Bocconi

With the scientific support of Enel Foundation

SCENARIOS AND PERSPECTIVES OF THE ELECTRIFICATION OF LOCAL PUBLIC TRANSPORT

A socio-economical and environmental analysis on electric bus-fleet and its supply chain at a EU27+3 countries level

Executive Summary

This study has been prepared by a joint research team of GREEN - Bocconi University and Enel Foundation coordinated by Oliviero Baccelli and Carlo Papa with the researchers Gabriele Grea, Antonio Sileo, Pietro Morosini, Mirko Armiento and Simone Martinelli. Luca Pelliccia (Enel X) contributed to the study.

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Executive Summary

The goal of the study is to analyse the socio-economic and environmental benefits of 12 meters urban fleet electrification in the EU27 + 3 (UK, NO, CH) in different market scenarios at 2030 and 2040. The analysis considers three types of benefits: a) operational cost reductions; b) environmental externalities reductions c) revenues streams for local public transport (LPT) operators deriving from 2nd life of the batteries and bus-to-grid (B2G): these services to the grid will become increasingly important as Europe makes the transition to a renewable-led electricity system. The study explored three market scenarios:

1. Baseline scenario, related to the one already outlined by policies approved at the European level based in particular on the package of initiatives called "Fit for 55" and the Clean Vehicle Initiative regulations;
2. Acceleration scenario, with a 2-year anticipation of European-level targets;
3. Best practice scenario, with alignment of the targets of the 27 EU countries to the level of the most virtuous country in terms of speed of Battery Electric Bus (BEB) adoption (the Netherlands).

These scenarios do not attempt to be precise forecasts, since they represent “what if scenarios” that are designed to achieve long-term climate policy objectives and operational efficiency of LPT operators. The cumulated contribution of the operational cost reductions for LPT operators can be estimated in 21,1 billions Euro in 2022-2040, almost 5 billions Euro more than in Baseline scenario. The contribution to meeting the EU’s climate goals and to reduce the cost of environmental externalities linked of LPT have a value of 13,7 billions Euro in 2022-2040 in Best Practice scenario, 5,3 billions Euro more than in Baseline scenario. The contribution to meeting circular economy goals and to adding new revenue streams to LPT operators derived from synergies with energy sector due to B2G and 2nd life of the batteries have a value of 4,71 billions Euro in 2026-2040, 1,24 billions Euro more than in Baseline scenario.

The analysis also shows that the scenario defined “Best practice” will guarantee the highest benefits both for LPT operators and for society has a whole with total benefits of 39,5 billions Euro in 2040, 11,5 billions Euro more than in Baseline scenario. In this scenario the project results underline that in 2040

Objectives and approach of the study

The in-depth study includes the following steps:

- Analysis of the literature on the topic of **socio-economic and environmental impacts** of the electrification of the bus in local public transport sector;
- Analysis of **operational impacts** arising from reduced costs for LPT operators resulting from lower operating and maintenance costs;
- Assessment of **environmental impacts** resulting from the reduction of greenhouse gas emissions, local pollutants, and noise;
- Evaluation of the role of the valorization of residual values of batteries and synergies with electricity grid in terms of **new revenue streams** for public transport operators coming from B2G and 2life of the batteries.

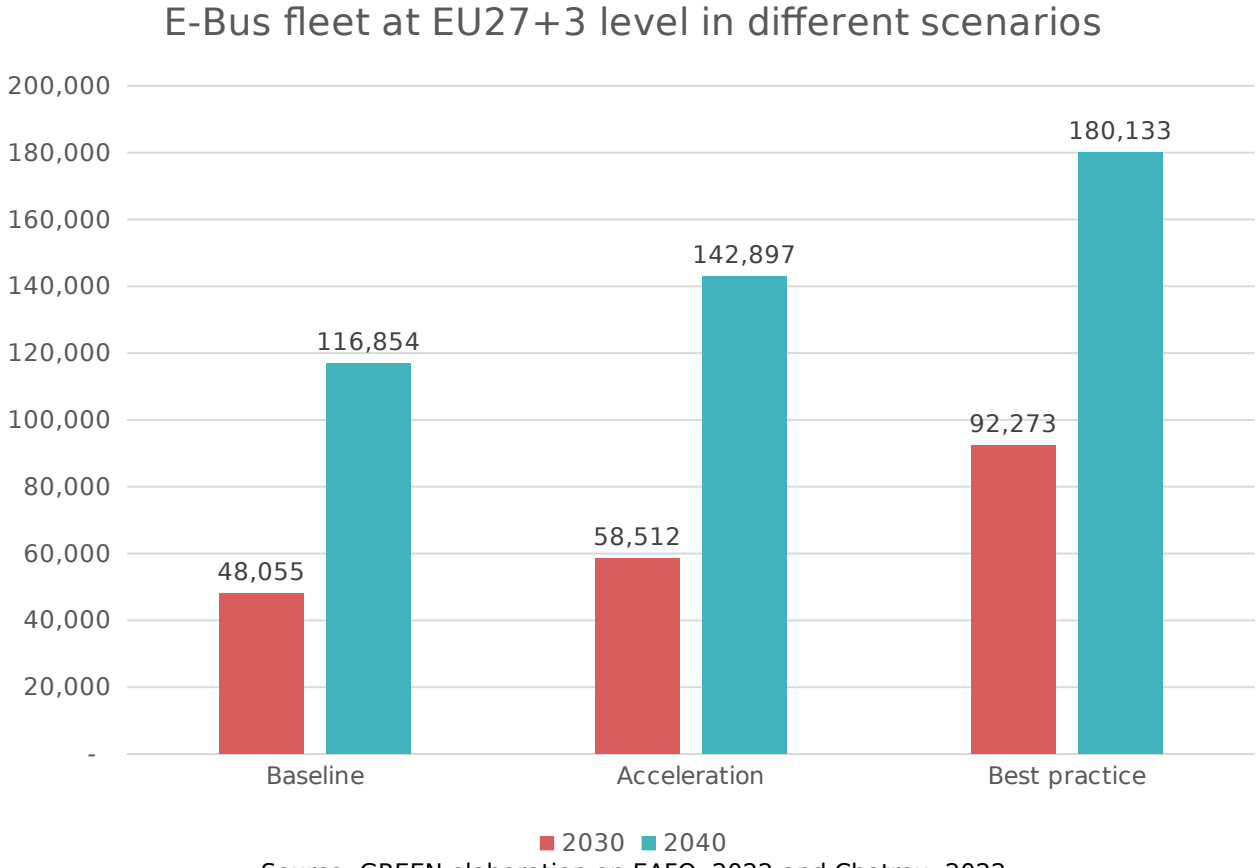
For the projections of the electrified bus fleets (national and EU27+3), market scenarios have been based on three different policy options and they are as follows:

1. **Baseline scenario**, related to the one already outlined by policies approved at the European level based in particular on the package of initiatives called "Fit for 55" and the Clean Vehicle Initiative regulations;
2. **Acceleration scenario**, with a 2-year anticipation of European-level targets;
3. **Best practice scenario**, with alignment of the targets of the 27 EU countries to the level of the most virtuous country in terms of speed of BEB bus adoption (the Netherlands).

These scenarios do not attempt to be precise forecasts, but instead they represent “**what if scenarios**” that are designed to achieve long-term climate policy objectives and operational efficiency of local public transport operators.

Synthesis of the results of bus fleets electrification scenarios 2022-2030-2040 for EU27+UK+NO+CH

The following projections have been elaborated at aggregated level for the three scenarios.



Source: GREEN elaboration on EAFO, 2022 and Chatrou, 2022

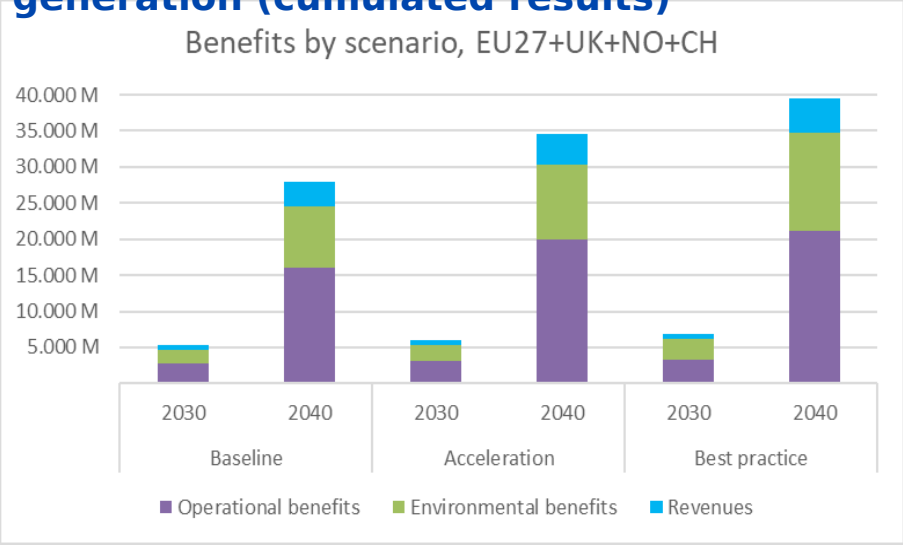
The TCO and TCRO methodological approach

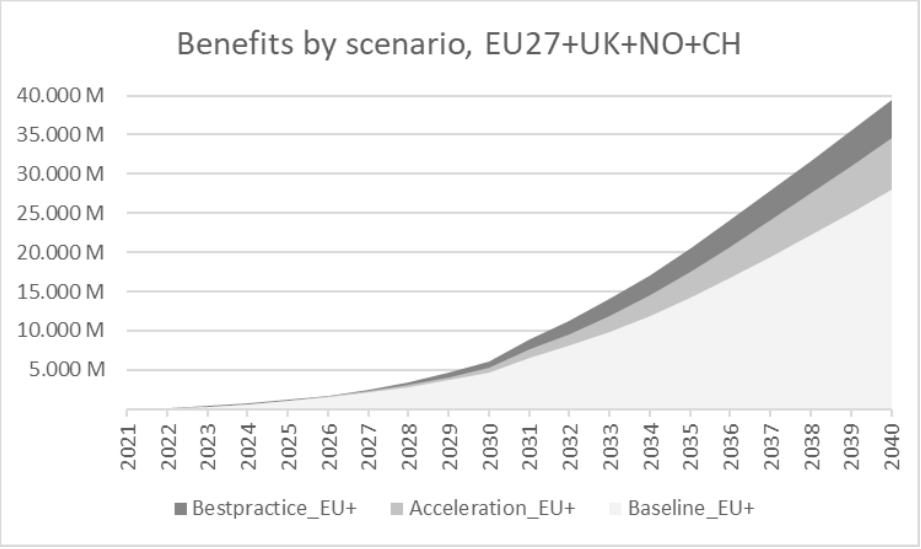
COMPANY COST COMPONENTS
Bus and infrastructure costs including the cost of charging/fueling infrastructure necessary to operate the buses (overnight and opportunity chargers, electrolyzes, fuel tanks, etc.)
Energy costs for traction
Bus maintenance (ordinary) including the ordinary costs of replacing tyres, lubricants, components subject to wear
Bus maintenance (extra-ordinary) including the replacement of components such as batteries or transmission components and allows the extension of the useful life of the bus (includes both opex and capex elements)
Infrastructure maintenance
COMPANY REVENUE COMPONENTS
Bus2Grid (Buses equipped with batteries can generate revenues by participating in the dispatching services market, which requires infrastructure investments typically made by the electricity distribution network operator)
End-of-life batteries valorization (the sale of batteries for other purposes (for example stationary applications in grids, buildings etc.), can be a source of revenue)
SOCIAL COST COMPONENTS
Environmental externalities (CO2 emissions, local pollutants, noise, PTW emissions)

“Total costs of ownership” (TCO) and “Total costs and revenues of ownership” (TCRO) approaches were adopted, including the monetization of environmental externalities (C02, pollution and noise), focusing on standard 12-meter buses dedicated to urban transport

TCO and TCRO values per km are the result of the sum of discounted variables. Since the TCO and TCRO values per km processed by the model are the result of the sum of discounted variables, the monetary value of the operating components of TCO and TCRO will be lower than the starting value indicated in the data sources used for the calculation.

Bus fleets electrification scenarios, operational+environmental+ revenues stream benefits EU 27+3 level – years 2022-2040 - 100% renewables case for electricity generation (cumulated results)





Source: GREEN elaboration

The contribution of swapping from diesel to electric buses to meet the efficiency goals of local public transport operators and to reduce the cost of environmental externalities for the society as a whole is relevant: up to 6,88 billion Euro in 2030 and 39,49 billion Euro in 2040 in Best practice scenario (anticipating 100% BEB new registrations by 2028).

In this scenario the project results underline that in 2040 the total benefits of each of the 180.133 e-bus part of the EU 27+3 stock market will be on average around 219.242 Euro.

Bus fleets electrification scenarios, benefits EU27+ 3 level – years 2022-2040 - 100% renewables case for electricity generation (cumulated results)

Country	EU27+UK+NO+CH					
Scenario	Baseline		Acceleration		Best practice	
Year	2030	2040	2030	2040	2030	2040
Operational benefits	2.761 Mio €	16.112 Mio €	3.142 Mio €	19.976 Mio €	3.329 Mio €	21.086 Mio €
Environmental benefits	1.906 Mio €	8.368 Mio €	2.130 Mio €	10.293 Mio €	2.807 Mio €	13.697 Mio €
Revenues	590 Mio €	3.473 Mio €	672 Mio €	4.314 Mio €	743 Mio €	4.710 Mio €
Total	5.257 Mio €	27.953 Mio €	5.944 Mio €	34.582 Mio €	6.880 Mio €	39.493 Mio €

Source: GREEN elaboration

At EU 27+3 level, operational benefits show a higher value than the environmental ones, representing between 53% (BASELINE scenario 2030) and 58% (ACCELERATION scenario 2040) of total benefits. As an example, in the BEST PRACTICE 2040 scenario, **2nd life, B2G revenues contribute for 12% of total benefits in Italy, 8% in Spain and 27% in UK**, where the market for 2nd life batteries is at an advanced stage and the relevance of the London metropolitan area increases the average value for batteries for stationary storage.

The cumulated benefit generated by the increase of BEBs in city fleets goes from **27,9 billion Euros** under the BASELINE scenario up to **39,5 billion Euros** in the BEST PRACTICE in 2040. **Anticipating 100% BEB new registrations by 2028 compared to the indication of Clean Vehicle Directive (100% BEB new registrations by 2035) will generate incremental 11,5 billion Euro in 2040**.
Considering that the purchasing cost differential between BEBs and ICE buses is decreasing significanty between 2021 and 2030, and expected to be zero by 2035, the benefit/cost ratio of the fleet renewal in EU is expected to be over 1 in all scenarios.

The outlook of the transition to e-buses in EU 27+3

The results of the study underline the socio-economic importance of the acceleration of the transition to zero emission buses in all three scenarios, while using a mid-range costs assumption differentiated among countries and acknowledging the inherent uncertainties in a market context where all the major bus manufacturers have committed to increasing their production of BEB and important investment are occurring in battery field.

It is also worth noting three further positive impacts not quantitatively tackled by the study:

- the **impact on the competitiveness** of local public transport, in terms of attractiveness for passengers compared to private mobility in city areas, thanks to a better quality of service (less noise, less vibration, less pollution);
- A **potential increase of the number of buses or of additional and more capillary services**, that might be delivered thanks to the expected savings in operational costs for local public transport operators;
- While the study calculates the net impact on the operational costs as a whole, it does not provide a detailed analysis of the **changes within the public transport sector** itself (e.g. on maintenance department, energy suppliers, depot management, etc.)

Moreover, the study do not evaluate the strategic importance of the **shift from mainly imported fossil fuels to domestically produced 100% renewable electricity**.

Policy recommendations

The analysis has shown that the scenario defined “Best practice” of electric buses deployment will guarantee the highest benefits both for public transport operators and for society has a whole.

The potential enablers of the acceleration identified in the study are the following:

1. Reinforce e-buses business by potentially **enforcing new skills and abilities** for reducing the purchase cost through a greater standardization and joint procurement **and supporting synergies among local public transport operators and energy utilities** in order to accelerate investments in depots and electricity grid upgrades and facilitate the goal of 100% renewables public transport services;
2. **Streamline regulatory framework and industrial policies to support innovative business models** designed around the characteristics and opportunities presented by BEB providers and associated charging or refueling infrastructure managers. (Example: early approval of Eu Batteries regulation or fast track permits in order to be able to increase the % of self-produced renewables);
3. In EU context, the renewable energy sources production will rapidly increase leading to the reduction of thermal plant operation and enhancing the role of storage and other flexibility resources, therefore **the role of circular policies supporting 2nd life and B2G services will increase, and local public transport operators could have new revenues streams**. Example could come from a regulatory framework that could facilitate the use of batteries inside bus depots that can enhance their potential as central elements of urban electricity networks both as a producer (thanks to photovoltaic panels on roofs) and as a stabilizer of the network, in B2G logic, or being part of an energy community that could protect the residual value of batteries.