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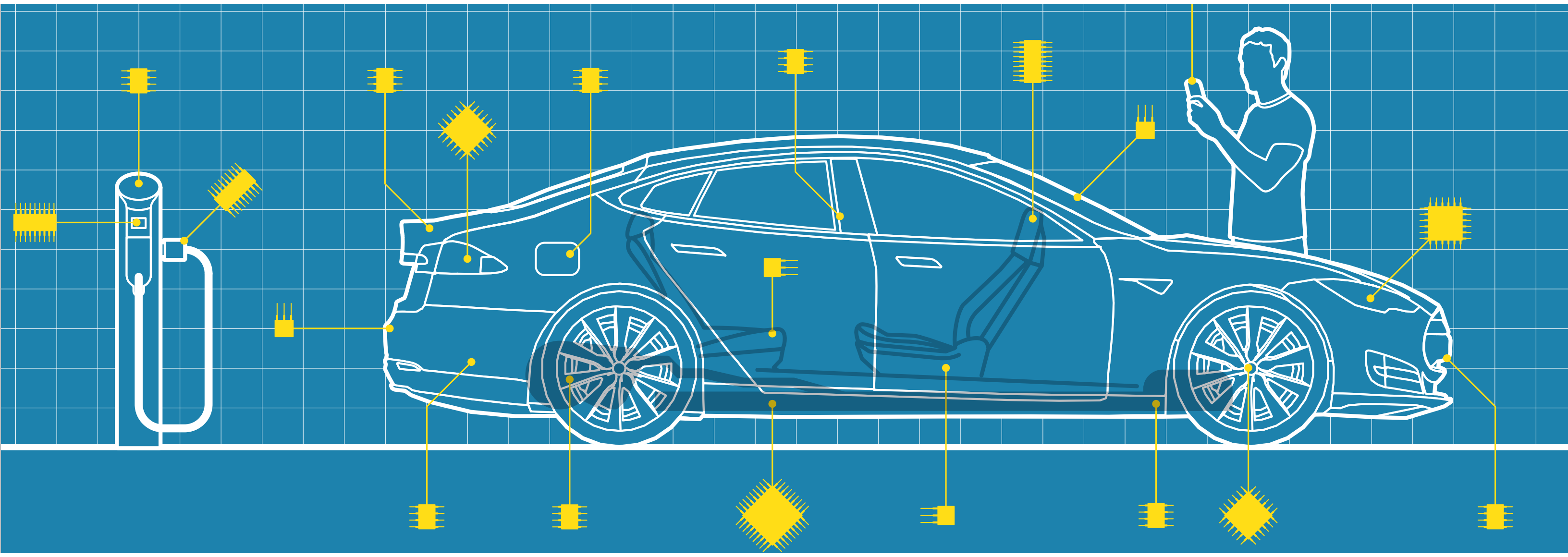

SEMICONDUCTORS

Mobility trends: What's ahead for automotive semiconductors

New mobility trends are diversifying demand for automotive semiconductors. Here's what companies need to know about new opportunities.

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Consumers who arrived in Las Vegas for the 2017 Consumer Electronics Show—one of the premiere exhibitions of new technologies for the general public—might have wondered if they were at an auto show. This annual conference, which attracts leading high-tech companies across sectors, featured more than 500 exhibits on mobility solutions for cars. Many global automotive OEMs and automotive suppliers participated, introducing innovative sensors, mapping applications, connectivity platforms, and other new technologies. These improvements, combined with the expansion of electric vehicles (EVs), will alter mobility—the market that includes public and private transport, as well as the transportation of goods. In the new environment, a car's electronic components and functionalities—already an important buying consideration—may become the feature that differentiates it from the crowd.

Semiconductors have enabled most of the recent innovations in automotive technology, including vision-based, enhanced graphics processing units (GPUs) and application processors, sensors, and DRAM and NAND flash. As cars become even more complex, demand for automotive semiconductors will continue to rise steadily and provide a major new long-term growth engine.

With many semiconductor companies aggressively pursuing automotive opportunities and forming partnerships along the value chain, players that move more slowly might be left behind. This article discusses three topics that all semiconductor companies must consider as they prepare for the future: trends shaping the automotive landscape, factors that affect demand for automotive semiconductors, and major strategic issues that players must address as they adapt to the evolving market.

The evolving automotive market

The automotive market has seldom experienced so many simultaneous disruptions. In the past few years, we have seen various technologies increasingly incorporated into the mass production of cars, including matrix LED lights, enhanced lidar sensors—those that use lasers to measure distance to a target—and better camera-based sensors. We have also seen improvements in 3-D mapping applications, EV batteries, and augmented-reality technologies, such as heads-up displays. And 5G networks—the next generation of mobility solutions—could soon be available. On the customer side, we are seeing new preferences and attitudes toward cars—for instance, a decrease in the number of consumers who consider vehicle ownership important.

In a 2016 McKinsey report, *Automotive revolution—perspective towards 2030*, we reviewed the major forces shaping the industry, focusing on four that we deemed particularly important.

Vehicle electrification. Excluding full hybrids—cars that can run using just battery power—EVs represented less than 1 percent of new-vehicle sales in 2016. Over the next decade, however, their sales could surge as technological advances address two major impediments to growth: high battery costs and limited charging capabilities. EVs could represent about 5 to 10 percent of car sales by 2020, depending on the extent to which they comply with emission regulations, and between 35 and 50 percent by 2030. The latter estimate is broad because it is difficult to predict many factors that affect growth, including the rate of technological advance, government regulations, and shifts in electricity and oil prices.

Increased connectivity. With hands-free mobile service and online navigation now standard in most new vehicles, automotive players have moved to the next wave of innovation in connected cars. New offerings include telematics services that rely on human–machine interfaces, including voice assistance (such as turn-by-turn audio instructions) and eCall (a program that prompts vehicles to make automatic calls to emergency services in the event of a crash). Both vehicle-to-infrastructure and vehicle-to-vehicle connectivity are increasing and will be supported by 5G networks by around 2020. For instance, BMW vehicles connect to smart-home services such as Deutsche Telekom's SmartHome app, which allows drivers to adjust their home's heating and lighting while they are on the road.

Connectivity strongly influences vehicle-purchase decisions and may have an even greater impact in the future. In a 2016 McKinsey survey of 3,000 consumers in three countries, 41 percent of respondents stated that they would switch to a new vehicle brand to obtain better connectivity.[1] The survey also showed that connectivity features are particularly important in certain countries. For instance, 62 percent of Chinese buyers stated that they would be willing to shift to a new brand to obtain the latest connectivity features, compared with 37 percent of drivers in the United States and 25 percent in Germany. As connectivity solutions become more important, the revenue they produce for OEMs could rise from about \$30 billion today to more than \$60 billion by 2020.

The growth of autonomous driving. Although OEMs have introduced many new advanced-driver-assistance-systems features, such as automatic braking and adaptive cruise control, highly autonomous vehicles—in other words, level 4 cars—are not expected to hit the road until sometime between 2020 and 2025 (see sidebar, "How are autonomous cars classified based on their driving capabilities?"). They could then experience steady growth, with McKinsey's most highly disruptive scenario for 2030 suggesting that 35 percent of cars sold will have conditional automation (level 3) and 15 percent will have high automation (level 4). The exact growth trajectory will depend on multiple factors, including improvements in core technologies, pricing, consumer acceptance of self-driving cars, and the ability of OEMs and suppliers to address fundamental concerns about safety and the potential for hacking.

Shared mobility services. While car-ownership rates have been increasing in developed markets, they are expected to slow or remain flat with the rise of shared mobility services and the rapid growth of car-sharing and e-hailing services such as car2go. In North America, for instance, membership in car-sharing services increased more than 400 percent between 2008 and 2015. Even greater gains are expected in the future. One McKinsey forecast suggests that e-hailing or ride-sharing services could account for 10 percent of vehicle purchases by 2030—a shift that is prompting many OEMs to increase their efforts to capture this market.

A shifting and diversifying revenue pool

Global automotive revenue now totals about $3.5 trillion annually, with the vast majority coming from new-car sales and the aftermarket (repairs and other services provided after an initial vehicle purchase) (Exhibit 1). Only $30 billion, or less than 1 percent of the total, can be attributed to recurring revenue—a broad category that includes proceeds resulting from e-hailing or car-sharing services, as well as those from data-connectivity services such as

How are autonomous cars classified based on their driving capabilities?

SAE International, a global association of engineers and experts in the aerospace, automotive, and commercial-vehicle industries, created a classification system for autonomous vehicles that is standard throughout the industry. It divides cars into six categories based on the amount of driver intervention required during operation:

Level 0, no automation. Drivers control all vehicle functions, but vehicles may issue warnings about obstacles or other safety threats.

Level 1, driver assistance. The vehicle controls either steering or acceleration and deceleration, but drivers must be ready to assume control at any time. Drivers also control all other critical tasks.

Level 2, partial automation. Vehicles control accelerating, decelerating, and steering. Drivers can take control of these functions at any time, however, and still control other functions.

Level 3, conditional automation. Vehicles control all driving functions, but the system may request that drivers intervene in certain situations; without driver input, the vehicle will not perform appropriately.

Level 4, highly autonomous. Vehicles control all tasks. The system may ask drivers to intervene at some points, but it can still direct the car appropriately if there is no response.

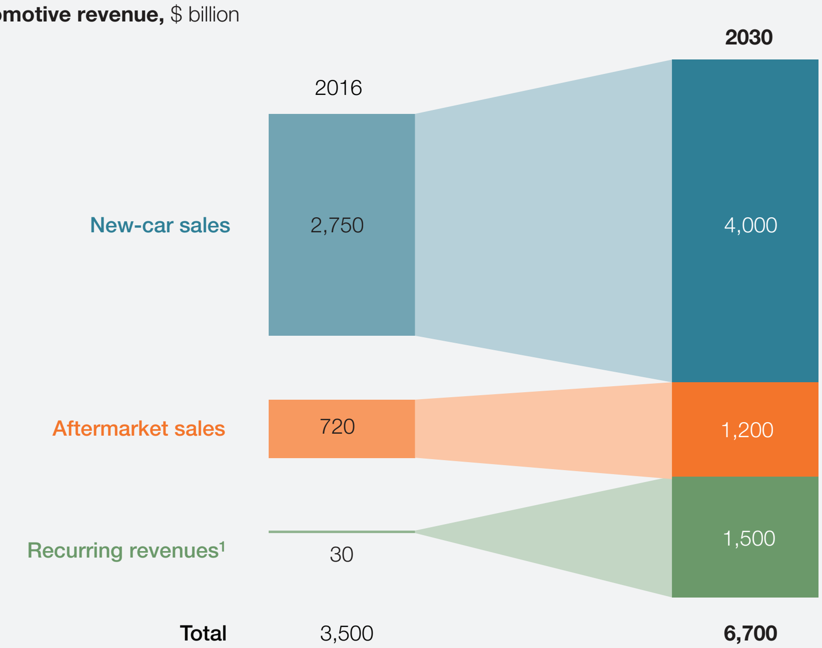
Level 5, fully autonomous. Drivers must start the car and establish the destination, but vehicle software makes all other decisions without further assistance.

The next wave of technology advances will allow vehicles to transition from level 3 capabilities to level 4.

Exhibit 1

Global automotive revenues could reach about $6.7 trillion by 2030, a growth rate of around 4.4 percent annually.

Global automotive revenue, $ billion



[1]Does not include traditional taxis and rentals.
Source: McKinsey analysis

apps, navigation tools, in-vehicle entertainment, and software upgrades.

We are about to see major changes in both the size and composition of the revenue pool, however. Under one highly disruptive scenario, it could total more than $6.7 trillion by 2030, with $5.2 trillion, or about 78 percent, coming from new-car sales and the aftermarket. Recurring revenue, expected to total more than $1.5 trillion, would account for the remaining 22 percent—a 50-fold increase from 2015.

The four trends just described will play an important role in the revenue pool's diversification and growth. The increase in recurring revenue that results from the rise of mobility services and greater connectivity is perhaps the most striking change. But the four trends will also affect other areas. For instance, autonomous vehicles (both levels 3 and 4) have high price points, which will increase revenue from new-car sales. Within the aftermarket, new mobility services will raise revenue, because shared vehicles have higher maintenance costs. However, there will also be downward pressure in the aftermarket, because EV powertrains are less expensive to maintain than those for conventional vehicles, and crash-repair costs for autonomous cars can be up to 90 percent lower. All of these shifts could change the source of demand for semiconductors and other components.

Implications for the automotive-semiconductor market

Despite the potential uncertainties, we expect demand for automotive semiconductors to increase over the mid- to long term as the industry tries to enhance safety, comfort, and connectivity features within vehicles. The move to automated-driving capabilities will be particularly significant. Over the long term, the growth of the EV segment will also accelerate growth, because hybrid EVs contain about $900 worth of semiconductors, while standard EVs have more than $1,000 worth—much higher than the average $330 value for the semiconductor content of conventional vehicles.

Between 1995 and 2015, semiconductor sales to automotive OEMs rose from about $7 billion to $30 billion (Exhibit 2). With this increase, automotive semiconductors now represent close to 9 percent of the industry's total sales. Current projections suggest that sales of automotive semiconductors will continue on their upward trajectory, increasing about 6 percent annually between 2015 and 2020—higher than the 3 to 4 percent growth predicted for the semiconductor sector as a whole. That would put annual sales for automotive semiconductors in the $39 billion to $42 billion range.

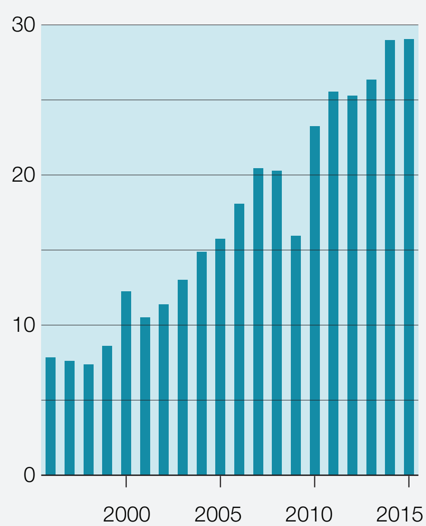
Although the opportunities ahead appear vast, our analysis of the automotive-semiconductor sector suggests that they will differ significantly by geography, automotive-application segment, and device segment. We have explored some of these variations to guide semiconductor companies in strategic planning.

Geographic growth: New forces rising in the automotive-semiconductor industry

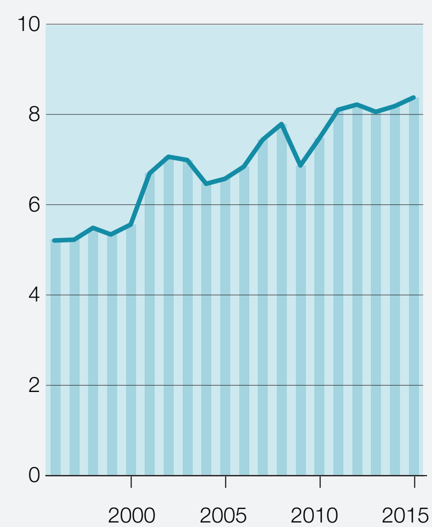
Although the Americas and Europe account for most demand in automotive semiconductors, China now leads the world in annual sales growth, with average gains of 15 percent between 2010 and 2015 (Exhibit 3). China is expected to remain the world leader in sales growth, although average gains will fall to 10 percent through 2020, since the country's economy is slowing and car sales, which have been surging, may flatten.

Exhibit 2 **The automotive market increasingly generates a large portion of semiconductor sales.**

Automotive-semiconductor sales,
$ billion

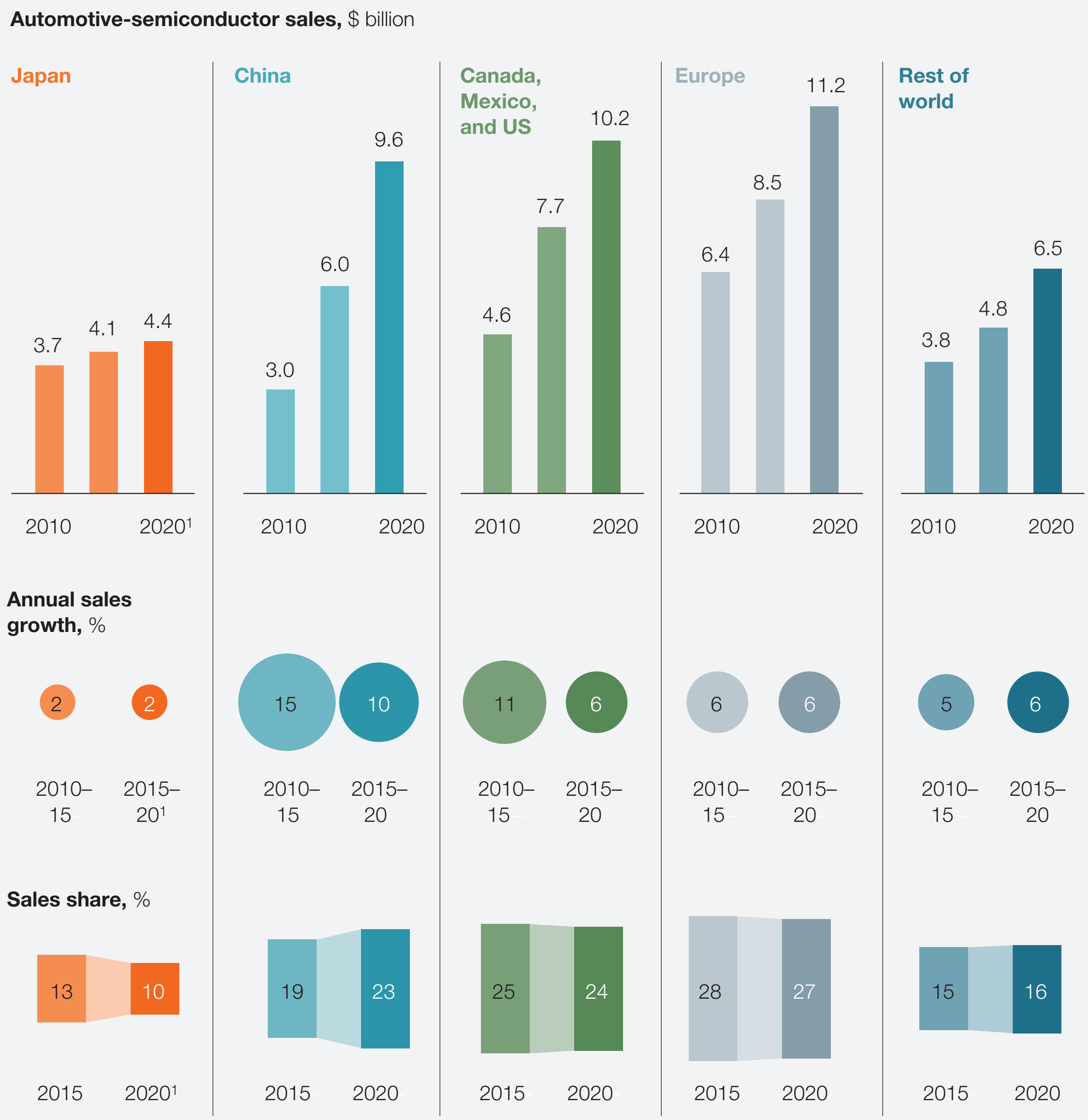


Automotive-semiconductor sales,
as % of total semiconductor sales



Source: IHS; McKinsey analysis

Exhibit 3 Sales growth for automotive semiconductors should continue.



[1]2020 is estimated.

Source: Strategy Analytics; McKinsey analysis

Demand by device and application segment: A shifting landscape

In addition to studying geographic trends, we explored how semiconductor demand might change for core automotive-application segments and device categories.

Identifying pockets of growth among diverse automotive-application segments. We examined growth patterns in the core-application segments: safety, powertrain, body, chassis, and driver information. Trends suggest that the greatest growth through 2020 will occur within the safety segment (Exhibit 4).

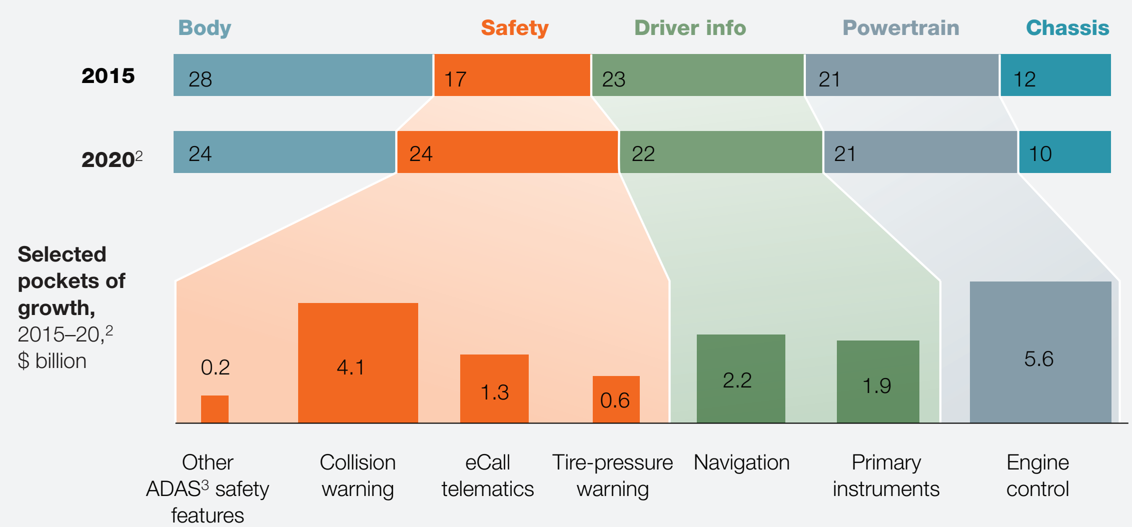
Within each core-application segment, some product categories will see much higher growth than others. For instance, within the safety category, collision-warning systems are expected to have a compound annual growth rate (CAGR) of 22 percent between 2015 and 2020, when sales will reach $4.1 billion. Looking at long-term developments after 2020, we expect continued growth in the engine-control segment, including e-motors and power electronics. We will also see more growth in integrated systems and solutions, such as engine-control units (ECUs) for fusion sensors and integrated-control systems that enable level 4 autonomous driving.

Understanding device growth. We also examined semiconductor demand across device segments: memory, microcomponents, logic, analog, optical and sensors, and discretes. While some segments will see more growth than others, we do not expect any major shifts through 2020. Around that time, EVs will begin to proliferate. In addition to containing more semiconductor content than conventional vehicles, EVs also require different types of

Exhibit 4

Within each core application segment, there will be pockets of growth.

Automotive-semiconductor demand by core segment, % of total[1]



[1] Figures may not sum to 100%, because of rounding.
[2] 2020 is estimated.
[3] Other advanced-driver-assistance systems include safety features other than those mentioned in the chart above, such as parking assistance or drowsiness monitoring.

Source: Strategy Analytics; McKinsey analysis automotive semiconductors, which will shift demand patterns. For instance, up to 10 percent of automotive semiconductors in conventional cars are incorporated into discretes (power electronics). By contrast, about 35 to 40 percent of automotive semiconductors in hybrid EVs are in discretes, as are up to 50 percent of those in other EVs. Even though EVs are not expected to gain widespread popularity until around 2020, sales of these vehicles are already trending upward. That means demand for automotive semiconductors is already beginning to shift.

As with the core automotive-application segments, there will be pockets of opportunity within each semiconductor-device segment. For instance, with the microcomponent segment, the CAGR will be highest for microprocessor units (14 percent) and more moderate for microcontroller units (MCUs) (9 percent) and digital signal processors (3 percent) (Exhibit 5). After 2020, we still expect growth to continue in all core segments. However, the growth of autonomous driving and EVs will benefit some applications, such as GPUs and sensors, more than others.

Strategic questions and next steps

We have engaged in many discussions with semiconductor-industry leaders, as well as experts in the Americas, Asia, and Europe, about the challenges ahead in the automotive industry. Their critical questions include the following:

How can we differentiate our offerings?

Most leaders mentioned that a focus on hardware would not deliver the desired value in the evolving automotive industry. They all wanted to provide systems or solutions by adding software algorithms to their offerings, and some are also working with partners to differentiate their products in other ways. For example, NVIDIA recently announced that it plans to continue collaborating with the high-definition (HD) mapping player HERE. Together, they will develop HERE HD Live Map, a real-time mapping product for autonomous vehicles. Intel also announced the creation of the Intel GO Automotive 5G platform. This is the one of the first 5G platforms that would allow automotive manufacturers and tier-one suppliers to proof their designs for 5G.

If companies focus on systems, rather than the addition of individual chips, they can avoid intense price pressures. For example, NXP Semiconductors just launched a software-defined radio solution for in-vehicle infotainment (IVI) systems called the SAF4000. The company claims that this is the world's first one-chip system covering all global audio broadcast standards, including AM/FM, DAB+, DRM(+), and HD.

Will we see any changes regarding the life cycle of semiconductors in vehicles?

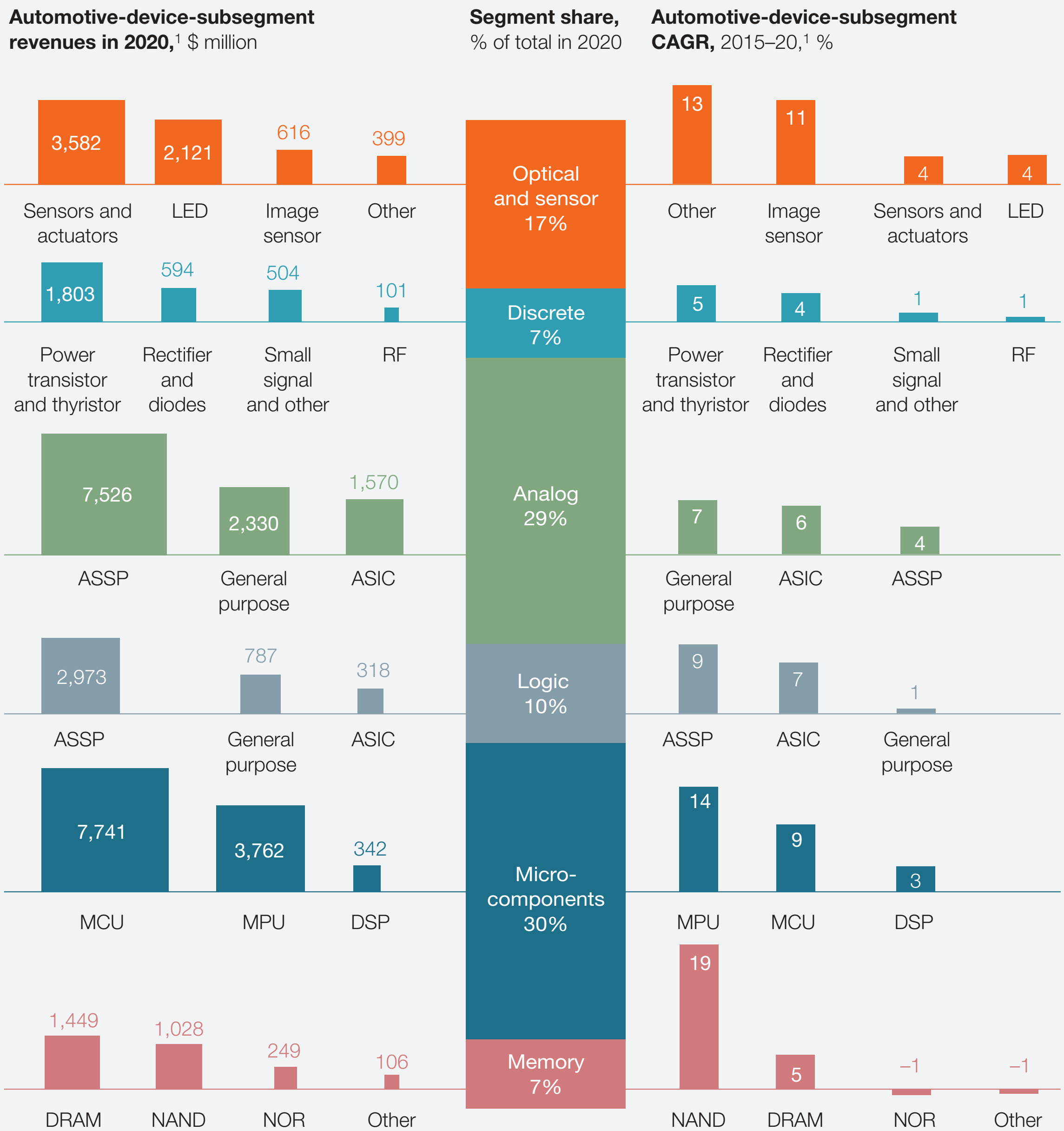
In the future, we may see OEMs purchasing chips at more frequent intervals, as long as a car is on the market. This trend will gain momentum as upgrades for optional features, such as IVI, are decoupled from other hardware upgrades, such as those related to powertrains.

How much integration is needed to reduce material costs while ensuring redundancy?

Some leaders are trying to build systems as an integrated unit, with multiple MEMS, MCUs, and other sensors, to ensure redundancy. In this context, redundancy refers to duplication of critical components or functions of a system to increase reliability of the system. For instance, redundancy may provide a backup or fail-safe. OEMs might also find that certain redundancies improve performance, such as the inclusion of additional ECUs. Some have also investigated the use of x-by-wire (electrical or electromechanical systems that perform vehicle functions traditionally controlled by mechanical linkages) for braking or steering.

Questions remain, however, about how much redundancy is needed and when industry players will feel comfortable with less of it.

Exhibit 5 **All major automotive-semiconductor-device segments contain pockets of growth.**



[1]2020 is estimated.

Note: Acronyms in this exhibit include the following: ASIC = application specific integrated circuit; ASSP = application specific standard product; CAGR = compound annual growth rate; DSP = digital signal processor; MCU= microcontroller unit; MPU = microprocessor unit; NOR = nonvolatile memory (with NOR logic gates); RF = radio frequency.

Source: IHS iSuppli; McKinsey analysis

How should semiconductor companies collaborate with automotive OEMs and tier-one suppliers?

Semiconductor companies are increasingly working directly with both OEMs and tier-one automotive suppliers. For instance, BMW, Intel, and Mobileye announced that they have collaborated to create a fleet of about 40 autonomous test vehicles that will be on the roads by the second half of 2017. Similarly, Audi said that its continued collaboration with NVIDIA will introduce innovative features to its newest A8 luxury sedan, including systems that enable automated driving in complicated situations, such as those involving highways and traffic jams. Audi and NVIDIA have also formed a partnership to create what they have described as the "world's most advanced AI [artificial-intelligence] car," which they hope to have on the road by 2020.

For collaborations to succeed, semiconductor companies must first identify the areas where these opportunities bring complementary skills—for instance, a venture where their hardware expertise could benefit a company with strong software skills. They should then decide which form of collaboration—M&A deals, joint ventures, exclusive partnerships, or strategic partnerships—will best suit their needs.

How will the automotive landscape evolve and will this affect semiconductor companies?

Some shifts in the competitive landscape and the value chain could affect semiconductor players. Although leading global OEMs are expected to remain dominant within the global market, those that focus on the mass market may start to lose revenue share as disruptive players, including new Chinese OEMs, establish or expand their operations. Information and communication technology (ICT) players in other countries are also seeing demand grow for their products, including sensors and software, which could give them a larger role in the value chain. Finally, some tier-one automotive suppliers could gain bargaining power equivalent to that of less dominant OEMs.

How far should we expand into security offerings?

It will be critical for semiconductor companies to incorporate security features into chips, but this will not entirely address all safety concerns, including those related to hacking. In consequence, they should also consider developing other security solutions, especially in the neglected area of automotive connectivity. A few semiconductor players, such as NXP Semiconductors, are already working with automotive partners to develop end-to-end security solutions, and others may follow their example. As they embark on security ventures, semiconductor companies may find some inspiration from companies in other high-tech sectors that have created innovative offerings. For instance, Bosch recently announced a keyless entry and start product that allows drivers to access their vehicles securely, using only a smartphone that provides full encryption.

How should we address the China market?

Semiconductor companies should look at the China market from several angles. While it will be an important source of demand, the country could also become a major testing location for autonomous cars and EVs, partly because the consumer market has some unique characteristics. In the 2016 McKinsey survey of more than 3,000 car buyers in three countries, we found that Chinese consumers were more open to car-to-car data sharing—having vehicles exchange information about location, speed, and other factors—than drivers in Germany and the United States.[2] We also found that they were more willing to upgrade the IVI within their vehicles. Both of these factors might encourage automotive OEMs to test and market new automotive technologies in China, especially since car-ownership rates are rapidly growing.

China also provides semiconductor companies with a large and diverse pool of potential partners for automotive ventures. This fact was on display at the 2017 Consumer Electronics Show, where Chinese companies had more than 1,300 displays and accounted for more than 20 percent of the 500 exhibits on vehicle technology. As in the United States and other countries, some of the most promising partners may be new entrants into the automotive sector. For instance, Baidu, the Chinese web giant, is attempting to develop its autonomous-driving and EV technology through partnerships with global OEMs.

Semiconductor companies can also be optimistic about China—both as a market and a source of partners—because the Chinese government has launched several initiatives to support domestic manufacturing. For instance, the government's "Made in China 2025" policy provides subsidies and other incentives to local companies that upgrade their facilities and focus on innovation. Semiconductor companies may thus find that the pool of potential partners will become even more substantial in coming years. The Chinese government has also displayed a strong interest in promoting technologies for autonomous cars and EVs, as well as technologies related to the Internet of Things that enable many connected car features. The government's support has already encouraged more automotive and ICT players to establish a stronger presence in China.

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Many semiconductor companies are moving quickly to develop automotive innovations, with some poised to become leading suppliers to OEMs that market autonomous vehicles and EVs. Other players, however, have been slow to form partnerships with automotive players or further invest in technologies that will meet their needs, perhaps because they are reluctant to assume the risks associated with an uncertain and rapidly evolving market. But those companies that hesitate to address strategic questions may now lose market share to more aggressive competitors, even if they take decisive action later. With the automotive market poised to serve as one of the semiconductor industry's greatest growth drivers, their lack of action is the real risk. ■

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[1] McKinsey connectivity and autonomous driving consumer survey, 2016.
[2] Ibid.

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