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Electric vehicle battery technologies: From present state to future systems

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ABSTRACT

Electric and hybrid vehicles are associated with green technologies and a reduction in greenhouse emissions due to their low emissions of greenhouse gases and fuel-economic benefits over gasoline and diesel vehicles. Recent analyses show nevertheless that electric vehicles contribute to the increase in greenhouse emissions through their excessive need for power sources, particularly in countries with limited availability of renewable energy sources, and result in a net contribution and increase in greenhouse emissions across the European continent. The chemical and electronic components of car batteries and their waste management require also a major investment and development of recycling technologies, to limit the dispersion of electric waste materials in the environment. With an increase in fabrication and consumption of battery technologies and multiplied production of electric vehicles worldwide in recent years, a full review of the cradle-to-grave characteristics of the battery units in electric vehicles and hybrid cars is important. The inherent materials and chemicals for production and the resulting effect on waste-management policies across the European Union are therefore reported here for the scope of updating legislations in context with the rapidly growing sales of electric and hybrid vehicles across the continent. This study provides a cradle-to-grave analysis of the emerging technologies in the transport sector, with an assessment of green chemistries as novel green energy sources for the electric vehicle and microelectronics portable energy landscape. Additionally, this work envisions and surveys the future development of biological systems for energy production, in the view of biobatteries. This work is of critical importance to legislative groups in the European Union for evaluating the life-cycle impact of electric and hybrid vehicle batteries on the environment and for establishing new legislations in context with waste handling of electric and hybrid vehicles and sustain new innovations in the field of sustainable portable energy.

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1. Introduction

Battery electric vehicles (BEV) are becoming increasingly integrated in several cities across Europe and the US [1,2], as a result of the legislative measures implemented to reduce traffic pollution and limit greenhouse gas emissions [3]. Since the advent of the industrial revolution, the environmental stress caused by fossil fuel combustion [4] from the automotive and industrial park has increased to such as extent that oceans are experiencing a decline in pH value [5], crustaceans and several species across the globe risk extinction [6], and polar regions and ice-shelves across the world are overall experiencing a decline in total volume [7,8]. Albeit this critical state, the implementation of BEV has progressed more slowly compared to the pace of the BEV-technology development, due to legislative and bureaucratic processes and also given a series of complications for implementing these more environmental friendly solutions in the society [9]. Such complications are for instance a lack of a proper availability of recharging stations, inexistent uniformity in adapters for different car-types and high custom-costs for import and implementation of vehicles in the European markets compared to the environmental benefits BEV pose [10].

BEV technologies are however missing a proper and full recycling framework in several countries, and the usage of BEV and general electric equipments causes altogether still a considerable energy consumption which in turn results in increased CO_2 emissions, particularly in countries without renewable energy resources [11]. BEV represent also a class of consumer items which generate a considerable amount of toxic waste, given emerging and more advanced powering systems for automotive vehicles. Therefore, in order to meet an eventual scenario of extensively used BEV through the society, an assessment of the types of available battery technologies is critical, as many of these are based on nickel and cadmium metals, which are considerably toxic and an increased amount of battery-driven vehicles can affect the environment if proper recycling strategies are absent. In order to survey this, an initial state of the art of BEV technologies is introduced, followed by a review of applied battery technologies, and their recycling scheme. Finally, a survey of emerging green energy sources with applicability on BEV is included along with elementary chemical descriptions of their properties, ultimately followed by the concept of *biobatteries*, systems relying on biological components for the generation of low electric currents.

2. Battery for EVs – state of technology

Battery electric vehicles (BEV) have an internal source of energy – an electric motor powered by electric batteries located in the vehicle. The powertrain gives BEV's the possibility to operate with zero emissions in the place of use. Many of the manufactured solutions adopted to build BEVs also make use of an “energy recovery” technology that allows the electric motor to be used both as a propulsion source and as a generator when braking or when the vehicle moves freely under the action of gravity. This has an important effect in increasing the overall energy efficiency of the electric vehicle.

The advantages of using a BEV in traffic are the high torque of the electric motor that is transmitted to the wheels and the smoother acceleration (and deceleration) compared to vehicles with internal combustion engines (ICE – Internal Combustion Engine). BEVs also do not emit noise while operating the electric motor and they don't produce pollutant emissions [12]. The aspects make BEVs the ideal vehicles to be used in cities and / or urban areas. But besides the above advantages, there are some disadvantages to using BEVs:

- High production costs.
- Reduced overall size (compared to vehicles equipped with ICE).
- Limited autonomy and top speed.
- Large recharging times or the need for special charging places.
- The lack of electric motor noise can cause traffic accidents (persons with hearing disabilities, pedestrians, cyclists, etc.).

Currently there are two constructive types of BEV, widely accepted by most companies in the automotive industry, according to the mode of transmission of the electric power developed by the electric motor to the drive wheel:

- The electric motor replaces the classic internal combustion engine. The power produced by the electric motor is transmitted to the wheels via transmission (gearbox) (Fig. 1a).
- Each drive wheel is fitted with an electric motor (hub motor) (Fig. 1b).

Fig. 1 shows that the manufacturing solutions are similar in that the size and location of the battery are the same. The use of a central electric motor design offers the advantage of using the same design as existing vehicles on the market. Also using the gearbox increases the efficiency of the usage of the power developed by the electric motor depending on load being placed on the vehicle based on traffic conditions. However, it should be mentioned that the use of a gearbox lowers the overall efficiency due to inherent friction in the mechanisms that compose it.

The reduction of these mechanical losses can be achieved by using a periphery hub motor construction type for electric vehicles, but in the lack of a gearbox, this solution can be used mainly for lightweight vehicles whose transport capacity is also small (e.g. small vehicles for 2 passengers). In any of the above cases, if the construction of the electric vehicle makes use of the regenerative braking technology, this will lead to substantial improvements in the energy efficiency of the electric vehicle [13,14]. The election of a proper drive and optimal control strategy of electric vehicles are the major factors to optimize energy management to extend the running distance per battery charge [15]. A number of battery's manufacturing technologies are suitable to equip an electric vehicle, technologies that today, are widely accepted by the companies in the manufacturing industry:

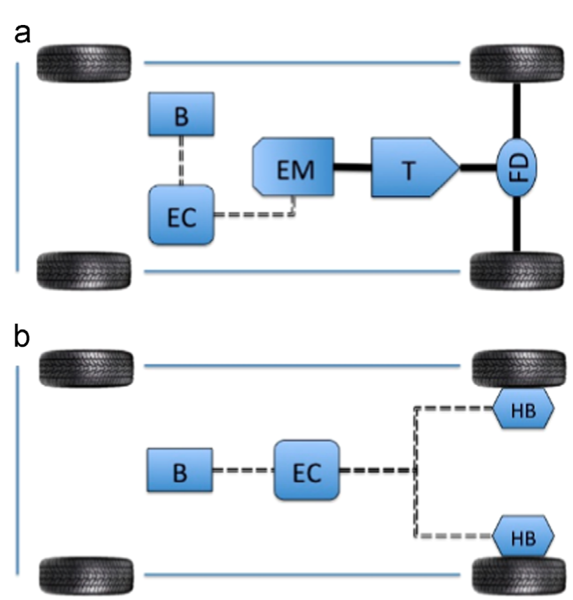

Fig. 1. Constructive types of 2WD (wheel drive) battery electric vehicles (a-with a single electric motor; b-with hub motors; B-battery, EC – electronic control, EM-electric motor, T-transmission, FD-differential, HB-hub motor).