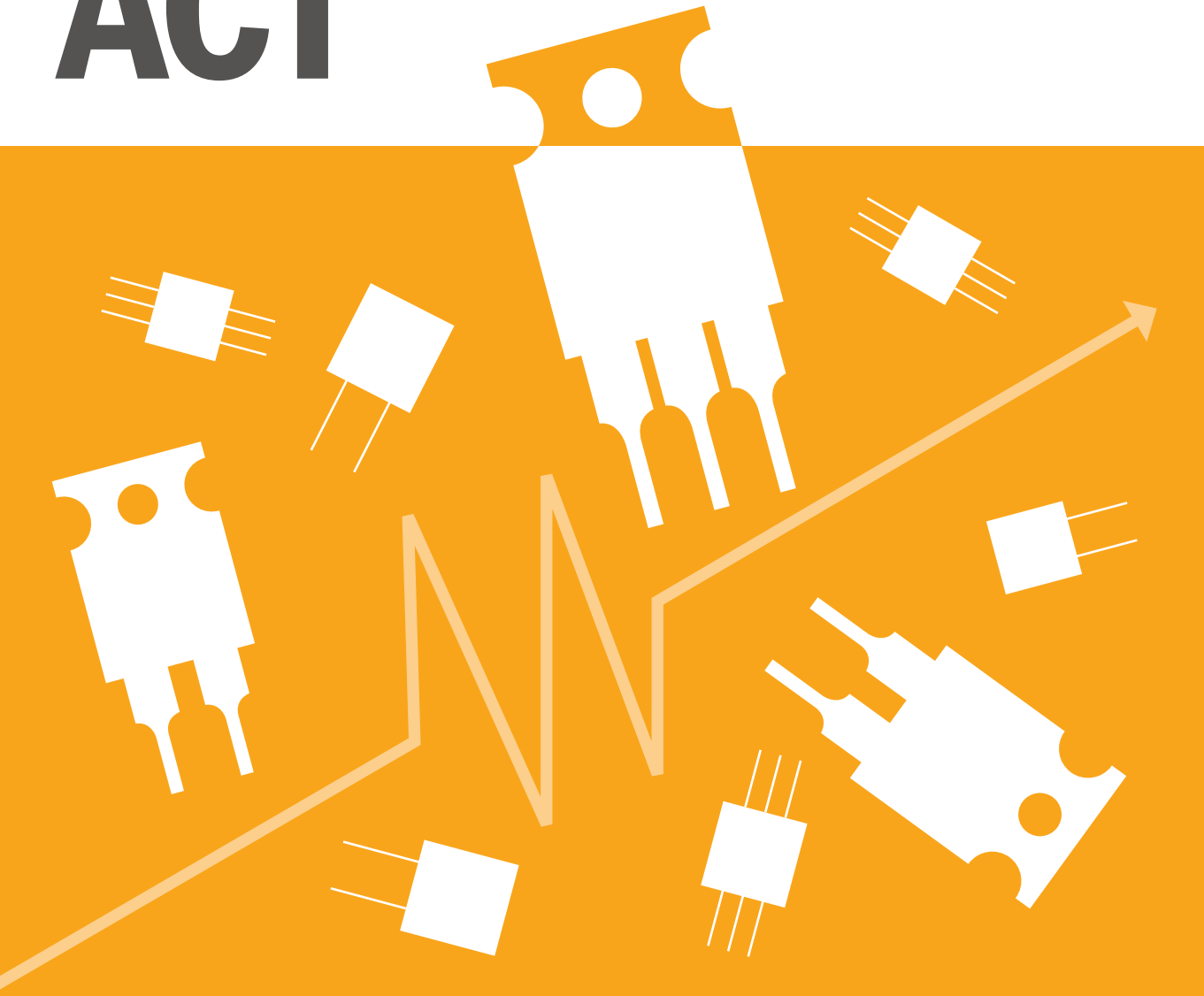


THINK ACT

BEYOND MAINSTREAM



POWERING AHEAD

Developments in power electronics mean a prospective bonanza for smart players

JULY 2015

Roland Berger
Strategy Consultants

THE BIG 3

 **7%**

will be the average annual volume growth in the global power electronics market in the coming years. Major drivers are growing demand from electrical automation and the trend toward energy-efficient solutions.
p. 3

 **USD 200+ bn**

is the expected value of the power electronics market by 2018. Industry currently accounts for about a third of this market, automotive for a quarter – but automotive is set to take over as the key sector.
p. 3

 **By 2020**

automotive players in all regions must dramatically step up their investment in electric technology to meet upcoming emissions and fuel efficiency targets driven by regulatory changes.
p. 7



**No Industry
4.0 without
power
electronics
p. 5**

Power electronics. Players in this market deliver products and solutions to control and convert electric power. Changes in their key customers' markets – industry and automotive – are expected to open up new profit pools.

1 Power electronics providers are looking toward a bright future. Until 2018 the overall market is expected to grow at an average of 7% per year. Even more important: It will deliver double-digit margins. On this interesting playground we see manufacturers of electronic components, of actuators, generators and other electromechanical equipment, and providers that integrate those components. Each of these players will participate in the overall growth to another dimension. While system integrators and suppliers of electronic components will grow only moderately – 5 and 6%, respectively – providers of actuators, generators and other equipment will see their business increase at a rate of 9%. In total this translates into an expansion of market value of about USD 220 billion by 2018. This is likely to be an exciting place to be for both established players and newcomers hoping to carve out a share of the market for themselves. **A**

Let's take a closer look at the sector's profit pool: We identify three main drivers: productivity, regulatory change, and companies' desire for a "green" image.

Productivity. Power electronics makes it possible to automate processes. Automation, in turn, leads to substantial gains in productivity and convenience – and that means cost savings for both industry and consumers. Energy-efficient processes can save a significant amount in operating expenses; depending on

the energy consumption of the industry in question, this can have a major impact on the bottom line.

Regulation. The second factor behind the growth of the power electronics sector is regulation. Specific laws define the requirements with regard to power efficiency. The Kyoto Protocol, for instance, commits signatories to reducing greenhouse gas emissions, on the premise that man-made emissions are causing global warming. The Protocol has led to the introduction of strict regulations, particularly in Europe and the United States. More recently, the G7 nations reinforced their commitment to further reduce CO₂ at the 2015 summit in Ellmau. Developing countries are following suit, albeit at a slower pace. Looking forward, regulation will likely continue to shape the key industries that make use of power electronics. This is a trend that will last several years, forming a sustainable growth driver for the power electronics sector.

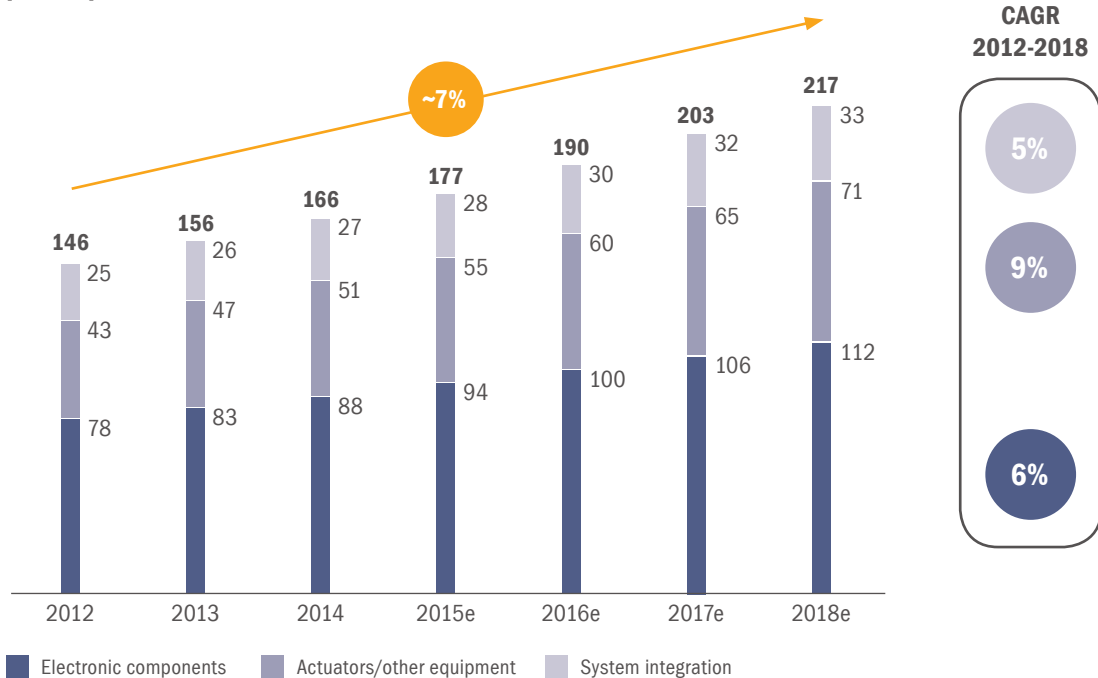
Responsibility. In recent years we have seen numerous corporations use energy efficiency to market their brand to clients and the general public. While the desire for a green image is a less important driver than cost savings and developments in regulation, nevertheless it is a trend that also contributes to growth in the sector.

The key elements of the value chain are special materials, power components, and full power electronic systems. Special materials are articles such as direct bonded copper (DCB) substrates, commonly used

A

MAPPING THE POWERTRAIN BONANZA

Productivity, regulation and responsibility are driving the change in the period 2012 through 2018
[USD bn]



in power modules, and special float-zone (FZ) silicon ingots, used in the production of special integrated circuits. The special materials segment has an estimated market volume of USD 5-6 billion and delivers EBIT margins in the range of 5 to 15%. Highly specialized players (e.g. Wacker, Sumitomo, KEC) dominate the market, operating in global oligopolies. Europe, Japan and Korea lead the way.

The next step in the value chain is the manufacture of power components. Power components are technologies such as chips (e.g. insulated gate bipolar transistors – IGBTs – or metal oxide field effect transistors – MOSFETs), power modules, chokes and sensors. The market for power components is worth an estimated USD 50-60 billion and EBIT margins are an attractive 10-25%. The key technology within this segment is without doubt chips and modules, with a market of around USD 20 billion. Here, oligopolies dominate the land-

scape, especially in the European Union, Japan and Korea. In addition there are many niche specialists, such as LEM (the Swiss company behind Hall current sensors) and Isabellenhütte Heusler (high-precision resistors).

Power electronic systems form the last value process – items such as inverters, drives and converters. This USD 100 billion market is home to a huge number of players specializing in different applications and geographies. EBIT margins range from 10-15%. Players include both electric multinational corporations (e.g. Siemens, ABB, GE) and small and medium-sized enterprises, some of which have a global presence (e.g. the Danish company Danfoss) while others have a regional focus (e.g. Spanish-based Ingeteam). Many new companies are also emerging in China.

The customer base of power electronics firms is quite diverse. It includes major multinationals (ABB, BOSCH, GE, Siemens, Sumitomo) and fragmented small and me-

dium-sized enterprises (SMEs) – the latter especially in Asia. They build applications like: forklifts trucks, robots, computer numerical control (CNC) machines, and the like.

Industry 4.0 – first shaker of the power electronics market

Many different sectors use power electronics. Industry represents the largest segment, accounting for around one-third of the total market. Other key areas are information and communication technology (ICT) and consumer products, each representing less than 20% of the market. Smaller applications are found in the segments rolling stock, lighting and renewable energy. A large user is the automotive sector, making up about one-quarter of the total industry.

Industry is worth a closer look since it is experiencing disruptive change. The expansion of automation, digitization and connectivity in factories, called "Industry 4.0" is changing the game already and will change it even more in the future. Production processes are being fully integrated and digitized. Within the industrial value chain new technologies from the "cyber" world are combined with traditional production systems from the "physical" world. Typical developments associated with this trend include self-optimizing systems, predictive maintenance, optimized logistics management, and demand-response energy management systems. Industry 4.0 relies on power electronics as it is a key enabler for automation. A major shakeup can therefore be expected. The structure of the market may change fundamentally and a number of opportunities and risks will emerge. **B**

As we mentioned earlier, the primary use of power electronics is to modify electric power in an economically efficient way. Modern electric motors need a constant supply of modified AC in order to function; that AC is provided by a piece of power electronics called a drive. Drives can also adjust the power intake of electric motors to match the actual requirements of the applications, e.g. keeping the rotation speed constant even under variable load. This can reduce the consumption of motor energy by anything between

20% and an impressive 50%. Efficiencies of over 97% are feasible – a vast improvement on legacy technology.

With new applications, such as novel kinds of robotics, Industry 4.0 will generate an increasing need for controllable electric motors, which will fuel the demand for drives. In parallel, the transparency created by Industry 4.0 with regard to the energy efficiency of individual products will pave the way for more energy-efficient products, pushing demand for state-of-the-art power electronics.

Robotics is a good example of how Industry 4.0 stimulates the power electronics market. The global robotics market has shown exponential growth in recent years. Its value has increased from around USD 6 billion in 2000 to USD 11 billion in 2005, and USD 25 billion in 2010. The current market (2015) is worth an estimated USD 34 billion, and that figure could almost double by 2025.

The drivers in robotics are both "physical" and "cyber" in nature. On the physical side they include lightweight construction, low-cost sensors, dual-arm robots and parallel kinematics. On the cyber side they encompass visual serving, computing and embedded systems, trainability, and self-learning (or "deep learning").

We have taken robotics as an example of the opportunities found in the emerging applications, which have a number of implications for the power electronics industry. First, the growth rate of the robotics market is an indicator of upcoming developments in Industry 4.0. At the same time, the widespread use of robotics will lead to increased customer expectations regarding flexibility, with all the implications this has for the power electronics market. These developments will also generate fiercer competition for component and system producers in high-end and high-speed functions due to substitution.

In the end it is not all good news. Industry 4.0 will make it even more difficult for companies to differentiate themselves through hardware. Physical limitations restrict the possibilities for innovation. Instead, they will have to build their USP through software and intelligent algorithms. This harbors a risk that today's "high-end

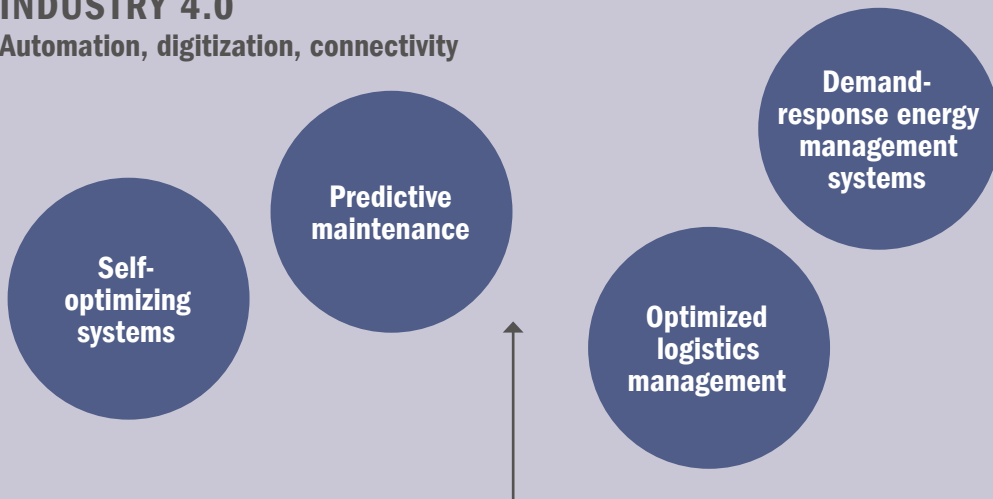
B

INDUSTRY 4.0 – TRIGGERED BY POWER ELECTRONICS

AUTOMATION, DIGITIZATION AND CONNECTIVITY ARE KEY OPPORTUNITIES FOR UNIQUE POSITIONING

INDUSTRY 4.0

Automation, digitization, connectivity



POWER ELECTRONICS

Key enabler for automation

Grid/battery

Source of power

Control unit

Microcontroller/
driver

Power
ICs

Consumer of power

Actuator/
electric motor

Flow of power

Feedback

hardware, standard software" products will be ousted by "mid-end hardware, high-end software" products.

Automotive takes the lead

Although Industry 4.0 will drive the power electronics segment in the next few years, it is very likely that the automotive industry will become even more important in the next wave after that. This shift in roles will be driven by the changes in regulatory requirements, which will push improvements in almost all regions over the next four to five years.

Let's look at some examples. The EU has corporate emission targets in place that represent a reduction of 41% between 2013 and 2025. Japan has fuel efficiency targets representing a 26% reduction between 2013 and 2020, with targets for 2025 still to be decided. The US, for its part, plans a 43% reduction in CAFE between 2013 and 2025. And China is potentially aiming for a 44% reduction in corporate CO₂ emissions.

As a reaction to regulatory requirements, the competitive game on the field of electric vehicles ("xEV") has already begun. We closely monitor innovations across the whole landscape: battery electric vehicles or BEVs, plug-in hybrid electric vehicles or PHEVs, hybrid electric vehicles or HEVs, and range-extender electric vehicles or REEVs. Of course, we have yet to see how fast a mass market for electric vehicles will develop in the end. But to achieve the required across-the-board fuel economy savings, OEMs will have to massively step up their investments in xEVs, adopting electric vehicles across all segments. While full hybrids will dominate in Japan, the hybrids in the EU and the US are likely to be predominately plug-ins. Most OEMs will have rolled out PHEVs in their key segments by 2017, fully establishing the technology before it becomes mandatory.

The key factor here is the cost of batteries and how fast battery technology develops in the coming years.

3 Beyond 2020 it is likely that electric vehicles will become competitive in terms of total cost of ownership due to the steady decline in battery costs. Indeed, the price of an EV pack is expected to reach 125 EUR/kWh in 2025 at 95% gross pack utilization. At the same

time, the broader penetration of electric vehicles could potentially be limited by the availability of infrastructure and established vehicle usage behavior; consumer mobility habits die hard.

Thus, automotive applications are likely to be the driving force behind power electronics in the future. Take current sensors, for example. Here, significant growth is expected in the automotive sector in parallel with a long-term move toward semiconductor-based technologies. A number of factors drive the rise of semiconductors, including the increasing miniaturization and integration of systems requiring smaller components, the ongoing price pressure calling for cheaper solutions, the increasing connection of periphery consumers of electricity (e.g. windshield wipers, windows) needing more low-current measurement, and the growing implementation of digital signal processing on chips.

Power chips are another case in point. MOSFETs and IGBTs dominated the market in past decades. Now, two new materials have come onto the scene: silicon carbide (SiC) and gallium nitride (GaN). They are both superior in terms of performance, efficiency and size – but not yet in terms of cost.

We believe the transition to these new "wide band-gap" materials will be slow. The key to bringing down their cost is scale, and scale comes with automotive applications. In all the areas where GaN chips can be used – at least up to 650V – they will come to dominate the market, seriously disrupting the application and system sides. The cost/learning curve will profit from silicon semiconductors and LEDs, while SiC will require stand-alone investment.

Although huge opportunities exist in automotive power electronics, players should prepare for the risks that accompany them. Automotive powertrain applications are an example of one possible future battlefield. Competition from Tier-1 suppliers may intensify as they realize that power electronics component manufacturers could potentially deal with automotive OEMs directly.

Increased cost pressure may also lead to a greater degree of standardization in components as a way to achieve economies of scale in production. Cost pres-

C

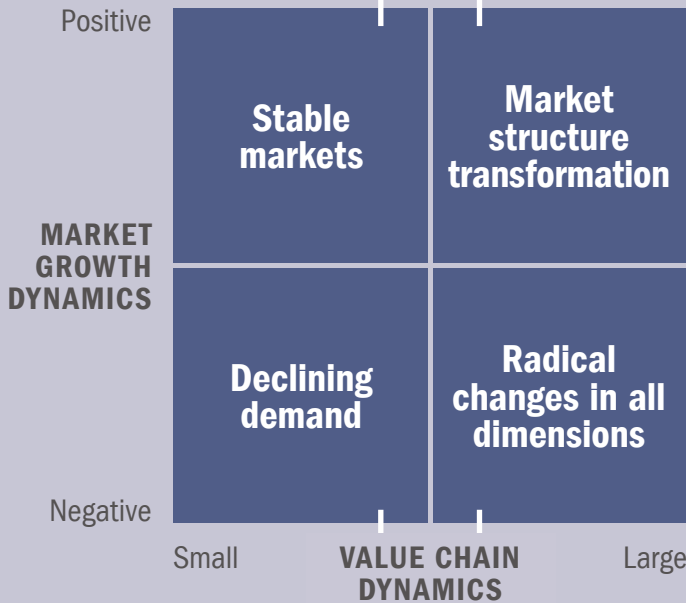
TWO MARKET SEGMENTS

Low/medium power segment:

Applications delivering power level <42 kW like forklifts and photovoltaics applications: significant changes expected

Overall market growth on volume basis
Increasing commoditization
Lower prices and simpler products
Low-voltage applications up to 650V will be based on GaN power modules
No disruptions in competitive landscape

Overall market growth intact
Applications on system level move toward lower voltages
Wide-bandgap materials are able to penetrate >650V area
Automotive will replace industry as the driver of power electronics (technology and costs)
Chinese suppliers and newcomers disrupt the market



Shrinking demand due to macroeconomic crisis
Increasing commoditization
Lower prices and simpler products
Low-voltage applications up to 650V will be based on GaN power modules
No disruptions in competitive landscapes

Overall market growth intact
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Source: Expert panel, Roland Berger

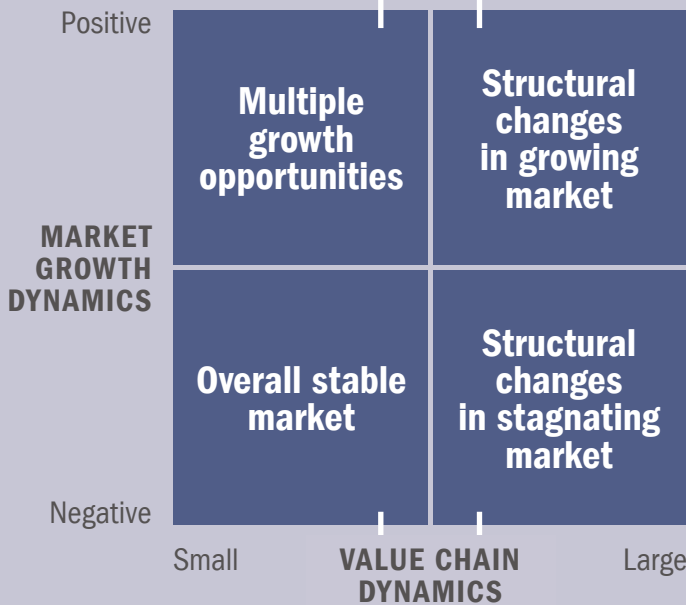
DIFFERENT SCENARIOS

High power segment:

Applications delivering power level >42 kW like wind power, automotive and power supply: moderate changes expected

Significant growth in new and current end markets
Technology shift toward wide-bandgap materials – automotive switching to SiC
No significant changes regarding new suppliers of power electronics or power conversion systems or move toward large (integrated) ones

Significant growth in new and current end markets
Technology shift toward wide-bandgap materials in niche applications in high voltage
Market consolidation on power electronics supply side



Overall declining market in current product segments due to macroeconomic crisis
Limited growth in new product segments
Technology shift toward wide-bandgap materials
No significant other changes in status quo

Limited growth in new applications
Declining market in current applications
Technology shift toward wide-bandgap materials in niche applications
Market consolidation on power electronics supply side

sure could also result in more modularization and integration. The risk for the industry is that the bountiful margins it has come to love may rapidly be cannibalized. Power electronics companies need to be constantly on guard against this threat.

We mapped potentials and future developments in power electronics using the scenario method. We found that the market could be divided into two segments: the low/medium-power and the high-power market. "High" signifies a power range between 42 kW and 10 MW. In this segment we find applications like wind energy converters, power supplies for hospitals or nuclear plants, and e-mobility. Low/medium power is 2 to 42 kW, a dimension where vehicle batteries, forklifts and machine tools operate. In terms of requirements, the high and low/medium segments are completely different. Take the value share of power electronics in proportion to the overall cost of the device: It is much higher in the low/medium power than in the high-power segment. Also, the technologies and the structural configuration differ significantly. However, our scenario analysis revealed that the low/medium-power market will face much more dramatic changes than the high-power market. **C**

What should smart players do to claim their share of the expected bonanza in power electronics? Our recommendations differ for the two main types of players: those who are already in the market ("established players") and those who are hoping to enter it ("newcomers").

Established players. They fall into two camps: component companies and system application companies. Component companies who are already in the market need to strengthen their global customer intimacy and move toward a more value-based line of reasoning in sales. At the same time they should strengthen their presence in the automotive business – or move into this area if they have not already established themselves there. Forging partnerships with wide-bandgap material, especially GaN, players will be increasingly important. Companies must also ensure that they maintain their technological edge by means of extended partnerships and pilot projects with multi-

ple partners, while not forgetting to build their competency in software. All the time they must keep their cost base flexible, thinking in scenarios and being prepared for whatever lies around the corner.

Established system application companies will have different priorities. We recommend they pursue co-development with OEMs and end customers. They should cooperate with the best component suppliers as technology partners, steering well clear of the "commodity trap". At the same time they should develop new product lines based on innovative technology and develop or foster their own upstream competency, especially in software. Tapping synergies between the automotive and industrial sides is highly advisable.

Newcomers. They find themselves in a very different situation. Component companies who have yet to enter the market must be sure to take a long-term approach. They will need deep pockets to fund their entry into the sector – and they must carefully select the niche they hope to occupy. Forging partnerships with incumbents is a promising approach. They would also be well advised to focus on new, disruptive technology (such as GaN) and innovative business models. System application companies who hope to enter the market also need a long-term approach. They, too, must have sufficient funds to support their first steps into this new playing field. They must design from scratch, breaking with the existing rules to fully leverage new technology. Using innovative incumbent component or Tier-1 companies as technology partners can pay off. At the same time they can create products that are better and cheaper than previous solutions by taking a "good-enough hardware, best software" approach.

The power electronics market offers a potential bonanza for smart players in the coming five to ten years. For companies that have already established themselves in the market, the focus should now be on improving customer intimacy and maintaining a technological lead, while always keeping costs as low as possible. New entrants, on the other hand, should carefully select their niche and look to the longer-term horizon. The power electronics market is a market where staying power pays off. **◆**

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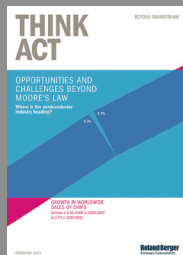
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Further reading



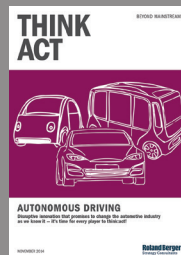
DIGITAL TRANSFORMATION

Digitization is a key innovation that will determine whether European industry remains competitive in the future. If we succeed in realizing the potential of connected, more efficient production and new business models, Europe could see its manufacturing industry add gross value worth 1.25 trillion euros by 2025. But if European industry misses out on the digital transformation, the sum of 605 billion euros could be at risk in the years ahead.



SEMICONDUCTOR INDUSTRY

The semiconductor industry has been plagued with declining growth rates for some time now. Over the past five years, the global market for microchips grew on average by just 2.7% a year. From 2000 to 2007, growth was an annual 3.3%. The slowdown is due to overcapacity and strong cyclical fluctuations. New Asian companies are taking over the global mass market for computer chips – to the detriment of established European and Japanese semiconductor manufacturers.



AUTONOMOUS DRIVING

Autonomous driving has the potential to fundamentally transform the automotive industry in the coming years – be it through innovative software technologies and vehicle models or new ways of using cars, such as "Mobility on Demand". The expectation is that cars will be able to drive completely autonomously from 2030 onward.

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Publisher

**ROLAND BERGER
STRATEGY CONSULTANTS GMBH**

Sederanger 1
80538 Munich
Germany
+49 89 9230-0
www.rolandberger.com

Editor

DR. CORNELIA GEISSLER
cornelia.geissler@rolandberger.com

The authors welcome your questions, comments and suggestions

DR. MICHAEL ALEXANDER
Partner, Engineered Products & High Tech CC
+49 89 9230-8244
michael.alexander@rolandberger.com

DR. WOLFGANG BERNHART
Partner, Automotive CC
+49 711 3275-7421
wolfgang.bernhart@rolandberger.com

DR. RALPH LÄSSIG
Partner, Engineered Products & High Tech CC
+49 89 9230-8541
ralph.laessig@rolandberger.com

SVEN SIEPEN
Partner, Switzerland
+41 43 336-8670
sven.siepen@rolandberger.com