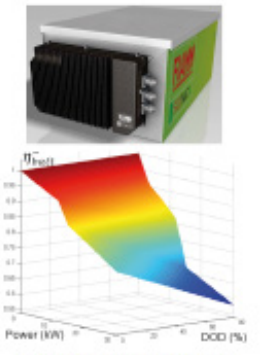
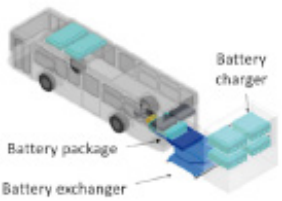
Sustainability Evaluation of an Electric Bus Fleet for the Urban Public Transport System of Padova

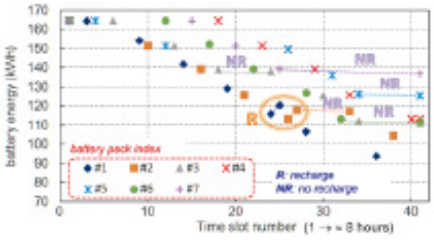
The development of a sustainable and reliable urban public transport service calls for a better integration between novel clean technologies and efficient management of the vehicle fleet. The research focused on the benefits deriving from the introduction of an electric battery-supplied bus (EBB) fleet in the urban transportation context of the city of Padova, provided with exchangeable batteries coupled to recharging stations (battery swap stations). Its main features are the reduced recharging time limited to battery package replacement, the load reduction on the electrical infrastructure with respect to rapid charging systems, the extended battery lifetime due to the optimized state of charge management and charging conditions and the consistency with different battery technologies. After an extensive analysis of the actual urban bus fleet (2014), equivalent bus configurations are defined for both diesel and compressed natural gas vehicles, by means of an analytical elaboration of reference driving cycles. Such elaboration also includes the performance deterioration over the vehicle life by applying a derating function to the propulsion system and catalyzer efficiencies. Then, the EBBs characteristics and operation are determined by an algorithm aiming at the minimization of the battery investment and operating costs on a ten years service. The algorithm includes the efficiency models elaborated from experimental charge/discharge operations of a Sodium Nickel Chloride (ZEBRA) battery, deemed to be the more suited technology in terms of specific energy, purchasing cost, fault tolerance and operating life.
The equivalent buses with different length are compared in terms of energy consumptions and pollutant emissions on the same reference routes.
Such comparison is carried out by numerical simulations, taking into account both the engine practical behavior and the battery charge/discharge operation.
By way of example, the simulations evidence the following savings by replacing 8 m diesel buses with corresponding EBBs : -58% primary energy consumption, -72.6% NOx,-77.7% from HC and NMVOC comparison and -92.8% PM.
In addition to such benefits, a significant noise reduction is expected.
The estimated overall average annual cost is 0.48 €/km, competitive with the actual well-established technologies .



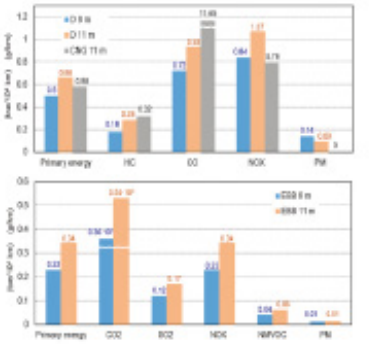
38 Ah ZEBRA battery module and discharge efficiency map (courtesy of FIAMM)



Battery swap principle



Variation of the battery energy with the time slot number (APS DP route, 5 bus fleet, 7 battery packs)



Specific energy consumption and gas emissions for 8 m and 11 long buses; (a): ICE buses (D: diesel type); (b): EBBs.

Mobilità sostenibile
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Main research topics:

- Electrical Generation from Renewable Sources
- Electrical Energy Storage
- Electrical Systems for the Sustainable Mobility
- Small Electrical Motors and Drives for Home Appliances