TECHNO ECONOMIC FEASIBILITY STUDY ON FUEL CELL AND BATTERY ELECTRIC BUSES – AUSTRIA

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Introduction

Transformation towards a cleaner energy is an important agenda on the United Nations sustainable development goals [1]. Cleaner energy is especially important in the mobility sector in the transformation in Austria as transport has been the most polluting sector in the last decade in Austria which aims to transition towards cleaner public transport technologies by 2030 [2, 3]. Diesel buses used for public transportation are major contributors to global greenhouse gas (GHG) emissions. In this study, the feasibility of employing alternate zero emission buses in the city of Graz (which has a public transport fleet of 162 diesel buses) has been explored. The alternate zero emission bus technologies considered are battery electric buses (BEBs) and fuel cell electric buses (FCEBs). The major drawbacks of the BEBs are the short range (<200 km), seasonally increased energy requirements (for heating and cooling), and long recharging period. In the city of Graz 45% of the routes have a daily range of greater than 200 km. BEBs do not suffice operating in this high mileage requirement everyday throughout the year. Hence, FCEBs are considered because of their higher range (>350 km), energy sufficiency during different seasons, and lower refuelling period.

The objective of this study is to compare the carbon footprint (cradle to grave) of fuel cell dominant electric buses (FCEBs) and battery dominant electric buses (BEBs), to choose the best available option from both environmental and economic perspective. It explores the techno-economic feasibility of BEBs and FCEBs to replace the entire diesel bus fleet in Graz. Therefore, daily average route ranges and average electricity mixes for operation are considered specifically pertaining to Austrian region. Life cycle assessment (LCA) is used to estimate the carbon footprint while total cost of ownership (TCO) is used for economic analysis.

Methodology

The methods employed in this study are market research, LCA, and TCO. Market research is carried out in the form of secondary literature research to analyse the state of the art of the buses and identify the FCEB and BEB manufacturers that are likely to be deployed in the city of Graz. Hence, the important parameters related to the performance and configuration of the buses have been identified [4, 5]. These data also form the input basis for LCA. LCA, a tool used for environmental impact assessment is employed in this study to assess the carbon footprint of the buses from Well to Wheel (WTW). WTW assessment consists of GHG emissions at manufacturing, operation, and end of life (EOL) phases. The software used for LCA is GREET. Different pathways have been modified according to the specific case scenarios to estimate the total GHG emissions. The functional unit used is g CO_2-eq / km for WTW emissions. While lifetime fleet emissions use kt CO_2 eq / lifetime mileage. TCO (Euros / km) is used to estimate the capital and operational expenditure of the buses.

Results

The results are divided into two major sub-sections: (1) carbon footprint for FCEBs and BEBs and (2) TCO under different case scenarios. Figure 1 shows the lifetime emissions (in kt CO_2 eq) for FCEBs and BEBs. Separate fleets of FCEBs and BEBs or mixed/heterogenous fleet operating on the Austrian electricity mix produce high WTW GHG emissions which fall just short of what the average diesel bus fleet produces [6]. However, operating on renewable electricity, these bus fleets (either separately or mixed fleet) produce comparably lower WTW emissions. A mixed fleet operating on renewable electricity produces 126 kt CO_2 eq less lifetime emissions than an average diesel bus fleet. Figure 2 shows the comparison of TCO for different case scenarios. TCO for BEB fleet operating on overnight charging

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(ONC) infrastructure is the lowest but still double the cost of diesel bus fleet. TCO is higher for BEBs operating on opportunity charging (OPC) because of higher electricity prices. Heterogenous fleet consisting of FCEBs and BEBs (operating on ONC) has a slightly lower TCO. Hence, a heterogenous fleet is ideal because of lower emissions and TCO, while FCEB fleet solves the range issues.

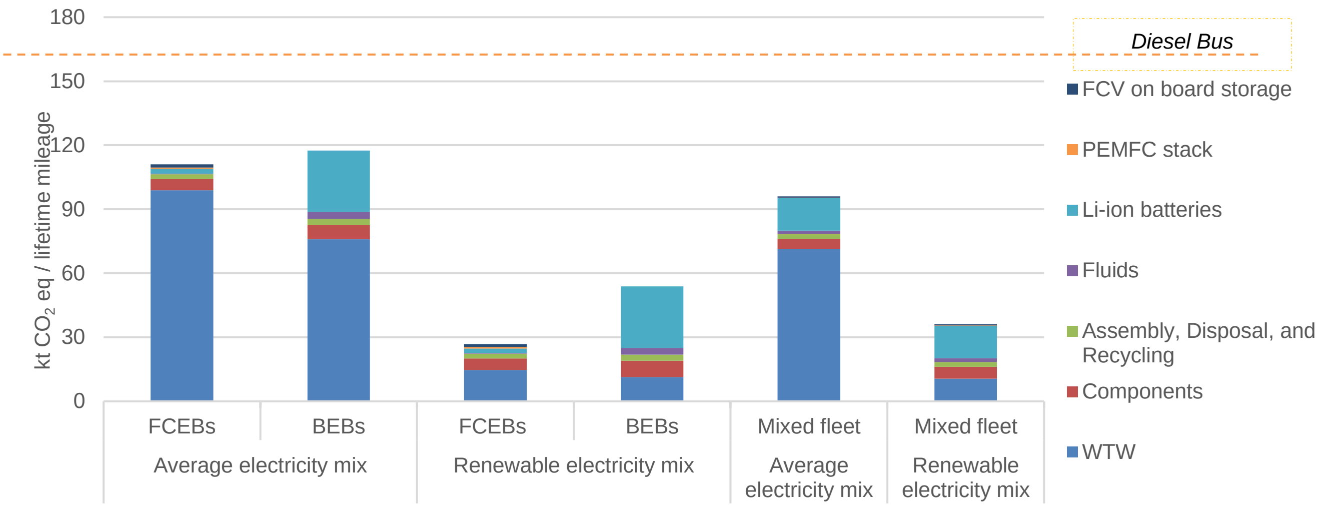

Figure 1: Comparison of GHG emissions for different case scenarios.

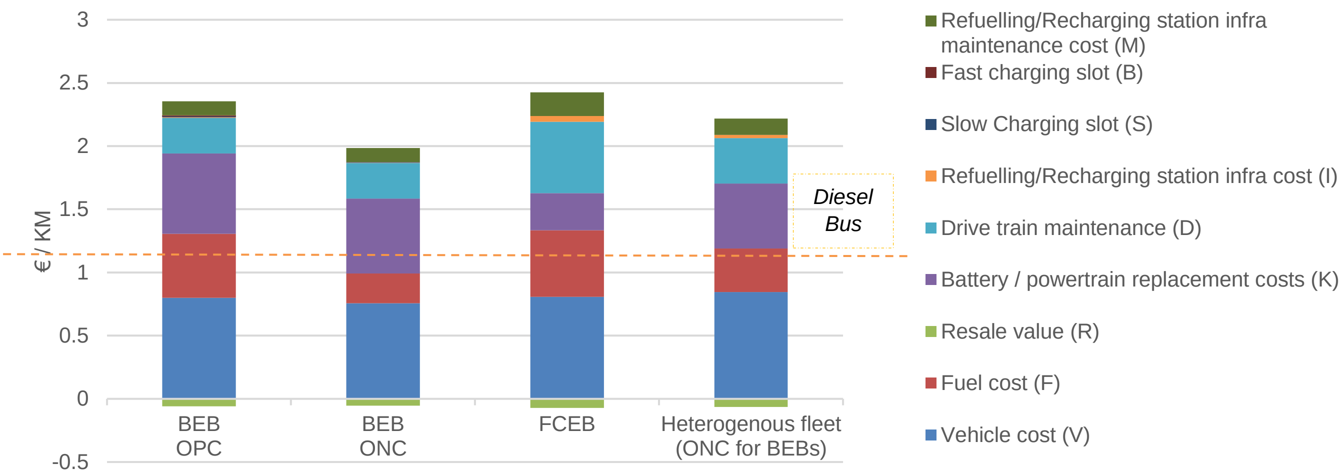

Figure 2: TCO comparison for different case scenarios.

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