# *Output factsheet*: Pilot action for planning the city bus transport electrification in Dubrovnik FUA

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| **Project index number and acronym** | CE243 |
| Lead partner | City of Vicenza |
| **Output number and title** | O.T3.3 Pilot Action for planning the city bus transport electrification in 2 FUAs ( Dubrovnik) |
| Responsible partner (PP name and number) | UNIZAG (PP 3) |
| Project website | http://www.interreg-central.eu/SOLEZ |
| Delivery date | 01/2020 |

| **Summary description of the pilot action explaining its experimental nature and demonstration character** |
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| The pilot action in Dubrovnik first considered characterisation of existing (conventional/Diesel) city bus transport based on continuous, six-month, 24 hour/day GPS/GPRS telemetry tracking of representative fleet consisting of 10 buses. The main aim of the pilot action was to apply the developed software tool to virtually simulate different electric bus fleets over the recorded driving cycles, in order to determine optimal bus fleet and charging infrastructure configurations and analyse cost competitiveness of electrified city bus transport systems.<br>The pilot study has first involved the processing of raw driving cycle data using Data Post-Processing Module (DPPM), in order to extract a wide set of driving cycles for virtual simulation of the city bus fleet, as well as to provide comprehensive statistical analysis/characterisation of city bus transport behaviours.<br>Next, the virtual simulation study of different types of city bus fleets over the recorded driving cycles has been conducted in E-Bus Simulation Module (EBSM), with the main aim to analyse the extent of fuel/electricity consumption and CO2 emissions reductions when using e-buses. The considered/simulated types of city buses include: conventional (diesel-engine) vehicle (CONV), hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV) and fully-electric or battery electric vehicle (BEV).<br>The conventional bus model has been validated with respect to recorded fuel consumption data. Furthermore, the Charging Optimisation Module (COM) along with the expert knowledge has been used to carry out repetitive fleet simulations to determine an optimal configuration of the charging system (i.e. charger locations, types, controls) for PHEV- and BEV-type city bus transport systems. Finally, the bus and charging infrastructure investment cost and energy (fuel and electricity) and other exploitation costs have been calculated in the Techno-Economic Analysis Module (TEAM), in order to calculate the total cost of ownership (TCO), compare its values for different types of buses and charging scenarios, and provide recommendations. |

**ABBREVIATIONS**

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| BEV | Battery Electric Vehicle |
| COM | Charging Optimisation Module |
| CONV | Conventional (vehicle/bus) |
| DPPM | Data Post-Processing Module |
| EBSM | Electric Bus Simulation Module |
| FUA | Functional Urban Area |
| HEV | Hybrid Electric Vehicle |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning System |
| ICT | Information and Communications Technology |
| PHEV | Plug-in Hybrid Electric Vehicle |
| TEAM | Techno-Economic Analysis Module |
| TCO | Total Cost of Ownership |

## NUTS region(s) concerned by the pilot action (relevant NUTS level)

HR037, Dubrovačko (neretvanska župani)ja

## Expected impact and benefits of the pilot action for the concerned territory and target groups

The developed tool-supported pilot study on transport electrification has provided wide insights into the city bus transport behaviour and benefits of electrification and recommended suitable bus fleet and charging system configurations. The transport system analysis has pointed out that the city buses are resting in the depot during a relatively short period over the night (typically 3 hours), while they are dwelling at endstations for a significant time (between 15 and 25 minutes per stay). Having in mind these results and the fact that Dubrovnik does not have a city transport electric grid (from trams or trolleybuses), fast charging at end stations (based on a stationary charger equipped with pantograph) has been found to be a favourable solution. The virtual simulation results have shown that the use of HEV and PHEV city buses results in reduction of fuel consumption of up to 50% and 70%, respectively, when compared to CONV buses, while BEV buses does not consume fuel, at all. The CO2 emissions reduction equals up to 50% for HEV, 65% for PHEV, and ≈95% for BEV, provided that the electricity is produced from renewable energy sources in the PHEV and BEV cases. The charging system optimisation has shown that the optimal number of endstations equipped with fast chargers is 7, where a single bus is marginally needed in reserve in the BEV case. The TCO analysis has pointed out that the BEV fleet cannot be competitive to CONV fleet in the worst-case scenarios, while HEV fleet is competitive and PHEV fleet is marginally competitive.

## Sustainability of the pilot action results and transferability to other territories and stakeholders

The pilot action methodology and tools are directly transferrable to other cities/FUA, which is explained in what follows. The results of the pilot action were obtained by applying the developed ICT tools to recorded driving cycles. Different transport companies can also record the driving cycles, then pre-process the data in a tool-friendly format, and finally use the tool to obtain the pilot results for their city/FUA. The pilot action results are transferrable, as well, in terms of knowledge generated that can be transferred to make decisions for other cities of comparable transport system characteristics.
Pilot action results have been obtained for a representative bus fleet and taking into account that the city bus transport system does not significantly change its behaviour, the obtained pilot action results should be sustainable on a long time horizon. The advantage of the applied approach is that even if the transport behaviour changes significantly, the pilot study can readily be repeated based on a fresh set of recorded driving cycles.

## Lessons learned from the implementation of the pilot action and added value of transnational cooperation

The high share of fuel cost, coming from high utilisation of bus fleet (250 km/day/bus in average), is the reason why e-buses, which need less fuel (HEV, PHEV) or use much cheaper electricity (PHEV, BEV), can be competitive in Dubrovnik (or nearly competitive in the BEV case).
Because of high utilisation and short resting time of buses at the depot, particularly for cities where additional space for mini-depot-like city recharging stations is expensive, one should lean towards the fast charging solution at endstations. This is especially suitable because the buses dwell for a considerable time at the endstations (ready for charging) and the routes between endstations are short.
Since the fast charging station utilisation is low, it becomes attractive to establish e-hubs located at the endstations and powered from the bus-charger power stations (with the charging priority given to buses), which would be an additional boost to e-mobility, and which would increase utilisation of power stations and effectively reduce PHEV/BEV fleet TCO (and thus boost its competitiveness). Fast chargers do not have to be installed at all endstations if buses alternate dominantly over some of them. PHEV can be cost effective solution even for the most difficult scenarios, without special incentives or regulatory changes, and can, thus, represent an excellent transitional solution. Once the fast charging infrastructure is paid off through PHEV fleet, the next generation of fleet can be based on BEVs and it would then be cost effective and provide maximum passenger satisfaction.
Although HEV is competitive to CONV (12% lower TCO when compared to CONV case and the worst-case scenario) and can reduce fuel consumption and emissions by up to 50%, it still shares the basic disadvantages of CONV (noisy, no e-drive option in LEZ, presence of emissions, etc.).

## References to relevant deliverables and web-links
## If applicable, pictures or images to be provided as annex

The pilot action results were documented in the deliverables/reports designated as D.T3.3.1 and D.T3.3.2. During pilot implementation, the software tool was updated and fine-tuned, as documented in D.T2.4.3.
Outline of the main results and description of experiences and lessons learned from the pilot actions on city bus transport electrification, including indications and recommendations for follow up actions, were documented in D.T3.4.3.
An overview of Pilot Action results are publicly available at web site of the International Conference "*Smart solutions for urban and regional mobility in Europe*", which was held on June 6, 2019 in Brno, Czech Republic.
Link: [https://final-solez.webnode.cz/english/](https://final-solez.webnode.cz/english/)

*Fig 01 – Tracking device installation*

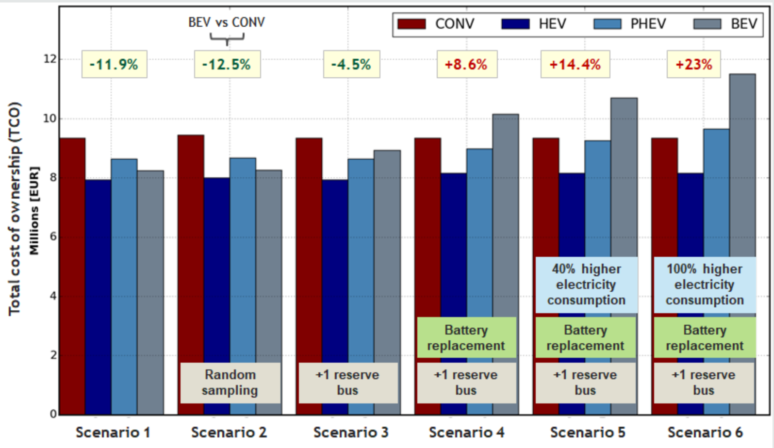


*Fig 02 - TCO analysis results*