Bocconi

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SCENARIOS AND PERSPECTIVES OF THE ELECTRIFICATION OF PUBLIC ROAD TRANSPORT

An benchmark analysis on 11 countries based on an innovative Total Cost and Revenues of Ownership (TCRO) analysis.

The Italian case

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Sustainable Bus Tour, 17th of May 2022

Università Bocconi

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Centro di ricerca sulla geografia, le risorse naturali, l'energia, l'ambiente e le reti

Objectives and approach of the study

The objective of the study is to support the decision-making process of local public transport companies and LPT services contracting bodies on bus fleets renewal in urban contexts thanks to **an innovative systemic benchmark analysis among different management models and power supply alternatives**.

The following countries have been analyzed: **Italy, Spain, UK, Brazil, Chile, Colombia, Mexico, Peru, US, Australia**.

"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) and incentives linked to ESG policy, focusing on standard 12-meter buses dedicated to urban transport.

Analyzed motorizations at different time scenarios (2021, 2025 e 2030) are the following:

- Diesel
- CNG-LNG e biomethane
- Elettric
- Hydrogen

This complexity of the analysis is determined by the rapid and pervasive growth of a range of innovations:

- **Policy and regulation** innovations at different levels (international, national and local, among them UE Directive on Clean Vehicle and the Batteries regulation) aimed at greater environmental and economic sustainability;
- **Organizational** innovations creating synergies between LPT operators, energy utilities and the financial sector;
- **Industry** innovations (e.g. batteries, chassis), with the entry of new players in the vehicle supply market.

Methodological approach for the analysis and for the 3 scenarios

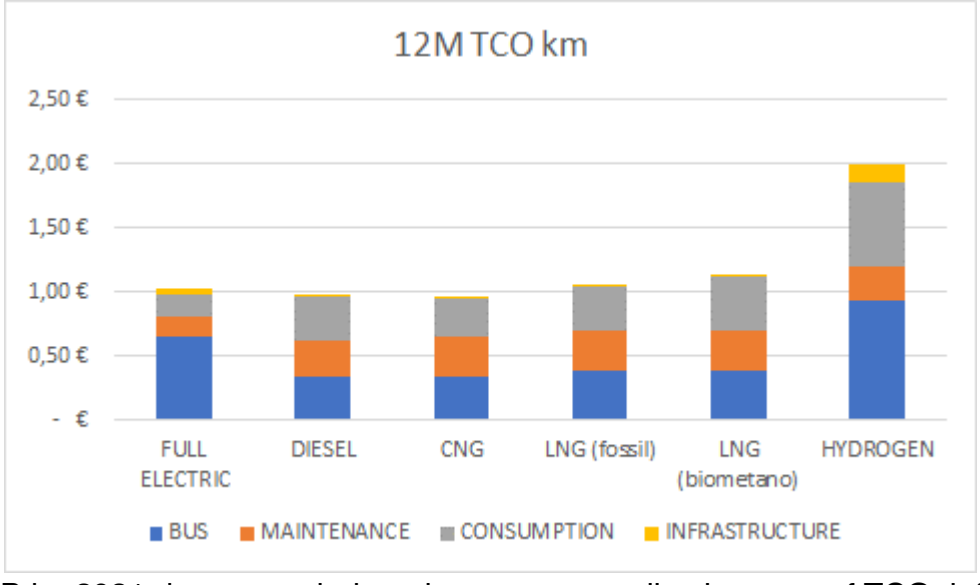
COMPANY COST COMPONENTS
Bus and infrastructure costs including the cost of charging/fueling infrastructure necessary to operate the buses (overnight and opportunity chargers, electrolyzes, fuel tanks, etc.)
Energy costs for traction
Bus maintenance (ordinary) including the ordinary costs of replacing tires, 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
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)

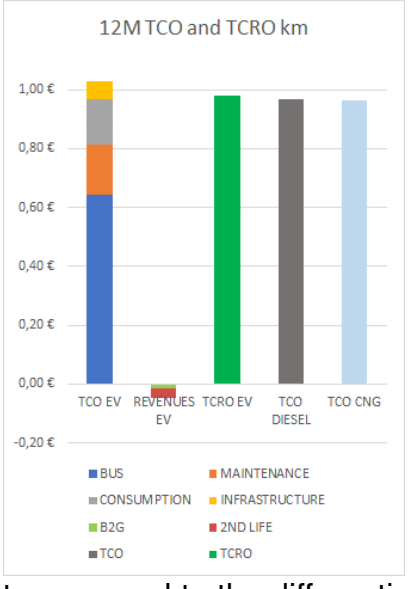
1. "**Current policy**" scenario, combining TCO and available incentives;
2. "**Comprehensive**" scenario, based on TCRO, incentives and externalities;
3. "**Long term market**" scenario, where we assume that revenues can be generated on the market (TCRO) and the compensation of externalities is applied for all technologies (thus generating additional costs, but competitive advantage for full electric, hydrogen and bio LNG).

Costs and revenues by component for 12M, base year 2021

	FULL ELECTRIC	DIESEL	CNG	LNG (fossil)	LNG (biometano)	HYDROGEN
BUS	0,642 €	0,334 €	0,343 €	0,379 €	0,379 €	0,923 €
MAINTENANCE	0,170 €	0,289 €	0,310 €	0,310 €	0,310 €	0,273 €
CONSUMPTION	0,158 €	0,341 €	0,297 €	0,353 €	0,433 €	0,661 €
INFRASTRUCTURE	0,058 €	0,003 €	0,014 €	0,007 €	0,007 €	0,130 €
B2G	0,0153 €					
2ND LIFE	0,0327 €					
Total TCO	1,028 €	0,968 €	0,963 €	1,049 €	1,129 €	1,986 €
Total TCRO	0,979 €	0,968 €	0,963 €	1,049 €	1,129 €	1,986 €

GREEN elaborations, year 2021, based on Italian market, expressed in Euro*bus*km





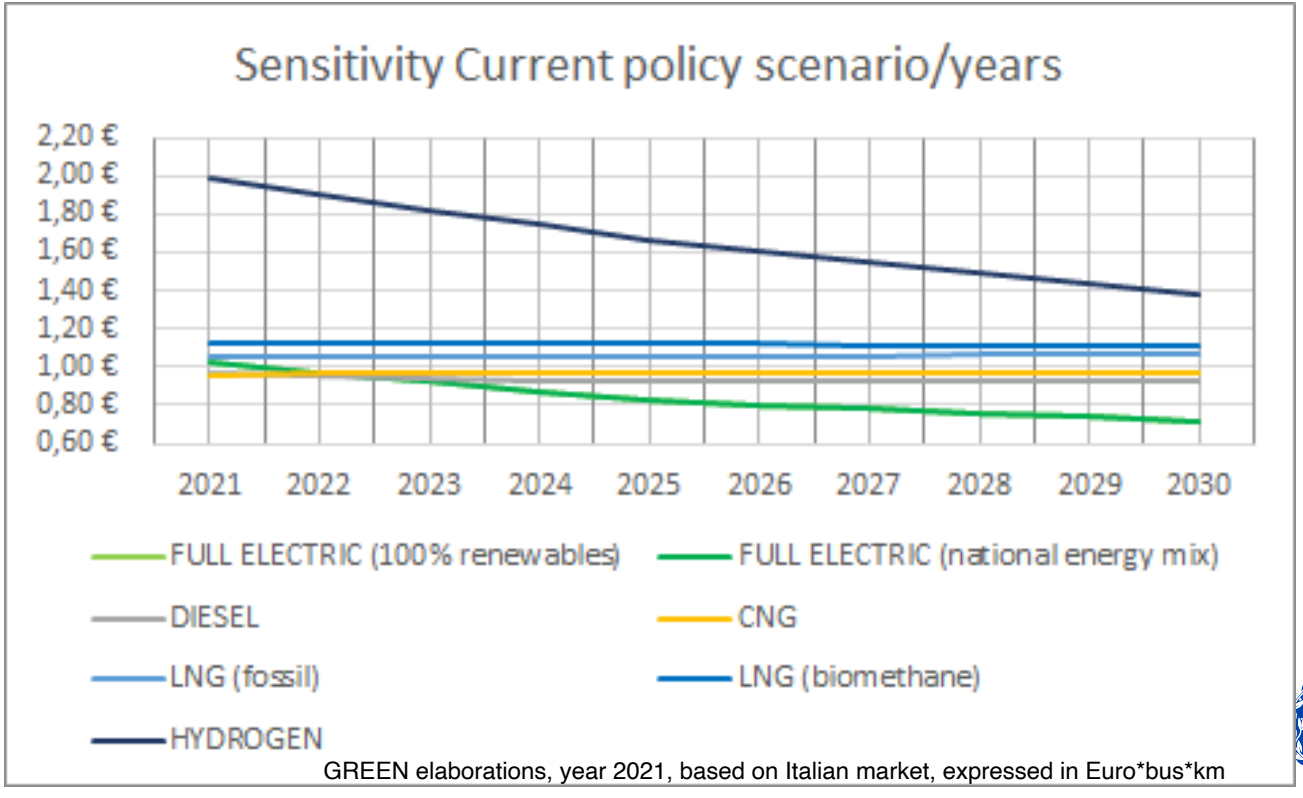
BEB by 2021 do not reach the other power supplies in terms of TCO: infrastructure costs are equal to the differential with DIESEL and CNG (approximately € 6 cents); revenues reduce the gap below € 2 cents. The role of TCRO should also be highlighted: although the values introduced are largely based on experimental estimations, the impact is not negligible (4.8 cents per km). This suggests, with particular reference to low mileage, the importance in the future of generating revenues through B2G, where possible.

Scenario 1: Current policy (scenario combining TCO and available incentives)

Ability to minimise the upfront capital costs of vehicles, technology and infrastructure through incentives and ESG financing models could be relevant in some market. For Italy, the role of incentives is limited to the co-funding available according to Alternative Fuel Initiative (within the Connecting Europe Facility), focused on depot and opportunity charging infrastructure. According to the TCO model elaborated, this results in a decrease of 0,5 Eurocents per bus*km, thus contributing to a very slight anticipation of the break even point.

Dynamic comparison of TCO over time for 12 meters buses shows the **FULL ELECTRIC option already competitive against diesel in 2022**.

From 2023 the advantage of BEBs is constantly increasing until 2030 thanks to the foreseen reduction of upfront capital costs of buses and infrastructures (TCO -20% compared to diesel)

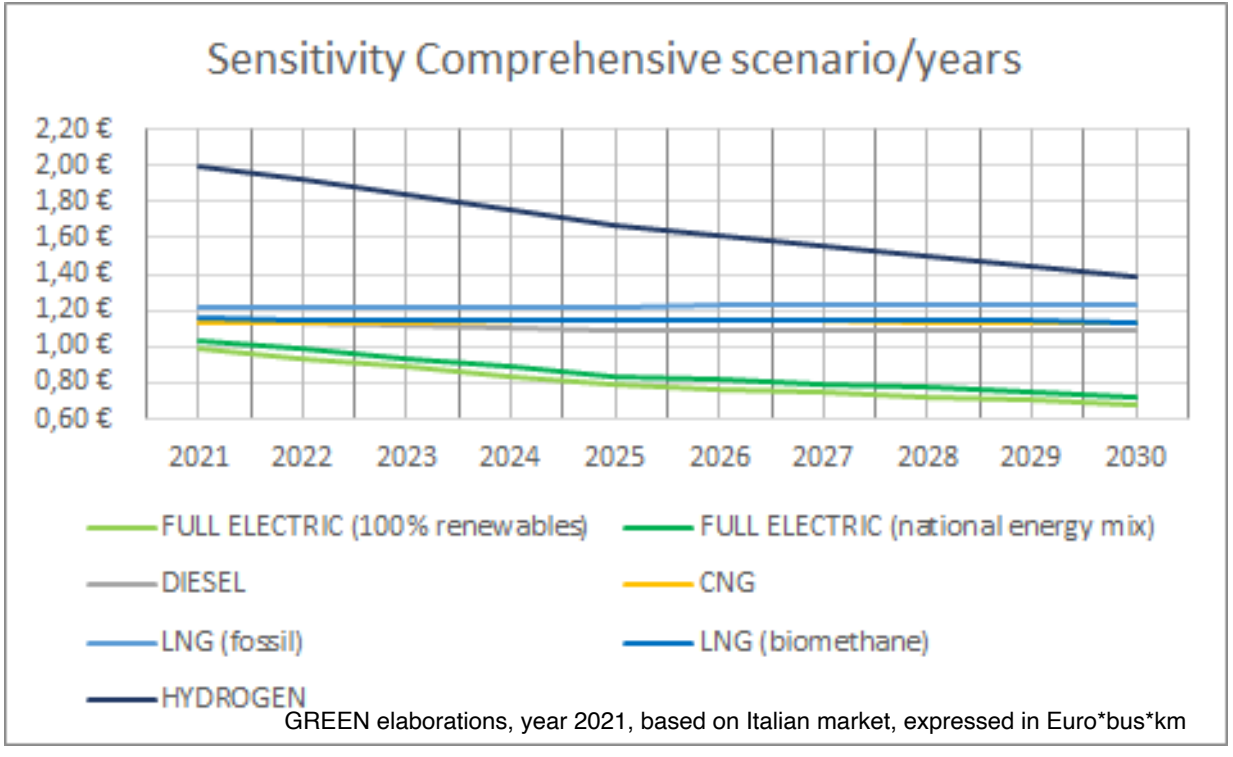


GREEN elaborations, year 2021, based on Italian market, expressed in Euro*bus*km

Scenario 2: Comprehensive (scenario based on TCRO, incentives and externalities)

The combination of **synergies with the electric market** (B2G), **protection of the residual value of batteries** (2° life) and **monetisation of externalities** could accelerate the transition to zero emission buses. Compared to the previous, here we can see how the combination of the three factors generates a relevant competitive advantage for electrified public transport. Another interesting aspect of this scenario is that, thanks to the integration of externalities, the costs of fossil based options raise significantly (and fossil LNG overcomes bio LNG).

BEB and hydrogen buses have up to 63-92% of savings in production-to-wheel carbon emissions, local pollutants (PM10, SO2, NMVOC) and noise as compared to its diesel equivalent in Italy

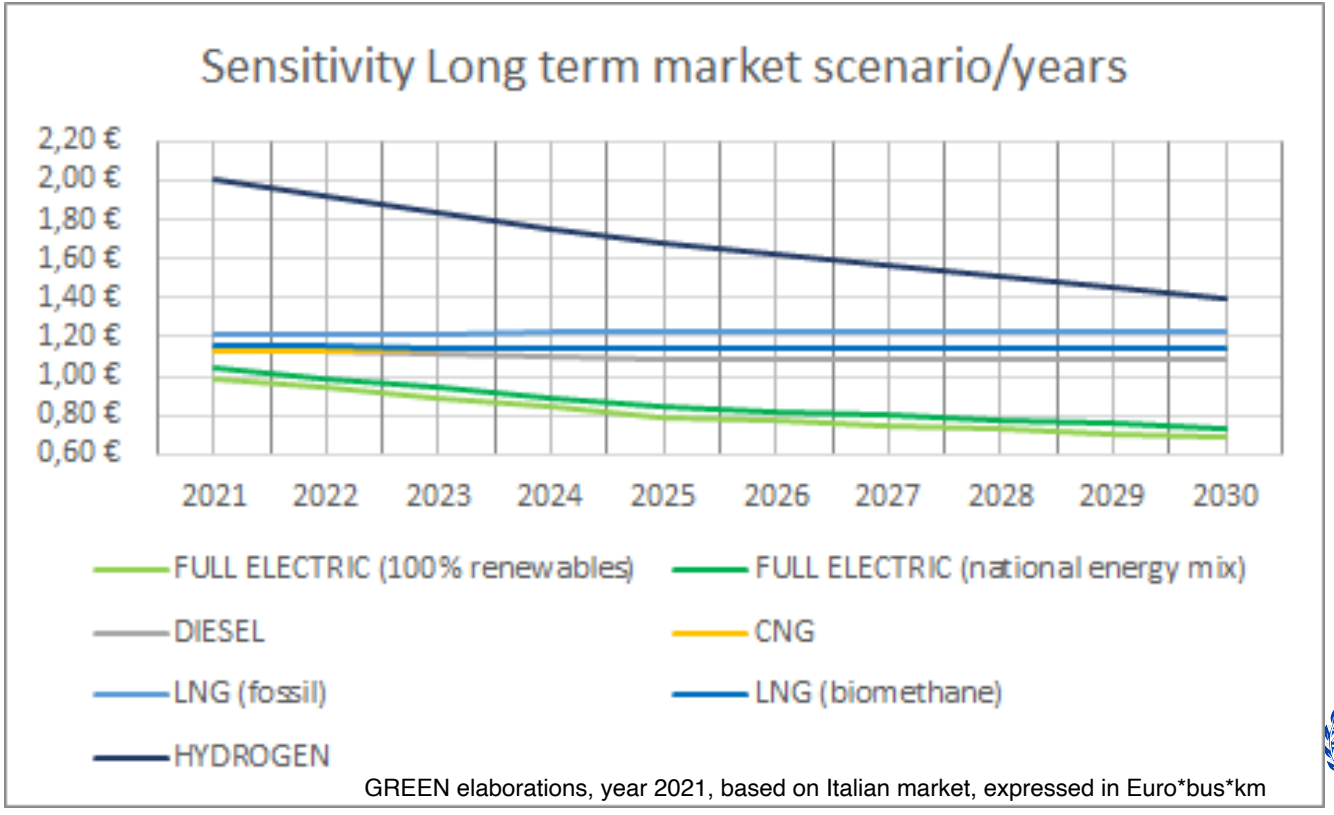


GREEN elaborations, year 2021, based on Italian market, expressed in Euro*bus*km

Scenario 3: Long term market (based on TCRO, compensation of externalities but without incentives)

The combination of synergies with the electric market (B2G), protection of the residual value of batteries (2ndlife) and internalisation of externalities (through compensation) **could accelerate the transition to zero emission buses even without considering incentives**. For Italy, it shows that even without incentives a correct assessment of the comparative benefits combined with the possibility of generating revenues with b2g and 2nd life batteries makes **the electrification choice strongly competitive**.

TCRO of hydrogen buses remains the highest even in «Long term market» scenario in 2030



GREEN elaborations, year 2021, based on Italian market, expressed in Euro*bus*km

Key themes and trends arising from the TCO and scenario analysis

The TCO comparison between Battery Electric Buses (BEB) and ICE (with reference to Diesel) is already in favor of the former in most of the countries analyzed by 2021, with few exceptions due to initial investment costs much higher compare to ICE buses.

In the Italian case study, the higher upfront capital costs associated with technologies and infrastructure for the zero emission bus transition are mitigated by the **lower operational** (-54%) and **maintenance costs** (-41%) for e-buses (not for hydrogen even in the long run).

According to our analysis, most relevant investment cost reductions will happen in the next years (before 2025) thanks **to economies of scale generated by the demand growth and by the diversification of the supply**.

Big improvements will occur as result of the **important investments that manufacturers have made in recent years in the batteries field and in new factories dedicated to e-buses**, especially in US (e.g. Navistar, Thomas Built, Lion's Electric), Brazil (BYD and Mercedes Benz), in Australia (BusTech Group with Proterra, Nexport Pty Ltd with BYD and Volgren with Volvo), Italy (Industria Italiana Bus) and United Kingdom (e.g. Alexander Dennis -ADL- factories in Scarborough and Falkirk, Switch Mobility near Leeds and Wrightbus in Ballymena, Northern Ireland).

The outcomes of these investments will add huge capacities to the market and raise the competition level among the already established manufacturers .

Key themes and tools arising from the TCRO, environmental externalities (CO2, pollution and noise) and incentives analysis

Policy initiatives in the fields of environment, industry and circular economy represent an important factor in fostering and accelerating the transition toward zero emission fleets, **anticipating the social and environmental benefits** and **enhancing the contribution to climate change targets.**

The **protection of residual values of batteries and synergies with electricity grid** could contribute to reduce the risks for public transport operators and accellerate the transition, but they require a **clear regulation framework** and a **proactive role by financial and utilities operators**.

Revenues deriving from B2G and 2ndlife of the batteries will contribute to keep the operating cost for public transport operators to be as low as possible, with **potential benefits for public finance.**

Monetization of externalities underline the **opportunities for the society as a whole of decarbonising bus sector,** that benefits are absolutely striking (-92% compared to diesel) when considering the option of consuming energy coming from 100% certified renewable sources as it is the case for the public transport operators in Milan and Turin, for example**, this means up to 10.000 Euro annual value reduction of the cost of externalities for each bus.**

...THANK YOU FOR YOUR ATTENTION

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