E-BUS
SOLUTION BOOKLET

EU Smart Cities Information System

SCIS Smart Cities Information System | April 2019 | version 2.0

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WHAT IS THE SMART CITIES INFORMATION SYSTEM?

The Smart Cities Information System (SCIS) brings together project developers, cities, institutions, industry and experts from across Europe to exchange data, experience, know-how and to collaborate on the creation of smart cities and an energy-efficient urban environment.

WHAT IS A SOLUTION BOOKLET?

A summary of the management framework, primarily written for cities. It seeks to reduce the effort, speed up the process, strengthen quality and confidence in outputs, align across disciplines, and generally prepare a city to engage the market to acquire a solution.

WHAT IS “PACKAGING”?

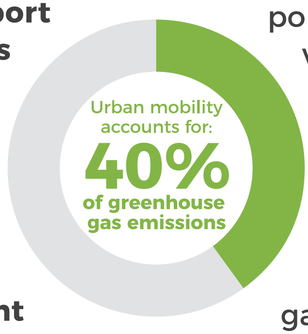
‘Packaging’ addresses the societal needs, technical solutions, business models and financing for a measure – and offers ways to put these in the particular context of the city/ cities in question. It is supported by a growing number of templates to speed up and make consistent the resulting output.

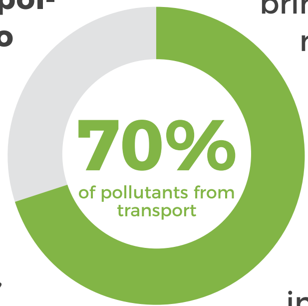
WHAT & WHY

WHAT & WHY

Urban mobility accounts for 40% of greenhouse gas emissions of road transport and up to 70% of other pollutants from transport[1]. Congestion and traffic accidents remain problematic with increased number of vehicles on the road. Particulate matters and nitric oxides that are emitted by road transport can significantly affect the environment and human health, while the noise pollution from urban road traffic can do harm to both human health and behaviour.

European cities are working together to improve life quality for their citizens and strengthen the economy, and they aim to achieve sustainable, safe, clean and energy efficient urban transport systems by reducing congestion, accidents, pollution and the dependency on conventional fuels.





The public transportation system plays an important role in resolving congestion and various environmental issues in urban areas, especially by using clean fuel. The electric bus (e-bus) offers considerable advantages for sustainable public transportation systems in European cities. It can significantly reduce the emissions of greenhouse gases, air pollutants and noise, but also bring greater passenger comfort while making public transport more attractive for the citizens. Many of the leading European public transport authorities have released clear and strong messages (e.g. Clean Bus Deployment Initiative) to move towards cleaner public transportation systems in the upcoming years and decades.

This solution booklet presents electric buses' replication potential and barriers from a technical, financial, social and governance perspective. Desk research, expert interviews with different stakeholders and webinars were conducted in order to gather experiences from various EU/national/regional/local projects in different European countries.

1 European Commission

CITY CONTEXT

CITY CONTEXT

E-buses accounted for 1.6% of all municipal buses on the roads in Europe in 2017[1], and the e-bus market continues growing. Over the past years, many European cities have launched different pilot projects on electric buses. The typology of the bus route could be both in the city centre and suburban area, while the topography could be both hilly and flat. The scale of e-bus implementation could range from one single service line to the entire bus fleet of a city or region. The average economic lifetime of an e-bus is approximately 15 years.

The solution of the electric bus is closely linked to other smart city solutions, such as grid flexibility, multi-modal transport, mobility as a service (MAAS) and urban data platform.

Project	E-bus solution
Triangulum	Rogaland County Council (Stavanger) has deployed 3 new battery buses in Triangulum project. The aim is to gain experience on state of the art technology, and reduce carbon emissions. The County Council has decided to have a fossil free fleet by 2025.
REPLICATE	REPLICATE Lighthouse City San Sebastián aims to electrify one public bus line with 2 electric and 2 hybrid buses, which links the district with the city centre.
REMOURBAN	REMOURBAN Lighthouse City Valladolid deployed 3 electric buses (1 full electric bus and 2 hybrid buses) with 4 fast charging stations. Nottingham City Council is developing a fleet of 50 e-buses to serve existing Link services and the 2 park and ride bus services. Tepebasi municipality will also purchase 4 e-buses.
MAtchUP	The MAtchUP project aims to implement 24 e-buses in its three Lighthouse Cities: Valencia (10 full electric buses + 8 hybrid), Dresden (4 e-buses) and Antalya (2 e-buses).
mySMARTLife	The City of Nantes is implementing 22m bi-articulated e-buses with opportunity charging along the 7 km bus line with 4 charging points (2 terminus and 2 regular stops). The City of Helsinki also aims to electrify the current bus fleet with full battery electric buses from both EU and Chinese manufactures.
IRIS	In the IRIS project, the City of Utrecht, together with its partner Qbuzz, is accelerating the switch to zero-emission public transport. Currently there are already 10 full battery electric buses in service.[1]

1 Bloomberg New Energy Finance

1 The IRIS partner Qbuzz, will help the Dutch region Groningen-Drenthe to deploy a fleet of 181 electric buses. The e-fleet will consist of 159 battery-electric and 22 hydrogen-electric buses. The introduction of the e-fleet in Groningen-Drenthe amounts to the biggest transition to electric transport in Europe so far.

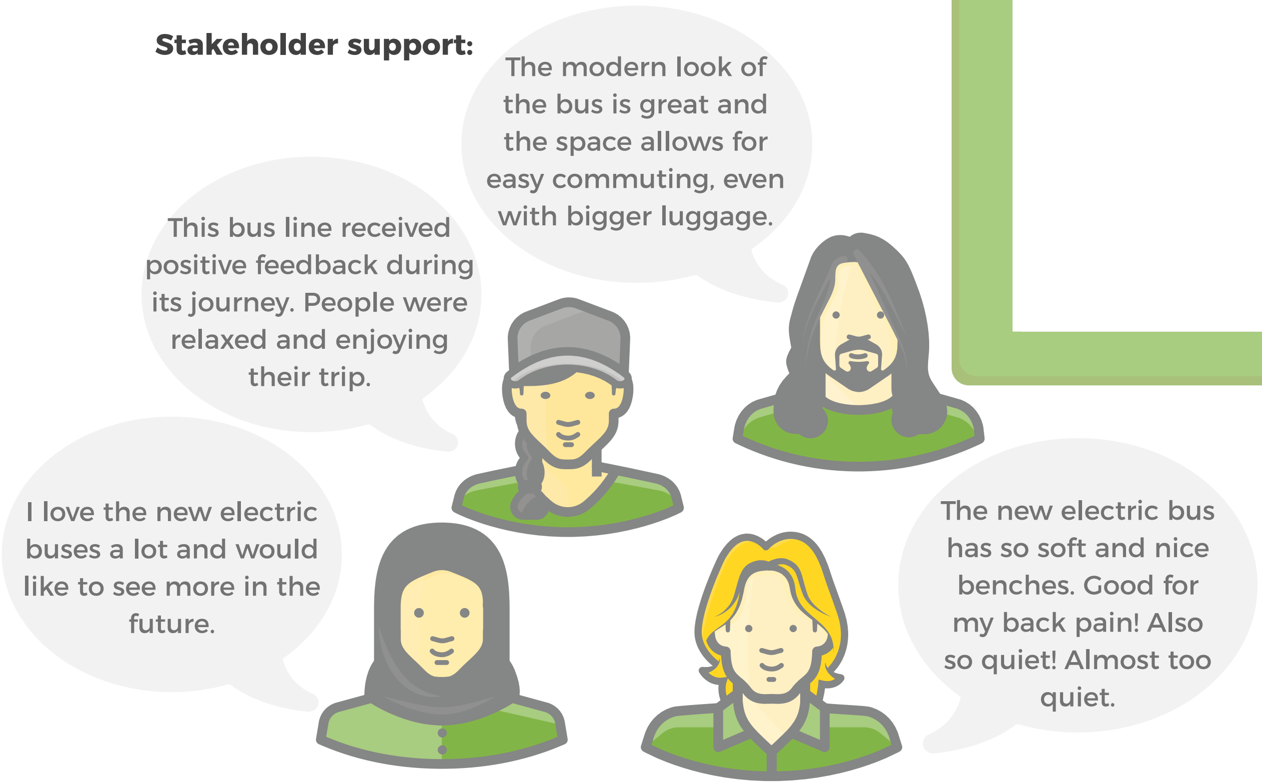
SOCIETAL & USER ASPECTS

SOCIETAL & USER ASPECTS

Stakeholder support, citizen engagement & co-creation

Due to growing environmental pollution, many different stakeholders start to realise the importance of clean solutions in the public transportation systems. Therefore, the e-bus, as one of the most sustainable solutions, is generally well supported by the whole society.

Stakeholder support:



CITYZENS

- ✓ Less noise in the streets
- ✓ Less pollution, better air quality
- ✓ Less greenhouse gas emissions

PUBLIC TRANSPORT AUTHORITY (PTA)/ PUBLIC TRANSPORT OPERATOR (PTO)

- ✓ Achieve low emission target
- ✓ Improve air quality
- ✓ Reduce congestions with well-planned electric bus lines and timetables
- ✓ Better service to the passengers
- ✓ A better image of the city
- ✓ Reduced societal cost on public health due to better air quality

Stakeholder support:

INDUSTRIES

- Stimulate e-bus related business
- Create more jobs
- Improve corporate public image with this sustainable solution

Special events (e.g. bus outfit design competition, free electric bus tour) could increase the public awareness of the clean electric buses and engage the citizens to use these buses.

BUS DRIVERS:

- Less vibration
- Comfortable and easy to drive

BUS USERS:

- Less noise inside the bus
- Less vibration
- Improved passenger comfort and better customer experience

Resistance:

Cities have noticed the importance and benefits of having electric buses. However, in reality, there still exist different voices in the implementation phase, which are mostly related to charging.

- Getting the permit for constructing the charging infrastructure could be time-consuming and increase the risk level for e-bus project.
- Different stakeholders need to work together and find an optimal location for the charging infrastructures, as different aspects need to be taken into account: impact on the electrical grids, other road users and overall urban planning.
- Electrical grid operators might have concerns about the impact on the electrical grids from e-buses.
- Public transportation authorities and operators might need to alter the bus time table for electric buses, which might further lead to subsequent changes on all the other transportation time tables.
- Bus drivers might have difficulties in fully trusting e-buses in the beginning, however, they can quickly adapt their driving habits to e-buses under proper guidance.

Lessons learned

Barriers		Suggested actions
Range anxiety/fear	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 psychological interventions and training (eco-driving, energy monitoring training), and communicate real time information (battery status, remaining range) to drivers via dashboard.
Maintenance	The practical experience on the maintenance and repairing of e-buses are lagging behind (not yet available at the same quality as with internal combustion engine).	Offer trainings to the work force on electrical equipment, high-voltage technology, and maintenance procedures. The available experience and existing expertise from trams and metros could be beneficial.
Safety on road	Buses are running silently without too much noise, therefore, some safety measures might need to be taken in order to avoid the situation that other drivers or pedestrians don't notice the buses.	Increase the awareness by polite warning bells for pedestrians, similar to trams, and colourful designs of the buses.
Battery safety	Battery safety remains an issue in case of fire and unexpected accidents.	Inform different stakeholders (drivers, maintenance staff, neighbours, firefighting department) in advance and avoid misperceptions related to battery safety.
Change route and time table	Charging brings issues within the framework of transport regulation orders. Public transportation authorities and operators might refuse to alter the bus route and time table for electric buses, which might further lead to changes on all the other transportation time tables.	Be open to adapt route or timetables to better match the e-bus profile, since now, the whole system is designed based on the use of diesel buses. Analyse and optimise the route and time table, which will bring economic savings.

TECHNICAL SPECIFICATIONS

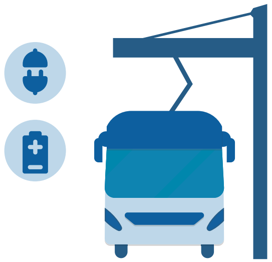
TECHNICAL SPECIFICATIONS

Description
– components of the system

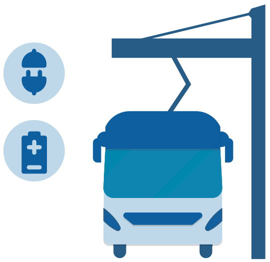
Different types of electric buses

An electric bus is powered by electricity from the storage devices (e.g. batteries, fuel cells). Different types of electric buses are available on the market, including:

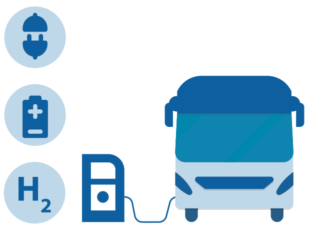
Plug-in hybrid bus



Full battery electric bus



Trolleybus with batteries



Fuel cell bus

A **plug-in hybrid bus** combines the characteristics of both conventional and full electric bus: it is equipped with both an internal combustion engine and an electric motor, thus it can use either conventional fuel in the fuel tank (i.e. diesel), or electricity stored in batteries which are rechargeable by plugging into the electrical grid.

Unlike the conventional plug-in hybrid bus with both internal combustion engine and electric motor, a **full battery electric bus** is propelled solely by an electric motor and its related controllers, with the electricity from on board battery packs.

A **trolleybus** with batteries is propelled by an electric motor, and the electric energy is supplied either directly via the overhead wires, or from on-board rechargeable batteries. It can be charged either via overhead line or ground contact.

A **fuel cell bus** is another emerging type of electric bus, and it uses hydrogen fuel cells as the power source for regular operation through the electro-chemical reaction (hydrogen -> electricity), with batteries and supercapacitors serving as peak power source. It is argued as "hybrid" due to the hybrid architecture with hydrogen fuel cell and batteries. The fuel cell needs to be re-fuelled at hydrogen refuelling stations.

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

Charging options and infrastructures[1 2]

The most typical charging options for the **full electric battery bus** are overnight charging and opportunity charging.

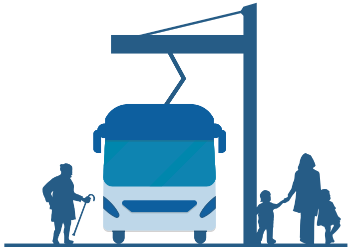
With **overnight charging**, electric buses are charged statically overnight from the grids at the depot using mechanical and electrical equipment, while **opportunity charging** allows the electric buses to be charged at the bus stops along the bus route or the bus terminal. There are two main types of infrastructure for charging electric buses: **pantograph** overhead charging for opportunity charging mode and **plug-in** systems for overnight charging mode.

Both options have pro's and con's:

Opportunity charging aims to minimise the weight of the on-board 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 the charging begins when the bus arrives at the charging site and the pantograph is extended to make contact with the charger. E-buses with opportunity charging usually have small to medium battery capacity (typically 40-150 kWh) and need regular high power (150 up to 600 kW) rapid charging at intermediate bus stops within a short period of time (less than 1 min) or the terminal (a few minutes). Opportunity charging is becoming more and more popular for new e-bus fleets in European countries.

Overnight charging needs the electric bus to carry the battery (typically >200 kWh) which is required to drive the entire bus route without recharging. Currently, overnight charging with plug-in systems at the depot is a lot cheaper and more popular compared to the opportunity charging with pantograph.

Overnight charging



Opportunity charging

Opportunity charging	Overnight charging
• Small battery size • Short free range: <100 km • Unlimited range during operation • Limited route operational flexibility • Recharging needed multiple times a day • Short charging time: seconds to some minutes • Charging infrastructure en-route in the city • Expensive	• Large battery size • Medium free range: 100 - 250 km • Insufficient range during operation • Higher route operational flexibility • Recharging at the end of each day (overnight) • Long charging time: usually in hours (2 up to 10 hours) • Charging infrastructure only at the bus terminal • Cheap

1 Transport& Environment, electric buses arrive on time
2 CIVITAS, Smart choices for cities - Clean buses for your city

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

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

Siemens eBus charging station (photo © Siemens Mobility)

KPIs

TRL

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

Energy

Charging the e-buses with electricity generated from renewable sources has a major impact on primary energy consumption and CO_2 emissions.

KPI's

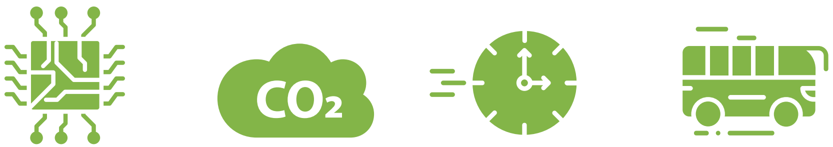
- Time need to charge to 80% respectively 100%
- Average electrical energy consumption in kWh per km
- Annual electricity consumption in MWh
- Peak power when charging in kW
- Presence of regenerative breaking technology

GHG emissions KPI's:

- GHG emissions saved in g CO_2 per km
- Annual GHG emissions saved in ton CO_2

Other solution specific KPI's:

- 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



Innovative technology | Saving tons of CO_2 emissions | Shortening charging time | Increasing driving range

TYPE	DIESEL BUS		CNG		E-BUS (full battery) - opportunity charging	E-BUS (full battery) - overnight charging
Range [km]	600-900		350 – 400		<100	100 - 250
Refilling/charging time	5-10 min		5-10 min		Seconds to a few minutes	2 -10 hours
Emission - CO2eq [g/km]	1000 (EURO V)	1000 (EURO VI)	1000 (CNG 2013)	800-850 (CNG 2020)	500	
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		1.58	1.68
Noise [dB]	80		78		60	

1 These numbers are extracted from expert interviews and the 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 learned

Barriers		Suggested actions
Reliability and lifetime of battery pack	Battery degradation and reliability remains a primary issue, and its lifetime is influenced by various factors: battery type, driving profile, climatological situation, charging strategy, battery management system.	Make contractual arrangements (maintenance, extended warranty) to cover risks associated with battery life expectancy. Regular battery warranty is usually 5-7 years, and can be optionally extended with extra warranty fee
Total weight limitation	The total maximum weight describes a vehicle, that is in operation, and is used to specify weight limitations and restrictions. The total weight limitation issue is caused due to the extra weight of battery pack. This might lead to a loss of passenger carrying capacity and capacity to accommodate unexpected fluctuations in route demand. This also influences the acceleration and payload of the electric bus.	Increase total weight allowance for e-bus, which helps e-bus to have the same carrying capacity as conventional buses. Battery is becoming lighter and with more energy density
Energy consumption due to heating and cooling	Heating and cooling could significantly influence the energy consumption and driving range of the electric buses.	Use additional heat pump/heater with biodiesel or hydrogen.
Interoperability	Charging infrastructure and e-buses from different manufactures might not be compatible.	Develop open standards to prevent "lock-in solutions" and as precondition for public funding and market uptake. Standardisation of charging infrastructure is important.
Impact on grids	Electric buses (especially with opportunity charging) could have a huge impact on the electricity grids. Current electricity network infrastructures might be under dimensioned. It might be difficult for suburban areas to get connections to the electric grids.	Involve grid operators at early phase, and plan the charging systems with various charging impact analysis scenarios on the grids.
Process management	Bus operational data (e.g. energy consumption, battery status) availability and back office functioning might cause unclarities during operation.	Monitor e-bus operational/charging data, analyse the data to get insights on the bus operation, and communicate this information among different technical stakeholders in an organised and structural way, in order to properly manage the bus operation and charging process.

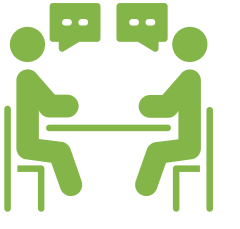
BUSINESS MODELS & FINANCE

BUSINESS MODELS & FINANCE

Description – possible business models

The most common business models are as follows[1]:

1. **Pay upfront for all:** still the most common option today, which is often funded by EU/national/regional/local governments, in combination with self-funding from operators.
2. **Pay for bus, battery leasing:** a way to reduce the high upfront costs, maintenance and repair costs for the battery are covered by the leasing company, which is responsible for the performance of the batteries through the life of the lease, removing operator risk.
3. **Joint purchasing/procurement:** by more than one party, to increase the volume and lower the high upfront costs.
4. **Capital lease:** a generally low-cost financing tool for local authorities, and the local authority can lease the bus with the option to own the bus at the end of the lease term.
5. **Operational lease:** pay for the use of a bus over time, with the option to own the bus.
6. **Rent all:** a short-term solution for bus authorities or bus operators looking to "test drive" before making a long-term purchasing decision.
7. **Bus sharing:** a few parties share the ownership of the electric bus.
8. **Other:** the e-bus ownership stays with the manufacture, in some pilot projects, cities could use the bus for free, in order to help the manufacture test the bus performance in real life. [2]



1 Bloomberg New Energy Finance

2 REPLICATE project – San Sebastián case

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;

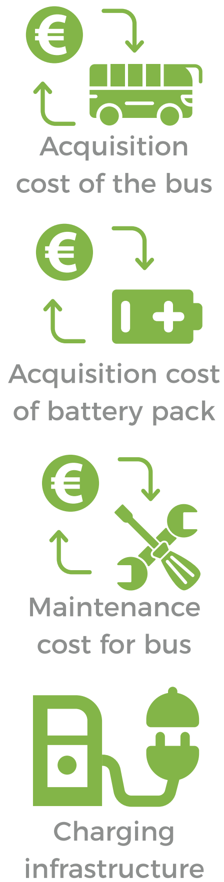
TCO depends on many different factors, such as battery cost, fuel/electricity prices, driving distance, charging infrastructure, maintenance, implementation scale and subsidies. It can vary largely according to the country or city specific context and the factors that are taken into account in the TCO 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. [1]

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.

1 Results based on expert interview



Replication opportunities & boundary conditions

E-bus solutions will become more and more important in the cities, especially for those cities that have committed towards a low carbon emission target. This market-ready solution offers the best way to go in order to decarbonise the public transportation systems.

The solution (e-bus type and charging option) is site specific and very much dependent on the city context and service requirements. The charging issue brings another level of complexity in large scale replication due to the cost, location and impacts on the electrical grids.

The demand for this solution is clear, while the main obstacle is the high upfront cost of both bus and charging infrastructure. Thus, the role of subsidies at all levels is still quite important nowadays, and the new emerging financing instruments could also facilitate the e-bus solution and help to increase the replication opportunities.

Lessons learned

Barriers		Suggested actions
High up-front cost	The cost of the e-bus is usually 1.5 - 2 times higher than the costs of a conventional bus. The cost of battery is around half of the whole bus cost, while the lifetime of the battery causes concern. Additionally, the associated charging infrastructure brings extra cost. Therefore there's not enough motivation from buyers to pay higher fares for e-buses.	Funding and financing supportive schemes on purchasing electrical buses. Incentives for implementing e-buses could be: • Subsidies (local, national, EU) • Fiscal (lower taxes for electricity) Automotive battery costs per kWh are going down at a rate of 10-14% annually, which will also reduce the upfront cost
Risks of battery usage	Battery usage is one of the major concerns for financiers.	De-risk by taking into account the extended warranty on battery parts and battery second life. In future, these second-hand batteries might be used together with PV for home energy storage.
Value depreciation and TCO	Value depreciation and TCO models are based on the specific local context.	Increase contract length to bus life time to spread depreciation over the whole life time of the bus.
Market competition	The production of electric buses in Europe are not at mass scale (low availability and high price) comparing with foreign manufactures, therefor European manufactures have to compete with foreign manufactures. Furthermore, some specific types of buses are not available on the current European market.	Set up a clear EU framework to stimulate market demand and drive the supply.
Charging infrastructure cost and installation	Investment in charging infrastructure is rather high, together with possible associated costs on additional infrastructure of electric grids.	Optimize the charging infrastructure and number of buses accordingly. Use charging infrastructure more frequently among different transport types and share the cost with: • heavy duty transport • private bus transport (e.g. freight logistic) Involve grid operators in an early stage to incorporate these costs.
Supplier reliability	Some smaller bus suppliers do not have local supporting offices. It might take time to get a fast response when problems occur.	Foresee these risks and include them in the contract.

GOVERNANCE & REGULATION

GOVERNANCE & REGULATION

Description – possible governance models & capacity building

In general, e-bus solutions are widely supported and encouraged by many cities and municipalities as measures to reach their targets of reducing CO_2 emission and air pollution.

E-bus project governance includes many different stakeholders related to transportation, energy and space planning, including:

- 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 responsible for urban/cities planning.

It is important for these different stakeholders to have a clear understanding and consensus about their roles and responsibilities. A systematic approach and good preparation of all stakeholders are key for the success in e-bus projects.

Capacity building:

In cities that already have e-buses, different stakeholders could learn from the e-bus implementation process. In addition, many international organisations (e.g. UITP) provide trainings on electric buses, with the aim to introduce e-bus to wider audiences interested in this solution but haven't implemented it yet in their cities and projects. Furthermore, drivers and maintenance crews could benefit from practical training courses provided by PTA, PTO, manufactures and service providers, and gain new skills on the electric bus driving, maintenance and repair. Specifically for drivers, targeted psychological guidance could be helpful to overcome their range anxiety.

Replication opportunities & boundary conditions

The technical and administrative procedure of the charging infrastructure planning could be complex due to the involvement of various stakeholders. Some authorities have a clear vision concerning electric buses, while others are hesitating between e-bus and other alternatives (e.g. CNG buses). A clear high-level regulation framework and political support is of utmost importance in pushing e-bus solutions to a larger scale.

A few European countries set good examples as frontrunners. For example, the Netherlands commits to switching to zero emission public transport (buses) by 2030, and all new public transport buses will be zero-emission from 2025 in order to achieve this target.

For many cities, it would still be challenging to move directly from the testing of single e-buses to the commercial tendering of e-bus services. A well-functioning e-bus eco-system is a must, and different stakeholders should take clear responsibilities and work together. EU best practice can give valuable input and guide EU cities in the transition process towards the electrification of the public transport.

CNG is around 1.1-1.2 times more expensive than a diesel bus.

An e-bus is 1.5-2 times more expensive than a diesel bus.

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.

Lessons learned

Barriers		Suggested actions
Lack of clear framework	Cities and municipalities do not have a clear regulation framework or legislative powers to introduce a framework for clean public transportation system.	Set a clear policy/legal framework at national level. Consider introducing low-emission zones by national governments (with public consultation and far ahead notice), and give a clear signal to potential investors.
Market competition	There's an increasing trend for pure electric powertrains (full battery electric and fuel cells). Meanwhile, diesel-hybrid, CNG and biogas have a stable percentage of the e-bus market.	Develop a policy framework for the development of e-bus systems at EU level. The other types of transport show little to no benefits in terms of CO_2 emission and/or air quality.
Planning of the charging infrastructure	There are many uncertainties and complexities when planning the charging infrastructure into the urban context. Many factors must be taken into account: charging locations, charging times, battery capacity, charging pole availability.	Clarify the responsibilities for electrification of public transport among different stakeholders at the political level (transportation, energy, city planning, etc.)
Stakeholder responsibility	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. System approach is important: involve stakeholders at an early stage, and identify the corresponding roles clearly.
Charing service	Charging service quality can suffer from too 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.

GENERAL LESSONS LEARNED

GENERAL LESSONS LEARNED

1. Cities should **try** and start with pilot projects, **learn** from e-bus real life operation, identify issues, find solutions, and **scale up**.
2. Public **funding** is still important in e-bus projects. **De-risking** is a must. The risks associated with battery life expectancy and reliability should be clearly 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 investment. Various TCO calculations have shown that e-bus can be **profitable**.
3. 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.
4. A flexible while systematic approach is vital when deciding on the **e-bus type** (full electric, hybrid…), **charging infrastructures and strategies** (opportunity charging, overnight charging) by taking into the account the local context and specific service requirements. At the same time, an optimized ratio between charging infrastructure and buses will also largely increase the profitability. Charging infrastructure could be possibly used more frequently among different transport types, thus the cost could be shared. Charging locations need to be planned well with the involvement of many different stakeholders.
5. It is important for different **stakeholders** to have a clear agreement and common consensus on the roles and responsibilities. A systematic approach and good preparation of all stakeholders are key for success in e-bus projects. All stakeholders should be involved as early as possible, identify their corresponding roles clearly, and finally work together to share the risks and at the same time learn from the collaboration process. A well-functioning e-bus eco-system is a must.

6. PTO should make efforts and **train** their staff well:
    - Psychological interventions and dashboards with bus operation information can be helpful for the bus drivers to overcome their range anxiety.
    - Trainings on electric systems should also be offered to the maintenance and repairing crew.
7. It is of great importance for the PTO and/or service providers to **monitor** the e-bus and acquire operational and charging data, analyse the data to get insights on the bus operation. This information should be communicated among different technical stakeholders in an organized and structural way, in order to properly manage the bus operation and charging process.
8. Communication should be clear towards various stakeholders as a precaution on possible **safety** issues in case of fire and accidents.
9. PTA and PTO should stay flexible to adapt current bus **routes** or public transport **timetables** to better match the e-bus fleet profile by taking into account the charging time. There might be cost savings along with these changes.
10. A clear high-level **regulation framework and political support** is of utmost importance in pushing e-bus solution to a larger scale, which will release the strong signal, further stimulate the demand and drive the supply in the EU e-bus market. Best practice can be very much valuable and guide EU cities in the transition process towards electrification of the public transport.

USEFUL DOCUMENTS

USEFUL DOCUMENTS & RELEVANT EXAMPLES WITH CONTACT DETAILS

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_2

ZeEUS eBus Report – An updated overview of electric buses in Europe

Zero Emissie Busvervoer Vlaanderen

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

mySMARTLife

Triangulum

REPLICATE

REMOURBAN

MAtchUP

IRIS

CONTRIBUTIONS:

SCIS

The Smart Cities Information System (SCIS) is a knowledge platform to exchange data, experience and know-how and to collaborate on the creation of smart cities, providing a high quality of life for its citizens in a clean, energy efficient and climate friendly urban environment. SCIS brings together project developers, cities, research institutions, industry, experts and citizens from across Europe.

SCIS focuses on people and their stories – bringing to life best practices and lessons learned from smart projects. Through storytelling, SCIS portrays the "human element" of changing cities. It restores qualitative depth to inspire replication and, of course, to spread the knowledge of smart ideas and technologies - not only to a scientific community, but also to the broad public!

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