the most suitable charging technologies by taking into account their specific context, including type and a number of electric buses, battery capacity, electricity grids, bus route (length, topography), passenger capacity, city planning and any other service requirements.



© Siemens Mobility

## KPIs

### Technology maturity

Electric buses are proven technologies and market-ready. From a technical point of view, there are little to no barriers to implementing e-buses on large scale.

### Energy

Charging e-buses with electricity has a major impact on primary energy consumption and CO<sub>2</sub>-emissions.

- Average electrical energy consumption in kWh per km
- Annual electricity consumption in MWh
- Peak power when charging in kW
- Presence of regenerative braking technology

### Emissions KPIs:

- GHG, NOx, and PM10 emissions saved in g per km
- Annual GHG, NOx, and PM10 emissions saved in tons (per year)

### Other solution-specific KPIs:

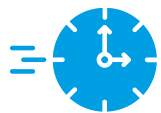
- Noise reduction
- Driving range in km
- Other pollutants emission saved in g pollutant per km
- Other pollutants saved annually in kg or ton pollutant per year
- Maximum amount of passengers
- Re-use of batteries in other applications, so-called 'second-life' (e.g., stationary energy storage)



Innovative technology



Saving tons of CO<sub>2</sub> emissions



Shortening charging time



Increasing driving range



Decreasing noise



Type	Diesel bus		CNG bus		E-bus (full battery) – Opportunity charging	E-bus (full battery) – Destination charging (often combined with opportunity charging)
Range [km]	600-900		350 – 450		<200	(currently up to) 550
Refilling/charging time	5-10 min		5-10 min		Seconds to a few minutes	Several hours
Emission - CO <sub>2</sub> eq [g/km]	1000 (EURO V)	1000 (EURO VI)	1000 (CNG 2013)	800-850 (CNG 2020)	0	
Emission - NOx [g/km]	3.51 (EURO V)	1.1 (EURO VI)	1.4 - 4.5 (CNG 2013)	0.88 (CNG 2020)	0	
Emission - PM10 [g/km]*	0.1 (EURO V)	0.03 (EURO VI)	0.005 - 0.03 (CNG 2013)	0.024 (CNG 2020)	0	
Energy consumption 2012 [kWh/km]	4.13		5.21		1.8	1.91
Energy consumption 2030 [kWh/km]	3.89		5		1.15	1.68
Noise [dB]	80		78		60	

\* Engine related emissions

Numbers extracted from the Clean Bus Report, Sustainable-bus.com, and CIVITAS report, [Smart choices for cities - Clean buses for your city](#)

The main difference between a conventional diesel bus and a CNG bus is the local pollutants (NOx and PM10).



## Lessons learnt

Barriers		Suggested actions
<b>Reliability and lifetime of battery pack</b>	Battery degradation and reliability remain a primary issue, and battery life is influenced by various factors: battery type, driving profile, the climatological situation, charging strategy, and operational battery use (depth of discharge, number of battery cycles, average state of charge).	<p>Make contractual arrangements (maintenance, extended warranty) to cover risks associated with battery life expectancy. A regular battery warranty is usually five to seven years and can be optionally extended with an extra warranty fee.</p> <p>Implement second-life battery use strategies or ensure they are part of the purchasing or leasing contract.</p>
<b>Total weight limitation</b>	The total maximum weight describes a vehicle in operation and is a parameter used to specify weight limitations and restrictions for its use. This might lead to a loss of passenger carrying capacity and capacity to accommodate unexpected fluctuations in route demand. This also influences the acceleration, driving range, and useful load of the electric bus.	<p>Compare various e-bus offers as continuous R&amp;D developments lead to the greater energy density of batteries.</p> <p>Evaluate the use of trolleybus systems to increase passenger capacity and decrease battery size, though considering the cost of infrastructure related to it.</p>
<b>Energy consumption due to heating, cooling, and ventilation</b>	Heating, cooling and ventilation could significantly influence the energy consumption and driving range of the electric buses.	<p>Opt for efficient heating, cooling, and ventilation technologies. Include the efficiencies of such comfort-providing technologies as part of the selection criteria during the tendering phase.</p>
<b>Interoperability</b>	Charging infrastructure and e-buses from different manufacturers might not be compatible with each other.	<p>Include compliance with standards (among others ISO 15118, prEN50696, and ISO 61851) in the tendering and selection.</p>
<b>Impact on grids</b>	Electric buses (especially with opportunity charging) could have a huge impact on electricity grids. Current electricity network infrastructures might be under-dimensioned. It might be difficult for suburban areas to get connections to the electric grids.	<p>Involve grid operators at an early phase, and plan the charging systems with various charging impact analysis scenarios on the grids.</p> <p>Implement solar parks on bus depots to decrease the impact on the local grid.</p> <p>Use smart charging technologies.</p>
<b>Process management</b>	Lack of bus operational data (e.g., energy consumption, battery status) and back office functioning might lead to a lack of clarity during operation.	<p>Implement charging/operational management software to monitor e-bus data, CO<sub>2</sub>-emissions, and charging costs.</p> <p>Ensure this information is communicated to the relevant stakeholders, to optimise the operational process.</p>



# BUSINESS MODELS AND FINANCE

## Cost parameters of e-buses

E-buses have much lower operational costs than their diesel equivalents; based on research covering multiple projects with fleets of over 100 e-buses, savings in the operational costs were over 50%, while savings in maintenance vary more with values [ranging from non-savings to nearly 40%](#).

Although operational costs are lower, high upfront costs\* are a characteristic of e-buses which can make them unattractive.

Currently, investment costs for both the e-buses and the infrastructure are nearly double the investment for traditional buses\*\*.

The different costs associated with e-buses are:

- Acquisition of e-bus;
- Acquisition of battery;\*\*\*
- Charging infrastructure;
- Operational costs (energy consumption);
- Maintenance costs of bus;
- Retraining of bus drivers.

\* Much of the upfront cost of E-buses is battery costs.

\*\* Potkány et al (2018), [Comparison of the Lifecycle Cost Structure of Electric and Diesel Buses](#).

\*\*\* E-bus batteries currently have an estimated battery life of 5-8 years, compared to a bus lifetime which can be up to 20 years. This means batteries must be replaced, and as a result, batteries can constitute up to 50% of lifetime costs



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The capital cost is mainly defined by the battery cost. However, it is expected that through research and development, the battery prices for e-buses will decrease by 9% to 12% annually on average from 2016 - 2030 depending on the level of demand in the European market.\*\*\*\*

\*\*\*\* E-bus are much heavier than diesel or hybrid equivalents, and the weight is distributed differently, thus, some training is required to help bus drivers get used to e-buses. Training is also required to teach drivers to drive efficiently



Local authorities could estimate the cost of implementation with decision **support tools** designed to assist cities and bus agencies in the deployment of the most suitable electric bus fleet technology based on data from pilot tests.

Pilot projects show that an effective cost estimation is to be **tailored to the local context** and includes assessment and changes to routes, evaluation of energy cost reductions through renewable energy and flexibility, and costs related to potential adaptations to the distribution grid.

When taking into account the broader picture by quantifying socioeconomic and environmental costs and benefits to society in the analysis, including **public health benefits** (noise, air pollution) and **environmental impacts** (climate change) that contribute to **achieving energy and emission targets**, the cost to society of e-buses is much lower than the TCO to the owner.

These benefits are part of the reason e-buses have been pursued even when, from a direct cost perspective, they may appear more expensive than diesel equivalents.

Reductions in the Total Cost of Ownership (TCO) due to reduced asset prices (mainly the battery and the charging infrastructure) and the exploitation of the buses' energy flexibility will encourage European cities to adopt e-buses following the example of leading cities such as Bergen (Norway), Eindhoven (Netherlands), and Groningen (Netherlands).



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## Possible funding models

1. **Pay upfront for all:** the most common option currently, which can be funded in a number of ways, including grants, concessional loans, and subsidies.
2. **Joint purchasing/procurement:** costs are shared by more than one party to increase the volume secured and lower the upfront costs.
3. **Capital lease:** a (generally) low-cost financing tool for local authorities, the local authority can lease the bus with the option to purchase the vehicle at the end of the term.
4. **Operational lease:** pay for the use of a bus over time, with the option to pay to own the bus.
5. **Battery supply contract:** owning the bus but reducing upfront costs by leasing the battery, which can be paid for per kWh of use or over a fixed period.
6. **The second life of EV batteries:** e-bus batteries can be reused for stationary energy-storage services that are suitable for their reduced capabilities after intensive use in the e-bus industry, and following this second life they can recycle for their [valuable rare-earth materials](#). Utilising this can reduce e-bus lifecycle costs thanks to providing a resale value to the batteries.

7. **Rental:** a short-term solution for bus authorities or bus operators looking to “test drive” before making a long-term purchasing decision.
8. **Other:** the e-bus ownership stays with the manufacturer, while in some pilot projects cities could use the bus for free, in order to help the manufacturer test the bus performance in real-world conditions.

There are also varying business models for the purchase of electricity for e-bus fleets.

		Sale of Electricity	
		Direct	Indirect
Ownership of e-bus fleet	Public	The local authority purchases electricity from the grid, and uses it for its fleet/ public bus fleets and does not charge for electricity.	The local authority purchases electricity from the grid, public fleet pays the local authority for charging of e-bus.
	Private	The private e-bus fleet operator pays for the electricity, local authority only charges for the occupation of a parking lot.	The local authority purchases electricity from the grid and the private e-bus fleet operator pays the local authority.

## KPIs

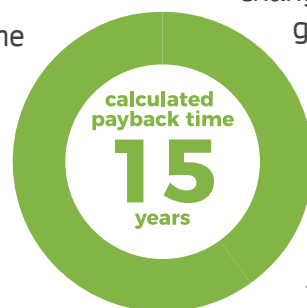
### Investment vs. total cost of ownership (TCO)

E-buses have lower operational costs which make them already cheaper than conventional diesel buses. However the high upfront cost of e-bus is still one of the major obstacles that makes e-buses less financially interesting and competitive comparing with the conventional buses.

The most influential cost parameters of the electric bus are:

- Acquisition cost of the bus;
- Acquisition cost of battery pack;
- Charging infrastructure cost;
- Operational cost - energy consumption;
- Maintenance cost for bus;

TCO depends on many different factors, such as **battery cost, fuel/electricity prices, driving distance, charging infrastructure, maintenance, implementation scale and subsidies**. It can vary largely according to the **country or city specific context** and the factors that are taken into account in the TCO calculation.



Some exemplary calculations have concluded that, electric buses could potentially offer better TCO than conventional buses, when taking into account the broader picture by quantifying socio-economic and environmental costs and benefits to society into the analysis, including public health (noise, air pollution) and environmental impacts (climate change). However, it should be noted that there is no generally accepted calculation method of accounting for these secondary benefits.

### Return on investment (ROI)

In the Netherlands, there are business cases with a calculated payback time of less than 10 years on large scale implementation in certain cities. In the Flemish region of Belgium, according to a feasibility study on zero emission buses, without taking into account flexibility matter, the business case of large scale electric buses could pay back between 10-15 years.\*

Revenue mainly comes from the saved operational cost of the electric buses. In general, e-buses are relatively more profitable with a longer total driving distance and in the cities/regions with lower electricity price and higher fossil fuel price. An optimised ratio between charging infrastructure and buses will also largely increase the profitability, while a detailed technical and economic analysis is a must.



Acquisition cost of the bus



Acquisition cost of battery pack



Maintenance cost for bus



Charging infrastructure

\* Results based on expert interview



## Financing schemes for e-buses

High upfront costs can make e-buses unattractive to local authorities. To counteract this, governments are offering financing schemes to encourage the procurement of e-buses. Currently, most cities use a form of a grant to cover the upfront cost of an electric bus. Grants usually come from the public sector and are given to public bus operators. The grants take one of two forms:

- Grants to cover **upfront costs** of electric buses, and the accompanying infrastructure;
- Grants to cover **operational costs**, as many bus operators may feel uncertain about operating new technologies.

These grants can either take the form of cash, tax breaks, or subsidies for user fares. Also, green bonds (similar to a regular bond, except capital raised is used specifically to finance climate-related or environmental projects) have previously been used to finance electric buses.

Grants and green bonds are common where bus operators are public. However, private bus operators are likely to finance their e-buses differently. In cases where private operators source the e-buses themselves, concessional loans have been provided by various bodies (e.g., banks and international funds) to finance both the purchase and operation of e-buses\*.

\* Thorne, R., Hovi, I., Figenbaum, E., Pinchasik, D., Amundsen, A., Hagman, R. (2021). Facilitating adoption of electric buses through policy: Learnings from a trial in Norway. Energy Policy, Volume 155, 112310.

An example of both grants and loans being offered is in **Poland** – in June 2020, the Polish Ministry of Climate Change announced that in order to promote the purchase of electric buses it will offer two schemes for the financing of up to 95% of purchase costs of e-buses.

According to the number of inhabitants and income per citizen, a city will get access to either a loan or a subsidy. The other number of inhabitants in the municipality and the income structure per inhabitant will decide which scheme is eligible for each municipality. The scheme will focus on municipalities with poor infrastructure. It is estimated that the financing will allow the procurement of up to 300 e-buses and 75 charging stations.

Further reading: [Polish Ministry of Climate launches e-bus support schemes - electrive.com](#).



Electric bus in Nantes, France. © mySMARTlife project

## Lessons learnt

Barriers		Suggested actions
High up-front cost	The cost of an e-bus and dedicated infrastructure is usually 1.5 - 2 times higher than the cost of a conventional bus. The cost of the battery is around half of the whole bus cost.	<p>Funding and financing supportive schemes on purchasing electrical buses. Incentives for implementing e-buses could be:</p> <ul style="list-style-type: none"> <li>• Subsidies (local, national, EU)</li> <li>• Fiscal incentives (lower taxes for electricity)</li> <li>• Grants</li> <li>• Green bonds</li> </ul> <p>Automotive battery costs per kWh are reducing at a rate of 9 - 12% per year, which will also reduce upfront costs.</p>
Risks of battery usage	Battery lifetime is one of the major concerns for financiers	<p>De-risk by taking into account the extended warranty on battery parts, and battery second life.</p> <p>In the future, second-hand batteries might be used together with PV for building energy storage or grid services.</p>
Value depreciation and TCO	Value depreciation and TCO models are based on the specific local context.	<p>Increase bus lease contract length to bus lifetime to spread depreciation over the whole lifetime of the bus.</p> <p>Increasing supply will have a secondary effect of reducing the price of e-buses and other associated costs.</p>
Charging infrastructure cost and installation	Investment in charging infrastructure is rather costly, together with possible associated costs of additional infrastructure of electric grids.	<p>Adapt and leverage charging infrastructure for other transport types to share costs, as mentioned in ELIPTIC Policy Paper*: e-trucks, electric private coaches, e-cars, etc. Involve grid operators in an early stage to incorporate these costs.</p> <p>Apply smart charging to benefit from dynamic prices and participate in grid services.</p>



\* ELIPTIC. [Policy Recommendations: electrification of public transport in cities](#).





# GOVERNANCE AND REGULATION

## Challenges faced by governments

The European continent is now committed to fighting climate change in part by achieving a net zero society no later than 2050. **Moving towards net zero means moving towards a society characterised by the stability of prices and security of energy.** The decarbonisation of public transport will be part of this process. Aside from national-level goals for decarbonisation, cities must understand the need to decarbonise and how this can be done.

Local authorities have the best knowledge of their area and thus are well-placed to deliver best practices in respect of their e-bus projects.

There are a variety of stakeholders involved in e-buses:

- Public transportation authorities (PTA);
- Public transportation operators (PTO);
- Manufacturers (both bus and charging infrastructure);
- Electrical grid operators (DSO, TSO);
- Service providers for maintenance and operations;
- Authorities are responsible for urban/city planning.

Due to the complexities e-buses present, all stakeholders must be clear on their roles. Policy papers provide a good framework for local governments to base their work on.



Electric bus charging. © Getty images

## Policy recommendations



The technical and administrative procedure of the charging infrastructure planning can be complex due to the involvement of various stakeholders.

A clear high-level regulation framework and political support are of utmost importance in pushing e-bus solutions to a larger scale.

The Eliptic policy\* recommendations are a framework that brings together various stakeholders in a city.

Evaluating various approaches for electrifying public transport in cities across Europe, the framework supports a multi-purpose charging infrastructure for public transport that will be more cost-efficient and therefore encourage procurement of electric public transport vehicles.

An example of where the **Eliptic strategy** has already been implemented in **Barcelona**. The city of Barcelona has 1.6m inhabitants, is known for its vibrant street life and tourism industry, and the city offers a wide range of bus and tram connections.

These are run by two organisations; TMB (local transport operator), in charge of operative connectivity and tendering tasks and CENIT (research institute), coordinating and controlling all other tasks and operations.

Together they have implemented **two types of charging infrastructures, both centred around charging e-buses utilising existing metro infrastructure**.

The first model involves **destination depot charging** while metro lines are not being used, while the second model involves **fast charging at opportunity charging points** on the line, with a short overnight charge to ensure batteries start the day fully charged.



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\* ELIPTIC. [Policy Recommendations: electrification of public transport in cities](#).



## Risk management

One of the biggest risks concerning e-buses is the uncertainty surrounding battery lifetime and performance. Certain aforementioned business models could potentially lower this risk.

Several parties should work together to share the risks and at the same time learn from the electric bus implementation process. In addition, it is also necessary to **lower the risk in the tendering process** by carefully **defining the service/operation provider's contract length and extensions**, and it is important to cover all possible scenarios (e.g. increasing maintenance costs when buses age, batteries aging faster than expected) in order to create trust and clarity.



© Getty image



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## Lessons learnt

Barriers		Suggested actions
<b>Lack of clear framework</b>	Cities and municipalities do not have a clear regulatory framework or legislative powers to introduce a framework for a clean public transportation system	Set a clear policy/legal framework at both the local and national levels. Consider introducing emission reduction targets and low-emission zones (with public consultation and far ahead notice), and give a clear signal to potential investors.
<b>Planning of the charging infrastructure</b>	There are many uncertainties and complexities when planning the charging infrastructure in the urban context. Many factors must be taken into account: charging locations, charging times, battery capacity, and charger availability.	Clarify the responsibilities for the electrification of public transport among different stakeholders at the political level (transportation, energy, city planning, etc.).
<b>Stakeholder responsibility</b>	Mobility (bus lines and timetables), energy (charging) and space (charging location) interact, and it can be complex to take into account all the different aspects in the planning, and take time for proper implementation.	Work together to share the risks and at the same time learn from the collaboration process. A system approach is important: involve stakeholders at an early stage, and identify the corresponding roles.
<b>Charging service</b>	Charging service quality can suffer from an overly complicated setup due to the involvement of too many stakeholders and complex procedures.	Use charging as a service model, especially when organising opportunity charging. Set up a clear interface between charging and operation, and service providers take care of charging, while PTO should provide the necessary data.
<b>Risk</b>	High upfront costs create a high level of risk for bus operators.	Consider the range of financing options available, such as; grants, green bonds and concessional loans.





## GENERAL LESSONS LEARNED



## GENERAL LESSONS LEARNT

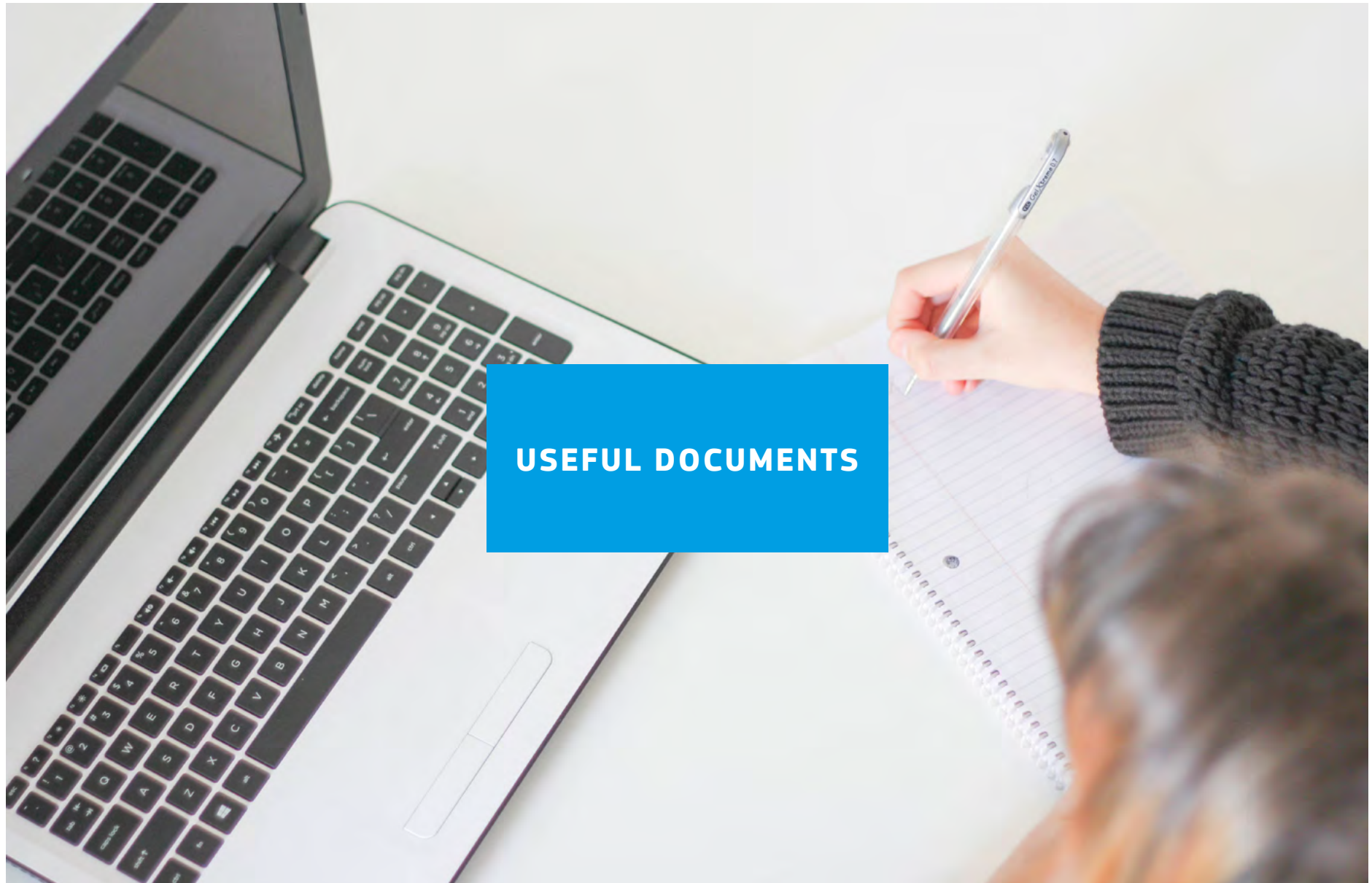
1. Cities should try and start with pilot projects, learn from existing deployments of e-buses and their operation, **identify issues, find solutions, and scale them**.
2. Cities and municipalities should try and **learn from real-life use cases** of e-bus implementation. Many cities have introduced e-buses into their public transport system; identifying cities with a similar typology and **learning from their successes and challenges** will be useful.
3. **De-risking** is a must. The risks associated with battery life expectancy and reliability should be foreseen and included in the contract during the tender process, and such risks could be managed by making contractual arrangements (e.g., maintenance, extended warranty on batteries). A **clear and detailed** risk-free (or risk-limited) **business plan** will help to convince financiers to make the required investments. Various TCO calculations have shown that **e-buses can be profitable**.
4. A clear **regional policy framework** is required to implement e-buses in a region. A **flexible yet systematic approach** is vital when deciding on the e-bus type (fully electric, hybrid), charging infrastructures and strategies (opportunity charging, destination charging) by taking into account the local context and specific service requirements. At the same time, an optimised ratio between charging infrastructure and buses will also increase the profitability of the scheme. Charging infrastructure can be used more frequently if shared among different transport types, and thus the costs can be shared. Charging locations need to be well planned with the involvement of many different stakeholders.
5. Exploring various options for funding e-buses (both upfront and operational costs), such as using grants, concessional loans, and green bonds, are likely to encourage both public and private bus operators to procure an e-bus fleet. Increasing market demand for e-buses will also reduce future costs.
6. Different stakeholders need to have a clear agreement and common consensus on roles and responsibilities. Coordination of bus operators alongside operators of other electrical infrastructure, city-level transport bodies, and other bodies such as research institutes. Allowing these stakeholders to work together under a clear framework will allow the e-bus implementation to be more effective and lower risk.

7. Demand bundling and aggregation could have a high impact, while joint procurement might be important to reduce the high upfront cost of both e-buses and charging infrastructure.
8. It is of great importance for the PTO and/or service providers to monitor the use of e-buses and acquire operational and charging data, and analyse the data to get insights on bus operation. This information should be communicated among different technical stakeholders in an organised and structural way to properly manage the bus operation and charging processes. Dissemination of this data could also help other regions implement e-buses.
9. PTAs and PTOs should be flexible in adapting current bus routes or public transport timetables to better match the e-bus fleet profile to take into account charging time.
10. A clear high-level regulation framework and political support are of utmost importance in pushing the e-bus solution to a larger scale, which will further stimulate the demand and drive supply in the EU e-bus market. Best practices can be very valuable and guide EU cities in the transition process towards the electrification of public transport



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## USEFUL DOCUMENTS AND RELEVANT EXAMPLES

### E-bus policy and information

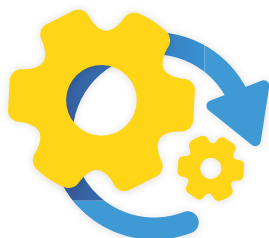
- ✈ [European Urban Mobility Policy Context](#)
- ✈ [Smart choices for cities - Clean buses for your city](#)
- ✈ [Electric buses arrive on time - Marketplace, economic, technology, environmental and policy perspectives for fully electric buses in the EU](#)
- ✈ [Electric Buses in Cities - Driving Towards Cleaner Air and Lower CO<sub>2</sub>](#)
- ✈ [ZeEUS eBus Report – An updated overview of electric buses in Europe](#)
- ✈ [Zero Emissie Busvervoer Vlaanderen](#)
- ✈ [ELIPTIC Policy Recommendations - electrification of public transport in cities](#)
- ✈ [UITP - The Impact of Electric Buses on Urban Life](#)
- ✈ [Going electric - a pathway to zero-emission buses](#)
- ✈ [Decarbonising road transport The role of vehicles, fuels and transport demand](#)
- ✈ [European Clean Bus Deployment Initiative](#)
- ✈ [OPTIMOB - Decision support tool for bus line electrification](#)
- ✈ [ELIPTIC - E-Bus Decision Support Tool](#)
- ✈ [Optimob decision support tool for bus line electrification](#)

### Smart Cities and Communities project websites and deliverables on e-buses

- ✈ [IRIS](#)
- ✈ [mySmartLife](#)
- ✈ [SmartEnCity.eu](#)
- ✈ [Triangulum](#)
- ✈ [REPLICATE](#)
- ✈ [REMOURBAN](#)
- ✈ [MAchUP](#)

## Smart Cities Marketplace

The Smart Cities Marketplace is a major market-changing enterprise supported by the European Commission bringing together cities, industries, SMEs, investors, researchers and other smart city actors. The Marketplace offers insight into European smart city good practice, allowing you to explore which approach might fit your smart city project. [Discover our digital brochure here.](#)



### Matchmaking

The Smart Cities Marketplace offers services and events for both cities and investors on creating and finding bankable smart city proposals by using our Investor Network and publishing calls for projects.

[Investor network](#)

[Call for projects](#)

[Project finance masterclass](#)



### Focus and Discussion groups

Focus groups are collaborations actively working on a commonly identified challenge related to the transition to smart cities. Discussion groups are fora where the participants can exchange experience, cooperate, support, and discuss a specific theme.

[Focus and Discussion groups](#)

[Community](#)



### EU initiatives

Apart from the smart cities marketplace, there are a number of adjacent EU initiatives focusing on making European cities better places to live and work.

[Other EU initiatives](#)



# **E-BUS SOLUTION BOOKLET**

Smart Cities Marketplace 2023

The Smart Cities Marketplace is managed by the European Commission Directorate-General for Energy