# Electric bus fleets in Europe

Three turbulent effects that will dominate in the rapid electrification of our public transport

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PERSPECTIVES

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# In summary

Quite apart from the exponentially increasing numbers of *Teslas* and other fully electric cars around nowadays, another surge in electric fleets is noteworthy. With 23,000 electric buses forecast to be in operation in 2025 (compared with around 1,200 buses currently), public transport is being electrified at a rapid pace. More specifically, Accuracy forecasts that France and the UK will lead this market development in Europe, supported by the Paris agreement and country-level zero-emission (ZE) legislation aiming for a fully ZE public transport bus fleet by 2030. Whilst incumbent operators in these countries are gaining experience with the first electric bus fleets, significant challenges remain – even for early adopters.

Market dynamics in public transport are characterised by competitive tender processes to earn the right to exclusively operate in a specific geographic area – a concession area – for (usually) a period of 10 years. Given the low margin and often subsidised operations in public transport business cases, it is crucial for operators to have a competitive edge in order to increase their win rate in tenders. One such competitive edge could be a more profound understanding of the life cycle of bus batteries and its implications for the investment case of electric bus fleets.

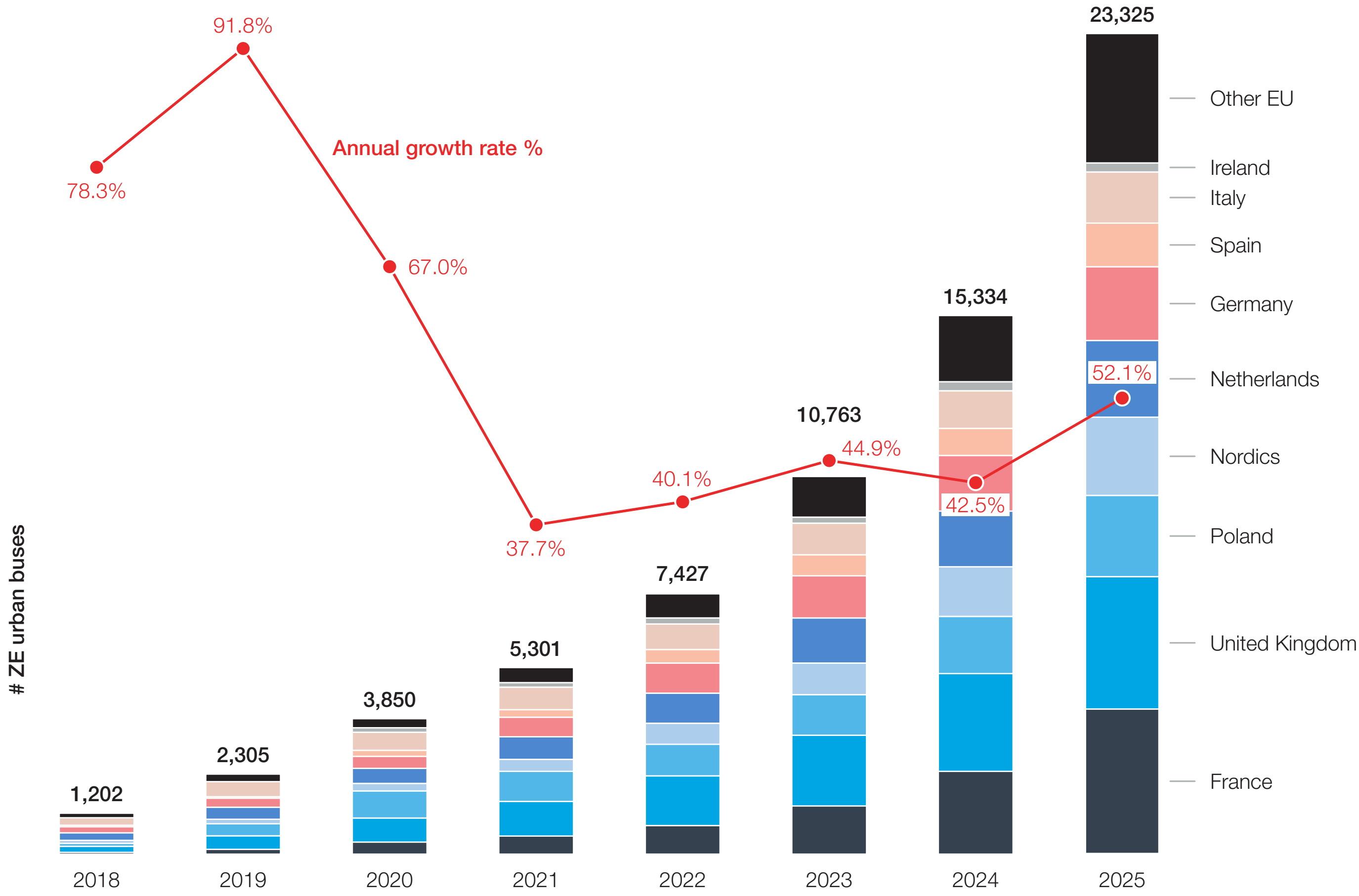
Our view is that many operators still lack a full understanding of the electric bus fleet business case and its operational complexities. They are therefore unable to compete effectively. Moreover, public transport operators will be forced to develop new skills (such as battery maintenance) and will need to reinvent themselves to accommodate the new dynamics in the value chain that coincide with becoming a large-scale energy consumer.

Operators who are on top of fast-track innovations and have an in-depth understanding of the financial sensitivities related to electric bus fleet management are able to set the pace in a potential winner-take-all market.

This article highlights three turbulent effects that we expect to dominate in the rapid electrification of our public transport in Europe and concludes with some recommendations to overcome short-term barriers to market adoption.

# 1 The bus market will electrify faster than you can imagine

**Forecast urban electric buses in operation in Europe** [by country 2018-2025]




Sources: Accuracy analysis

France, the United Kingdom, Poland, the Nordics, the Netherlands and Germany together account for more than half the total number of electric buses in Europe today. For these countries combined, we forecast a total of 3,900 electric buses in operation by 2021 and 16,710 buses by 2025. This implies a CAGR of 68% between 2018 and 2021 and a CAGR of 34% between 2021 and 2025.In 2015, 195 states and the European Union unanimously approved the COP21 agreement. Since 2016, 174 countries have begun adopting the agreement into their own legal system. Following this, municipalities have adjusted – or are in process of adjusting – tender criteria to induce a shift to ZE vehicles in new concessions.

## Legislation context: France and the Netherlands

Prior to the COP21 agreement, France adopted the Energy Transition Law. This law ensures that when public bus fleets are renewed, a minimum level of low-emission vehicles is respected. More precisely, the law states that *"the State, public institutions, territorial communities and their groupings, when directly or indirectly managing a fleet of more than twenty buses for scheduled or on-demand passenger transportation services, must purchase low-emission vehicles when renewing the fleet, with a minimum proportion of 50% as of 2020, then in full as of 2025. In the case of services provided by the Régie Autonome des Transports Parisiens (RATP), the minimum proportion of 50% applies starting from 2018"*[1].

In the Netherlands, in 2016, the transport authorities signed the Administrative Agreement on zero-emission public transport, which stipulates that by 2025, all new buses will be ZE 'at the exhaust' and by 2030, the entire fleet of more than 5,000 buses will be ZE.

## Bus fleet replacement schemes are quickly coming of age

After an experimentation phase, an increasing number of tender processes are being launched for electric buses ("e-buses" hereafter). In major cities committed to improving air quality, such as Paris and London, large-scale replacement schemes have already been set in motion:

- In France, in 2018, Ile-de-France Mobilités and RATP launched the largest call for tender in Europe to buy 800 e-buses (worth €400 million)[2]. This will help to achieve the target set by RATP in 2015 to make its fleet of 4,700 buses entirely clean by 2025.
- In March 2018, the Mayor of London published a strategic plan[3] for transportation, which stated the objectives for the city's bus fleet:
  - Starting from 2018, all new buses should be hybrid, electric or hydrogen.
  - By 2020, all single decker buses in central London (i.e. around 200 buses) should be purely electric or hydrogen.
  - By 2035, all single decker buses in inner and outer London will be purely electric or hydrogen (i.e. around 2,600 buses).
  - By 2037, all buses will be ZE.


***Notes***

*1) Art. L. 224-8 of the Environmental Code*

*2) RATP, Bus2025 : L'ambitieux Plan de la RATP pour un parc 100% propre, April 2018*

*3) Caroline Pidgeon, Going electric – The future of London's buses, January 2019*

# 2 Europe is losing control over access to batteries and

*China is running the show behind the scenes*

China is currently the market leader for both the production and operation of e-buses. In 2017, there were 385,000 electric buses in the world, 99% of which were located in China. In this market, 9,500 electric buses are deployed every five weeks. By comparison, the cumulative number of e-buses in operation in Europe reached 1,202 units in 2018, less than 13% of what is rolled out in China on a five-weekly basis.

European manufacturers like VDL, MAN, Mercedes, Volvo and Solaris are still in their scale-up or start-up phase in relation to e-buses. Although the quality of e-buses built in Europe is perceived as premium, European manufacturers are possibly too late to meet a large share of the steeply increasing demand for e-buses in the coming years. As a result, they have a slower innovation curve compared with Chinese players, which currently cover 90% of the market in Europe[4]. China has invested heavily in the development of this alternative mode of transport: the share of e-bus sales in the country jumped from 0.6% in 2011 to 22% in 2017[5].

Four major factors explain the rapid development of Chinese e-bus fleets. First, national and regional subsidies helped cushion the high upfront costs of e-buses. Second, significant urban pollution generated a growing concern, which acted as a catalyst. Third, Chinese transportation infrastructure started from scratch, whilst in Europe, for instance, the infrastructure is already established and new technologies must be incorporated into it. Finally, developing new technologies that are competitive in the world market is a long-term goal for the Chinese government.

## a China: on the ground in Europe

BYD, a Chinese company specialised in the production of e-buses and coaches, has invested €10 million in France to build an assembly factory (Beauvais, Oise). The factory's production capacity stands at 200 e-buses per year, but it has yet to receive sufficient orders to run at full scale[6].

## b Operators still largely in the dark with regard to battery performance data

Typically, OEMs that ucprode e-buses for transport operators do so without providing the owner-operator with access to the inner workings of the bus's battery (the battery management system or 'BMS') to understand its performance over time. This is crucial information because the battery's performance can quickly deteriorate if usage conditions are suboptimal – a painful issue if your battery becomes useless and you have an ongoing contractual obligation to service a concession area. In addition, access to the data can offer unique insights, which can make it possible to improve certain financial aspects or the battery lifetime by making operational adjustments (such as stabilising battery temperature, adjusting for frequency regulation effects and driver behaviour).

***Notes***

*4) Bernd Heid, Matthias Kässer, Thibaut Müller and Simon Pautmeie, Fast transit: why urban e-buses lead electric-vehicle growth, McKinsey&Company, October 2018*

*5) Electric buses in cities – Driving towards cleaner air and Lower $CO_2$, Bloomberg New Energy Finance. August 2018*

*6) Le Figaro, BYD investit 10 millions d'euros en France, 23 March 2017*

## Importance of knowing the battery's state of health

Although less rapid than other battery technologies, lithium-ion batteries exhibit a deterioration of their performance over time named battery aging or State of Health (SoH), which comprises a loss of available energy and power. This results from a loss of capacity or a rise of internal resistances (impedance).

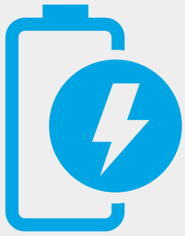
A battery's state of health (SoH) is critical in assessing its long-term economic value. Currently, SoH is estimated by the battery management system software, which is protected by the OEM and therefore not accessible to the battery's owner-operator. Additionally, battery performance degradation is difficult to predict precisely because it depends on 4 main factors:

**A.** Charging/discharging speed, measured in Coulomb-rate (C-rate), expresses the intensity of the electric current circulating through the battery. The higher the C-rate, the faster the battery ages[7].

**B.** Extreme temperatures adversely affect battery life. Higher temperatures increase internal activity so lead to capacity losses[8]. Below 0°C, the cell internal resistance increases dramatically so the usable capacity drops noticeably and accelerates the battery aging[9].

**C.** Battery aging occurs during energy exchanges but also when it is stored or just unused. The battery capacity is reduced and the impedance increases over the storage time. At constant temperature, the higher the State of charge (SoC) is, the more the capacity is reduced over the storage time because the SoC (% battery filling) corresponds to the level of activity inside the cell[7].

**D.** Depth of discharge (DoD) corresponds to the level of energy delivered by the battery before being recharged and therefore an average DoD characterises its usage profile. Higher DoD (deep cycle decharging) evolves in an acceleration of the aging mechanisms[10]. Consequently, the cell performance degrade slower by charging as frequently as possible but while keeping the DoD in the center of the capacity range.



We believe that an ecosystem of local manufacturers, maintenance providers and operators in Europe would make it easier to standardise technologies and open up the locked box of battery data. Having a local ecosystem would be preferable to seeking to establish one with distant Chinese manufacturers, as it would incentivise stakeholders to seek collaboration and joint investments and innovations.

***Notes***

*7) Battery University, How does internal resistance affect performance?, 2010*

*8) Noshi Omar et al., Rechargeable Lithium Batteries, Chapter 9 – Ageing and degradation of lithium-ion batteries, 2015*

*9) Discover Energy Corp., Temperature effects on battery performance & life, January 2015*

*10) Jean-Marc Timmermans et al., Batteries 2020 – Lithium-ion battery first and second life ageing, validated battery models, lifetime modelling and ageing assessment of thermal parameters, 18th European Conference on Power Electronics and Applications, October 2016, page 6*

# 3 The surge in electrification leads to three adjacent

## a Our electricity networks are not capable of managing the vast increase in electricity demand forecast to come from huge fleets of e-buses

For bus operators, it is essential to run a tight schedule. Limiting idle charging time makes it possible to meet passenger demand with an optimal fleet size. As a result, high capacity chargers are used throughout the day for fast charging (currently this is 450 kW but is expected to increase to 900 kW in the near future)[11]. As the capacity of these chargers is very high compared with fast chargers for cars (up to 175 kW) and many (sometimes dozens) charge simultaneously on a single grid connection, this has an enormous effect on the fluctuation of electricity usage.

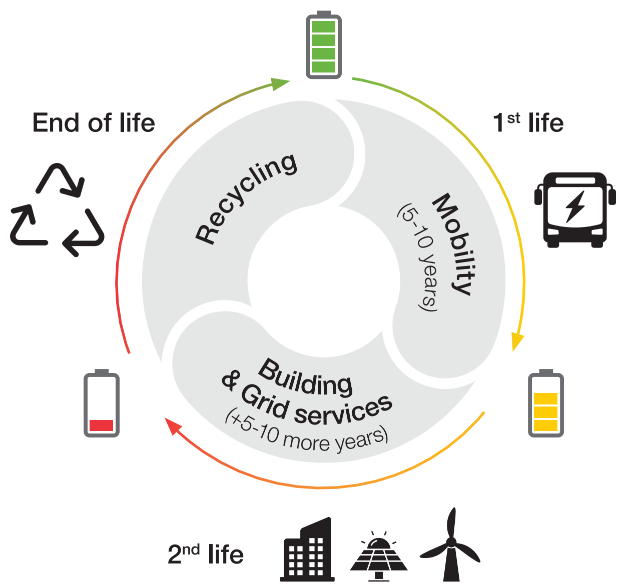
If one fast charger is installed for every ten buses on average, the peak in national energy consumption will be noticeably affected (for example, the peak energy demand of approx. 20 MW in the Netherlands will increase by 1%). Although this might not sound very significant, it creates challenges for the system. The demand for energy to charge buses is not constant, like industrial usage, but binary and volatile. A sudden increase or decrease in demand for energy puts tension on the grid, which, in rural areas, where power consumption is relatively low and mainly residential, can lead to grid blackouts. For some of these areas, again taking the Dutch market as an example, it is not even possible to operate an electric bus fleet at present, as the power capacity of the local grid is insufficient, and high-power grid connections cannot be established within 3–5 years.

To ensure further electrification of our public transport, the electricity grid operator will need to take into account these energy demand requirements and make appropriate investments in the energy grid. Without this, short-term solutions can be found through out-of-the-box solutions (e.g. mini-grid ecosystems using solar-PV projects at bus depots), but they present further complexities to (not only) public transport operators.

## b A flood of used batteries will come to market in 5 to 10 years, raising the question of a battery's "second life" and opening numerous use case possibilities

Although e-buses are already operational in many countries, the issue of the "second life" of e-bus batteries has yet to be solved. Indeed, e-bus batteries function optimally for a period of 5 to 10 years, depending on its use and operational set-up. After that time, partly due to intensive usage profiles, they are no longer fit for public transport, but they still have around 80% of their initial capacity[12]. Combined with the rapidly growing size of e-bus fleets, the number of batteries reaching the end of their "mobility" life will be a challenge that inevitably will have to be tackled. In addition to its environmental aspect, this challenge can be a source of many value-creating opportunities.

**Battery lifecycle and three-stage circular-economy approach**




*Notes*

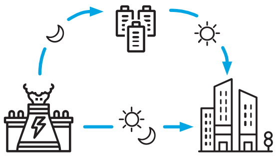
*11) State Grid Corporation of China, China aims for 900 kW hyper power charging standard*

*12) In any case, usually, OEM warranties end when batteries reach around 80% of SoH. According to industry experts, continuing the highly intensive mobility use after the 80%-norm would result in accelerated depreciation of the battery performance*

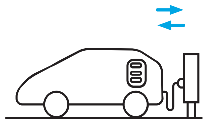
# ecosystem challenges for public and private investors _

Currently, e-buses are still being introduced gradually into the market. As a result, the track record of long-term battery performance and experience in determining actual “second life” use cases remain very limited. However, Accuracy has filtered these value-creating opportunities down to 13 distinct use cases that are adjacent to or extend the mobility use of the battery. Each case is linked to at least one of four key conceptual value drivers: (1) load management, (2) grid balancing, (3) lifetime expansion and (4) residual value. Some of the most attractive use cases include (one or more of) the following value drivers.

## Attractive use cases including key value drivers



Optimising energy usage
*(peak shaving)*



Supplying energy to the grid through bidirectional vehicle-to-grid set-ups
*(virtual power plant or VPP)*

Use of stationary batteries for non-mobility energy management

Bus batteries are particularly useful for “second life” (non-mobility or extended life) use cases for the following reasons:

- There will be a multitude coming to market. In 2017, in China alone, 87,000 additional e-buses were operational[13]. At this rate, close to 100,000 bus batteries would reach the end of their core mobility usage in 5 to 10 years and would represent significant potential for other applications.

- They have a much higher unit capacity compared with passenger EV batteries. This makes it easier to set up secondary use cases such as stationary energy storage facilities. Bus batteries have a high capacity of 150 to 300 kWh and are therefore suitable for heavy-duty charging infrastructure dedicated, for example, to short-haul heavy weight trucks or utility trucks.

There are already early examples of “second life” uses being implemented, although in most cases they relate to batteries from electric cars:

- In March 2018, MAN Truck & Bus and Hamburg’s public service provider VHH announced that they will construct a prototype stationary storage facility with “second life” e-bus batteries[14].

- In June 2017, Renault and Powervault announced a home stationary energy battery storage system based on “second life” electric vehicle batteries[15]. This partnership is said to reduce the cost of a Powervault smart battery by 30% and extend the useful life of a Renault battery by up to 10 years. Although this example refers to electric car batteries, it could be extended to e-bus batteries for larger scale applications.

- On 29 June 2018, the Johan Cruijff Arena in Amsterdam put into operation a 3 MW mega battery, which will ensure that football matches and concerts can continue in the event of power failures[16].

Again, electric car batteries (148 units) have been used for this “second life”, but similar applications could be designed for e-bus batteries.

***Notes***

*13) Electric buses in cities – Driving towards cleaner air and Lower $CO_2$, Bloomberg New Energy Finance. August 2018*

*14) Nora Manthey, MAN & Hamburg to give 2nd life to electric bus batteries, Electrive.com, 19 March 2018*

*15) Renault Press Release, Renault and Powervault give EV batteries a “second life” in Smart Energy Deal, 5 June 2017*

*16) Johan Cruijff Arena wordt superbatterij voor elektriciteitsnet, Website Johan Cruijf ArenA. 29 June 2018*

## c Current tender criteria inhibit adversarial effects to successful e-bus roll-outs

Policymakers have introduced tender criteria to promote the shift to electric fleets for recent bus concessions coming to market; however, they need to be considered carefully. In our opinion, these criteria do not always align with an optimal operational and financial investment case for e-bus fleets as they create specific complexities in the tender process and – unintentionally – force operators to make suboptimal financial decisions.

Currently, electric buses require a significantly higher investment than traditional diesel buses (up to 1.5x the CAPEX investment, not even including the charging infrastructure CAPEX needed), despite being cheaper in maintenance and propulsion. Current tender criteria contain hybrid or "soft" ZE criteria (allowing for the combination of traditional diesel and ZE bus fleets), whereas upcoming tenders are likely to have "hard" ZE requirements. In truth, some incentives and arrangements are made to help ZE bus set-ups win the call for tender, such as financial incentives (e.g. off-balance-sheet financing, carbon credits). However, in order to maintain the quality of public transport until ZE bus prices have dropped significantly, more needs to be done to ascertain what would be an attractive financial investment case for operators, given the higher risk and uncertainties involved that have not yet been resolved as demonstrated in some examples below.

Some examples of complexities in calls for tender for electric bus fleets (not exhaustive):

- As high-power grid connections and charging infrastructures are not present for new concession areas (i.e. those that have not yet had ZE bus operations, which is the case for most), uncertainties and investment requirements are much higher for operators, creating a huge disadvantage when compared with diesel fleet operations. Shared infrastructures with neighbouring corporates operating ZE fleets for their logistics are economically feasible but are difficult to achieve if tender processes do not adhere to more holistic economic perspectives.
- Day-one readiness timelines are challenging as the procurement of buses, infrastructure and grid connections can only be arranged once the concession is awarded. The handover from preceding concession operators has to happen in a short window, which – again – is much more challenging when compared with diesel fleet operations.
- Awarding the concession naturally coincides with awarding the subsidies for the concession period; however, the subsidy does not usually correlate to passenger traffic growth during the period. As a result, operators initially have undesirable fleet mix/sizes to be able to handle long-term passenger demand. This can make planning ZE bus routes and setting up charging infrastructure difficult, creating more challenges than traditional diesel bus operations.
- The transfer of charging infrastructure to the new concession holder after the 10-year operating period is common in current tender criteria, but it may not be tied to the same location. However, transferring the charging infrastructure from one location to another cannot be done overnight.
- Our recommendation to policymakers is to adhere to the above areas, if they want to maintain the quality of public transport and meet the electrification goals set.

## d Concluding statement

We consider that, for Europe to be a viable global player in electric buses as well as in the next wave of electrification of vehicles (e.g. the heavy-weight segments of cargo transport & logistics), it is crucial for European policymakers, energy grid operators, OEMs and public transport operators to work together and use their experience of scaled production to close the gap on China in today's market.This can only come about if the emerging barriers such as we identified in this article are quickly resolved. This includes the barrier facing bus fleet operators needing access to the energy grid; policymakers to align public tender criteria with the real 'cost of ownership' investment cases (including "second life" battery usage and (joined) infrastructure requirements); and manufacturers to unlock battery performance data to operators through, for example, open innovation.

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