

Development of powertrain semiconductors in conventional, hybrid and electric vehicles

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Engine Expo 2016
2016 Open Technology Forum

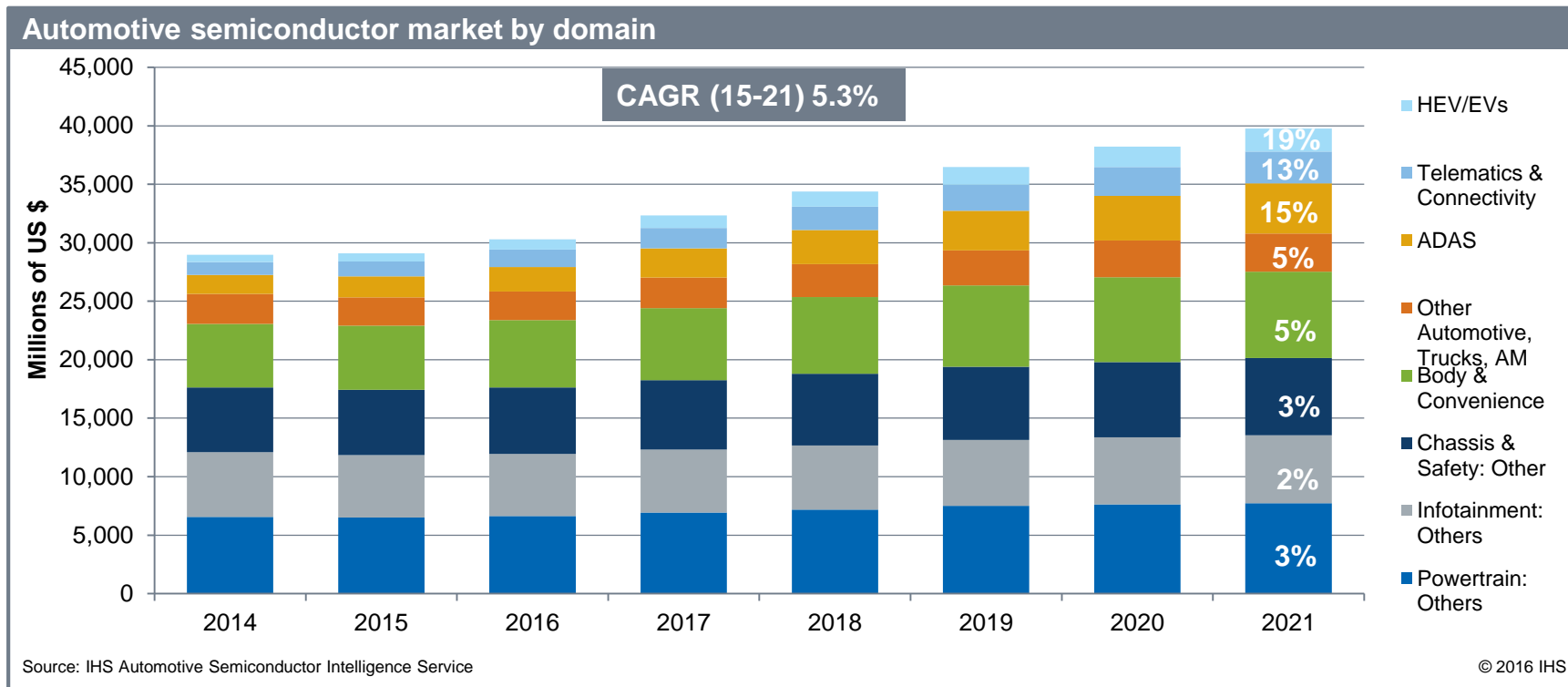
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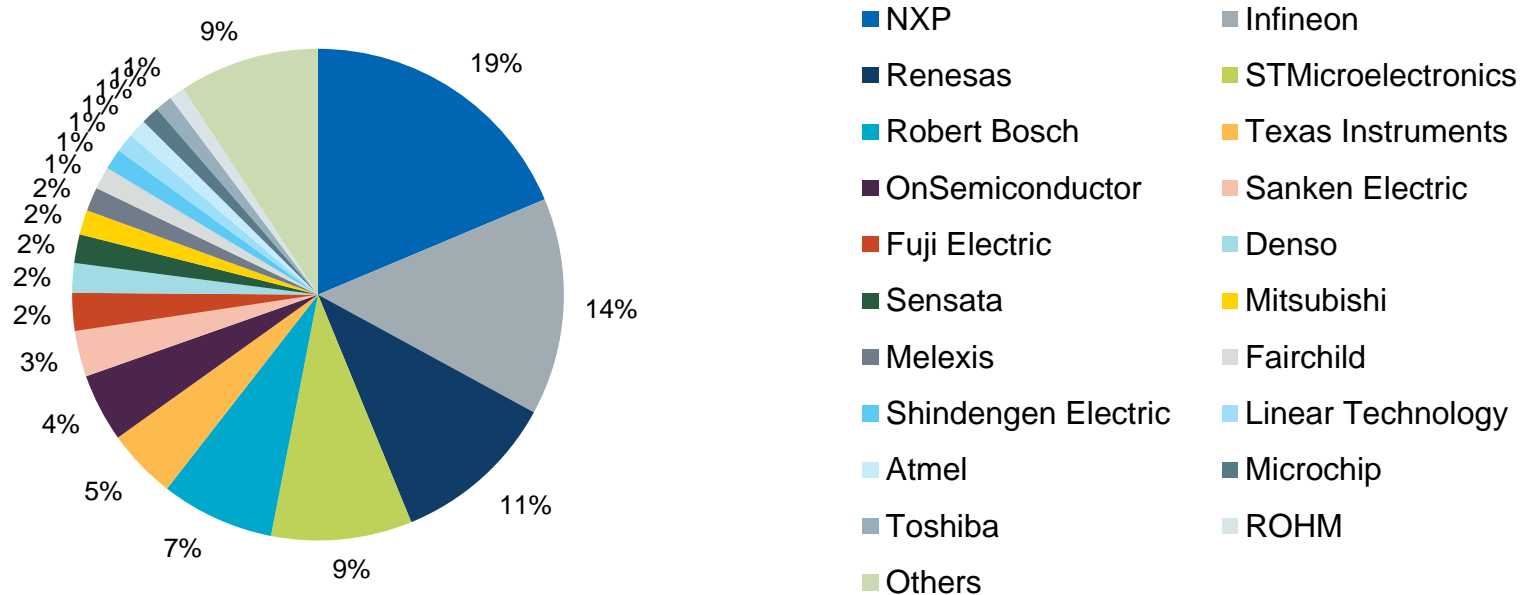
- Powertrain semiconductor market
 - Technological shifts
- Emission legislations
 - Impact on electrification
- Powertrain of hybrid/electric vehicle
 - Evolution of architectures
 - Evolution of semiconductors

Automotive Semiconductor market to cross \$39B by 2021



Top 20 powertrain semiconductor suppliers amount to more than 90% of the market in 2015

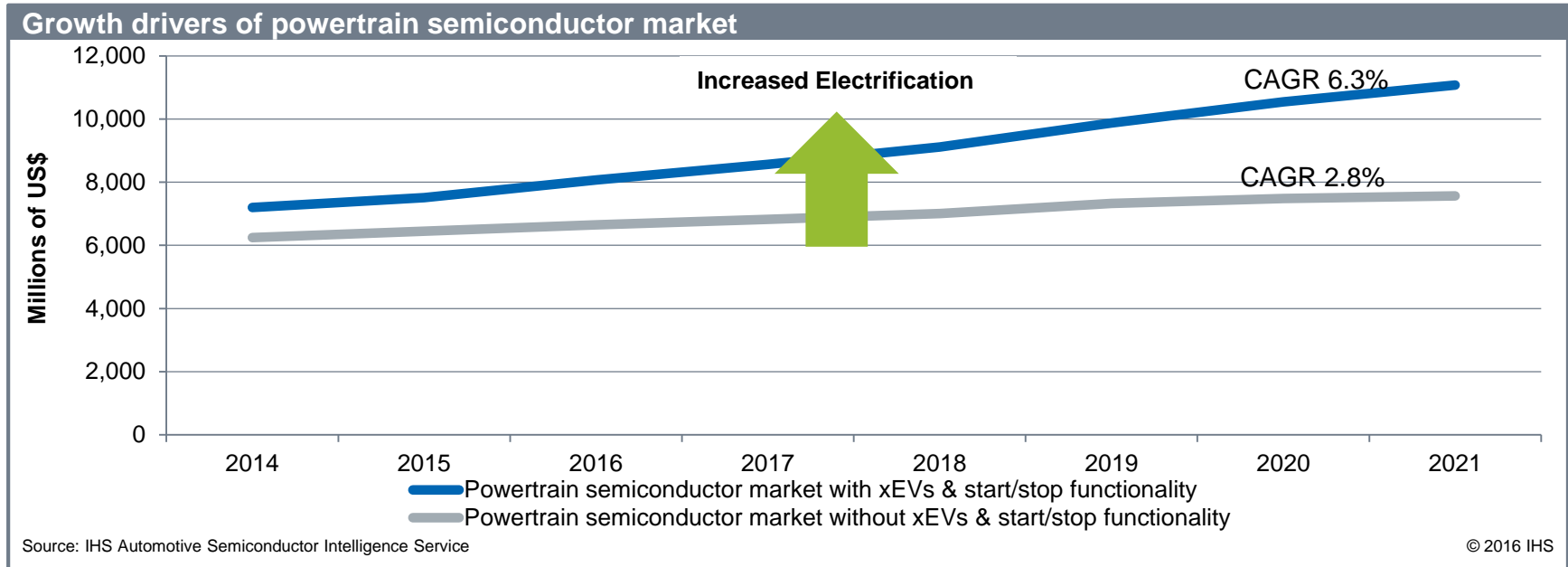
2015 market share of powertrain semiconductor suppliers



Source: IHS Automotive Semiconductor Intelligence Service

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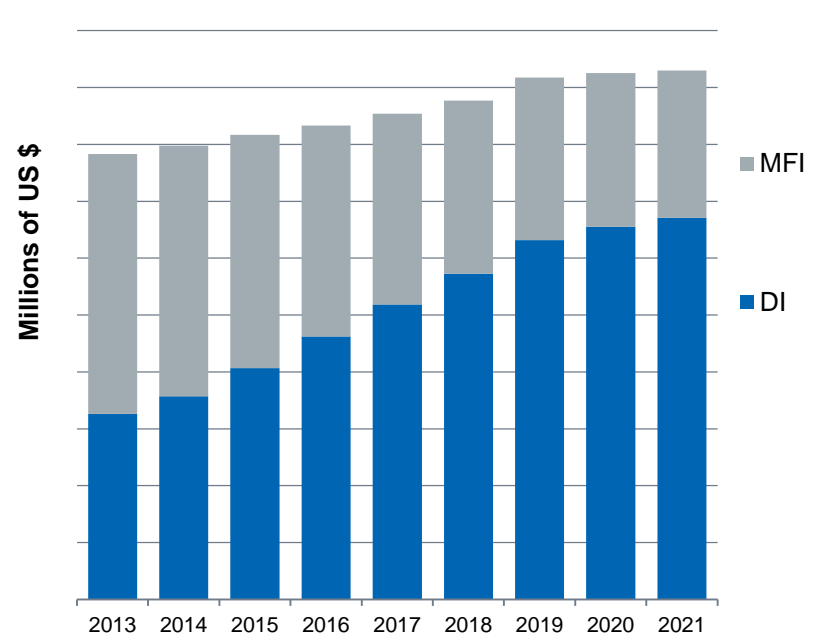
Powertrain semiconductors will progress smoothly



Increased number of vehicles and fuel efficient vehicle technology propels the powertrain semiconductor market

Technological shifts for control units within powertrain

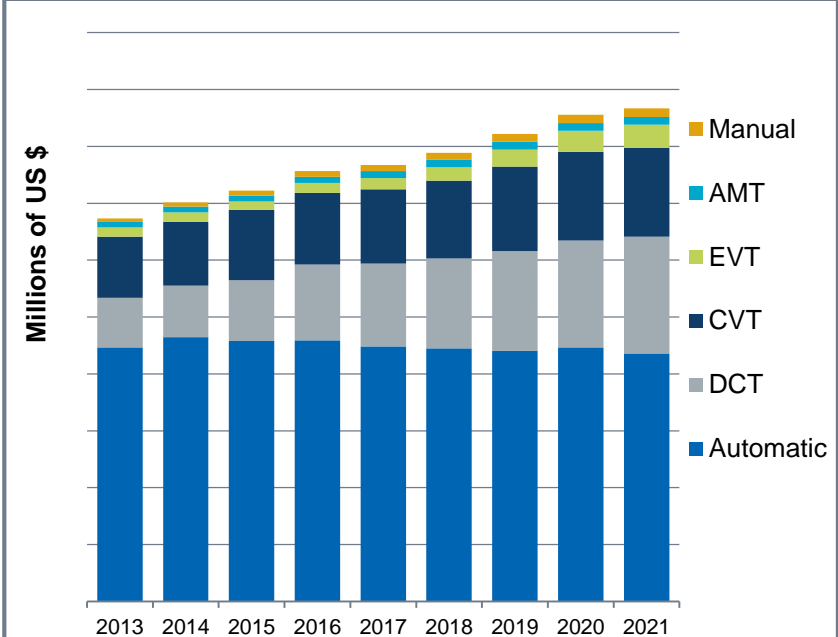
Semiconductor consumption of engine control units for different injection systems



Source: IHS Automotive Semiconductor Intelligence Service

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Semiconductor consumption of various transmission control units

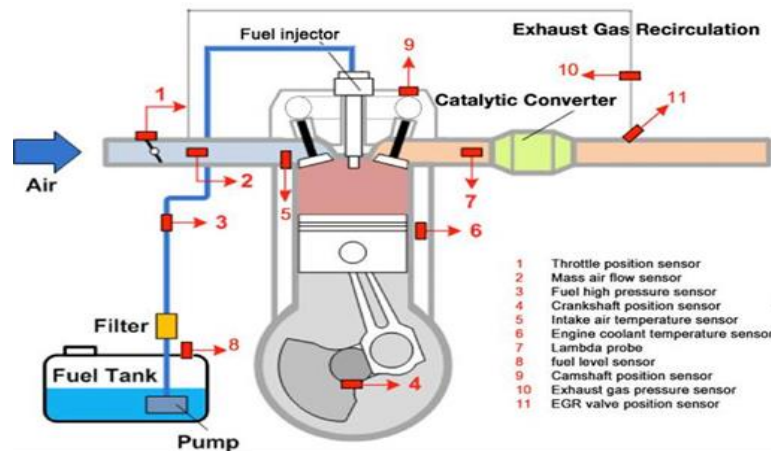


Source: IHS Automotive Semiconductor Intelligence Service

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Internal combustion engine reaching its limits in terms of efficiency gain!

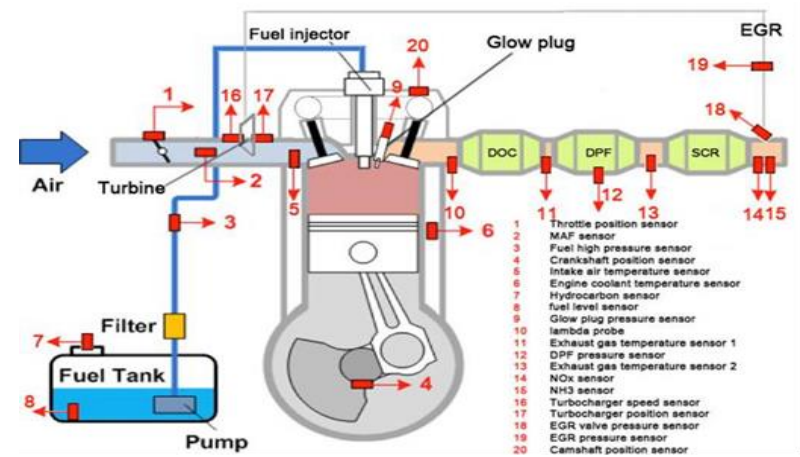
Diesel engine complying with Euro 3



Source: IHS Automotive Sensor Intelligence Service

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Diesel engine complying with Euro 6

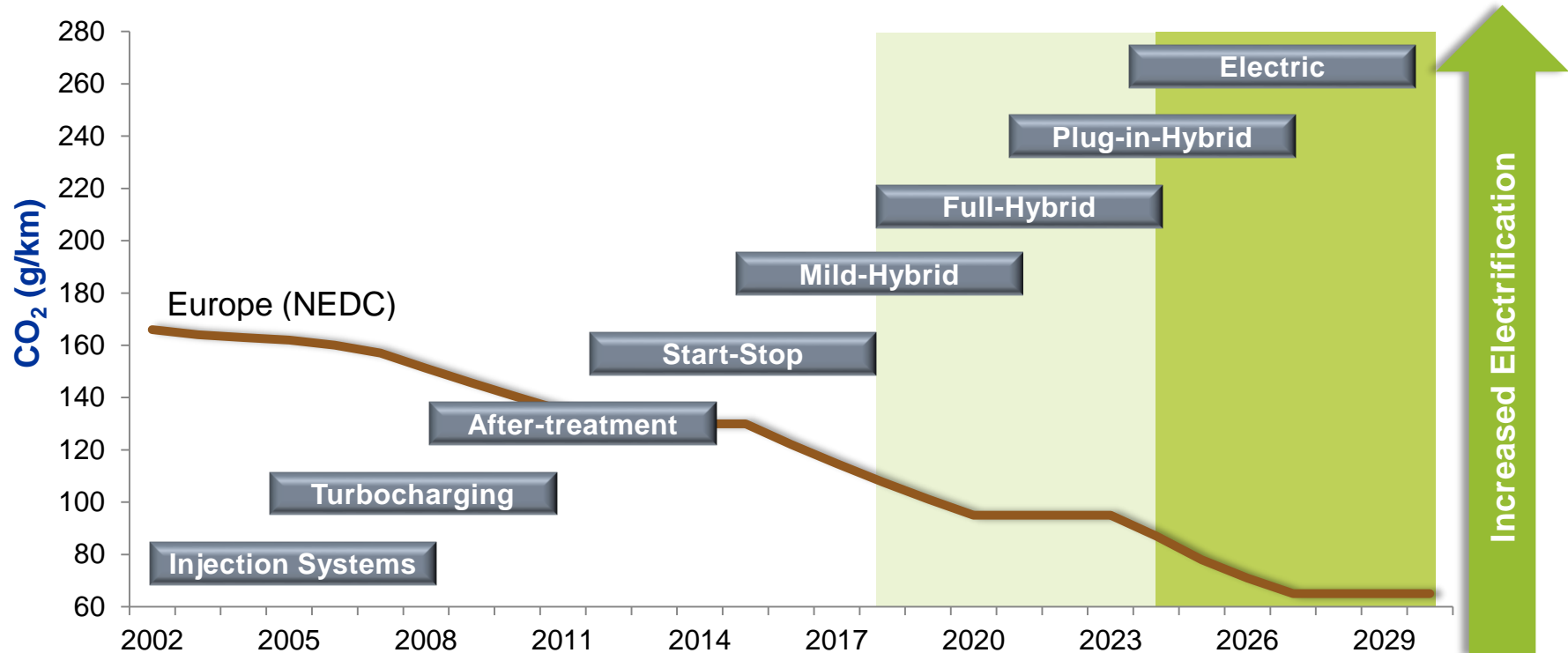


Source: IHS Automotive Sensor Intelligence Service

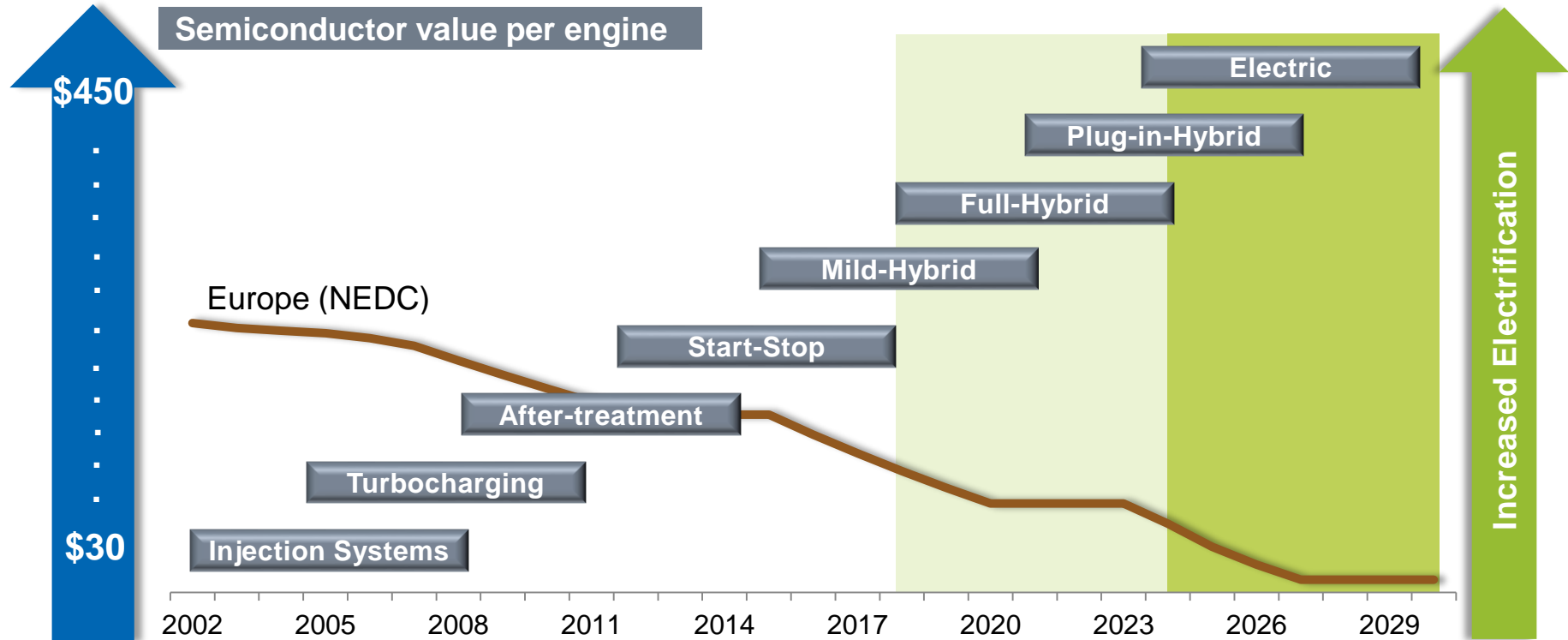
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Engine aftertreatment systems increasingly complex, higher costs and diminishing returns

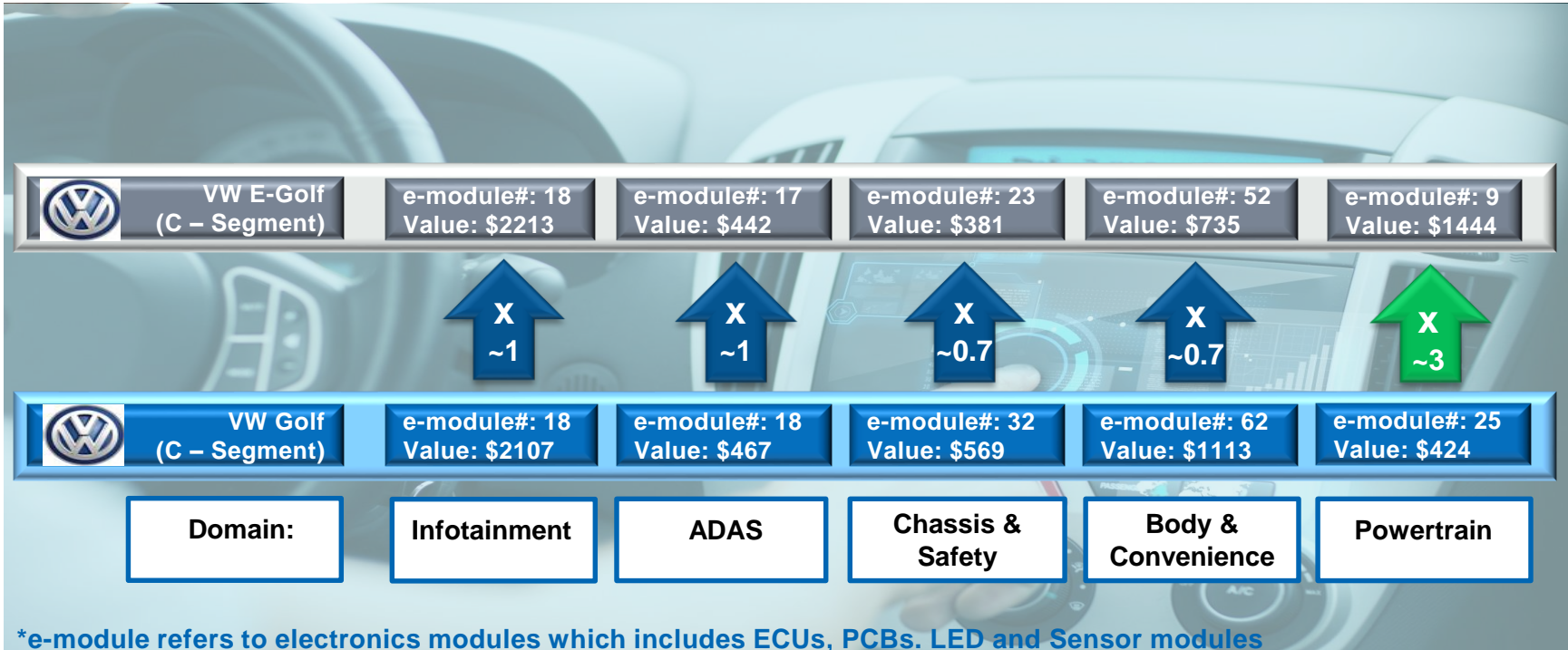
Coping with continuous CO₂ reductions



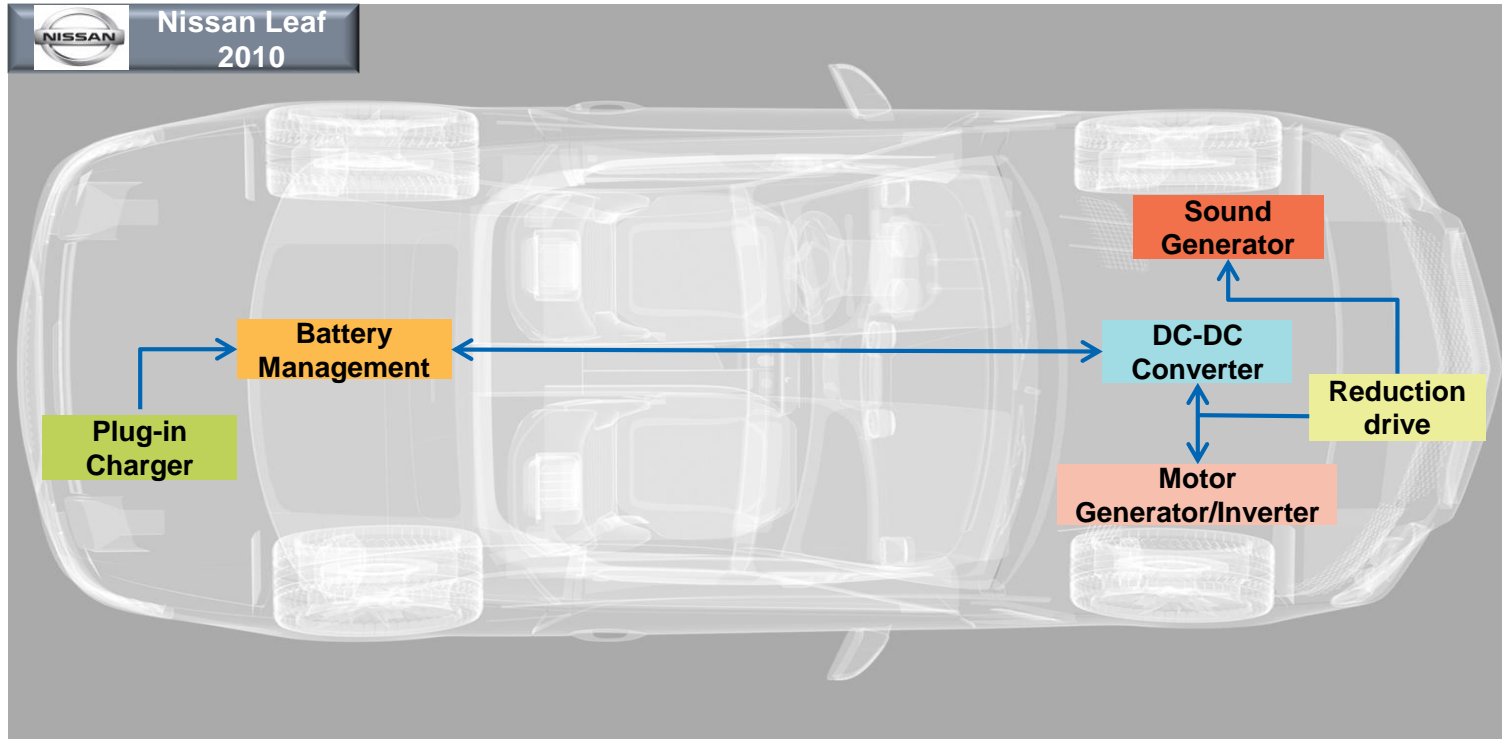
Coping with continuous CO₂ reductions



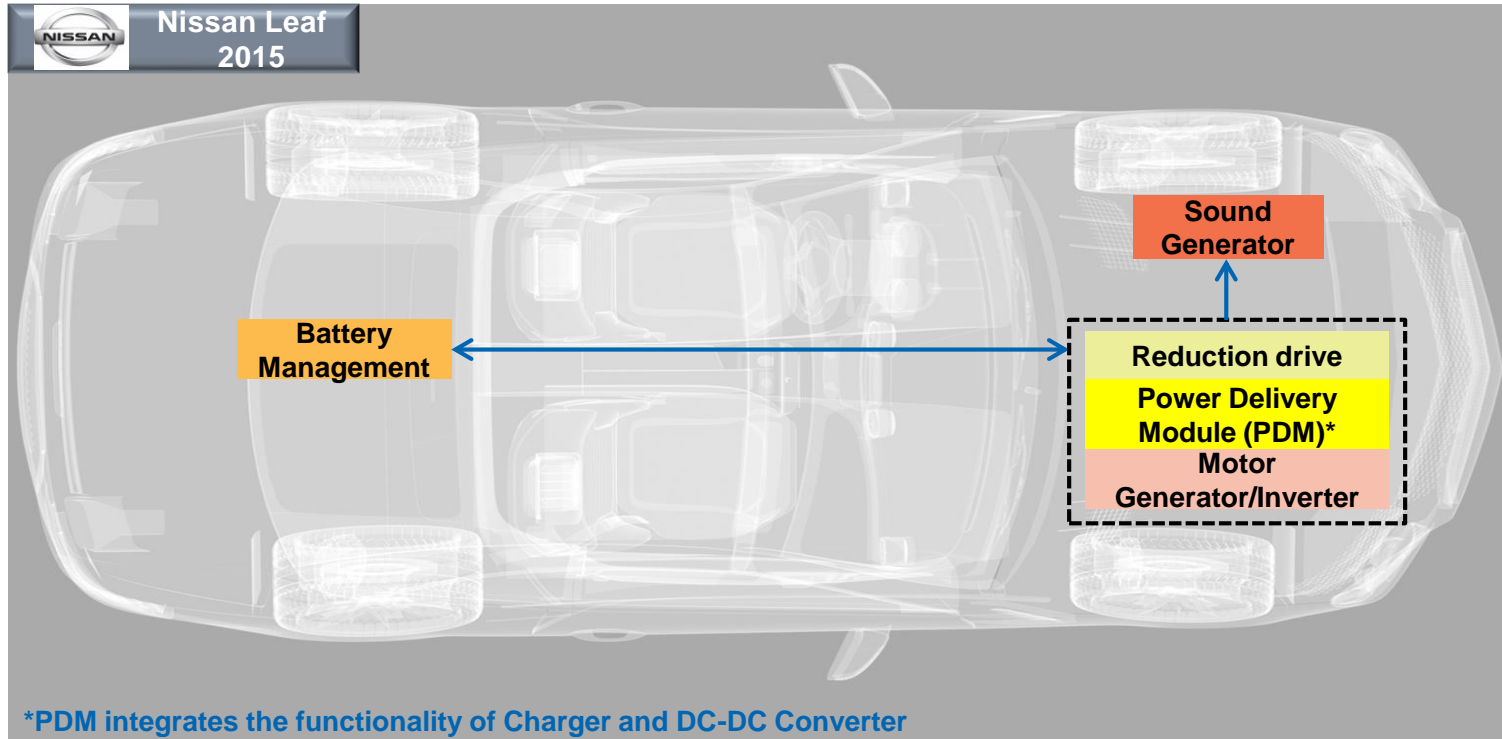
Powertrain electronic modules price by level of electrification: VW Golf vs VW E-Golf



Old generation powertrain architecture of 6 ECUs

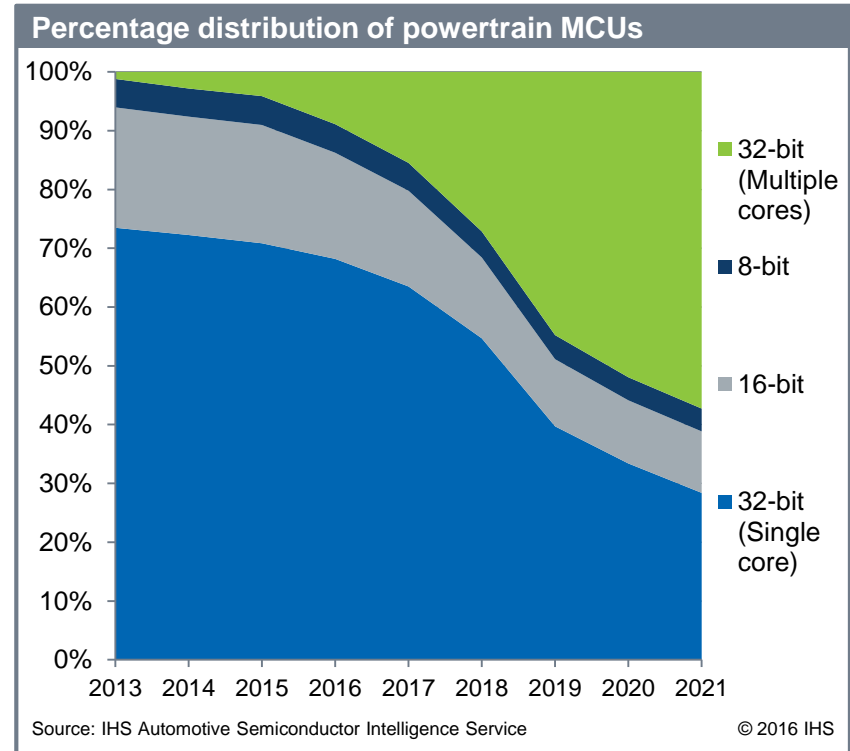


New generation powertrain architecture of 5 ECUs



Evolution of microcontrollers (MCUs) in powertrain

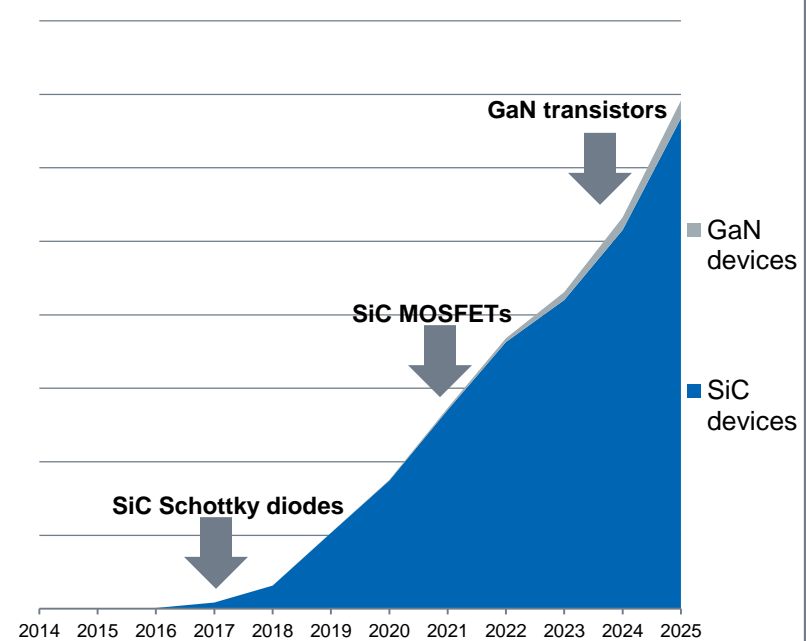
- Transformation in engine sensors have brought rapid advancements in MCUs
 - Increased embedded memory
 - Higher processing power
 - Higher operational frequencies
- New transmission systems have to handle multiple sources of torque
 - Driving modes such as freewheeling, gliding, sailing and coasting requires precise inputs
 - Functions like hill hold and electric parking brake needs support
 - Growing trend towards higher ASIL levels
- Integration of control units in hybrid/electric vehicles demand multiple operations from the MCUs



Wide-bandgap components take a role in future Hybrid/Electric vehicles (HEVs)

- Automotive players have shown keen interest in Silicon Carbide (SiC) and Gallium Nitride (GaN)
- Since 2012 Mitsubishi, Denso and Hitachi have made prototype motor inverters using SiC devices
- Infineon, ROHM, Wolfspeed and Exagan have partnered with research institutes and organizations
- SiC and GaN devices are more efficient than conventional Si devices
 - Reduces total system cost by as much as 10% and system size by up to 50%
 - Toyota expects fuel efficiency increase by up to 10%
- Today SiC Schottky diodes are used in plug-in chargers

Revenue forecast for SiC and GaN in hybrid/electric vehicles

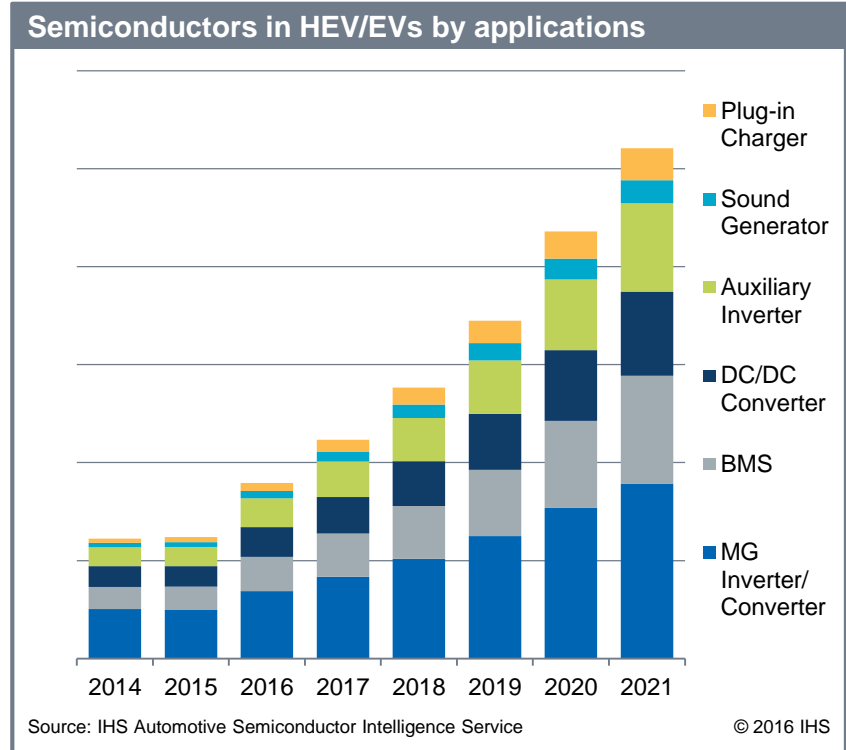


Source: IHS SiC & GaN Power Semiconductors

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Semiconductors in HEV/EVs forecast to grow at a CAGR(14-21) of 19%

- Semiconductors in HEV/EVs are forecast to rise from \$600Million in 2015 to \$2.6Billion by 2021
- Aggressive progression of 35% annually for plug-in chargers
- Battery management system (BMS) revenues to grow 25% annually
- NHTSA noise requirements to increase penetration of sound generators from 2018



Key takeaways & Conclusion



- Powertrain semiconductor market will be driven by hybrid electric/electric vehicles (HEVs)
- Emission legislations will stimulate the penetration of HEVs
- Complexity press on new technologies and architectures
- Semiconductors enable technology innovation and cost reduction
- New players will emerge and disrupt traditional automotive paradigms

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