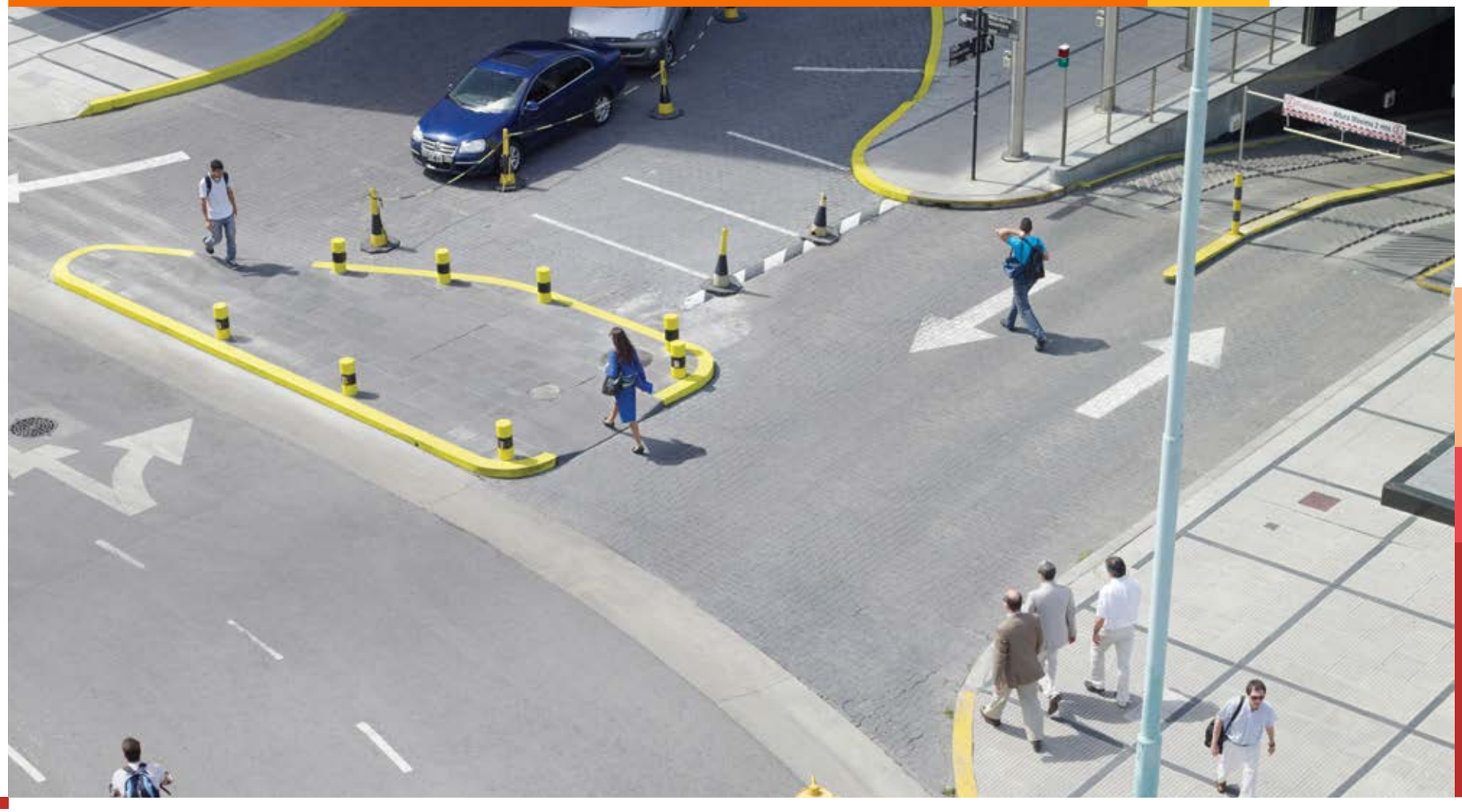
Spotlight on Automotive
PwC Semiconductor Report



Technology Institute

Interim Update Global Semiconductor Trends – Special Focus Automotive Industry.

September 2013

Launch

pwc

Preface

After a strong recovery in 2010-2011, 2012 was a difficult year for the global semiconductor industry. Due to continuing global economic challenges , annual semiconductor billings in 2012 lagged by US$8 billion or 2.7% behind the record sales of US$300 billion achieved in 2011. The industry is expected to resume growth in 2013 and is well positioned to register a healthy increase over the next five years.

End markets that stimulate overall demand for semiconductors are expanding as silicon-led technology exerts its influence on many different aspects of life. In this report, we examine global and regional trends, but focus most attention on one of the faster growing segments: automotive.

Why automotive?

For a number of reasons, the automotive sector promises to be a particularly dynamic driver of growth for the semiconductor industry. Not only is the semiconductor content of cars growing rapidly as they rely on greater intelligence, connectivity and sophisticated electronics, but the nature of the automotive industry model is also shifting in new directions. Concepts of product ownership will give way to service propositions to deliver mobility to consumers who will pay only for what they use. Creating and managing the systems to deliver that mobility will depend heavily on complex electronics.

Semiconductor companies focusing on the automotive industry as a key market will need to have a laser-sharp focus on quality from product design through to production and will require stringent programme change control in order to profit from the growth opportunity the automotive sector offers.

We would like to extend our sincere thanks to Dr. Reinhard Ploss, CEO of Infineon Technologies, and Rick Clemmer, President and CEO of NXP Semiconductors, whose insights have tremendously enhanced our report.

If you would like further information or to discuss any of the findings in our report and how they might impact your business, please do not hesitate to contact either of us (raman.chitkara@us.pwc.com or werner.ballhaus@de.pwc.com) or any member of our global technology team listed at the end of this document.

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Table of abbreviations

ASIC	Application-specific integrated circuit
ASIL	Automotive Safety Integrity Levels
ASP	Average selling price
AUTOSAR	AUTomotive Open System ARchitecture
BRIC	Brazil, Russia, India, China
CAFE	Corporate Average Fuel Economy
CAGR	Compound annual growth rate
CCID	China Center for Information Industry Development
CMOS	Complementary metal oxide semiconductor
CPU	Central processing unit
DRAM	Dynamic random access memory
eTPU	Enhanced time processor unit
EV	Electric vehicle
GDI	Gasoline direct injection
HCCI	Homogeneous charge compression ignition
IC	Integrated circuit
ISO	International Organization for Standardization
LCD	Liquid-crystal display
LED	Light-emitting diode
MCU	Microcontroller unit
MCR 13	IC Insights, Inc. – The McClean Report 2013
MIPS	Million instructions per second
MPU	Microprocessor unit
OEM	Original equipment manufacturer
OSD	Optoelectronics, sensors and actuators, and discretes
SRAM	Static random-access memory
WSTS	World Semiconductor Trade Statistics

Report structure

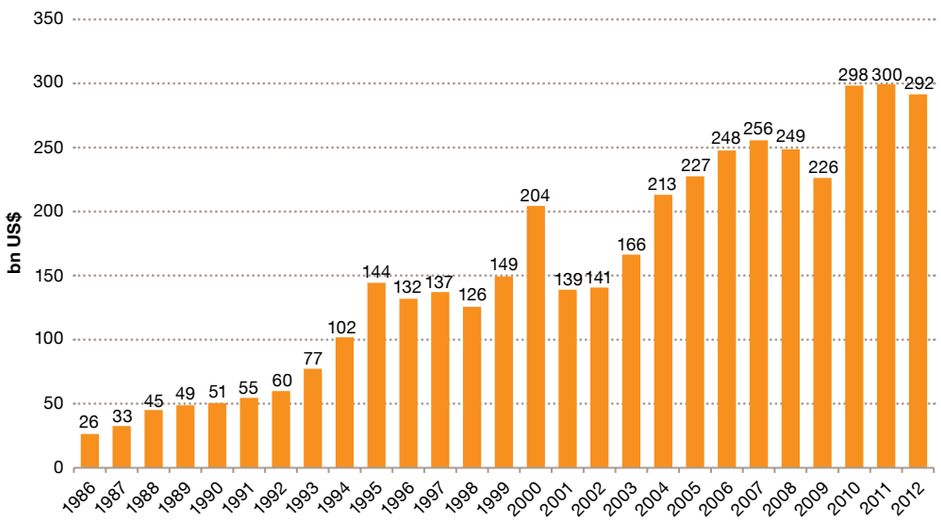
We start our review of the semiconductor industry with an analysis of global growth and prospects, broken down into component, regional and application categories. We then focus on the automotive sector, examining the range of key drivers that are together contributing to dynamic growth in this segment. Finally, we provide some suggestions about the questions and issues that senior executives will need to consider as they address the opportunities for their businesses arising from the automotive sector.

The global semiconductor market

The semiconductor industry continues to grow at a rate faster than global GDP. However, as the industry matures, the fortunes of the semiconductor industry closely follow those of the global economy. PwC's analysis (see Figure 1 below) shows how the shocks to the global economy in recent years have very rapidly shown up in semiconductor billings. The bursting of the 'dot.com' bubble in 2000 and the financial crisis in 2008 are both easily traced in the data for global semiconductor billings.

More recently, a recovering global economy is reflected in industry billings – with particularly strong growth coming from Asia generally and China in particular. According to World Semiconductor Trade Statistics (WSTS), the global industry posted near-record results in 2012. There are, however, considerable variations between components, regions and applications. In the following section we examine the likely drivers of demand across these for the next five years.

Figure 1: Global semiconductor billings – history



Source: WSTS

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Overall market forecast

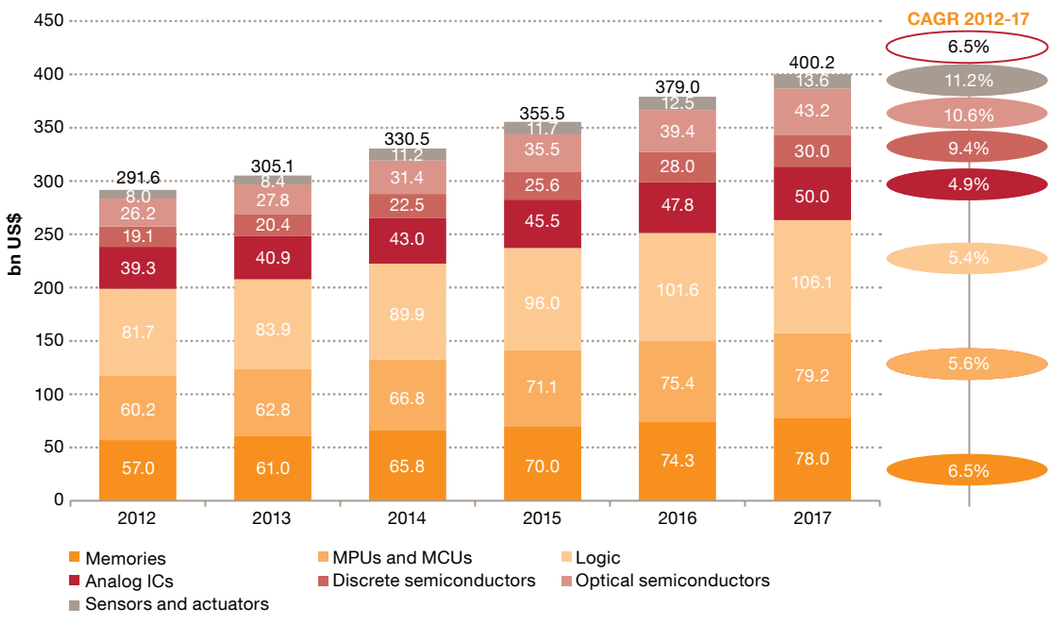
PwC's analysis for the global semiconductor market suggests that between 2012 and 2017 billings will increase by some US$109 billion, representing a compound annual growth rate (CAGR) of 6.5%.

Growth by component

Logic will remain the largest single segment, with a total of US$106 billion in 2017, followed by microcontrollers (MCU) and microprocessors (MPU) at US$79 billion and memory at US$78 billion. However, the strongest growth story will likely be in the smaller optoelectronics, sensors and actuators, and discretes (OSD) segments (CAGR: 10.2%, collectively).

Within the memory sector, NAND flash will surpass dynamic random access memory (DRAM) in 2013, with both technologies being driven by data processing applications and other wireless devices such as smartphones, e-book readers or hand-held video games; in addition, consolidation will drive average selling prices

Figure 2: Global semiconductor billings – forecast by component



Source: WSTS, PwC analysis

(ASPs) in the DRAM market. MPUs will remain the biggest and fastest-growing technology for micro components, driven mainly by rising tablet and smartphone penetration, whereas MCU growth will be fueled by communications, automotive, and industrial applications.

Special purpose logic for telecommunication, data processing and consumer electronics will contribute most to growth in the logic segment, while application-specific integrated circuit (ASIC) billings will remain fairly stable. Likewise, application-specific analogue products for the automotive and communications markets will foster substantial growth of analogue integrated circuits (ICs), whereas the general-purpose market will suffer from declining ASPs.

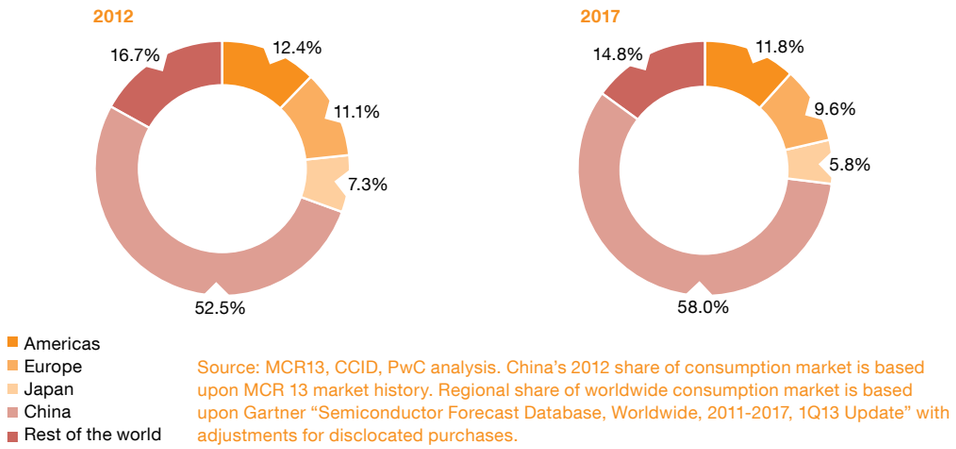
The OSD market is forecasted to grow faster than the IC market, propelled, for instance, by lamps and complementary metal oxide semiconductor (CMOS) image sensors, acceleration and yaw sensors and actuators and power transistors and rectifiers.

Continued

Growth by region

While the global picture indicates an annual growth rate of 6.5% to 2017, regional variations are likely to be significant over the next five years. Europe will grow by only 3.5% owing largely to the sluggish economy and the persistence of the unresolved sovereign debt crisis. The Americas will see stronger growth, but unlike in the past, South America will play a more significant role in driving the growth. In Asia, Japan is not likely to see significant growth in the projection period, but China will retain and expand its position as the number one semiconductor market in the world, buoyed by strong general economic growth and by the rapid growth of its IC design sector. For the rest of the region, growth is likely to be concentrated in Taiwan, South Korea and Singapore.

Figure 3: Global semiconductor consumption – forecast by region



Source: MCR13, CCID, PwC analysis. China's 2012 share of consumption market is based upon MCR 13 market history. Regional share of worldwide consumption market is based upon Gartner "Semiconductor Forecast Database, Worldwide, 2011-2017, 1Q13 Update" with adjustments for disclocated purchases.

A note on China – dislocated purchasing

China's reported semiconductor consumption market is greater than most market analysts' Chinese market share reports. That is because a significant portion of the semiconductor devices consumed in China continues to be purchased outside of China. This "dislocated purchasing" occurs because some customers – due to supply chain considerations such as control of key inventory items, intellectual property protection and/or toll processing business models – will buy semiconductor devices outside of China and transship them to China for use and consumption.

Since 2007 we have been identifying this dislocated purchasing for the Chinese consumption market by comparing consumption to purchasing TAM (total available market). Using a recently revised measure of purchasing TAM, we have found this dislocated purchasing to have only increased slightly since 2007, to just over 24% for the last two years. The largest share of this dislocated purchasing has occurred in Taiwan, Korea, Americas and Japan. However, we expect that the share will decrease gradually over a number of years in the future as:

- China's domestic market consumption increases its share of China's total semiconductor market;
- Multinational electronic equipment manufacturers and semiconductor companies presently offshore move design and purchasing activities to China;
- Chinese fabless semiconductor companies gain market share in the China market; and
- Leading multinational and regional distribution firms establish self-reliant purchasing and warehouse/ logistic centers in China.

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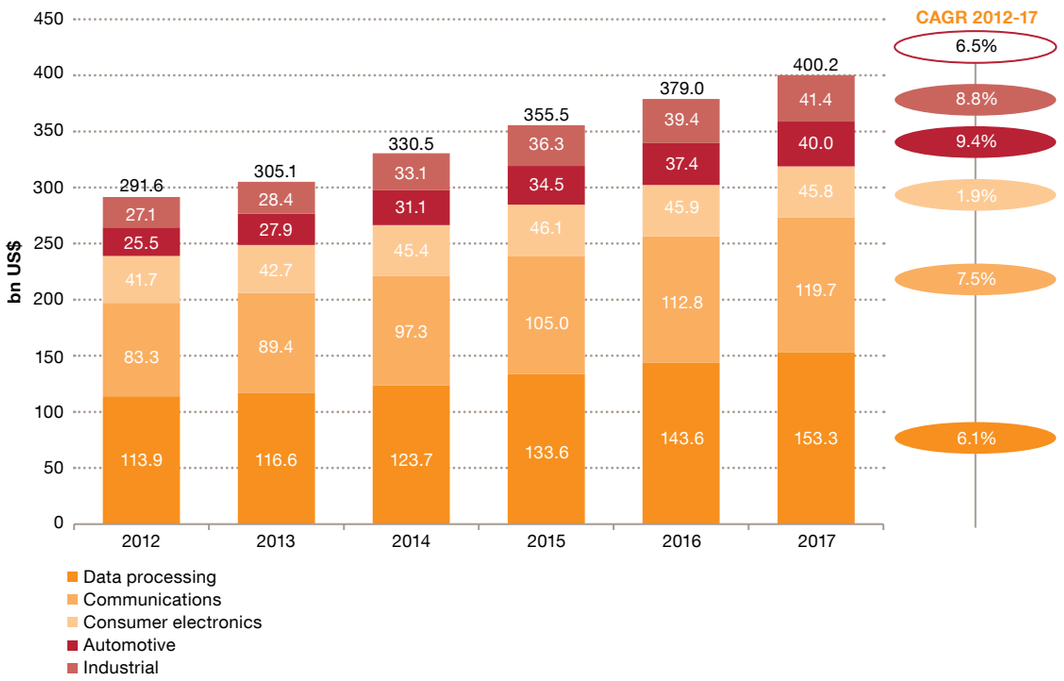
Growth by application

The largest overall industry segments will remain data processing and communications in the period to 2017. However, it is the smaller segments – automotive and industrial – that are likely to display the highest growth rates – with automotive set to grow by 9.4% annually and industrial by 8.8% CAGR until 2017.

Figure 4: Global semiconductor billings – forecast by application



Source: WSTS, PwC analysis

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Dr. Reinhard Ploss, CEO Infineon Technologies:

"We expect the global semiconductor industry to grow by 5-7% p.a. in the years going forward … Some of the key drivers for growth will be energy efficiency, mobility, (data) security and also connectivity – both of people and things."

Data processing

Notebook computers will remain the most powerful driver of semiconductor sales in the data processing segment, with total billings rising from US$26 billion in 2012 to US$34 billion by 2017. However, here again, things are changing. The rise of the tablet and the (relative) decline of the desktop PC will see a shift in the market by 2017, with the scale of semiconductor billings for tablets likely to exceed those for desktop machines. Even higher growth is likely to be seen in the convertible devices that form a bridge between the PC and the tablet – and internet enabled devices that can access cloud-based services and applications are also likely to make a noticeable impact on the semiconductor industry.

Communications

Growth in communications devices will continue to be determined by the extent to which they offer smart capabilities. The inexorable rise of smartphones will continue to eclipse traditional, basic and feature handsets. However, demand for a more basic smartphone in emerging economies is likely to reduce the requirement for semiconductors compared to more complex and sophisticated devices that will continue to hold sway in developed markets. In developed markets, the roll out of high-speed broadband networks (4G) – and the prospect of 5G – will drive smartphone sales. In developing economies, where feature phones still dominate, there is even more scope for smartphone penetration (albeit at lower specs than those for developed markets) – and that will increase semiconductor content per phone.

Consumer electronics

In consumer electronics the trend towards converged devices that combine computing, internet and TV in one digital set-top box will be a major driver of growth. Smart TVs will grow in popularity and we are also likely to see an upturn in the TV market – particularly in South America – to 2014 as both the FIFA World Cup and the Olympics (2016) are hosted by Brazil. New games consoles such as Sony's PlayStation 4, Nintendo's Wii U and Microsoft's Xbox One will all have a positive impact on semiconductor billings, especially in 2013 and 2014. While the continual decrease in sales of conventional CD and DVD players and recorders might be partially offset by Blu-Ray devices in the years ahead, sales of portable media players and digital still cameras are expected to continue their decline.

Industrial

Growth in industrial semiconductor billings is generally believed to be correlated to growth in GDP, multiplied by a factor of between 2 and 4. With that assumption, the industrial sector looks set for growth of between 6% and 12% in the period to 2017. Within the general segment, it is likely that energy related applications will be one of the strongest drivers, with efforts to increase efficiency across the energy value chain from generation through transmission and distribution to consumption all requiring sophisticated electronics. Other sectors that should exhibit growth in demand are healthcare where connected devices will become increasingly ubiquitous as health services shift from clinical settings to the home environment. And as homes become generally more connected to digitally connected devices (often referred to as the 'internet of things'), with , for example, security and building automation becoming more prevalent, these developments will also contribute to sustainable growth in industrial applications of semiconductors.

Automotive: Driving growth for the semiconductor industry

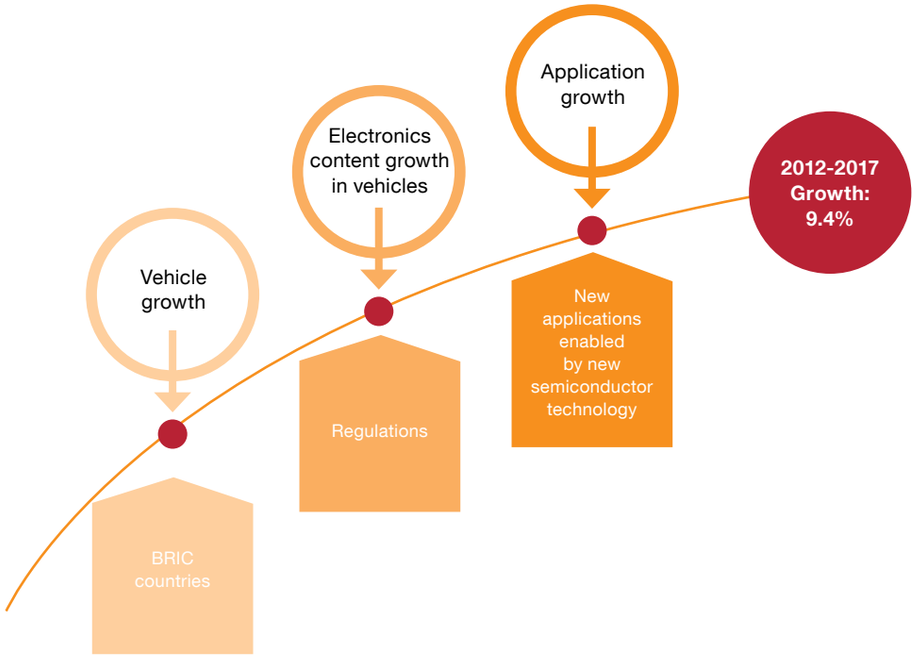
The growth in the automotive sector will come largely from two major trends: one is the extent and pace of change in the industry itself and the other is the significantly higher proportion of electronics that are increasingly standard in automobiles.

Automotive drivers for growth

More cars and light vehicles are now produced in emerging markets than in the developed economies – and these will become key markets for auto manufacturers, their suppliers and the semiconductor industry.

PwC believes that the BRIC nations (Brazil, Russia, India, and China) will remain the most important growth driver for global automotive demand, featuring average annual growth rates between 6.5% (Brazil) and 9.4% (China) for the years 2012-17. While car shipments in Europe (and especially in Germany) will see another drop in 2013, and grow considerably in the years going forward, demand in the US is forecasted to increase continuously with a CAGR of 4.4%. Globally, light vehicle assemblies are expected to grow by 5.0% p.a.

Figure 5: Key drivers for future automotive growth



Source: PwC analysis

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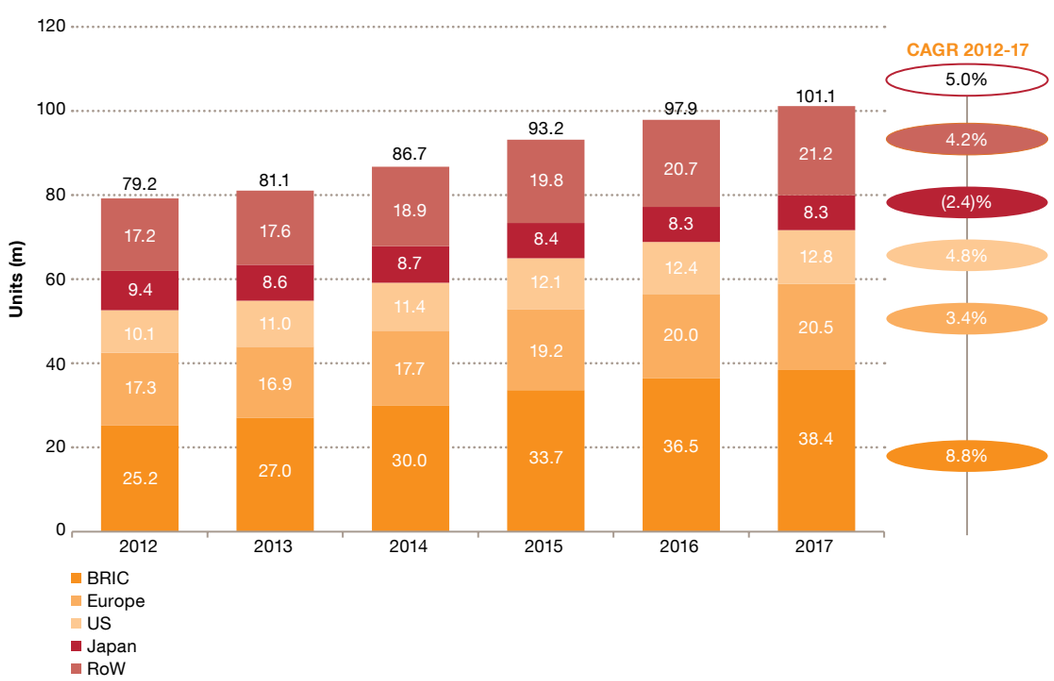
Improvements to semiconductor technology have enabled rapid growth in the last 60 years. The use of electronics in automobiles is the single largest driver of change in the sector – nearly all automotive innovation arises directly or indirectly from developments in electronics.

Data suggest that semiconductor content per car is likely to grow from US$315 in 2012 to US$385 by 2017, and the overall cost of electronics in cars is expected to reach more than 30% by 2017. Nearly all innovation that is taking place in automotive is electronic rather than mechanical. Innovations that are introduced to the luxury end of the market are being implemented in more standard vehicles faster than ever as costs continue to fall and innovation accelerates.

Figure 6: Global light vehicle assemblies – forecast by region



Source: PwC Autofacts (Q3 2013)

Rick Clemmer, President and CEO of NXP Semiconductors:

"We believe that a very significant portion of the growth in the industry will continue to come from the desire of car makers, Tier 1 suppliers and semiconductor companies to create and capture more value by offering innovations that will improve the overall driving experience."

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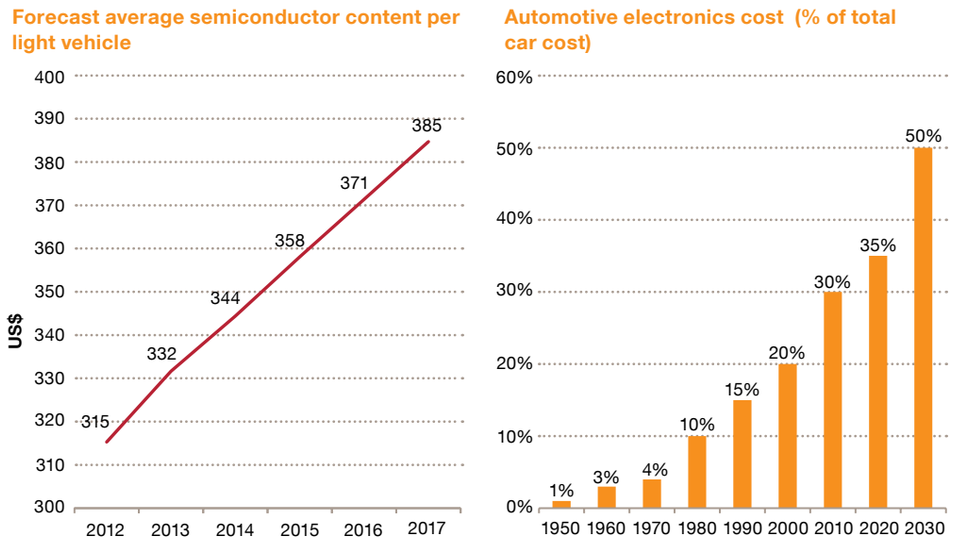
Electronic systems in cars address five key areas:

- Regulation
- Sustainability
- Safety and security
- E-Mobility
- Body and convenience

Figure 7: Growth in semiconductor content per vehicle and automotive electronics cost



Source: PwC analysis

Regulation

Regulation covering emissions and safety will drive the further need for connected devices and components in the vehicle to ensure compliance and provide monitoring and reporting. Energy efficiency, emissions and safety are likely to be the primary drivers. Various regulatory initiatives will place stringent demands on auto manufacturers and their suppliers. For example, environmental standards in the EU are likely to call for a 30% to 40% reduction in emissions by 2020. And as emissions standards have changed over the years, they require increasingly powerful semiconductors to ensure that vehicles' performance is in compliance.

Standards such as the NCAP scheme provide a star-rating system for vehicle safety. Achieving a maximum five star award has proven to be a strong selling point for auto manufacturers. Its achievement relies on complex and sophisticated assisted driving systems that require significant semiconductor content.

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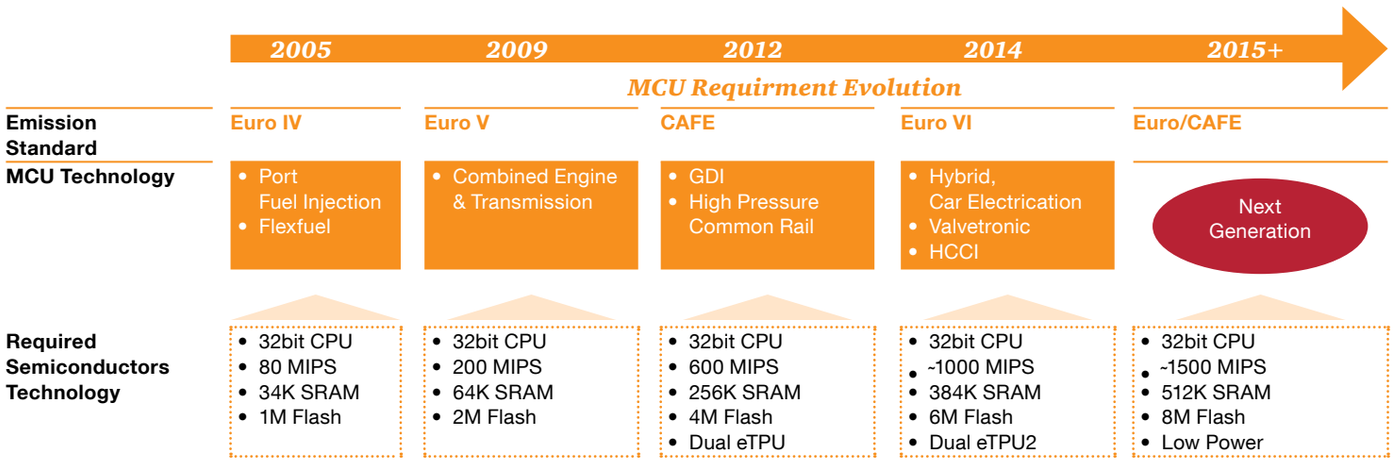
Figure 8: Emission targets requiring more powerful processing capabilities



Source: PwC analysis

Sustainability

In addition to the development of hybrid and fully electric vehicles, traditional internal combustion engines will have to become ever more fuel-efficient. The improvements in efficiency will depend heavily on semiconductors, with optimisation of an engine's performance increasingly reliant on semiconductors 'managing' mechanical components.

Achieving reductions in emissions in conventional engines relies on constant monitoring and correction of a vehicle's performance. Applications such as powertrain microcontrollers and power modules will be required to achieve targeted improvements for efficient engines. They will manage holistic performance, from reducing injection losses and optimising gear ratios and shifting to reducing energy waste from hydraulics and friction.

E-Mobility

The growth of electric and hybrid cars will create additional demands on electronic equipment. These will take the form of greater sophistication and reliability in power and battery performance. Applications to monitor and manage battery performance will therefore become increasingly sophisticated, as will stop/start systems and more efficient systems for charging at multiple speeds and controlling electric motors.

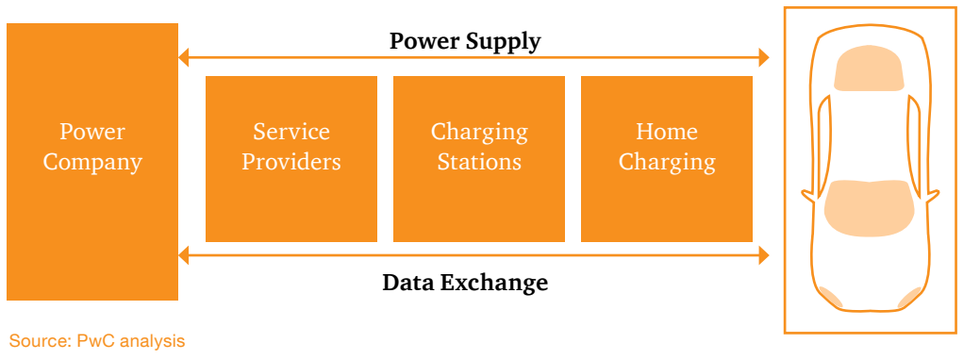
In addition, the rising trend of e-mobility as a mass phenomenon will depend heavily on the use of sophisticated intelligence and information processing, both in-vehicle and in the wider infrastructure. And the development of the smart grid could see electric vehicles (EVs) as a major component, enabling their drivers to recharge intelligently, pay securely and feed power back in the electricity grid.

Continued

Dr. Reinhard Ploss, CEO Infineon Technologies:

"Across the regions we see variations with regards to content growth. In Europe, advanced safety and driver assistance systems are key growth drivers, for example, adaptive cruise control, blind spot recognition, lane departure warning and adaptive lighting with LED front lighting technology. In China, the growth areas are more convenience features such as infotainment. The drive for CO2 reduction will provide global growth in semiconductors for advanced engine management systems as well as electric vehicle controls."

Figure 9: Electric vehicles forming part of the smart grid



Source: PwC analysis

Safety and security

Advanced safety and security features are no longer the preserve of the luxury end of the automotive markets. And as more and more affordable electronic equipment trickles down into entry-level vehicles it becomes increasingly available to consumers in emerging markets, fuelling an increase in the demand for in-car electronic devices to monitor conditions and prevent accidents.

These applications include systems for electronic steering, braking and stability as well as driver assistance systems such as cameras, radar systems and communications devices embedded in the vehicle.

The future is likely to see intelligent traffic management systems that will communicate both between cars and with an intelligent infrastructure. As the extent and array of smart and connected devices and applications develops, there will be a greater need to create security both to prevent devices being hacked or compromised and to provide greater levels of protection for drivers, their passengers and personal possessions.

Body and convenience

Optimising the experience that a vehicle provides to its drivers and passengers will be a priority driver for OEMs and their Tier 1 suppliers as they seek to achieve differentiation in a highly competitive market.

The trend towards increasing levels of comfort, entertainment and communications will spur growth in the semiconductor content in each vehicle. Everything from lighting to heating will be controlled electronically. The dashboard will become fully electronic with LCD and LED displays providing drivers with all the information about their vehicle, its performance and the external environment.

Information and entertainment systems will become ever-more sophisticated, with connectivity of systems within the car as well as communication traffic management and other sources of information increasingly common.

Driving with a different model – from product to service

The automotive industry itself is changing. Different models of vehicle ownership are coming to the fore and will grow. These take the form of schemes that offer mobility on a pay-as-you-go or as-needed basis, without the necessity to take on the 'burden' of ownership and maintenance. Mobility-as-a-service developments are largely in response to the growth of mega cities and extensive urbanisation. By 2050, more than 80% of the population in developed countries and 60% in developing economies will live in urban environments. That will create the need for energy-efficient, smart mobility solutions provided as a service – with electronics playing a key role in their delivery.

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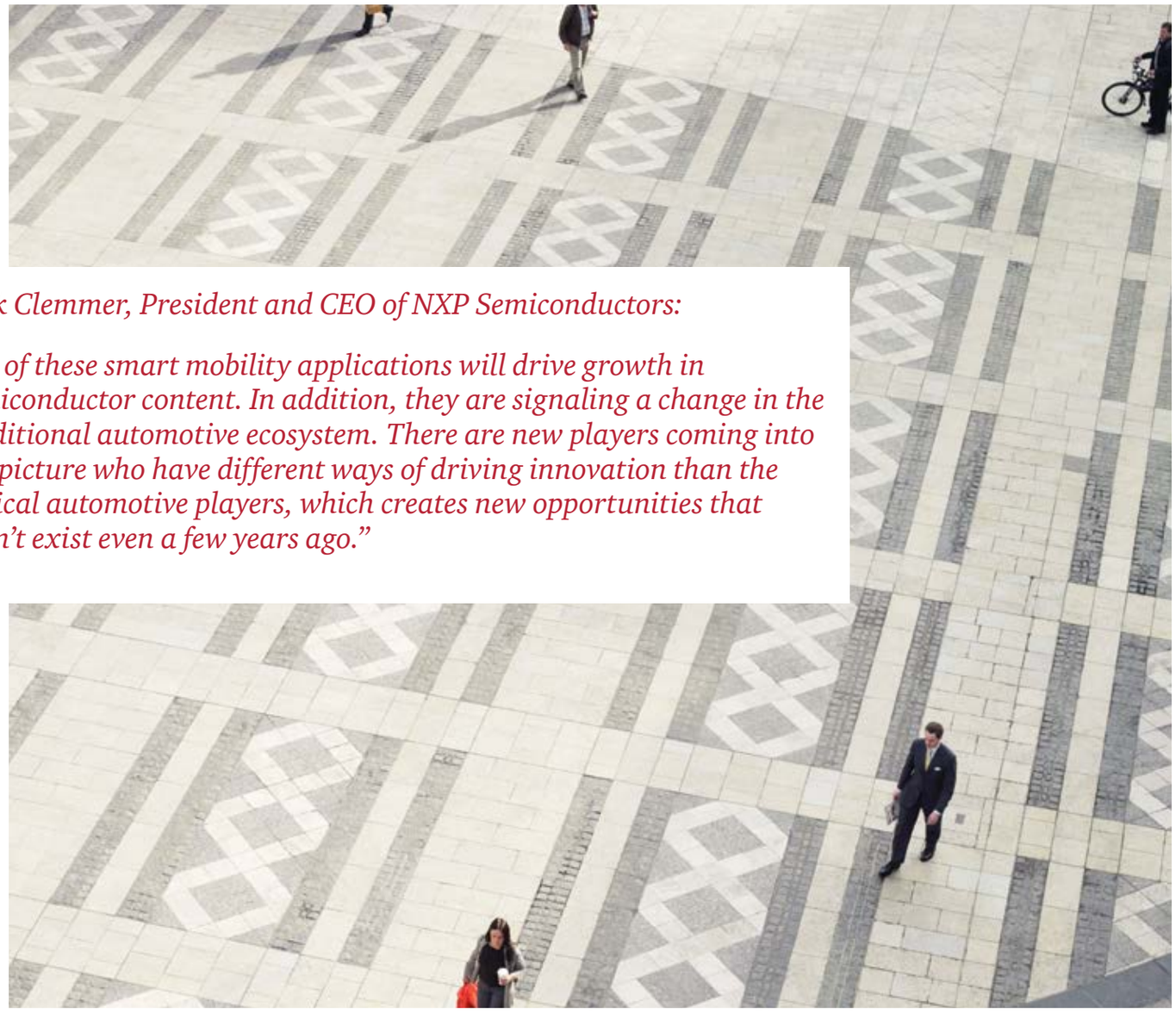
Managing smart mobility effectively requires extensive connectivity both between vehicles and the smart infrastructures in which they operate. From intelligent traffic and safety management, to advanced entertainment and information and sophisticated billing systems, semiconductors have a central role to play in delivering the future of driving.



Rick Clemmer, President and CEO of NXP Semiconductors:

"All of these smart mobility applications will drive growth in semiconductor content. In addition, they are signaling a change in the traditional automotive ecosystem. There are new players coming into the picture who have different ways of driving innovation than the typical automotive players, which creates new opportunities that didn't exist even a few years ago."

Challenges to realising the automotive sector's full potential

While the automotive sector offers definite growth potential for the semiconductor sector, it is by no means a trouble-free journey to get there. There will be a number of challenges to be overcome along the way.

Dr. Reinhard Ploss, CEO Infineon Technologies:

"Agreements covering product quality between suppliers and OEMs have become more and more detailed as the electronic systems increase in complexity. That means that the requirements set for suppliers are becoming more complex too."

The automotive industry is governed by strict safety standards – with compliance with ISO 26262 being one of the most important.[1] Much more than other industries, automotive products can be subject to recall, involving lengthy, complex and costly processes. Semiconductor manufacturers will have to ensure that they find ways to work effectively with OEMs and Tier 1 suppliers, and manage the risk of having to fund a full product recall – if a chip is detected as the root cause of an issue. The cost of recall could exceed all revenue from an automotive manufacturer – and OEMs often ask for a warranty provision. The table below (Figure 10) highlights the automotive sector's distinct and stringent demands of the performance it requires from semiconductor components.

Figure 10: Challenges for semi producers and OEMs

Parameter	Consumer	Industrial	Automotive
Temperature	0 – 40°C	-10 – 70°C	-40 – 160°C
Operation Time	2 – 5 years	5 – 10 years	Up to 15 years
Humidity	Low	Environment	0% – 100%
Tolerated Field Failure Rate	<10%	<<1%	Target: 0 failure
Documentation	Minimal	Conditional	Required
Supply	Average 1 year	~ 2 – 5 years	Up to 30 years

Source: PwC analysis

Rick Clemmer, President and CEO of NXP Semiconductors:

"Given the possible impact on passenger safety, product quality is clearly expected to be very high (zero defect) in the automotive industry. This generally creates significant barriers to entry as it requires not only highly qualified manufacturing capabilities, but also highly specialised skills of the chip designers (design for quality)."

[1]*Under the general title 'Road vehicles – Functional safety', ISO 26262 is "intended to be applied to safety-related systems that include one or more electrical and/or electronic (E/E) systems and that are installed in series production passenger cars", according to the International Organization for Standardization. Among others, ISO 26262) provides an automotive-specific risk-based approach to determine so-called Automotive Safety Integrity Levels (ASIL).*

Continued

The development of smart mobility will create new technical and performance challenges for semiconductor manufacturers. They will need to ensure high levels of reliability as well as providing guaranteed levels of service for wireless connections.

One of the keys to developing the future market is to achieve greater standardisation and interoperability between solutions. Initiatives such as AUTOSAR[2] are likely to come increasingly to the fore, and may help to drive the adoption of standards in global markets.

Greater collaboration between semi manufacturers, OEMs and Tier 1 suppliers will become more important, but it will require new business models that share development and R&D activities to create the right products and services.

Dr. Reinhard Ploss, CEO Infineon Technologies:

"We introduced our slogan 'From product to systems' to complement our strength in technology by understanding what our customers' systems require and how we can help them in solving their challenges."

Rick Clemmer, President and CEO of NXP Semiconductors:

"The best remedy is to avoid the recalls in the first place… We focus on first-class development and manufacturing processes and on very rigid change management."

[2]AUTOSAR (AUTomotive Open System ARchitecture) is "a worldwide development partnership of car manufacturers, suppliers and other companies from the electronics, semiconductor and software industries" (www.autosar.org).

Summary and conclusion

PwC's forecast for the global semiconductor market suggests that between 2012 and 2017 billings will increase by some US$109 billion, representing a compound annual growth rate (CAGR) of 6.5%. Data processing will remain the largest single segment, with a total of US$153 billion, followed by communications at US$120 billion. However, the strongest growth story will likely be in the smaller segments: automotive (forecasted 9.4% CAGR) and industrial (8.8% CAGR).

The automotive sector will create strong demand for semiconductor content in vehicles as more regulation, greater efficiency and the manufacturers' search for differentiation continues to increase the need for sophisticated electronics. These will control and monitor just about every aspect of a vehicle's performance and the experience it offers to drivers and passengers.

Making the most of the opportunity that automotive affords will require new ways of working, and the need to develop specific strategic responses to a number of key questions. Senior management will need to gauge both their understanding of and appetite for developments in the automotive market. That, in turn, will require them to explore the key trends across the automotive value chain and identify the specific implications that these will have for their business. New ways of working, based on collaboration, will become increasingly important as semiconductor manufacturers are tasked with helping to create solutions that respond to a specific business need or opportunity rather than simply supplying components. And as those opportunities become clearer, they will present the chance for semiconductor manufacturers to differentiate themselves and drive competitive advantage through innovation that aligns to the evolving needs of the automotive sector. To capitalise on the growing demand, organisations will need to assess the range of skills and competencies that success requires, identify any gaps and find ways to fill them.

Methodology

Sales forecast

Calculation of sales forecasts

Sales forecasts are based on analyses of technological trends, the main value drivers and the competition. This is followed by analyses of macroeconomic factors, changes in consumer behaviour and demographic developments. Mathematical forecast models are used as the basis for investigating the effects of individual value drivers and for forecasting the developments of the semiconductor market. The data obtained are then assessed by our industry experts, checked for consistency and adjusted where necessary.

Currency used for the sales forecasts

The currency used for the sales forecasts is the United States dollar, the "base currency" of the semiconductor industry, at least in the main commodity markets. Exchange-rate fluctuations have not been assumed. The figures are reported in nominal terms, and thus include inflation effects. The historical data is taken from WSTS. The sales are shown as "billing revenues".

Interviews with experts

Interviews with Dr. Reinhard Ploss, CEO of Infineon Technologies, and Rick Clemmer, President and CEO of NXP Semiconductors, were held in June and July 2013.

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Design Services 28327 (09/13).