Output factsheet: Pilot action for city bus transport electrification in Žilina's Functional Urban Area

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 (Žilina)
Responsible partner (PP name and number)	UNIZAG PP3
Project website	https://www.interreg-central.eu/Content.Node/SOLEZ.html
Delivery date	01/2020

Summary description of the pilot action explaining its experimental nature and demonstration character

The pilot activity in Žilina first considered characterisation of existing (conventional/Diesel) city bus transport based on continuous (i.e. one-year, 24 hour/day) GPS/GPRS telemetry tracking of representative bus fleet consisting of 15 buses. The main aim of the pilot activity 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. The pilot study has first involved the processing of raw driving cycle data using Data Post-Processing Module (DPPM), in order to extract the 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. 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). The conventional bus model has been validated with respect to recorded fuel consumption data, and the fuel economy benefits of recently deployed HEV bus has been characterised. 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

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

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

The pilot actions were implemented for the following NUTS (sub-regional/NUTS3 level):
Trójmiejski - SK031, Žilinský kraj

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 configuration. The transport system analysis has pointed out that city buses are resting in the depot during a long period in night and relatively long interval around the noon, and they are dwelling at endstations for a relatively short time and rather rarely due to long routes (approximately every 1:05 h). Having in mind these results and the fact that Žilina does have a trolleybus electric grid in the city centre, the future electric city bus transport should be based on fully electric buses equipped with an on-board charger and pantograph and having a large battery capacity (e.g. 250 kWh). 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 55%, respectively, when compared to CONV buses, while BEV buses do not consume fuel, at all. The CO_2 emissions reduction equals up to 50% for HEV, 54% for PHEV, and 94% 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 charging stations should include depot and at least four city centre stations with frequent and relatively long bus stops. The TCO analysis has pointed out that strictly-economically BEV (and also PHEV) fleet cannot be competitive to CONV fleet in any scenario, while HEV fleet is marginally competitive. The lack of competitiveness of e-buses is explained by low utilisation of city buses (predominantly in the peak morning and afternoon hours).

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 are 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 main lessons learned through the pilot action implementation have been related to realising that fuel costs are dominant in the case of CONV fleet. Therefore, the more expensive e-buses (particularly BEVs) including the associated charging infrastructure can only be competitive if the buses are highly exploited (resulting in high savings in energy/fuel **costs**). This does not apply to the case of Žilina due to strong intermittency of city bus duty cycles.

In the case of low fleet exploitation considering long resting time of buses at the depot, long routes, short staying of buses at endstations, and available trolleybus electrical grid in city centre, one should lean towards the fast charging stations at the depot and city bus stations that are aligned with the electric grid and have a large charging availability.

PHEV is not a viable solution for the above described electrified city bus transport system, because it has a relatively small battery capacity while the fast charging availability in the city centre stations is relatively low and the routes are relatively long. Although HEV is competitive to CONV (13% lower TCO when compared to CONV case) 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.). In the case of BEV fleet, there is generally a necessity for engaging reserve bus(es) to tackle the issue of battery depletion on some of regular BEV buses during peak-load days and irregular duties. This necessity can be minimized by using a reasonably high battery capacity (e.g. 250 kWh in Žilina case) and off-line or on-line bus service rescheduling for boosting the charging availability.

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.T3.3.3. During the course of 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/

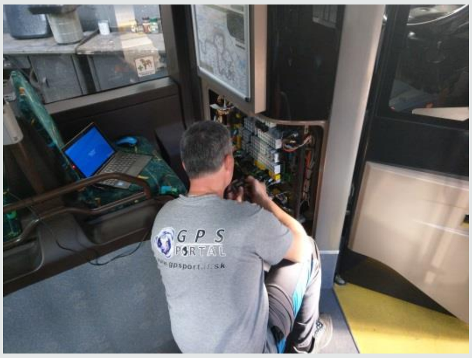

Fig 01 - Tracking device installation

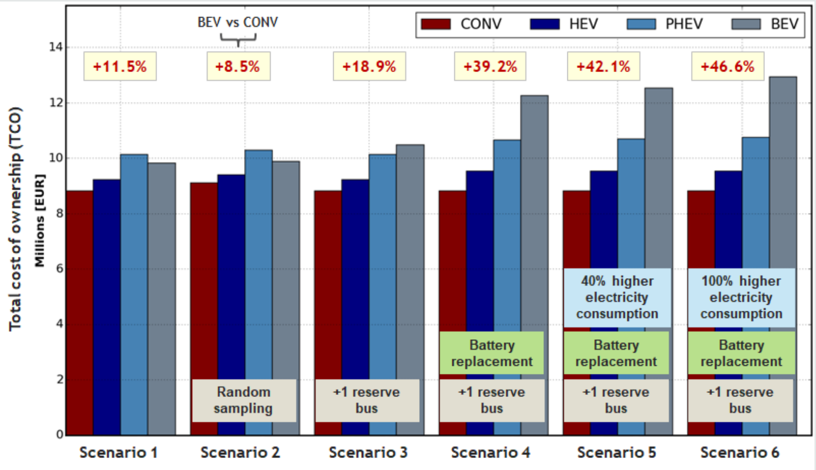

Fig 02 – *Total Cost of Ownership analysis results*