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To achieve a longer vehicle driving range: think beyond just a battery capacity increase

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Executive Summary

The driving range of an electric vehicle (EV) is mainly determined by the energy capacity of its battery. However, other systems have also a significant impact on the vehicle driving range: vehicle total weight, vehicle electrical circuitry, traction inverter, electric motor, vehicle aerodynamic drag, tires, etc. A combination of relatively small improvements on different systems results in a big improvement on the vehicle level. Innovative approaches and technologies are being developed to reduce the energy losses from the battery to the wheels. This not only reduces the cost of battery needed for a given driving range but results also in reduction of the vehicle environmental impact during its manufacturing and operation, and reduction of dependence on scarce materials, like lithium or cobalt. Different vehicle systems innovations are reviewed in this article.

Keywords:battery, AC motor, DC fast charging, electric vehicle (EV), inverter, SiC, market

1 Introduction

To reach governments' strict CO2 emission reduction targets, the electrification of vehicle fleets has become mandatory. Although different levels of electrification exist, an acceleration of transition towards full electric vehicle has been observed in the last years, Fig 1. The annual market for battery electric vehicles (BEVs) is rapidly growing and will reach 21 million cars by 2028, according to Yole Intelligence. However, a high vehicle price and a still relatively short driving range under real operating conditions are amongst the main barriers impeding even faster adoption of BEVs. Although the increase of driving range could be in principle easily obtained by increasing the battery energy capacity, this will also increase the vehicle cost, and results in other drawbacks such as higher environmental impact and poorer vehicle dynamic driving characteristics. Therefore, car manufacturers increasingly focus on other approaches how to increase the driving range [1-7].

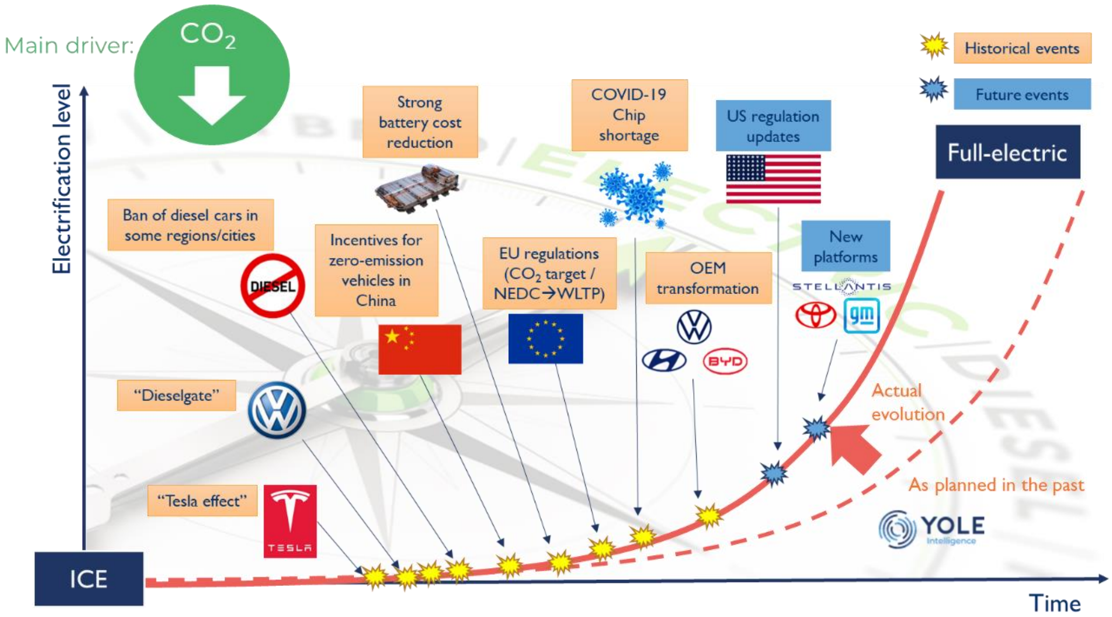

Figure 1: The initial strategic path for vehicle electrification has been accelerated by several singular events.

2 Different approaches to increase car driving range

There are multiple approaches to increase the driving range / reduce system costs, as shown on the Fig 2. All these approaches need to be balanced when evaluating a technology change. When different ways of improvement exist, the choice has to be done based on a global technology and cost analysis together with market environment and supply chain analysis.

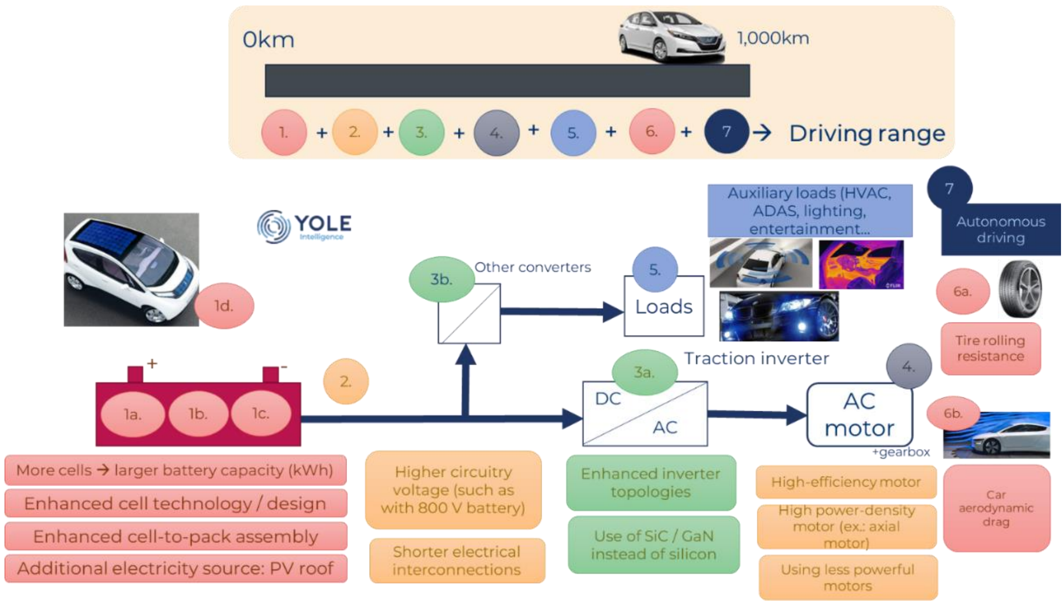

Figure 2: Different approaches to increase car driving range.

A simplest way to increase the vehicle driving range is the increase of battery energy capacity by adding more battery cells. Indeed, the useable battery pack capacity reaches the values above 100kWh for some long-range EV [2, 3]. However, this approach has many drawbacks: higher cost, higher battery weight, larger battery volume, negative impact on car dynamic driving behavior, longer charging time and higher dependence on raw material such as lithium or cobalt. Also the recycling of a bigger battery will lead to a higher environmental impact.

An alternative approach consists of reduction of energy losses from the battery to the wheels. This approach brings many benefits both on costs, environmental aspects and also car driving dynamics.

There is also a huge untapped potential for battery technology improvement, on cell, pack and manufacturing levels. Nickel-rich battery cell chemistries enable high energy density, whilst Lithium-Iron-Phosphate (LFP) battery are often used for their lower costs and absence of scarce and expensive cobalt. The Cell-to-Pack (CTP) and Cell-to-Chassis (C2C) battery pack assembly approaches enable higher pack energy density compared to commonly used modular battery packs, Fig.3. Several battery start-ups, backed often by EV manufacturers as well as established battery players are developing high-performance cell technologies, such as silicon-rich anode, nickel-rich cathode and solid-state batteries.

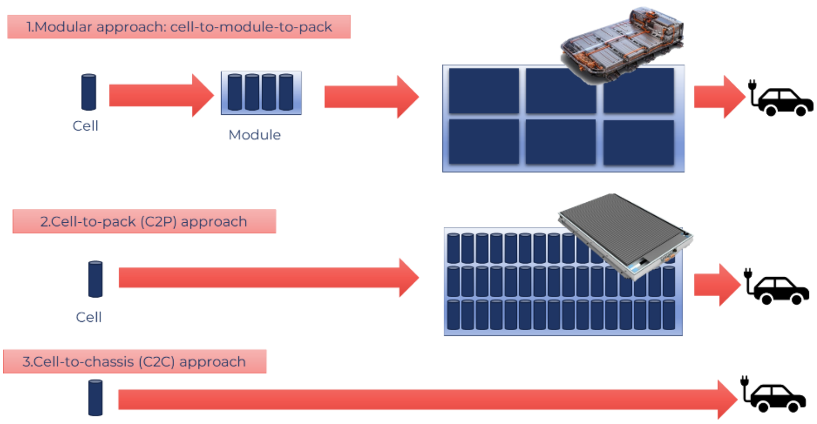

Figure 3: Modular and cell-to-pack approaches in design and manufacture of a battery pack.

To reduce the Joule losses in wiring, reduce the weight and cost of cables and enable faster charging, a growing number of vehicles adopt 800V battery voltage level instead of commonly used 400V. In 2012 AVL developed and implemented "AVL CoupE" – the first 800V electric car. Porsche Taycan was the first series produced 800V electric vehicle [6], followed by Hyundai's vehicles (Hyundai Ioniq 5, Kia EV6…) based on Hyundai's 800V E-GMP platform [7]. The 800V vehicle market is poised to grow and will reach about 25% share of newly produced vehicles in 2030 [8]. A higher voltage platform brings advantages, but also some challenges, such as compatibility with DC fast chargers, often designed for charging of 400V batteries. Different solutions have been developed to solve this issue, on battery level, on car inverter level or by adding an additional boost converter in the car [9]. The growing market of 800V vehicles drives also the deployment of DC chargers with a maximum DC voltage of 920-1,000V, able to charge directly the 800V batteries.Such chargers become increasingly common. Nevertheless, Tesla's extensive network of superchargers is still not designed for charging of 800V vehicles.

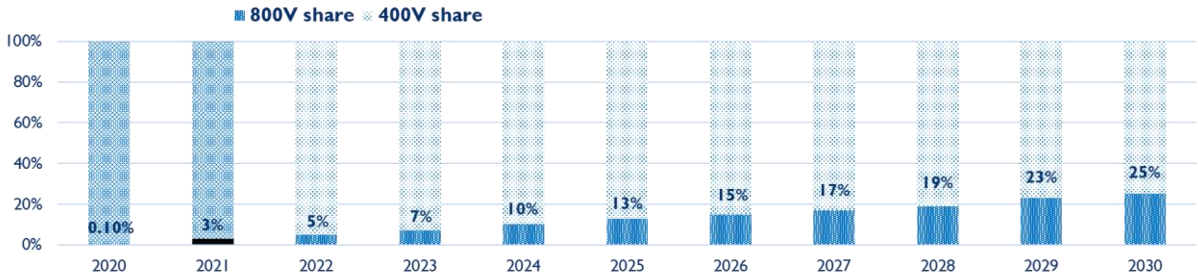

Figure 4: Forecast of 800V system production share in BEV, according to Yole Intelligence

Silicon carbide (SiC) technology was first adopted in traction inverters of commercial BEVs by Tesla in its Model 3 car. Compared to traditional silicon IGBT technology, SiC-based MOSFET transistors enable traction inverters with higher power conversion efficiency. Lower losses bring another advantage in reduction of cooling needs. The automotive players rapidly understood the potential of SiC technology and implemented car models with SiC inverters into their roadmaps. As of 2022, electric vehicles represent already the largest demand on SiC power devices.

Electric motor is another key system in an electric vehicle. In high-power vehicles, two (or more) motors are increasingly being used instead of a single motor. Two (smaller) motors are easier to be integrated in the vehicle compared to one (big) motor and the weight of motors is more equally distributed across the vehicle. In the case of two motors, each motor can be mainly used in the speed/torque range where its efficiency is maximal, thus increasing the total powertrain efficiency. A more powerful motor can be controlled by a SiC-based inverter, while lower-power motor by an IGBT inverter, to optimize the performance/cost balance for the EV powertrain.

Beside just optimizing the individual systems and their matching, the system integration is another technology trend in BEVs. There are different options for integration, such as electric axle (motor+gears+inverter) or integrated power unit (DC-DC converter + on-board charger), Fig.4. Trade-offs are needed including factors, such as compactness, performance, cost-saving, serviceability, supply chain management and flexibility.

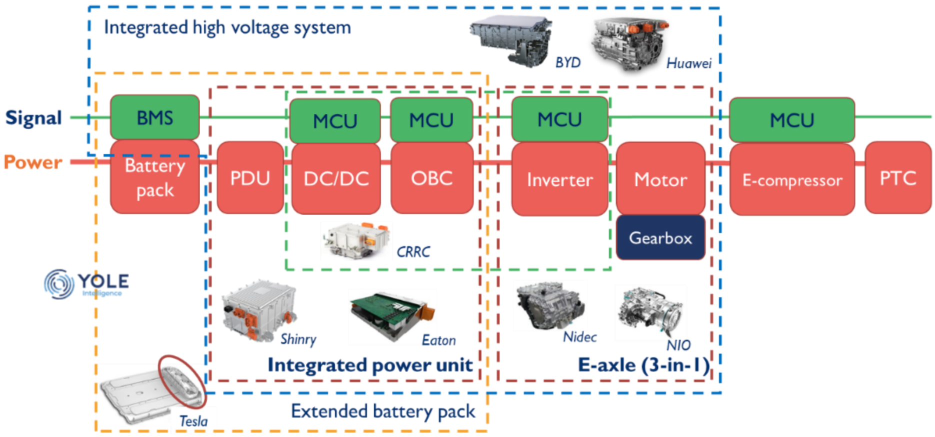

Figure 5: Integration choices in BEVs (non-exhaustive overview).

Different approaches are studied across the automotive supply chain to improve the BEV driving range. An optimal strategy regarding the performance gain and costs is to realize improvements on several systems and develop more integrated solutions.

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Presenter Biography

Dr. Milan Rosina is Principal Analyst, Power Electronics & Battery, at Yole Intelligence (Yole), within the Power & Wireless division. His experience includes due diligence, technology, and market surveys in the fields of renewable energies, EV/HEV, energy storage, batteries, power electronics, thermal management, and innovative materials and components. Dr. Rosina received his Ph.D. degree from National Polytechnical Institute (Grenoble, France). He previously worked for the Institute of Electrical Engineering in Slovakia; Centrotherm in Germany; Fraunhofer IWS in Germany; CEA LETI in France; and the French utility company ENGIE.