Light Electric Vehicles for Muscle

Subjects: Transportation

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Light electric vehicles (LEVs) facilitate a significant reduction in global warming potential (GWP) and other environmental impacts related to specific transport performance due to their lightweight construction. Low-voltage systems in the drive engine, an open vehicle design and online vehicle data processing allow LEVs to be repaired by independent workshops, thus enabling long vehicle use as well as conversion or retrofitting for periods of use beyond 20 years. LEVs are not yet very common in everyday life in Western Europe. In order to support the acceptance of muscle power-supported LEVs in the EU L7e registration class by users, the vehicle design and construction specifically address requirements in the areas of last-mile parcel delivery and other transport services, including passenger transport. Life cycle assessment was used to investigate two construction methods for LEVs, mixed construction and fibre composite construction, in terms of the production, service life phase and end of life. A vehicle configuration was developed which, in addition to resource-saving production and long-life operation, enables easy access for users and maintenance of the LEV for various purposes. The resource efficiency of light electric vehicles was proven with regard to the ecological aspects.

light electric vehicle | global warming potential | life cycle assessment

1. Introduction

The use of energy today, in the form of burned fuels in road-bound passenger and freight transport, is nearly constant in relation to 1995, with a slight increase of 7% in 2019 [1]. Life cycle assessment (LCA) studies on electric vehicles (EVs) show a correlation between vehicle equipment mass and environmental impact [2][3]. In addition to the use of electric drives, the lightweight construction offers approaches for reduced greenhouse gases with a moderate increase in manufacturing costs compared to conventionally configured road vehicles [4]. Further increases and the potential reduction in environmental impact have been identified for LEV freight transport in the “last mile” and trades [5]. Road-bound traffic density for the transport of goods and people in the “last mile” with conventional vehicles and conventional EVs has an increasingly negative impact on the quality of life in urban areas, due to particulate matter emissions from brakes and tires, noise and land use. As known from classical physics, the rolling resistance of a terrestrial vehicle is directly related to the mass, aerodynamics and rolling friction in the tires. Specific to EVs is a strong relation between vehicle mass and energy consumption, because of the good efficiency of electric machines [6].

The main subject of this paper is a comparison of two methods of construction for LEVs realized at prototypic scale, Cargo Cruiser 1 (CC1) with steel/GFRP construction and Cargo Cruiser 2 with GFRP construction. **Table 1** shows the orientation by weight and energy consumption of LEVs by two possible construction methods, steel/GFRP and GFRP construction, for one market-accessible EV and one market-accessible light-duty vehicle (LDV).

Table 1. Overview of construction methods considered for two LEVs, Cargo Cruiser 2 (CC2) with steel/GFRP construction and Cargo Cruiser 3 (CC3) with GFRP construction, in comparison to EV and LDV.

	LEV with Steel/GFRP Construction (CC2)	LEV with GFRP Construction (CC3)	EV (Accessible on Market)	LDV (Accessible on Market)
Weight (kg)	517.2	534	1200	1995
Approximate energy consumption without payload (kWh/100 km)	10 (electric)	10 (electric)	20 (electric)	80 (diesel)
Silhouette in same scale				

with low approach proposes examples of vehicles in “last mile” applications. Increased services such as car sharing [7] shows the acceptance of new models of transport if they correspond to daily life practice. Multimodal transport systems for freight in urban areas are at an early stage of development [8] and for passenger transport, the needed integration of different modes is an open challenge, as shown by the low sustainability in the user availability of such offers [9]. Residents of urban centres solve this challenge in individual information work, provided they are prepared to be flexible and have the necessary knowledge to deal with information and means of transport [10]. Due to historically grown infrastructure and spatial traffic conditions, intermodal transport systems, for both goods and people, usually require solutions for the so-called last mile in order to successfully integrate individual and public passenger transport [11] and to make the transport of end user-related goods more efficient [12].

The study investigated the circularity of a last mile-specific LEV for the transport of people or goods. The LEV was developed with two methods of construction: steel/glass fibre reinforced plastic (named CC2) and nearly complete glass fibre reinforced plastic (GFRP, named CC3). The circularity of both constructions was investigated, with a focus on three aspects: production, maintenance and the concept of safety gained by lightweight construction. Because easy access to the vehicle is important, the vehicle was conceived as a muscle-electro-hybrid-powered vehicle, which comes close to the user experience of a heavy cargo bike. To reflect its usability as a vehicle for last mile transport, an intermodal model was used to describe the LEV’s specifications. Since the planning effort required for intermodal transport in terms of logistics generates little additional expenditure compared to intermodal passenger transport, a life cycle assessment (LCA) comparison of the two methods of vehicle construction was focused on the last mile parcel delivery.

2. Development and Findings

In the cradle-to-grave LCA model, landfilling was selected for the end of life (grave) of the fibre composite components, as no primary or secondary data were available on the recycling of fibre composites and landfilling or storage at the end of their life was, therefore, assumed to be the practice. In this scenario, the use of fibre composites in vehicle construction has significant environmental impacts at the end of their life according to the EDIP 2003 indicator in comparison with conventional EVs (**Figure 1**). Other balanced environmental impacts reported, GWP and ReCiPe endpoints, show a significant reduction in direct relation to vehicle mass.

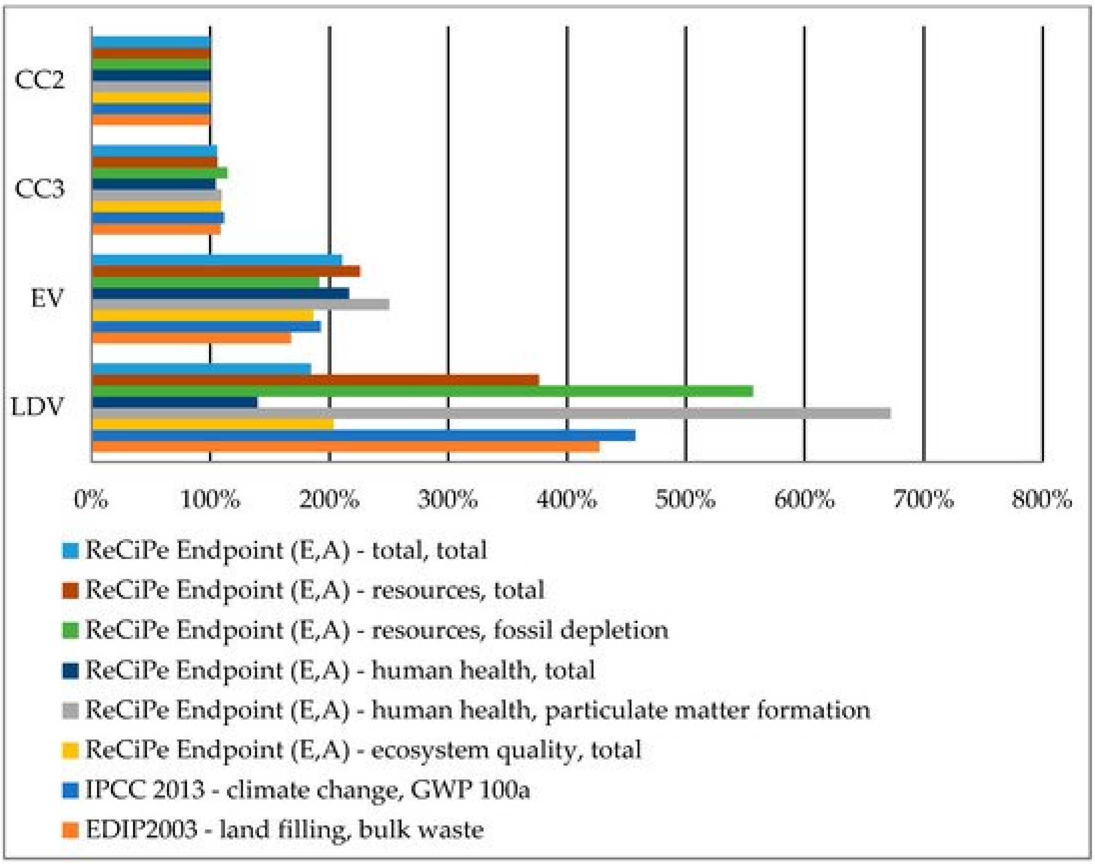

Figure 1. Relative comparison of transport vehicles (CC2 normalised to 100%) of IPCC 2013 GWP, ReCiPe key figures and EDIP key figure for landfilling of residual materials for CC3, EV and LDV, each with 250 kg payload, based on one tonne-kilometre (1 tkm).

The weight of the LEV, which is around 50% lower than that of a conventional EV, leads to a significant reduction of around 50% in environmental impact (**Figure 1**), despite the conservative assumed functional unit tonne-kilometre.

The resource and energy-efficient transmission of data by LoRaWAN was validated as a robust option for transmission of vehicle data for structural health monitoring (SHM). Therefore, existing LoRaWAN networks or singular networks with related databases for last mile traffic with LEVs can be used in urban areas. In addition, structural health monitoring, this assessment of vehicle data can be used for tracking overload events that occur unexpectedly in practical operation to be registered in digital "component biographies" of vehicle elements to support approaches for reuse or extended component service life.

The French repair index is currently not directly usable for the mapping of light vehicles. The parameter set for battery-powered electric lawnmowers just allows an initial appraisal for possible repair of LEVs.

In further investigations, the assessed approaches can be developed further to improve the usability and the mass-to-weight ratio of LEVs for last mile services in personal transport and the transport of goods.

In order to make the repair index directly applicable to LEVs, extending the parameter sets to include LEV-specific components, such as mechanical steering and mechanical coupling with muscle power, is needed.

To solve the problem of fibre composite end of life, it is proposed to investigate the use of natural fibre composites with non-genotoxic resin matrices. It should be investigated how such composites can be processed at the end of their life as biomass input for pyrolysis processes such as thermocatalytic reforming (TCR) into so-called plant charcoal as a soil substrate, to reduce the negative environmental impact.

The practical use of SHM using shape memory alloy (SMA) sensors has to be validated for practical use in vehicle operation, based on the findings of LoRaWAN data transmission. The use of SMA sensors for measuring the strain on vehicle parts enables the optimisation of vehicle construction by comparing theoretical predicted loads (via FEM) with real-life measured mechanical loads on composite parts and, if necessary, detecting misuse or mechanical stresses that can occur in practical use. Based on such a proposed SHM, future investigations will adjust the safety factors for the fibre composite design to optimise the mass balance (cumulative resource expenditure) for fibre composite structures in light-vehicle construction.

In order to specifically reflect the new mass–power–weight ratio of light vehicles on the last mile, a new kind of functional unit, “last mile delivery of standard parcels”, is proposed for future LCA of parcel delivery on the last mile with LEVs and electrically supported bicycles.

References

1. Umweltbelastungen durch Verkehr. Umweltbundesamt (Deutschland)/TREMOD. Available online: https://www.umweltbundesamt.de/daten/verkehr/umweltbelastungen-durch-verkehr#undefined (accessed on 30 September 2021).
2. Egede, P. Environmental Assessment of Lightweight Electric Vehicles; Springer: Braunschweig, Germany, 2017.
3. Del Duce, A.; Egede, P.; Öhlschläger, G.; Dettmer, T.; Althaus, H.; Bütler, T.; Szczechowicz, E. Guidelines for the LCA of Electric Vehicles (eLCAr). Available online: https://www.elcar-project.eu/downloads/guidelines/index.html (accessed on 13 December 2021).
4. Czerwinski, F. Current Trends in Automotive Lightweighting Strategies and Materials. Materials 2021, 14, 6631.
5. Brost, M.; Ewert, A.; Eisenmann, C.; Stieler, S.; Gicklhorn, K. Ich Ersetze ein Auto; Deutsches Zentrum für Luft- und Raumfahrt: Berlin, Germany, 2019.

6. Weiss, M.; Cloos, K.C.; Helmers, E. Energy efficiency trade-offs in small to large electric vehicles. Environ. Sci. Eur. 2020, 32, 1–17.
7. Kagerbauer, M.; Heilig, N.; Mallig, N.; Vortisch, N.P. Carsharing-Ein Neues Verkehrssystem! Nationale und Internationale Trends in der Mobilität; Springer: Berlin/Heidelberg, Germany, 2020.
8. Porsche Consulting. ONO Whitepaper: Urbaner Kombiverkehr mit Tram und Cargobike; Porsche Consulting: Berlin, Germany, 2020.
9. Willing, C.; Brandt, T.; Neumann, D. Intermodal Mobility. Bus. Inf. Syst. 2017, 59, 173–179.
10. Jarass, J.; Oostendorp, R. Intermodal, urban, mobil-Charakterisierung intermodaler Wege und Nutzer am Beispiel Berlin. Raumforsch Raumordn 2017, 75, 355–369.
11. Spieckremann, A.; Grienitz, V.; von der Gracht, H.A. Heading towards a multimodal city of the future? Multi-stakeholder scenarios for urban mobility. Technol. Forecast. Soc. Chang. 2014, 89, 201–221.
12. Wrighton, S.; Reiter, K. CycleLogistics-Moving Europe Forward! Transp. Res. Procedia 2016, 12, 950–958.