ELECTRIFICATION DISRUPTION

How not to get shocked, jolted and fried by the coming shift in automotive power sources.

PAUL EICHENBERG

INTRODUCTION

The internal combustion engine (ICE) -- more than 100 years old and counting -- will continue to be the dominant form of vehicle propulsion. However, global regulatory challenges focused on emission reduction and fuel economy improvement are increasing potential fully-electric, zero-emissions vehicles, a significant disruption to this 100-year-old technology. This white paper will examine how OEMs are addressing global regulatory challenges (emissions, fuel economy) through a portfolio of technologies, and what the future holds for the automotive industry; both OEMs and their suppliers alike.

Against this framework, this report (see figure 1) provides an overview of the electrification disruption and its impact on the automotive industry. This report is intended to assist industry players who have strategic decisions to make including:

1. **Automotive Suppliers** – what strategic actions are necessary to support a successful product portfolio?

2. **Silicon Valley Start-ups** – considering the industry dynamics, how to participate?

3. **Investors** – how to invest?

FIGURE 1 - REPORT METHODOLOGY

/ **FOUNDATION** – eight plus years of experience as the global Vice President Corporate Development and Strategy for Magna Powertrain and Magna Electronics

/ **RESEARCH** – substantial industry wide research covering perspectives from OEMs, suppliers, regulatory bodies, investment firms and academia.

/ **EXPERT INTERVIEWS** – extensive executive interviews and in-depth discussions with over 30 industry experts in Asia, Europe and North America.

KEY MESSAGES

GLOBAL EMISSIONS REGULATIONS

- Despite the efforts of President Trump, regulations will increase globally. Federal governments, states and major cities are driving new laws to reduce emissions and improve fuel economy.
- Europe has set the most stringent legislation for CO2 reduction. Europe has set the global standard for this legislation and is 5-8 years ahead of other major markets.
- The European market will define the future of automotive engine architecture. CO2 reduction technologies are adopted in Europe first, OEMs then leverage know-how to other markets.

VEHICLE ENGINE FORECAST

- The years between 2020-30 will be the decade of electrification. Technology breakthroughs and exhausted combustion engine potential will drive the market towards electrified vehicles.
- Vehicle electrification will come faster than currently anticipated. Take rates will be higher than industry prognosticators forecast today.
- Electrification technologies will affect almost all vehicles produced by 2030. Recent announcements in Europe and Asia raise the forecast for pure battery electric vehicles to 17 million by 2030 and will lead to 90% of vehicles to be electrified.

DISRUPTIONS IMPACT ON THE AUTOMOTIVE INDUSTRY

- Scale is critical in the electrified world and the future of automotive. Electronic products scale differently than traditional mechanical components.
- Scale and size of the opportunity in automotive will attract new entrants. New players will come with significant competitive advantages.
- Few suppliers will be able to make the transition. Most suppliers lack electronics and software competencies to compete for these new products.

PAUL EICHENBERG

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BIOGRAPHY

Paul Eichenberg has had 25 years working with Fortune 500 automotive suppliers, most notably eight years as the global VP of Corporate Development and Strategy for Magna Powertrain & Magna Electronics. As the Chief Strategist, Paul oversaw all strategic planning, product management and merger and acquisition activities. During his tenure at Magna, Paul successfully repositioned the business to focus on technologies for the optimization of the internal combustion engine, EV/Hybrid technologies, ADAS, and autonomous vehicles. Paul manages his own automotive consulting firm called Paul Eichenberg Strategic Consulting. Paul's clients include hedge funds, investment banks, private equity investors and automotive suppliers.

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REGULATIONS AND THE DRIVE TO REDUCE EMISSIONS

REGULATIONS WILL CONTINUE TO INCREATE FOR THE FORESEEABLE FUTURE

Lawmakers the world over are becoming more and more serious about energy efficiency and reducing automotive emissions through enforcement tools, as transportation accounts for 55 percent of the world's oil consumption. At the same time, global demand for greater mobility continues to increase, with annual vehicle production expected to grow from 90 million units today to almost 120 million units by 2030.

Today, CO2 emissions from light, medium, and heavy duty vehicles account for about 74 percent of emissions from the total transportation sector. As concerns over global warming and its impact on climate change continue to grow, consumers through choice and governments through legislation are driving for cleaner and greener technologies to reduce CO2, as well as, nitrogen oxide (NOx) emissions, which are sourced from as much as 47 percent from gasoline and diesel-powered vehicles in some U.S. regions, according to the U.S. Environmental Protection Agency (EPA).

In other parts of the world, NOx pollution from vehicles, especially in major metropolitan areas, is much more prevalent, and has resulted in drastic government-imposed measures to curb driving. For example, over the last three years, Paris and other French cities have enacted driving restrictions over periods of several days as air quality deteriorated. Similar bans have been enacted in Delhi, Mexico City, Bogota, London and Berlin.

EUROPEAN UNION LEADING THE REGULATORY PACK

Legislation to drive CO2 reduction and improve fuel economy is being driven by the European market, known for the most stringent regulations in the world. At the end of 2013, the European Parliament established the strictest legislation of its type, calling for mandatory year 2020 emission targets for new passenger cars and light commercial vehicles in the EU. Known as the Euro VI standards, vehicle emissions are limited to 95 grams of CO2 per kilometer driven (g/km). Factoring in the U.S. Corporate Average Fuel Economy (CAFÉ) standards, this would be the fuel economy equivalent to approximately 57 miles per gallon.

The next round of EU regulation, known as Euro VII, is being met with much speculation. However, if adopted, would take place prior to 2019 and placed in effect between 2025-2030, and would set a target of approximately 75 g/km, or the U.S. equivalent of just under 73 mpg, a quantum leap in legislative efforts, and a significant reduction in CO2 emissions and a gigantic boost in fuel economy.

EUROPE HAS SET THE MOST STRINGENT LEGISLATION FOR CO_2 REDUCTION

Looking even further ahead, several automotive industry and government reports place the EU and at least one of its member countries, Germany, on the path toward zero-emission cars by 2030, if the Euro VII targets become law. German Bundesrat (with support of VW, BMW and Daimler) passed a resolution to ban ICE starting in 2030. The resolution calls for the EU Commission to approve only zero-emission passenger vehicles for use on European roads. Although the Bundesrat (representing German states) has no legislative power, its recommendation will clearly shape the European debate and EURO VII legislation.

IN THE U.S., SIGNIFICANT IMPROVEMENTS ORDERED…FOR NOW

In the U.S., there are three distinct regulations that drive emissions and fuel economy and must be considered by the major OEMs. Two of these regulations are at the Federal level, and one at the state level. (Insert Overview Chart).

The first is the U.S. answer to reducing CO2 emissions set by the EPA, and is formally known as U.S. Greenhouse Gas (GHG) regulations (also adopted by Canada). U.S. GHG legislation measures grams of CO2 per mile and assessed as fleet average GHG emissions for each OEM. Companies must comply to sell vehicles. The U.S. CO2 reduction target is set at the equivalent of about 97 g/km or 156 g/mile or 56.2 mpg by the year 2025.

The second federal regulation is set by NHTSA and is known as the Corporate Average Fuel Economy (CAFÉ) regulation. This legislation measures fuel economy in the terms of miles per gallon or mpg. In 2015, this target was set at 31.6 mpg, and is expected to increase to an average of 56.2 mpg by the year 2025. To illustrate the rapid rate of increase, the CAFÉ target in 2014 was set at 25.1 mpg. This law assessed OEMs on an average fuel economy on the corporate fleet and OEMs who don't apply will pay fines.
In addition to this federal regulation, California has had its own regulations and targets for environmental and health improvement through the California Air Resources Board (CARB).

This is also known and the ZEV mandate. A completely different set of standards, CARB mandates the equivalent of 50,000 zero-emissions vehicles per OEM, and the regulation allows OEMs the opportunity to trade and sell credits to achieve compliance with CARB standards. States who have adopted the California standards include Arizona (2012 model year), Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico (2011 model year), New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington, as well as, the District of Columbia.

However, under a completely new U.S. presidency and much of the U.S. Congress carrying a more anti-regulatory tone, the door could be opened to a revamp of U.S. environmental and energy policies, potentially impacting future CAFE standards and other related mandates. US regulation targets 36.2 mpg in 2016; however, 56.2 mpg in 2025 will fall under the mid-term review in 2017 and the new administration.

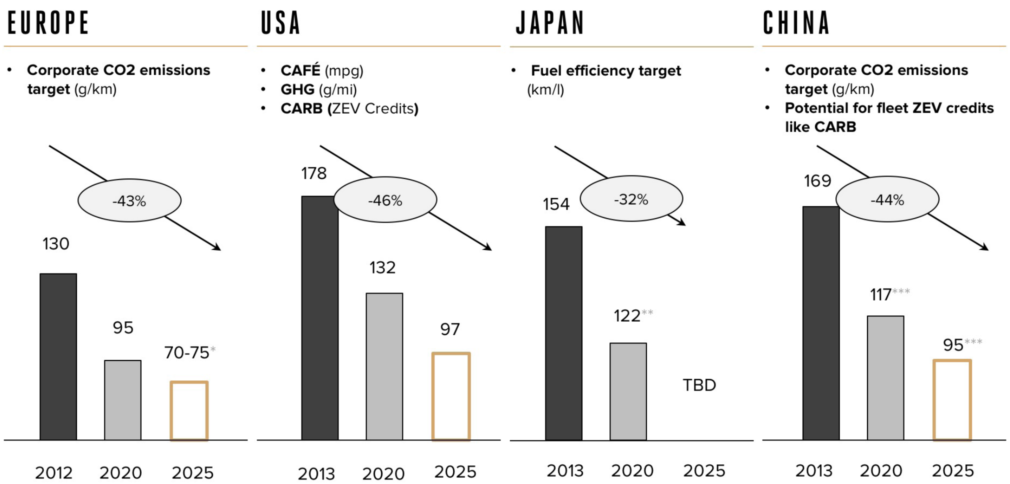
THE EUROPEAN MARKET WILL DEFINE THE FUTURE OF AUTOMOTIVE ENGINE ARCHITECTURE

DEVELOPING ECONOMIES JOIN IN FOR CLEAN AIR

While developed countries have long led the way with aggressive CO2 reduction targets, most all regions are enacting similar legislation, following the lead of EU legislation, versus developing their own national standards. Countries such as Brazil, Russia. India, and China (BRICs) are all evaluating the use of Euro VI regulations in major cities by 2025. Even today, most of these countries are following earlier-enacted EU standards (Euro V).

STRATEGIES AVAILABLE TO MEET CHALLENGES

Because the EU has been the most aggressive region for adopting CO2 and fuel efficiency standards, the very strategies and technologies for meeting those standards will be first applied to EU-produced vehicles, then expanded around the world as other countries adopt stiffer vehicular air quality regulations.



Sources: ICCT, EPA
*Notes: *Proposed level to be incorporated between 2025-30*
*** Japan meets this level today*
****Stated target for major cities, not nationwide*

Strategies available to OEMs as they move forward to meet stricter standards include:

/ A market shift towards smaller vehicle segments. Vehicles in smaller segments already dominate in the EU, so a change in consumer attitudes about even-smaller cars would have to take place.

/ Alternative fuels, such as natural gas, to propel vehicles

/ Reduction of drag and weight, with greater concentration on aerodynamic design cues, and greater use of lighter-weight materials, such as aluminum and carbon fibers

/ Introduction of new vehicle architectures or advanced propulsion technologies, such as gasoline-electric hybrid engines and fully-electric vehicles

/ Optimization of the internal combustion engine (ICE) to extract the most power and fuel efficiency per gallon of fuel

/ The option of trading credits or paying penalties

CO2 REDUCTION TECHNOLOGIES ARE ADOPTED IN EUROPE FIRST, OEMS THEN LEVERAGE KNOW-HOW TO OTHER MARKETS

While gasoline has long been recognized, next to diesel fuel, as the most efficient fuel source available to power motor vehicles, only 20 percent of the energy from gasoline propels the vehicle, while the remaining 80 percent is lost to engine and driveline inefficiencies, as well as idling. Even today's best combustion engines don't turn fuel into motion very efficiently. So, opportunities abound for OEMs to optimize ICE-powered vehicles.

OEMS READY TO RESPOND

Automakers live and breathe years-long vehicle development cycles, and work diligently to integrate the next level of emissions regulations into their product development activities. For example, to meet the EU's 2021 CO2 target of 95 g/km (Euro VI), the OEMs have fully developed those technologies, identified their supply base, and have finalized their product plans. These technologies will eventually spread from the European market to other markets like Japan, Korea, China and the United States as the OEMs work to meet the targets set for those markets by 2025.

Looking ahead, OEMs are now focusing on those technologies needed to leap the next regulatory hurdle – the proposed Euro VII rules, pegged at 70-75 g/km, with implementation expected to come between 2025 and 2030. Clearly understanding which technologies will be adopted to meet this legislation will provide clarity around a global technology roadmap and engine forecast for the next 15 years.

LONG LIVE THE ICE?

The internal combustion engine, says the Wall Street Journal (January 30, 2015), "is proving to be much more than a stubborn technological incumbent." Indeed, it has proved hard to beat engines in which fuel is ignited, drives pistons and propels a vehicle. However; the legislation that will drive the industry toward the target of 75 g/km, or the U.S. equivalent of just under 73 mpg, will force a technology shift and a significant disruption to the structure of the industry.

Our next segments will focus on the specific strategies OEMs will be utilizing to navigate the maze of regulations still ahead, including a look at new electrified vehicle architectures, powertrain technologies, and continued opportunities to optimize ICE performance and efficiency.

AUTOMAKERS WEIGH ARRAY OF VEHICLE ARCHITECTURE CHOICES

In the quest to improve fuel economy and reduce emissions to meet government mandates, global automakers have developed several powertrain options. These options include smaller, more highly-charged gasoline and diesel engines, turbochargers, variable valve timing and sophisticated direct injection engines, with the next levels of powertrain technologies having various levels of electrification built into each one.

As with any form of technology, each has its advantages and shortfalls. However, all of them offer significant CO2 reduction opportunities to meet requirements around the world. Integrating various degrees of electrification with the standard internal combustion engine (ICE) offers automakers a selection of hybrid powertrain options.

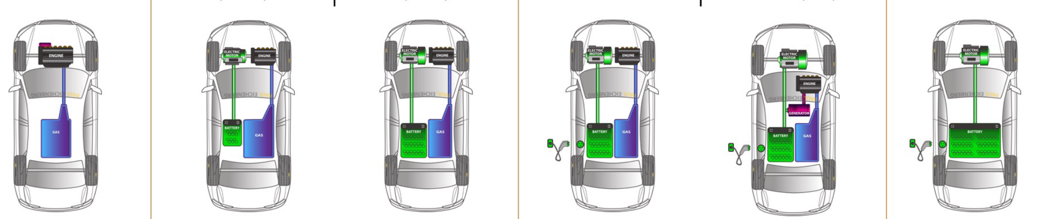
The illustration below is a look at the various electrification options being employed today, up to and including the fully-electric, zero-emissions category and some of the real-world vehicle applications applications found in the market today.

NEW VEHICLE ARCHITECTURES – INTRODUCTION

CO_2 reduction targets will require new “electric” vehicle architectures. A brief overview:

ELECTRIFICATION →

Micro HEV (Stop/Start)	Hybrid Electric Vehicle (HEV): Mild HEV (MHEV)	Hybrid Electric Vehicle (HEV): Full HEV (FHEV)	Plug-In Hybrid Electric Vehicle (PHEV): PHEV	Plug-In Hybrid Electric Vehicle (PHEV): Range Extended Vehicle (REX)	Battery Electric Vehicle (BEV)
• ICE drives wheels • Utilizes a 12V belt-driven integrated starter-generator in place of a common alternator	• A 48V power electric system supplements the ICE but never solely powers the vehicle • Auto start/stop systems shut down ICE when not needed (sail/coast) • 48V battery	• Vehicle can be powered by the ICE or the electric drive motor • 240-360V battery provides some electric range and is recharged by regenerative braking and/or by the ICE	• Similar to full HEV with few exceptions • Batteries are recharged by regenerative braking, by the ICE and/or by plugging in to an electric outlet	• Electric motor drives wheels • ICE used as a generator to recharge battery • Eliminates ‘range anxiety’	• Electric motor drives wheels • Energy supplied solely from battery pack • Zero emissions • Low operating costs • Range and battery costs challenges
Audi A4	Buick LaCrosse	Toyota Prius	Chevy Volt	BMW I3 REX	Tesla S



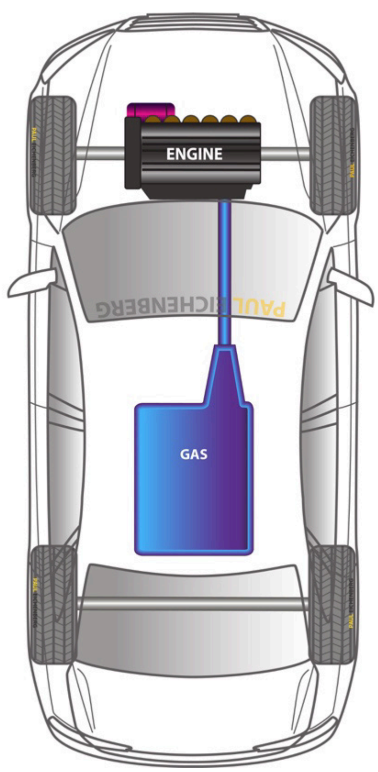
Sources: Expert Interviews

MICRO HYBRID: SIMPLE IN DESIGN, WIDELY EFFICIENT, EFFECTIVE

A micro hybrid utilizes the standard ICE, but substitutes the standard alternator with a 12-volt belt-driven starter generator. This minor change allows the engine to stop running when the vehicle is braked at idle, such as, when at a traffic signal, but restarts instantaneously (<400 milliseconds) as soon as the driver releases the brake pedal.

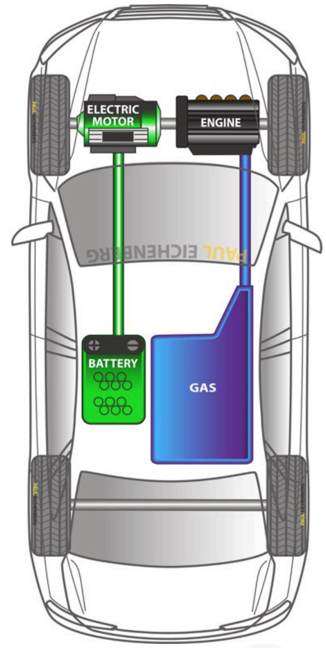
Micro hybrid technology offers OEMs a low-cost (about $100 U.S.) easily-adaptable way to improve fuel efficiency (usually 2-6%) and reduce CO2 emissions by about 3%. It's estimated that as much as 17.2% of vehicle inefficiency (fuel consumption, exhaust) comes from engine idling. Indeed, some estimates calculate that just five minutes of engine idling can consume .01 to .04 liters of fuel, and over the course of a year, fuel wasted can add up to as much as 20 gallons. In several European countries, including Germany, drivers are required to shut off their engines at active railroad crossings, primarily for environmental reasons.

Therefore, 90% of vehicles produced in Europe today have this simple stop/start feature. The Audi A4 is an excellent application of micro hybrid technology, and it's estimated that by 2020 more than 50% of vehicles produced globally will have micro hybrid technology, while still relying on even higher fuel efficient ICE propulsion. In the U.S., Ford is betting heavily on micro hybrid by making the feature standard beginning with its top-selling F-150 Eco-Boost pick-up trucks.



MILD HYBRID: WHY 48 (VOLTS) IS GREAT

Combining the micro hybrid start/stop system with electrical power regenerative braking and a 48-volt electrical system (versus the standard 12-volts) advances powertrain technology to mild hybrid architecture. Here, as with the micro hybrid system, the IC engine stops when at idle, and while coasting, disconnecting itself from the transmission. Meanwhile, the 48-volt battery can partially power the vehicle, while also powering its other electronic components. In addition, the mild hybrid's starter generator converts the vehicle's kinetic energy into electrical energy during braking and deceleration. The system, incorporating the starter generator and ICE, boosts engine torque and power, enabling OEMs to match it with smaller displacement engines. Conceptually for some automakers, it could mean downsizing its families of V8 and V6 engines to just one family of more-efficient four-cylinder engines.



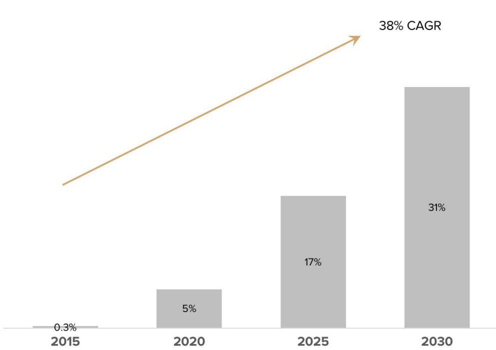
Mild hybrid technology provides OEMs a very attractive cost-to-benefit strategy, with the ability to achieve a significant 10-11% reduction in CO2 emissions at a cost of between $1,000-$1,200 per vehicle. When compared with full hybrid systems, mild hybrids offer 50% of the CO2 reduction for approximately 30% of the cost of a full hybrid system.

With OEM adoption of mild hybrid systems just beginning, it's expected that this technology will be a primary strategy for European automakers to meet Euro VII legislation and the 70-75 g/km target.

The 48-volt system offers additional advantages to OEMs as they continue to add more electrical and electronic features to vehicles, including additional

MILD HYBRID ADOPTION

GLOBAL ADOPTION RATE**



Sources: EPA, Expert Interviews, Ford
*Notes: *Net cost could be 30-40% less if paired with downsized engine*
*** Forecast based on industry expert interviews and Paul Eichenberg global analysis – IHS forecast 26% in 2030*

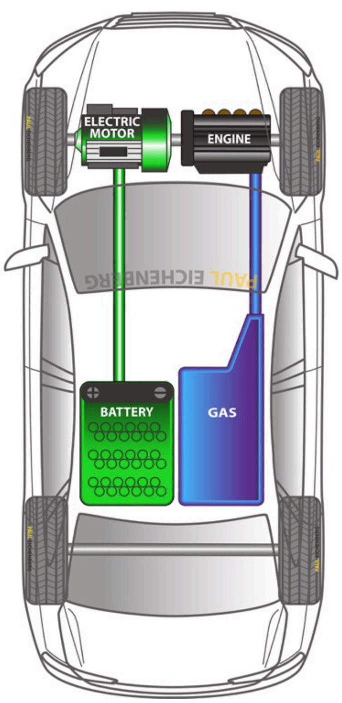
passenger climate control options, fuel efficient electronic auxiliaries (detailed later in the report) and vehicle connectivity to communication, diagnostic, autonomous features, and entertainment packages. These additional advantages, when combined with an attractive cost benefit analysis and the aggressive adoption by OEMs creates a significant market opportunity for suppliers. The 48-Volt Mild Hybrid is forecasted to become a $29 billion market by 2030 (for additional details, see supplier market overview).

NEW VEHICLE ARCHITECTURE – MILD HYBRIDS CONTINUED…

SUPPLIER MARKET OVERVIEW - Mild hybrids (48-volt) will grow to be a $29 billion market by 2030.

Component	Technology Description	Main Suppliers	OEM Price	2030 Global Market Size
Electric Motor/ Generator with integrated Inverter	Starts the engine, then helps the car to get going. Later charges the battery during braking. Converts DC battery power to AC motor power.	Conti*, Valeo*, Denso*, Bosch*, Delphi*, Shanghai E-Drive	$275[b]	$8.1 B
48-Volt Battery	Much larger than the standard 12-Volt battery. Charges and discharges at every stop and start.	JCI, Conti*, Valeo*, Denso*, Bosch*, Delphi*, LG, Samsung, Hitachi, Panasonic	$400[b]	$6.5 B
Battery Controller	Regulates the state of the charge in the battery.	Conti*, Valeo*, Denso*, Bosch*, Delphi*	$150[b]	$4.5B
DC/DC Converter	Changes 48-volt battery power to 12-volt in order to drive existing electrical systems.	Conti*, Valeo*, Denso*, Bosch*, Delphi*, TDK, Panasonic, Hella	$125[b]	$3.9B
12-Volt Battery	Not a new addition, the battery is used for traditional power supply for vehicle.	JCI, Excide	Standard today	
12-Volt ECU	12—Volt Electrical Distribution Center - for 12-volt devices like the center console, power seats, window regulators, etc.	Valeo, Denso, Delphi, Bosch, Conti	Standard today	
Electrical Architecture	Electrical connections and distribution content required to handle higher voltage.	Delphi, TE, Yazaki, Sumitomo, Leoni, Lear, Nippon	$200[b]	$6 B
		Total Systems Cost per Vehicle	**$1100[A]**	
		Total Global Market Size 2030		**$29 B**

Sources: ICCT, EPA, DOE, Expert Interviews
*Notes: *Suppliers look to provide turnkey solution*
[A] $50 for the alternator is subtracted from the total system cost
[b] ICCT forecast PHEV battery cost to drop from $400 to $175 by 2030 and non-battery cost expected to drop 20%
Suppliers proposing to integrate all three in one elegant solution



FULL, PLUG-IN HYBRID SYSTEMS FACE COST-BENEFIT CHALLENGE

A full hybrid vehicle; such as, the iconic Toyota Prius, shares the same powertrain components as the previously referenced mild hybrid, but has a larger battery system and an electric motor and generator. The vehicle can propel itself in full electric mode with the assistance of the generator, in tandem with the ICE, or simply the ICE itself.

And, like the micro hybrid and mild hybrid, a full hybrid system has engine start/stop in idle mode and while coasting.
A variation of the full hybrid is the plug-in hybrid, which shares all the same components, with the addition of an electrical outlet, which can be used to charge the vehicle when not in use. Now a feature on newer Toyota Prius models, the plug-in feature provides the opportunity for the vehicle to operate in full electric mode more often and can be powered directly by the electrical grid.

Vehicles equipped with a full or plug-in hybrid system can achieve CO2 reduction of 18-22% over a conventional ICE. However, such a reduction comes at a considerable cost – on average, $3,200-$3,600, for a vehicle with a very limited electric driving range. Vehicles such as a PHEV-40, with a higher range like 40 miles (which represents the distance the vehicle can travel on battery power alone) will have an incremental cost of more than $6000. When considering this larger battery size, this again produces an attractive market segment which could reach $54 billion in sales by 2030 (for additional details see supplier market overview).

NEW VEHICLE ARCHITECTURE – PLUG-IN HYBRIDS CONTINUED…

SUPPLIER MARKET OVERVIEW - Hybrids vehicles will grow to be a $54 billion market by 2030.

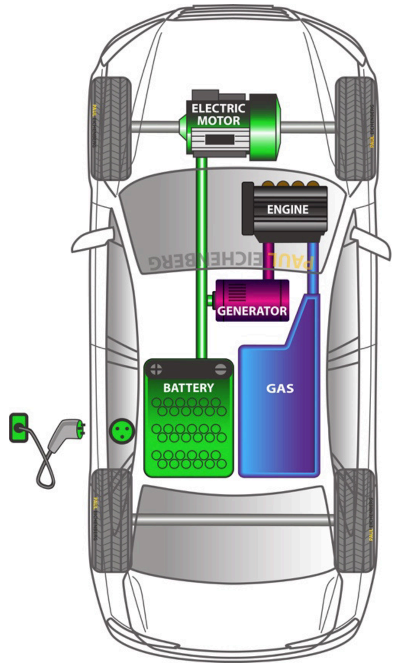
Component	Technology Description	Main Suppliers	OEM Price Today	2030 Global Market Size
Electric Motor/ Generator	Starts the engine, then helps the car to get going. Later charges the battery during braking. This system is coupled between the engine and the transmission and drives the vehicle in battery mode when conditions warrant. Is capable of driving in full electrical mode.	Conti, Bosch, Toshiba, Magna, Borg Warner, Mitsubishi, Zytec, Aisin, Hitachi, LG, BYD	$600	$7 B
Inverter	Converts DC battery power to AC motor power.	Conti, Valeo, Denso, Delphi, Bosch, Lear, Toshiba, TDK, Sanyo, A123, Bosch, BYD	$600	$7 B
High Volt Battery	240-360V battery provides energy during vehicle acceleration and is recharged during deceleration/braking.	A123, JCI, BYD, Cabasys, Li Tec, SB Limotive, AESC, Panasonic, LG Chem, Dow Kokam, Samsung, Hitachi, BYD	$3900[b]	$27 B
Battery Controller	Regulates the state of the charge in the battery.	Valeo, Denso, Delphi, Bosch, BYD	$200	$2.3 B
DC/DC Converter	Converts high-voltage power to 12-volt power in order to charge the traditional battery.	Conti, Valeo, Denso, Delphi, Bosch, Lear, BYD, TDK, Sanyo, A123, Delta	$150	$1.7 B
On-Board Charger	Connects the vehicle battery to the power grid which then recharges the high voltage battery so the vehicle can travel in full electric mode.	Valeo, Denso, Delphi, Bosch, Toshiba, Delta	$175	$2 B
Electrical Architecture	Electrical connections and distribution content required to handle higher voltage.	Delphi, TE, Yazaki, Sumitomo, Leoni, Lear, Nippon	$400	$4.6 B
Hybrid Controller	The brain of the system, this controller tells the engine controller when to stop and start, tells the motor/generator when to charge the battery or propel the car	Valeo, Denso, Delphi, Bosch, Toshiba, Visteon	$150	$1.7 B
		Total Systems Cost per Vehicle	**$6200[A]**	
		Total Global Market Size 2030		**$54.3 B**

Sources: ICCT, EPA, DOE, OECD/IEA 2016, Experts
Notes: [A] $225 additional for transmission modification
[b] ICCT forecast PHEV battery cost to drop from $350 to $170 by 2030 and non-battery cost expected to drop 20% (11 kwh PHEV 40 battery) a PHEV 10 battery would be approx. $3000 cheaper

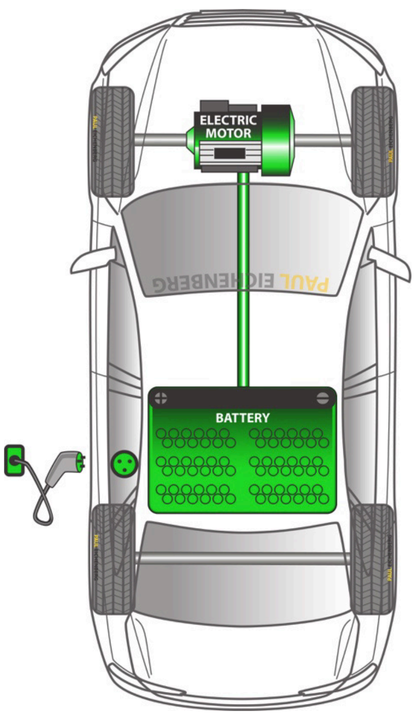
RANGE EXTENDED TECHNOLOGY MAY ONLY BE SHORT TERM

Cars such as the Chevrolet Volt and the BMW i3 are examples of range extended vehicles (REX), which are just one step away from being considered a fully-electric vehicle. A high-capacity battery powers the electric motors which drive the wheels. Vehicles of this configuration have a small gasoline-powered ICE/generator, which engages and charges the battery as it drains to give the vehicle a few extra miles of range, with the intent of getting the vehicle to the next charging station. In the case of the BMW i3, that amounts to about 80 extra miles; for the Chevrolet Volt, its range extender unit buys its owner an extra 260 miles.

The two most important advantages of REX vehicles are that their higher capacity batteries provide a longer fully-electric driving range vs. plug-in hybrids between charges, and the use of the gasoline generator provides drivers relief from "range anxiety," which remains an issue with battery-powered, fully-electric vehicles.



In fully-electric mode, a REX can be labeled a zero CO_2 emissions vehicle, but that technology comes with a high cost. It's considered by OEMs the most expensive option between a full/plug-in hybrid and a full-battery electric vehicle. It's expected that OEMs will steer clear of producing REX vehicles as battery technology improves, and electric-powered driving ranges are extended.



MOVE ON DOWN THE ROAD TO BATTERY ELECTRICS

A truly zero-emissions vehicle, battery electric vehicles (BEVs) use large-capacity batteries and electric motors to power the wheels. When depleted, the batteries are recharged off the grid from a wall socket or at a dedicated charging station. With no carbon fuel-powered generating system onboard, BEVs are considered "all-electric" vehicles.

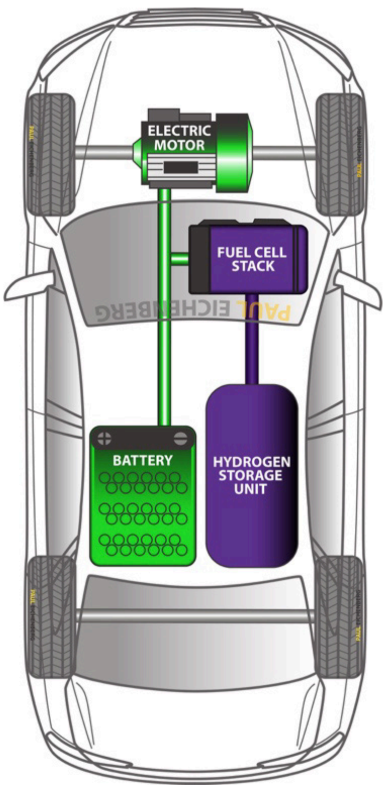
The hurdles ahead for growth in this technology include battery costs, limited driving range and the lack of a reliable charging infrastructure.

Except for a handful of dedicated manufacturers (e.g., Tesla Motors, Fisker Automotive, Tango Commuter Cars) major OEM interest in BEVs has been slow to develop, with currently less than 1% of all vehicles produced globally being all-electric. However, over the next 10 years, BEV market share is forecast to grow to more than 14% of total global vehicle production. When that happens, this becomes a major market onto itself at $130 billion annually (see supplier market overview for further details).

ONE LAST NEW VEHICLE ARCHITECTURE, FUEL CELL VEHICLES (FCV)

Another truly zero-emissions vehicle is the fuel cell vehicle. This is very similar to the BEV; however, instead of batteries to generate electricity, FCVs utilize fuel cell stacks. The stack is used to combine hydrogen gas stored on board with air to produce electricity, which power the electric drive motor just like in a BEV. These hydrogen vehicles are true zero CO_2 emissions, with the only emission being the generation of H_2O.

The range is also superior to BEVs, for now. In addition, refueling is a matter of minutes (3-5) versus hours for BEVs today.



Despite significant development from OEMs like GM, Toyota and Honda, we will not see any significant volumes for FCV for a minimum of 20 plus years. There are significant challenges which include high vehicle costs, limited infrastructure for the consumer market and the fact that hydrogen supply is very limited.

As reviewed in further details in the report, evidence will be presented to the aggressive OEM strategies for the adoption of PHEVs and BEVs. It will become more evident that the electricity from the grid is a significant enabler of these new vehicle architectures.

In a global auto market of more than 90 million passenger cars, that leaves still the clear majority of vehicle sales placed in the enhanced ICE and hybrid categories. In the next section, we will explore opportunities for optimizing the ICE, with a market forecast and technology outlook, and what the future holds for OEMs and their supplier community.

OPPORTUNITIES ABOUND FOR ICE OPTIMIZATION

While the integration of hybrid and fully-electric powertrains will help automotive OEMs gain mileage and emission efficiencies, don't rule out the many opportunities available to optimize existing internal combustion engines. The next 15 years will bring a series of major developments to leverage the potential for greater fuel efficiency and CO2 reductions.

These developments include:

- Smaller displacement engines equipped with turbo-changing and supercharging
- Engine control systems; such as, variable compression, cylinder deactivation and variable lift/timing
- Direct injection engines
- HCCI – homogeneous charge compression ignition
- EGR – cooled exhaust gas recirculation

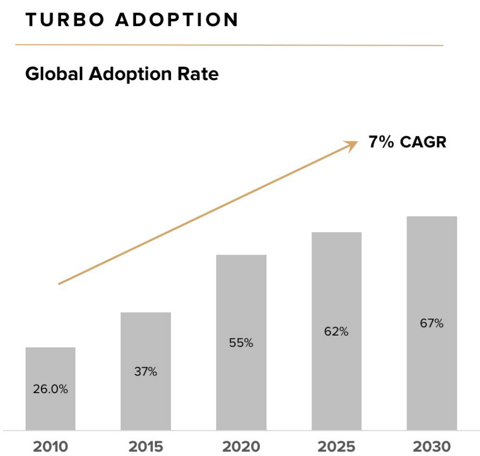
In addition to engine enhancements, other emission-reducing technologies available to OEMs include:

- Thermal Management Module (E-water pump system)
- E-booster – electrically-assisted charging
- Electronic cam phasing
- EPS – electric power steering
- Active grille shutters
- E-RAD (rear wheel axle drive) – electronic all-wheel drive system

Automotive transmission systems may also benefit – in performance and fuel efficiency – from these systems, already in a wide number of production vehicles;

- CVT – continuously variable (belt-driven) transmission
- AMT – automated manual transmission (no clutch)
- DCT – dual-clutch transmission
- AT – automatic transmission
- Optimization of automatic transmission with additional gear ratios (6-8 speeds)

Here is a brief description of each of the major technologies and their impact on vehicle performance and on the environment.

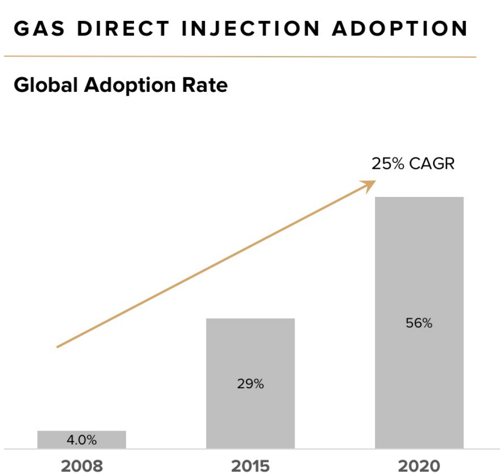


TURBOCHARGING

Improved power output, together with a 12-14% reduction in CO_2 emissions has sparked many OEMs to integrate turbocharging into their powertrain portfolios, particularly in smaller-displacement engines. The "turbo" is a turbine-driven device that boosts engine efficiency and power by forcing extra air into the combustion chamber by reusing exhaust kinetic energy for turbine power. Among the 2017 winners in Ward's Automotive "10 Best Engines" runoff, 7 of the 10 engines are gasoline-powered turbos. In Europe, turbocharged diesel engines are the norm, and set to be standard for European OEM gasoline engines by 2020, with other markets eventually adopting the technology. The turbo market is growing at a compounded annual growth rate of more than 7%, and we expect that 67% of all vehicles produced globally in 2030 will have a turbo.

ENGINE CONTROL SYSTEMS

Several strategies are available to improve fuel efficiency and reduce CO_2 (3-7%) with the use of internal combustion engine control systems. They include electronic cylinder deactivation, which automatically shuts off some engine cylinders when not needed (currently in use in some GM trucks and SUVs), variable valve timing, which alters the timing, lift and duration of engine valves to improve performance fuel efficiency and emissions (example: Mercedes Benz GLS 450 SUV), and variable compression ratio technology, which adjusts the compression ratio while the engine is running (coming to the 2018 Infiniti QX50 crossover).



GASOLINE DIRECT INJECTION

One of the most universally-adopted OEM powertrain technologies (now at about 47% globally), gasoline direct injection, forces, under high pressure, gasoline directly into each cylinder (versus traditional multiport systems) for a leaner and more powerful usage of fuel, thereby reducing CO_2 emissions 3-12% depending on the engine displacement size.

HOMOGENEOUS CHARGE COMPRESSION IGNITION (HCCI)

A longer-term technology for adoption, HCCI, is one of the more promising available to optimize the internal combustion engine, offering diesel-like fuel efficiency in a gasoline engine, with the capability to reduce fuel costs by 30%. In this technology, air and fuel are mixed ahead of compression and ignited at a high temperature, achieving high levels of fuel-burning efficiency. Most of the R&D around HCCI is being conducted by European and Japanese OEMs, with Mazda expected to launch its HCCI engine by 2020. The cost burden will be lighter than electrification of vehicles (BEVs and full hybrids). There is; however, a significant technology hurdle, specifically around a required improvement in compression ratio and stable operation in low temperatures. Expect the market to develop slowly, considering the rising acceptance of vehicle electrification.

COOLED EXHAUST GAS RECIRCULATION

Another method of reducing emissions, cooled exhaust gas recirculation (EGR) takes a portion of the engine's exhaust gas and reintroduces it to the combustion chamber through the engine intake system, significantly reducing NOx emissions.

ELECTRONIC AUXILIARY TECHNOLOGIES

OEMs also have several electronic auxiliary technologies available to further drive vehicle efficiency by reducing parasitic losses and providing power on demand. These include:

- **Thermal management module** – Combining sensor-controlled valves with an electronic water pump, this can precisely regulate the powertrain temperature balance, and allows the optimum operating temperature to be reached in the shortest time possible, thereby reducing fuel consumption and CO2 emissions by up to 4%. This technology is especially useful in automatic engine stop/start systems.
- **E-booster** – The E-booster is an electrically-assisted charging system which uses a flow compressor driven by an electric motor, and is placed as a component before or after an engine's turbocharger to boost charging pressure.
- **Electronic cam phaser** – The "e-phaser" is an electrically-driven engine cam phaser available in a wide range of applications to reduce emissions and improve fuel economy. Compared with conventional hydraulic cam phasing, the e-phaser achieves faster response times and provides an increased phasing range.
- **Electric power steering (EPS)** – EPS, with its on-demand electric motor, provides further fuel efficiency advantages as it eliminates a constantly-running hydraulic pump, along with a belt-driven engine accessory and several high-pressure hydraulic hoses.
- **Active grille shutters** – By automatically and mechanically adjusting the airflow going into the vehicle's radiator, these shutters reduce drag, thereby improving aerodynamic efficiency for further fuel efficiency.
- **E-RAD (electronic all-wheel-drive system)** – This on-demand AWD system, combining a generator with an electric motor propels the front wheels if slippage is detected. Apart from the fuel savings, this system eliminates the expensive, heavy, and bulky torque transfer differential, and a prop shaft running to the rear axle, allowing for better interior space and significant mass reduction.

TRANSMISSION TECHNOLOGIES: MORE SPEEDS

The continuing evolution of vehicle transmission designs and technologies is also a key tool to greater fuel efficiency and CO_2 reduction. While the basic manual transmission, still highly popular in Europe, remains the most efficient transmission design, with excellent fuel efficiency and power, other entries on the automatic front continue to be developed and enhanced. OEMs continue to add additional speeds for higher efficiency. The shift to 8-speed automatics from 6-speeds equals a 3-4% reduction in CO_2, with 10-speed transmissions now beginning to enter the market. North American OEMs are expected to continue the tried-and-true multi-gear automatic, while Japanese automakers are focusing their attention on continuously-variable transmissions (CVT).

LOWER-COST, GREATER VALUE OPTIMIZATION TECHNOLOGIES

While OEMs routinely evaluate introducing new technologies/features on a cost-per-vehicle basis (many coming in at considerable cost), there are several powertrain optimization technologies which offer greater value at lower cost, particularly with the challenge of reducing CO_2 emissions.

Some of these include:

Estimated cost of <$25 per vehicle

- Predictive powertrain thermal management control
- Insulated oil pan to improve heat retention
- Insulated transmission case – heat retention method
- Variable engine oil pump to optimize oil flow per engine requirements
- Reduction of oil sump capacity – offering a 20% mass reduction
- Engine thermal mass reduction – achievable with better design/integration of components, plus use of lighter-weight materials
- Polymer material heat exchanger for high conductivity and mass reduction vs. metals

Estimated cost of $25-$50 per vehicle

- Passive cabin ventilation to allow heat transfer to continue after engine, HVAC shutoff
- Encapsulated engine compartment to reduce heat losses and achieve faster engine warmup
- Variable water pump, offering optimized coolant flow characteristics
- Smart water valve integrated electric water pump for more efficient operation
- Split engine cooling for improved performance
- Transmission rapid warmup system for lower fuel consumption and reduced emissions

Considering all the optimization technologies discussed thus far in this report, we now turn our attention to the market demand for these technologies through our next section dealing with vehicle trends and forecasts.

VEHICLE FORECAST: WHAT'S DRIVING CARS IN THE YEARS AHEAD?

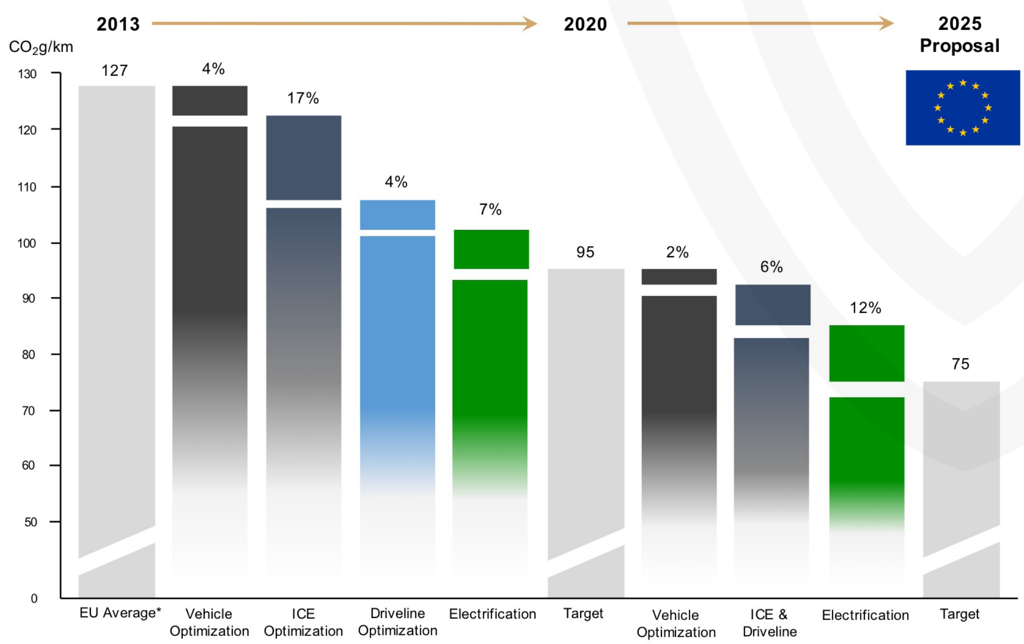
2020-2030 WILL BE THE DECADE OF ELECTRIFICATION

As discussed earlier in this report, the European Union is leading the campaign to reduce CO2 emissions to a targeted 95 grams per kilometer driven by the year 2021, followed by another major push to a target of 70-75 g/km in the 2025-2030 timeframe. Achieving these targets will require a wide combination of technologies, with heavy reliance on powertrain optimization – internal combustion engine enhancement plus the range of hybrid technologies.

In order to meet the 2020 legislation, ICE and driveline optimization are the primary area of focus. However, starting in 2021 as the industry shifts towards the next target, electrification will become the primary driver as the cost of ICE optimization raises to the point where electrification becomes a more cost-effective alternative. (Please review EU TECHNOLOGY ROADMAP CHART). Current industry forecasts don't consider technology breakthroughs or the (stand-alone) exhausted combustion engine potential which will drive the market toward electrified vehicles. Take rates will be higher than industry prognosticators forecast today.

CO_2 REDUCTION - ROADMAP TO 75 G/KM

The technology roadmap example from the EU shows that ICE optimization technologies will become less of a priority in the future as the utilization of electrification increases.



*Sources: *European Environment Agency, Expert Interviews*

TECHNOLOGY BREAKTHROUGHS AND EXHAUSTED COMBUSTION ENGINE POTENTIAL WILL DRIVE THE MARKET TOWARDS ELECTRIFIED VEHICLES

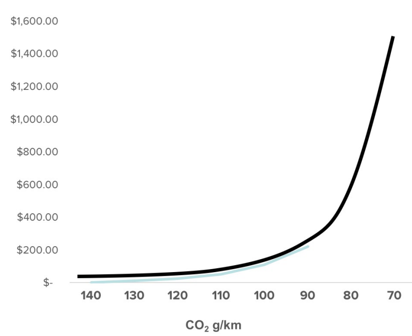
This is supported by growing evidence that these predictions are understated; that vehicle electrification development will increase faster than originally thought. Some of the reasons for this include:

/ Pressure for tighter emissions compliance (the 70-75-g/km target) is driving up the cost of internal combustion optimization. Over the past decade, such costs have been minimal. Today, OEMs spend about $5,200 per vehicle. By 2020, those costs are expected to increase to $5,400, and then balloon to $6,700 by 2030. *(Please see CHART)*

1 COST OF ICE OPTIMIZATION TO INCREASE OVER NEXT DECADE

Cost to optimize ICE has been minimal over past decade, however, the cost will increase significantly (and will be exhausted) in order to meet CO_2 70-75 g/km.

ICE COST FORECAST:



Sources: ICCT, Expert Interviews
**ICCT 2020-30 CO2 Standards for Cars and LCVs in Europe, Nov. 2016*

ICE COST SUMMARY:

ICE System	2015	2020	2030
Engine	$3200	$3330	$4500
Transmission	$1350	$1400	$1500
Fuel System	$350	$350	$350
Exhaust	$300	$320	$350
Total	$5200	$5400	$6700
CO2 Level	~124g/km	~95g/km	~75g/km

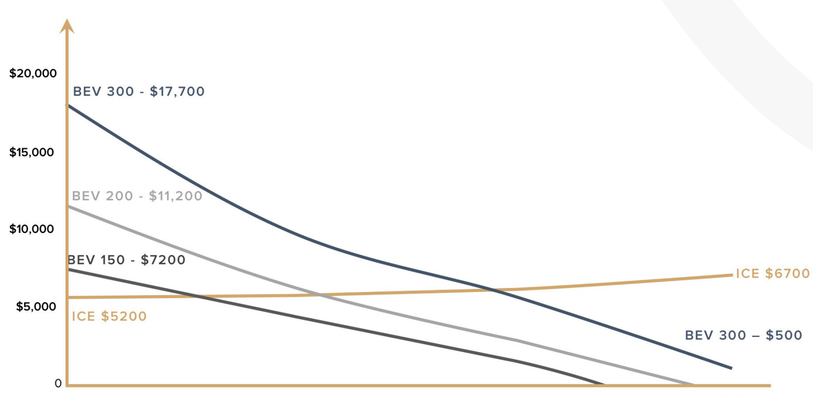
Assumptions:

- Assumes minimal OEM electrification portfolio additions which will off-set cost of investment in ICE in order to meet standards
- Expert interviews show that exhausting combustion engine potential at ~70 g/km

/ The cost of batteries is expected to significantly decrease as power storage and range technology improves, and battery manufacturing volume itself increases. In 2015, a battery pack cost $270 USD per kWh. This is expected to drop to $110 USD per kWh by 2030. The industry is well on its way to the 2030 target for a battery pack with Tesla acknowledging in 2016 it is already at the cost of $190 kWh. *(Please see CHART)*

3 THE COST OF BATTERIES WILL SIGNIFICANT DECREASE

Between 2020 and 2030 the cost to optimize the ICE will increase significantly as technology and cost of battery packs sharply decrease.



Sources: ICCT November 2016 Battery Technology Forecast - 2015 $270 USD, 2030 $110 USD per kWh – battery pack Bloomberg News Energy Finance estimates $270 kwh battery pack = $74 per pack and $196 per cell (Tesla acknowledges at $190 pack and GM at $145 cell price today).

- Over the years, we've seen increased interest among automotive buyers for improved acceleration performance. Recent developments have greatly reduced zero-to-60 mph times on a wide range of luxury and performance vehicles. We've seen electric vehicle torque and acceleration rival not only the competitors, but also "super cars" like Porsche and Lamborghini in terms of overall performance.
- Future regulations over emissions standards are expected to continue to tighten globally, despite pressure from the new U.S. administration to relax its standards. In China and several EU countries, bold proposals and resolutions have been launched on a nationwide and citywide scale to curb new production; as well as, operation of gasoline and diesel-powered vehicles.

EVOLVING STRATEGIES

In addition to the above-described reasons, recent tightening of government regulations, especially in the EU, have forced automakers to change their long-term strategies, pulling up their product development schedules for electrification, and introducing new products, as well.

In Europe, German OEMs are taking the lead toward electrification. VW, Daimler and BMW have announced they will be introducing plug-in hybrid vehicles across most of their product range starting this year. However, as mentioned earlier, the German Bundesrat (with support of VW, BMW and Daimler) passed a resolution to ban ICE starting in 2030. The resolution calls for the EU Commission to approve only zero-emission passenger vehicles for use on European roads. This would eliminate the use of all ICE vehicles, including plug-in hybrids, and drive the industry to battery electric vehicles.

Building on this concept, VW announced a strategy in June of 2016 referred to as **"TOGETHER – Strategy 2025."** The strategy states:

> *"With regard to vehicles, and drivetrains, special emphasis will be placed on e-mobility. The group is planning a broad-based initiative in this area: it intends to launch more than 30 purely battery-powered electric vehicles (BEVs) over the next ten years. The company estimates that such vehicles could then account for around a quarter of the global passenger car market. The Volkswagen Group forecasts that its own BEV sales will be between two and three million units in 2025, equivalent to some 20 to 25 percent of the total unit sales expected at that time."*

BMW and Daimler have followed up with a similar strategy, which is 15-25% of the global fleet to be electric vehicles – which both organizations define as pure BEVs and PHEVs.

In Japan, which has invested heavily in hybrids and plug-in versions, OEMs Nissan, Toyota and Honda are all exploring options for greater battery-powered vehicle (BEV) development and production. In November of 2016, Toyota Motor appointed its president to lead their newly formed electric car division, flagging its commitment to develop a technology that the automaker has been slow to embrace.
The change comes as the United States, China and European countries are encouraging automakers to make more all-electric battery cars as they push alternative energy strategies. Akio Toyoda, grandson of the company's founder Kiichiro Toyoda, has been at the helm of automaker since 2009. He will head the company's electric vehicle planning department, along with Executive Vice Presidents Mitsuhisa Kato and Shigeki Terashi. This signals a significant shift in strategy by the automaker.

At an annual press conference in February of this year, Honda president & CEO Takahiro Hachigo confirmed the following: "We will strive to make two-thirds of our overall unit sales from plug-in hybrid/hybrid vehicles and zero-emissions vehicles; such as, FCVs and battery EVs by around 2030."

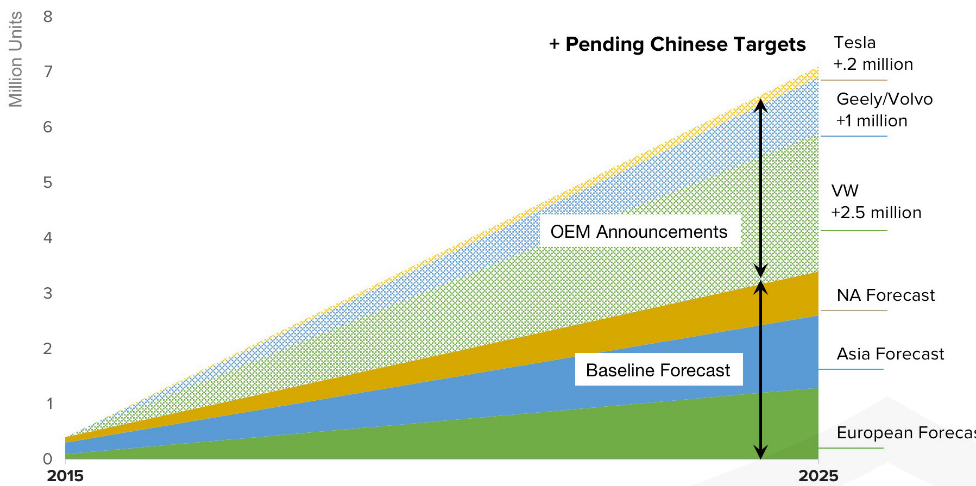
Chinese OEMs, driven by their country's air quality issues and recent government regulations, are expected to also have lead roles in the development of electric vehicle and battery technology. Geely, parent company of Volvo, is targeting a 2019 launch of Volvo's first BEV, and Volvo cars has set a target to producing one million BEVs by 2025. The other two Chinese OEMs, BYD and SAIC, are also setting aggressive electric vehicle plans.

These announcements more than likely are based on pending aggressive new targets to be set by Chinese regulators. Industry Minister Miao Wei proposes draft legislation requiring all automakers to sell a specific quota of zero and low emission vehicles, starting at 8% of overall sales by 2018. This target would rise to 10% in 2019 and 12% in 2020. OEMs who fail to comply will pay penalties or would be forced to buy credits from competitors. 12% of the Chinese market in 2020 would be the equivalent of 3.5 million vehicles - just imagine how aggressive targets could be for 2030?

In North America, OEMs have been taking a more cautious approach toward full electrification of their vehicle fleets. Media reports over the past few years depict Elon Musk's Tesla EV venture as the most ambitious (and only) dedicated BEV maker, with two models in production, and a third "mass market" model in the works this year. GM, despite its long history of EV development, has limited electrification plans beyond two Chevrolet models (Chevy Spark and Chevy Bolt). Ford and Fiat Chrysler now offer a limited number of plug-in hybrid models, with no other production plans yet announced.

TAKE RATES WILL BE HIGHER THAN INDUSTRY PROGNOSTICATORS FORECAST

The announcements by the German "Big Three:" VW, Daimler, and VW, together with Volvo-Geely are significant, and if the Asian OEMs and others follow suit, a revised BEV forecast of an additional 3.7 million units will far exceed the original estimates. This would more than double the of approximately 3 million vehicles being forecasted by IHS in September of 2016.



Based on these developments, we return to the overall industry global engine roadmap to find a revised ICE and hybrid market accounting for 86 percent by 2030 versus the originally-predicted 95 percent.

Component	Technology Description	Opportunistic Global Take Rate Estimates				2030 Price Assumption vs. 2017
		2015	2020	2025	2030	
Stop/Start – Micro Hybrid	12V belt-driven integrated starter-generator, which replaces a common alternator and provides stop/start functionality and shuts down the engine at idle.	28%	53%	42%	34%	20% REDUCTION
Mild Hybrid	The concept of the mild hybrid like the micro hybrid, but adds additional features like regenerative braking and has a larger battery to provide additional assistance when the vehicle is in high electrical demand mode (thus 48-volts). In this architecture, the bigger battery supplements the ICE but never solely powers the vehicle.	.3%	7%	19%	31%	
Full Hybrid & PHEV	The concept of the full hybrid builds upon the concept identified in the mild hybrid except for a larger battery system and an electric generator. The vehicle can operate in full electric mode with the assistance of the generator or can be driven by utilizing a smaller ICE. Plug-In Hybrids (PHEVs) include a charger that connects the vehicle to the grid.	2%	5%	9%	12%	
Battery Electric Vehicle	Battery electric vehicles, or BEVs, use electricity stored in large capacity battery packs to power an electric motor and turn the wheels. When depleted, the batteries are recharged or plugged-in using grid electricity, either from a wall socket or a dedicated charging unit. Since they don't run on gasoline or diesel and are powered entirely by electricity, battery electric cars and trucks are considered "all-electric" vehicles.	.4%	3%	8%	14%	
		Assumption Cost kWh				
BEV Battery	Technology evolution, R & D and mass production has lead to the rapid decline in battery cost over the past decade from $1000 kWh in 2008. Forecast assumes:	$270*	$195*	$140*	$110*	~60% REDUCTION

Sources: ICCT, EPA, DOE, OECD/IEA 2016, Expert Interviews
*Notes: * ICCT November 2016 Battery Technology Forecast - 2015 $270 USD, 2030 $110 USD per kWh – battery pack*
***Analysis based on expert interviews and Paul Eichenberg global analysis*

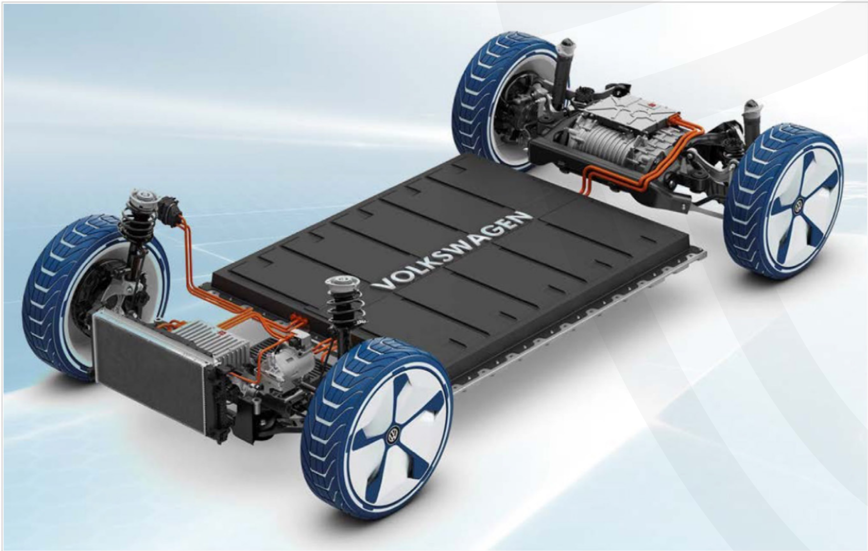
CONCLUSIONS:
WHAT THE INDUSTRY CAN EXPECT FROM ELECTRIFICATION

SCALE IS A CRITICAL ADVANTAGE IN ELECTRIFIED POWERTRAINS

In an industry that has traditionally operated on lengthy product development cycles, this represents a significant shift toward greater degrees of electrification, and is expected to have a profound impact on the structure of the auto industry in the years to come.

While the electrification of the auto industry won't happen overnight, the technology advances leading to higher reliability, driving range and economies of scale will have a profound impact on the entire structure of the industry in the years ahead, signaling the end of the industry's mechanical age and the beginning of a digital transformation. This will lead to some serious disruptions for automotive companies and their suppliers going forward. Four of the most significant issues to expect include:

SCALE IS CRITICAL IN THE ELECTRIFIED WORLD AND THE FUTURE OF AUTOMOTIVE.



Sources: VW

Electronic systems scale differently than mechanical components. Considering, this will drive significant changes to the industry. OEMs will use this concept to drive competitiveness thru large-scale electrification strategy; such as, in the earlier-mentioned reference to VW's strategy to build 2-3 million electric vehicles by 2025 on its MEB platform to achieve scale across its entire car group.

ELECTRONIC PRODUCTS SCALE DIFFERENTLY THAN TRADITIONAL MECHANICAL COMPONENTS

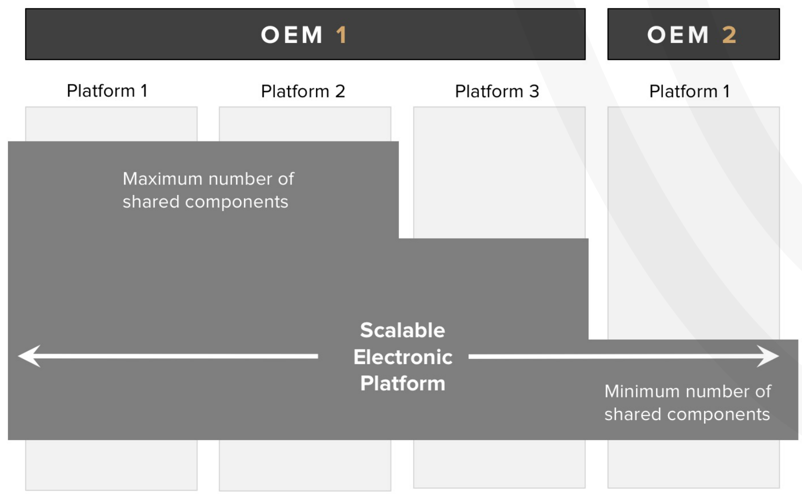
And, much like the VW example, OEMs are expected to standardize electronics architectures across vehicle platforms. This opens the potential for suppliers to leverage its hardware offerings across multiple OEMs. This also means that longer-term, there will be limited differentiation opportunities for both OEMs and suppliers. Therefore; longer-term, most OEMs will eventually outsource key electrical vehicle systems, including batteries, electric drive motors and power electronics.

SCALE WILL CHANGE THE STANDARD OPERATING MODEL

As our industry undergoes this digital transformation, the fields of electronics, electrical systems and the importance of software development will fundamentally change the auto industry's standard operating model.

For example, today's industry product development domains encompass powertrain, body, chassis, electrical, interior and exterior. As the use of electronics increases across the various domains, electrical systems become the backbone of all major automotive systems, and core to vehicle development. Due to the fact there is limited technical differentiation with these systems, scale is the main source of competitiveness. Thus, the consumer/industrial electronics operating model will be critical to those organizations that focus on vehicle electrification. Therefore, companies; such as, LG, Toshiba, Bosch and Panasonic are critical partners to OEMs as they develop their electric vehicle strategies.

SCALE WILL LEAD TO SHARED ELECTRONICS ARCHITECTURE

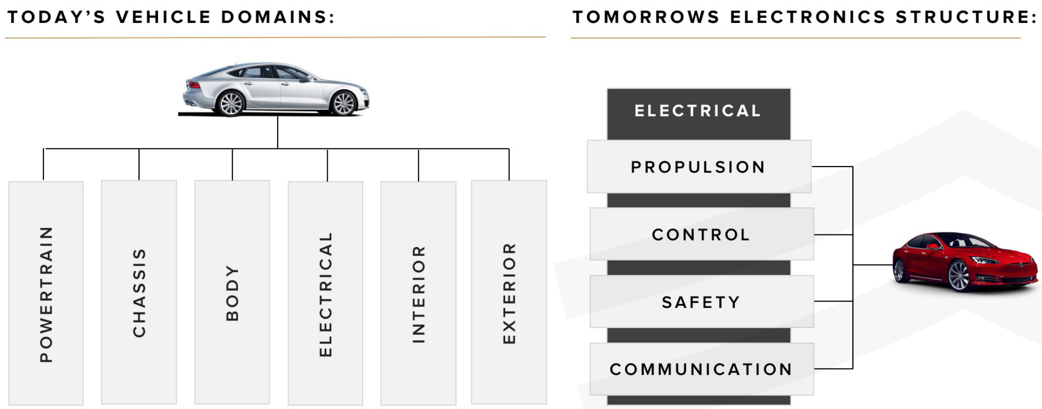


Sources: Expert Interviews

NEW ENTRANTS WILL HAVE SIGNIFICANT ADVANTAGES OVER TRADITIONAL AUTOMOTIVE COMPANIES

As electrification progresses, OEMs with the ability to achieve economies of scale with key components position themselves for a competitive advantage. These key components and systems will be coming from an entirely new group of suppliers best known today for consumer electronics.

SCALE WILL CHANGE THE STANDARD OPERATING MODEL

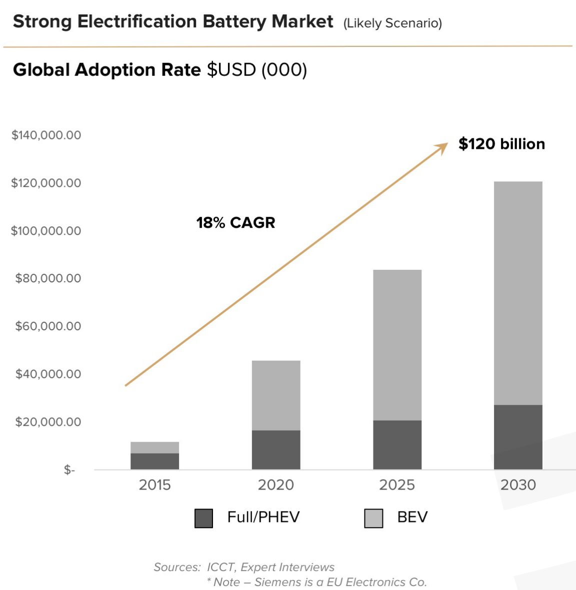


Sources: Expert Interviews

For battery packs, companies like LG, Panasonic, Samsung, Toshiba and Hitachi all bring expertise in high volume production of Lithium-ion batteries from the consumer electronics industry. Likewise, future sources for electric drive motors and control systems include the companies whom also produce large industrial motors. For electric drive motors, 60% of the unit cost comes from rare earth magnets and copper. Thus, large scale electric motor production for industrial applications is a significant advantage. Power electronics will be similar. For instance, 40% of the cost of the inverter comes from the IGBT (insulated gate bipolar transistor) and capacitors. This power semiconductor technology again favors companies with extensive consumer electronics capabilities of companies like Toshiba, Hitachi, Samsung, Panasonic and Mitsubishi, along with power semiconductor manufacturers like Infineon, ON Semi, Qualcomm and ST Micro. In these instances, advantage comes from high volume and high levels of automation.

SCALE AND SIZE OF OPPORTUNITY IN AUTOMOTIVE WILL ATTRACT NEW ENTRANTS

An example to consider is GM's new Chevy Bolt, battery electric vehicle. To achieve industry leading levels for lithium-ion battery packs, GM partnered with LG. LG leveraged its expertise from the consumer electronics into a position to produce not only the battery pack, but also electric drive motors and power electronics. Many industry insiders have been shocked by the amount of the critical electric vehicle system that has been outsourced to LG. However, when you consider how critical scale is for a competitive advantage, one can see why this is another example of the eventual industry shift.



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The market potential for these new entrants to our industry is expected to be enormous as electrification takes root and grows. We estimate the market potential for the year 2030 to be approximately $120 billion for batteries alone, $200 billion for all these key hybrid and electric vehicle components. This market size creates a very attractive opportunity for these consumer and industrial electronics companies.

HUMAN RESOURCE CHALLENGE: A SHIFT IN COMPETENCIES

Electrification will also bring with it a dramatic shift in required engineering skill sets. With traditional technologies such as mechanical and materials engineering being reduced in importance, the industry will shift to a new set of soon-in-demand competencies – chemical engineering for advanced battery development, and electrical and software engineering for propulsion and other electronic systems. This shift will create significant challenges for existing automotive companies, but arises as an opportunity for new entrants which can

MOST SUPPLIERS LACK ELECTRONICS AND SOFTWARE COMPETENCIES TO COMPETE FOR THESE NEW PRODUCTS

quickly attract and deploy these new, needed engineering resources. New entrants, like those from consumer and industrial electronics, which can quickly deploy resources, have a significant advantage when you consider the following:

/ *Flexibility – Has existing electronics "backbone" or operating model.*
/ *Scale to leverage – Serves multiple industries currently.*
/ *Competencies – Deployable workforce of electrical talent.*
/ *Speed – Experience in fast pace consumer electronics.*
/ *Financial – Greater financial flexibility from investors which allows them to move quickly and take greater risks.*

FEW SUPPLIERS WILL BE ABLE TO MAKE THE TRANSITION

As the industry undergoes this digital transformation, many companies will struggle to transition to an electronics operating model and win long term. Some of the barricades they face include:

/ **Wrong vision** – *In which the organization lacks an understanding on how the industry and the company should evolve.*
/ **Wrong time horizon** – *In which the organization believes it should focus on electrification later – when volumes and returns are higher.*
/ **Wrong assets** – *In which the company's manufacturing assets are dedicated to a dying portfolio of products.*
/ **Wrong organizational set-up** – *The company operates on a traditional organizational model with no electronics backbone, scale or platform concept.*
/ **Wrong staff** – *Engineering skill sets are focused on mechanical and materials engineers versus electrical and software engineers.*
/ **Wrong risk profile** – *The company's investors seek a safe return on deployed assets versus the high risk/high reward profile associated with a transition to a digital future.*

OPPORTUNITIES FOR SOME, TROUBLE FOR THE UNPREPARED

The shift towards electrification will create tremendous opportunities for OEMs and suppliers which are prepared to meet the digital drive head-on. However, the disruption and introduction of an entirely new set of emerging competitors will lessen the chances of survival for traditional suppliers who fail to act – with a clear vision, a winning strategy and the right technical resources.

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