

POWER ELECTRONICS FOR ELECTRIC & HYBRID ELECTRIC VEHICLES 2020

Market & Technology Report - January 2020

Stronger vehicle electrification means more power electronics content, resulting in a reshaping of the supply chain.

WHAT'S NEW

- Analysis of the different OEMs' strategies to reach governmental CO₂ emissions reduction targets
- Insight into electric vehicle (EV) and hybrid electric vehicle (HEV) architectures

KEY FEATURES

- 2018 - 2024 market metrics and forecasts for each EV type, from vehicle sales and power converter market, up to power devices
- Deep analysis of technology trends and roadmaps (modular platforms, system integration, 800V battery, 48V vehicles, fuel-cell EVs, and EV charging)
- Detailed discussion regarding wide-bandgap semiconductors (WBG) adoption
- Detailed supply chain analysis and evolution trends, plus new business opportunities
- Focus on China's EV/HEV ecosystem and its evolution

REPORT OBJECTIVES

- Provide an overview of the main global drivers for vehicle electrification, as well as drivers for each vehicle electrification approach
- Furnish an analysis of each vehicle electrification approach, along with forecasts for vehicles and systems
- Identify the key technology trends that will influence future power electronics system and component choices
- Produce an overview of the EV/HEV supply chain, focusing on power module suppliers, system makers (Tier1s), and vehicle manufacturers (OEMs)
- Analyze the changes in business models, synergies with other EV/HEV business segments, and other applications beyond EV/HEV

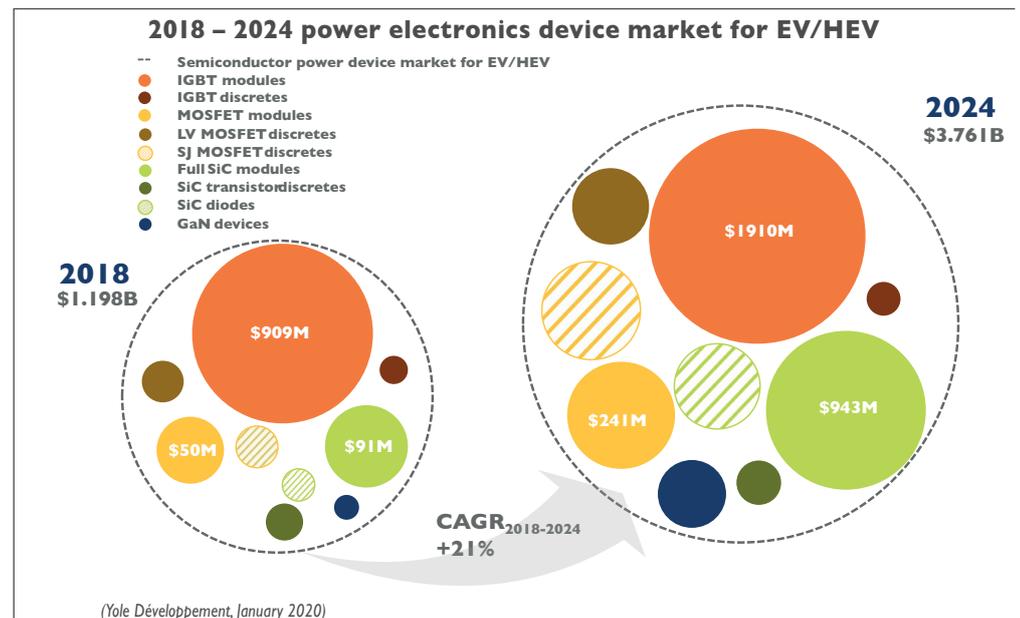
A PROSPEROUS EV/HEV MARKET IS DRIVING POWER SEMICONDUCTOR DEVICE GROWTH

The EV/HEV race has begun. More than \$300B of EV/HEV investments have been announced by different OEMs, clearly confirming the automotive industry's commitment to governmental CO₂ reduction targets.

Indeed, the market figures are promising. In 2018, 1.32M battery electric vehicles (BEV) were purchased, along with 0.75M plug-in hybrid electric vehicles (PHEV) - compared to 0.78M units and 0.41M units in 2017, respectively. This equates to year-over-year growth of 68% and 84%, respectively. Moreover, sales of other hybrid cars have also increased.

Driven by the prosperous EV/HEV market, the market for semiconductor power electronics devices should have a bright future, with value exceeding \$3.7B in 2024 at a 2018 - 2024 CAGR of 21%. IGBT modules represent the largest market, which is expected to double in five years. Silicon carbide (SiC) power modules will also grow fast, with a 2018 - 2024 CAGR of 48%.

This report explores EV/HEV market dynamics and explains how different power electronics markets (i.e. power converters and power modules) relate to EV/HEV applications.



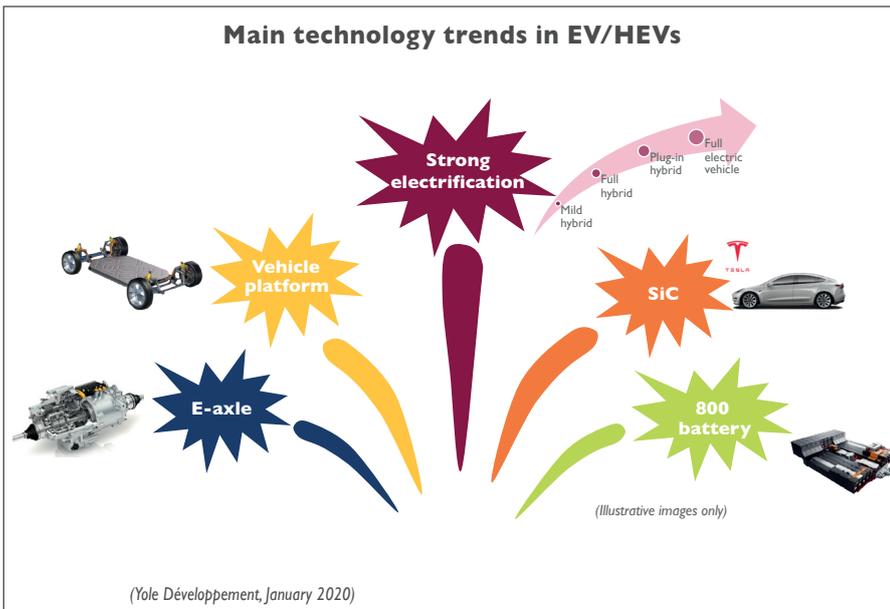
THE EV/HEV INDUSTRY FEATURES DIVERSE TECHNOLOGY APPROACHES

A large variety of different technology approaches is typical of the EV/HEV industry, which is far from being consolidated on the technology end or the supply chain end. Nevertheless, several main technology trends have been identified by Yole Développement (Yole) and detailed in this report.

Fast scaling of battery manufacturing capacities, significant battery cost reduction, and regulatory changes have accelerated the transition towards stronger vehicle electrification and full EVs. Indeed, PHEVs and full EVs offer the significant CO₂ emission-reduction essential for automotive OEMs to reach CO₂ reduction targets.

Modular vehicle platforms like the Volkswagen MEB enable cost reduction and reduce development time for new car models.

A higher integration of different systems and subsystems enables automakers to use less parts - thus reducing cost, weight, and volume. In an electric axle (e-axle) electric motor, power electronics and gears are integrated in one compact system. As outlined in our report, the e-axle approach has strong support from Tier1 companies like Bosch, Schaeffler, GKN, and others, which see e-axle as a more complete EV/HEV solution to offer to different automotive OEMs.



Trends towards higher vehicle power and larger battery capacity have led to a new battery-voltage level in passenger cars: 800V. Today, the only commercially-available vehicle with an 800V battery is the Porsche Taycan sport electric vehicle. However, Hyundai plans to launch a new generation of EVs based on its new E-GMP vehicle platform, with 800V technology.

The implementation of SiC power devices in the Tesla Model 3 EV's traction inverter has created plenty of interest. Indeed, high-power traction inverters represent a huge new business opportunity for suppliers of SiC devices, suitable device packaging solutions, and SiC-based systems. Also, interest in gallium nitride (GaN) has recently revived, mainly as a potential candidate for future EV/HEV 12VDC - 48VDC converters and onboard chargers. The potential offered by SiC and GaN power electronics devices is analyzed in this report.

VEHICLE ELECTRIFICATION IS TRANSFORMING THE GLOBAL AUTOMOTIVE INDUSTRY

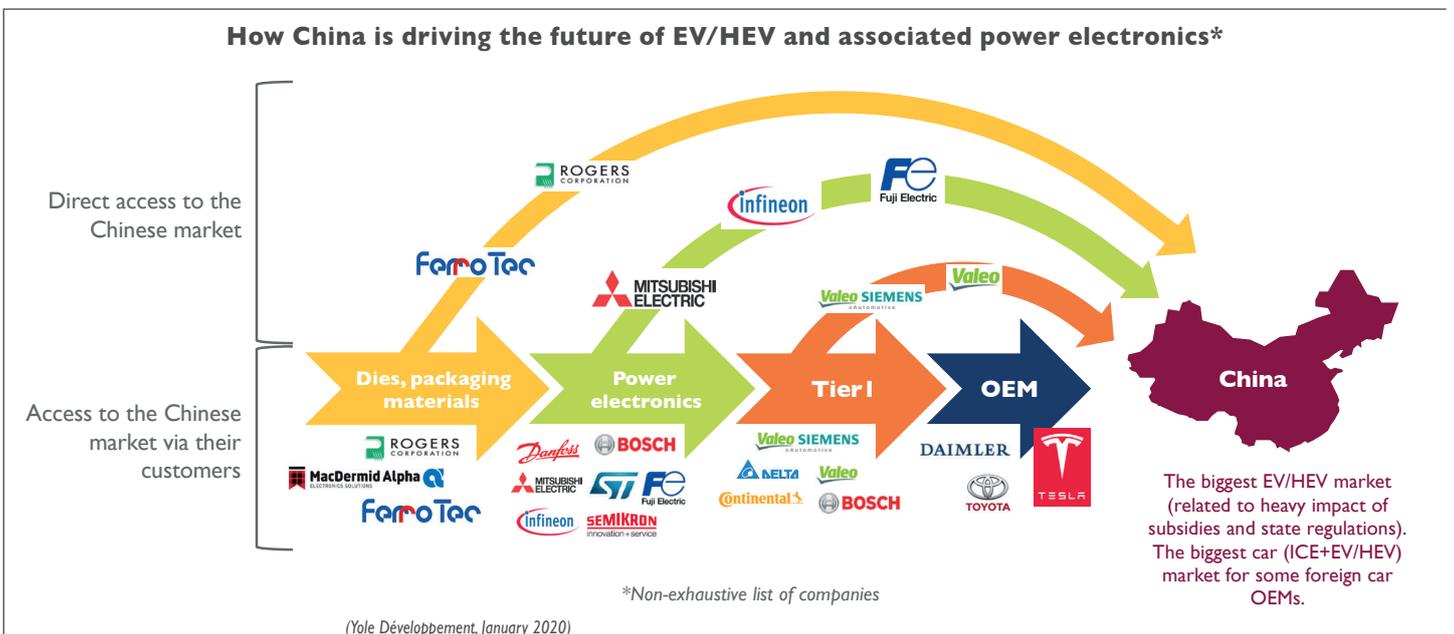
A rapidly growing market like EV/HEV brings not only plenty of opportunities, but also many challenges for players across the supply chain.

Regarding EV/HEVs, conventional internal combustion engine (ICE) vehicle manufacturers are now at the same starting line and competing with newcomers like Tesla, which was the #1 BEV vendor in 2018. ICE automakers must invest significant effort to balance EV/HEV development with their existing ICE activities during a "transition period" - the length of which is hard to determine because of rapidly-changing incentive mechanisms and evolving customer needs.

Within the EV/HEV supply chain, Tier1 companies are particularly exposed to different challenges, such as revenue decrease for ICE-related products.

To compensate, Tier1s are increasing their efforts in EV/HEV-related products. However, OEMs are becoming more and more intrusive, particularly in main inverters, with the objective of controlling the key EV/HEV elements. Established semiconductor device suppliers are in a similar situation, on the one hand facing the entrance of some Tier1s in the device market, and addressing challengers from the emergence of WBG devices on the other.

The transformation of the automotive supply chain is ongoing. In particular, many questions involve China, which is today the biggest market for electric cars. So far, there are two different ways for suppliers to access the Chinese market: either directly (by producing in China or selling to Chinese integrators) or via their customers that sell to



Chinese integrators. For EV/HEV components, China has different levels of technology and independency. Regarding battery, China has top suppliers like CATL and BYD. However, the majority of IGBT power modules used in Chinese cars are still manufactured outside of China, which is not a sustainable solution for the Chinese industry and particularly for China's government. The trend towards increasing the

share of Chinese-made products is clear, and some companies have started working to build a local supply chain - for example, BYD built its own IGBT product line and is developing SiC MOSFETs.

This report includes our analyst's opinion of supply-chain changes and new business opportunities.



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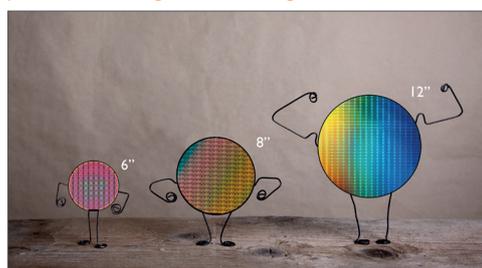
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