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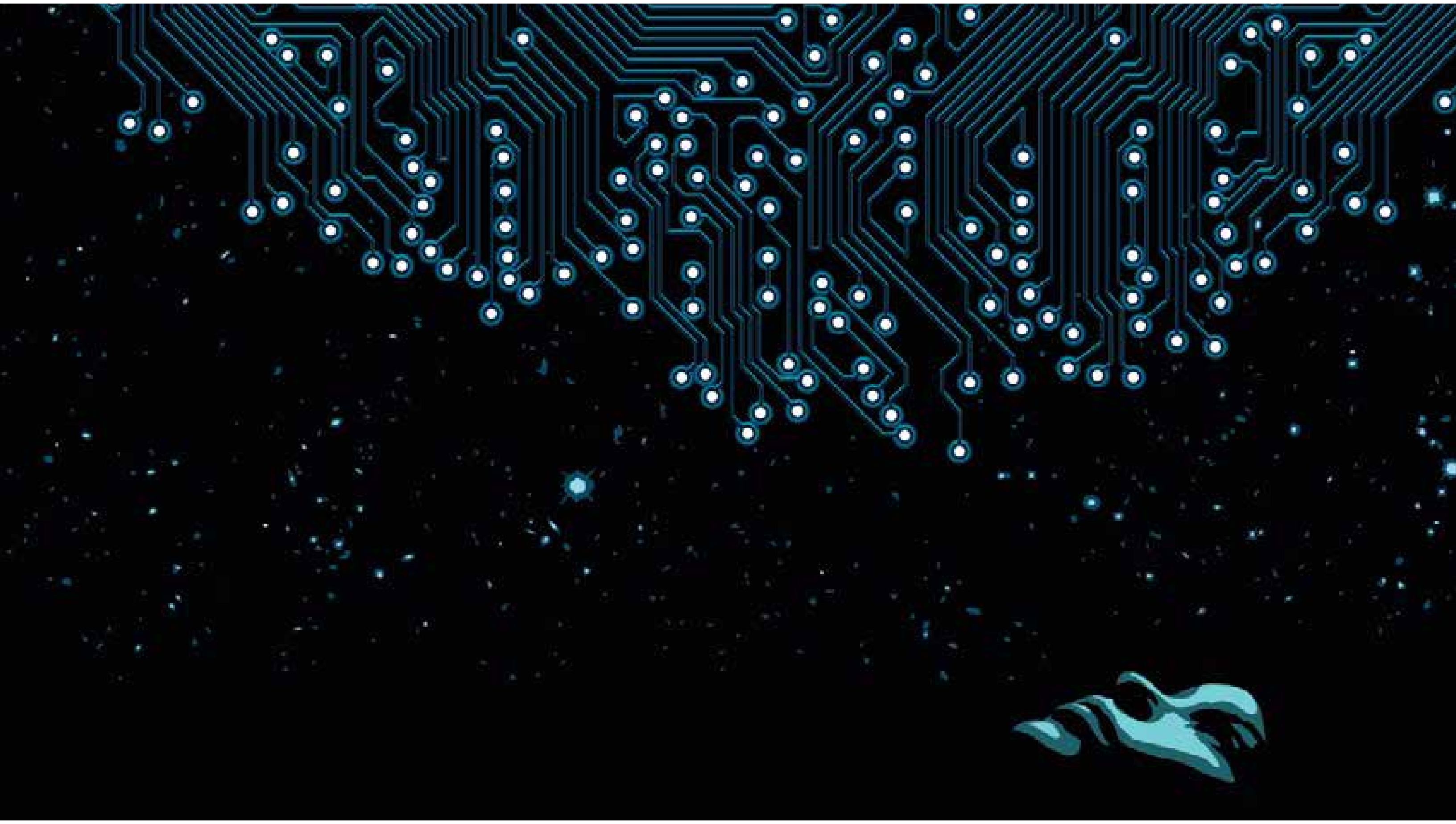
# McKinsey on Semiconductors

Number 2
Autumn 2012





*McKinsey on Semiconductors* is written by experts and practitioners in McKinsey & Company's Semiconductors practice along with other McKinsey colleagues.

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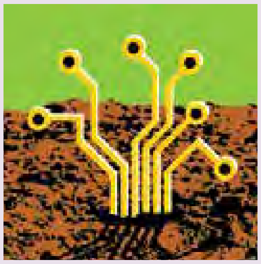
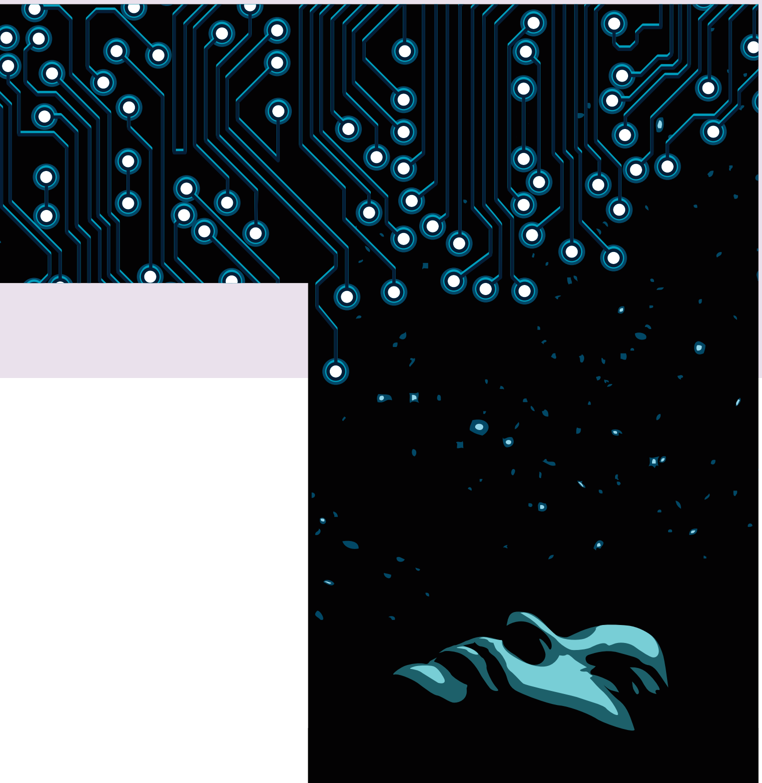


# Introduction

**André Andonian, Harald Bauer, Sri Kaza, Nick Santhanam, and Bill Wiseman**



As we approach the end of 2012, two big themes continue to play out in the semiconductor industry: the rise of the smartphone at the cost of the traditional PC market and the increasing pressure for a more sustainable style of growth as the industry matures and organic-growth rates stagnate. This paradigm shift has had the most profound impact thus far on the PC segment, and we expect continued softness in semiconductors into 2013. Even firms that don't play in the affected markets recognize the significance of these themes as they affect the entire semiconductor ecosystem.

The mobile-device segment, which includes smartphones and tablets, promises to be the key driver behind the next several years of industry growth. We cover this impact in several articles in this year's edition of *McKinsey on Semiconductors*. Starting with "Finding the next $100 billion in semiconductor revenues," we look at how each segment of the industry will be affected by mobility and other major global trends. We also present a high-level examination of the contest between technical architectures and business models in the communications end of the chip market ("The supercomputer in your pocket") and take a more tactical look at the shifts in opportunities in the mobile segment ("Semiconductors for wireless communications: Growth engine of the industry”). Given this focus, we include an extended Q&A with an executive at the center of the communications-chip market, Broadcom CEO Scott McGregor.

As the overall industry matures, the pursuit of other types of growth becomes all the more important. In “What will enable alpha growth?” we explain that industry players should transition from relying on organic market growth to creating their own future through focused execution and M&A. The level of M&A activity will expand, as segment leaders have record levels of cash on their balance sheets and few organic options for growth. As a result, the likelihood of further industry consolidation seems quite high. Because it is not always easy to get M&A right, we present “Creating value through M&A and divestiture,” an article on what works and what doesn’t in M&A strategies.

In addition to these two major themes, we cover other topics that are relevant to today’s semiconductor leaders. These include stepped-up approaches to sales (“Unlocking sales-force potential in the semiconductor industry”), the next steps for the solar industry (“Solar power: Darkest before dawn”), and the impact of massive data sets and machine-learning technologies (“Big data and the opportunities it creates for semiconductor players”).

With this new issue of *McKinsey on Semiconductors*, we hope to provoke your best thinking on how to map a path to a successful future. We invite comments at McKinsey_on_Semiconductors@McKinsey.com.

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# Finding the next $100 billion in semiconductor revenues

**In 2010, the global semiconductor industry crossed the $300 billion revenue mark for the first time. But the industry is at an inflection point: if players position themselves to tap the right microsegments, industry sales could approach $400 billion as soon as 2015.**

**Aaron Aboagye, Sri Kaza, and Nick Santhanam**

The global semiconductor industry had a banner year in 2010. For the first time, industry revenues exceeded $300 billion. To put that number in broader context, the industry has been rebuilding its sales ever since the bursting of the Internet bubble, from a low of $157 billion in 2001 to a previous high of $275 billion in 2007. The financial crisis and recession that followed in 2008 and 2009 took another big bite out of sales. But by 2010, the industry had battled back and was posting record revenue.

Several important tailwinds powered that growth, including further progress along Moore's law and wave after wave of killer applications, from PCs to networking gear, from portable MP3 players to mobile phones. And an increasing number of chips find their way into automobiles, household appliances, and industrial equipment.

However, those are not the only changes afoot. Costs for semiconductor R&D, such as advancing process technology or building leading-edge fabs, continue to rise, even as chip prices face downward pressure. Then there is increased competition from companies that weren't traditionally thought of as semiconductor players, such as Apple, which designs (but does not manufacture) the A5 chip at the heart of the iPhone 4S and the A5X chip

that powers the latest iPad. Governments and sovereign-wealth funds have also made investments to bankroll new competitors in low-cost markets. As such, the traditional centers of economic value for the industry are shifting.

Analysis of the major trends shaping IT adoption over the intermediate term uncovered four high-potential opportunities to pursue; combined, these would allow industry players to capture almost 90 percent of the growth potential between now and 2015. By that time, we project that the semiconductor industry will have added almost $100 billion in new annual revenues, so the opportunity is large indeed and well worth pursuing. To get it right, semiconductor players will need to know both where to play and how to approach the opportunity. In this article, we will offer thoughts on what successful companies can do to claim their share of the value created in the coming years.

### Breaking the $300 billion barrier

Over the last 15 years, the semiconductor industry has enjoyed its share of ups and downs, but after a couple of severe setbacks it seems the industry has regained its swagger. Much of its growth resulted from three categories of tailwinds. First, the technological progress dictated by Moore's law has enabled substantial increases in processing power and enabled a wave of devices that were the stuff of fantasy as recently as a decade ago. (Who would want to buy a tablet computer with a virtual keyboard? No one, until the iPad debuted.)

Next, the number of interested end markets and killer applications has grown. In the late 1990s, most semiconductor growth came from PC sales, whereas WiFi networks and mobile phones were far from commonplace. Automobiles featured few chips 15 years ago; that is hardly the case today. Then there are the chips that control dishwashers, coffee makers, and many other types of household appliances that used to be purely mechanical. In addition, the rise of middle-class consumers in countries across Asia created important markets for both semiconductors and electronic devices of all sorts.

Last, collaborations and consortia have come together to enhance the industry's flexibility and its responsiveness to customer demands. An example of this is the federation of companies involved in the customization, fabrication, and packaging of power-saving ARM processors—the dominant processor architecture in mobile phones and tablets. Governments and sovereign-wealth funds have also made a series of investments to promote indigenous players across the developing world.

Put all of these factors together, and the path to $300 billion in revenues becomes clear. However, a number of challenges will make it hard to move beyond the $300 billion level in the near term. One is how semiconductor companies can capture a "fairer share" of the value created for end users. A second is how to monetize the software dimension of the semiconductor business. And a third involves new entrants in the marketplace: many of these competitors come from outside the traditional semiconductor sector, and they bleed market share and revenue from established players.

### Leaving money on the table

While $300 billion in sales is nothing to sniff at, the semiconductor industry actually leaves a fair bit of money on the table. Fully half of the industry's revenue, for instance, is derived from products that are less than six months old. While other industries are able to exert a certain degree of pricing power, based on demand for their goods or fluctuating costs of inputs, the semiconductor industry seems to exist in a state of permanent deflation, thanks to its rapid innovation cycles.

At the same time, the industry has struggled to charge for the performance increases that it has delivered. To put it another way, if the auto industry had evolved its technology as rapidly the semiconductor industry has with microprocessors, the top speed of a sports car would be approaching 4,000,000 miles per hour instead of the 202 miles per hour that a current Ferrari 458 Italia model can deliver.

In several product segments, such as flash memory, chips have become commoditized. Memory is a tough segment because the designs for the most successful forms of memory chips are relatively simple and the drive for higher capacity and improved speed is relentless. Despite constant innovation, there is also constant downward pressure on prices. Between 2000 and 2008, memory prices declined, on average, by 5 percent a year. Once the financial crisis and global recession hit in 2009, major players like Qimonda and Elpida were driven into filing for bankruptcy protection. In October 2011, Elpida's CEO, Yukio Sakamoto, summed up the situation in a comment to investors: "Elpida is using the state-of-the-art production technology, yet the finished products are sold for half the price of a rice ball." In other words, the chip makers' inability to differentiate their products leads to continuous pricing pressure. (In July 2012, Elpida was acquired by Micron Technology, in a move seen as a step toward consolidation in the crowded memory-chip market.)

So, if chip companies have not captured the majority of the value produced by their technology, who has? An analysis of the value created suggests that electronics companies and consumers got the lion's share of excess value created. We calculated that the compound annual growth rate of the processor business during that period was 16.3 percent. Yet the industry captured a share of only 1.5 percentage points, with the rest swallowed up by price declines, which benefit original equipment manufacturers and consumers. Similar dynamics are playing out in mobile phones, light-emitting-diode (LED) lighting products, and all sorts of consumer electronics.

A second challenge is the industry's inability to monetize the increasing value of the software bundled into their chips. In general, semiconductor companies tend to bet on hardware and focus their innovation efforts on the engineering side of a project, rather than the software dimension. Few major chip makers have more software engineers than hardware engineers, even though the software layer is a key component of chips for mobile phones and other portable devices. There is additional money to be made, such as

The industry is at an inflection point, but there are several reasons for optimism. Nine global trends—including mobile convergence, next-generation wireless, and the rise of immediacy—should power significant growth for semiconductor players.

when the logic content of what normally might be an application-specific integrated-circuit chip is sold as ready-to-implement software in a field-programmable gate array.

A third, more serious, challenge faces the industry. At the same moment that costs are jumping at rates of as much as 35 percent for each new node along the path from 130 nanometers to the current 22-nanometer standard, there are outsiders such as Apple breaking into the semiconductor business, designing their own chips, and capturing value.

In sum, the industry is at an inflection point in 2012. But there are several reasons for optimism. An analysis of nine global trends shows they should power significant growth for the semiconductor players who align their offerings with the biggest opportunities.

## Capturing the next $100 billion in revenue

To understand the market and create a forecast for the semiconductor industry, we studied nine major IT trends likely to evolve and drive growth between now and 2015. Not every trend benefits semiconductor players in a meaningful way. Rather than presenting an exhaustive review, the following section highlights the four trends likely to power about 90 percent of the growth potential and notes the specific types of chip technology that should benefit from each trend. By targeting the most lucrative microsegments, the industry has a good chance to turn 2010's $300 billion in revenues into 2015's $400 billion (Exhibit 1).

### Mobile convergence

The hottest high-end electronics products today are tablets and high-tier smartphones, followed by middle-tier smartphones and feature phones. Smartphone sales are expected to grow at a compound annual rate of 24 percent between now and 2014, according to IDC and Strategy Analytics. Tablet sales will grow at a 35 percent annual rate in that period. We believe components will converge in this broad category of devices as mobile phones become more computerlike and computers shrink and become increasingly portable. As devices in general become more mobile, demand for nonvolatile memory and low-power processors will

Exhibit 1

## A few major IT trends will drive the bulk of revenue growth in the semiconductor industry.

High growth: over $3 billion
Medium growth: $1 billion–$3 billion
Low growth: $0.5 billion–$1 billion
Broadly flat: less than $0.5 billion
Negative growth: less than –$0.5 billion

**Industry growth**

2010 revenue $300 billion + 5-year baseline growth $41 billion + **Megatrends $67 billion** – Double counting $10 billion = Estimated 2015 revenue $398 billion

**5-year revenue growth, $ billion**[1]

| | Cloud computing | Mobile convergence | Immediacy | Next-generation wireless | Security standards | Energy efficiency | **Total** |
|---|---|---|---|---|---|---|---|
| Memory (volatile) | –0.2 | 0.6 | 0.2 | 1.7 | N/A | N/A | 2.3 |
| Memory (nonvolatile) | 4.0 | 10.3 | 1.1 | 2.5 | 0.0 | 0.1 | 18.0 |
| Microcomponents | 1.6 | –0.2 | 6.4 | 2.0 | 1.2 | 1.9 | 12.9 |
| Logic | 0.8 | 3.9 | 3.5 | 5.4 | 0.0 | 0.1 | 13.7 |
| Analog | –0.8 | 1.8 | 1.8 | 2.2 | N/A | 0.1 | 5.1 |
| Discretes | 0.1 | 1.4 | 0.6 | 0.9 | N/A | 0.2 | 3.2 |
| Optical | 0.2 | 2.5 | 2.3 | 1.8 | N/A | 3.0 | 9.8 |
| Sensors | –0.1 | 0.7 | 0.1 | 0.8 | N/A | 0.2 | 1.7 |
| **Total** | 5.6 | 21.2 | 16.0 | 17.3 | 1.2 | 5.6 | 66.7 |

[1]Figures may not sum, because of rounding.
Source: iSuppli; McKinsey analysis

rise significantly. More specifically, based on data from Gartner, IDC, and iSuppli, we expect that current x86-based chips will lose around 10 percent of their market share to ARM-based processors over the next five years (Exhibit 2).

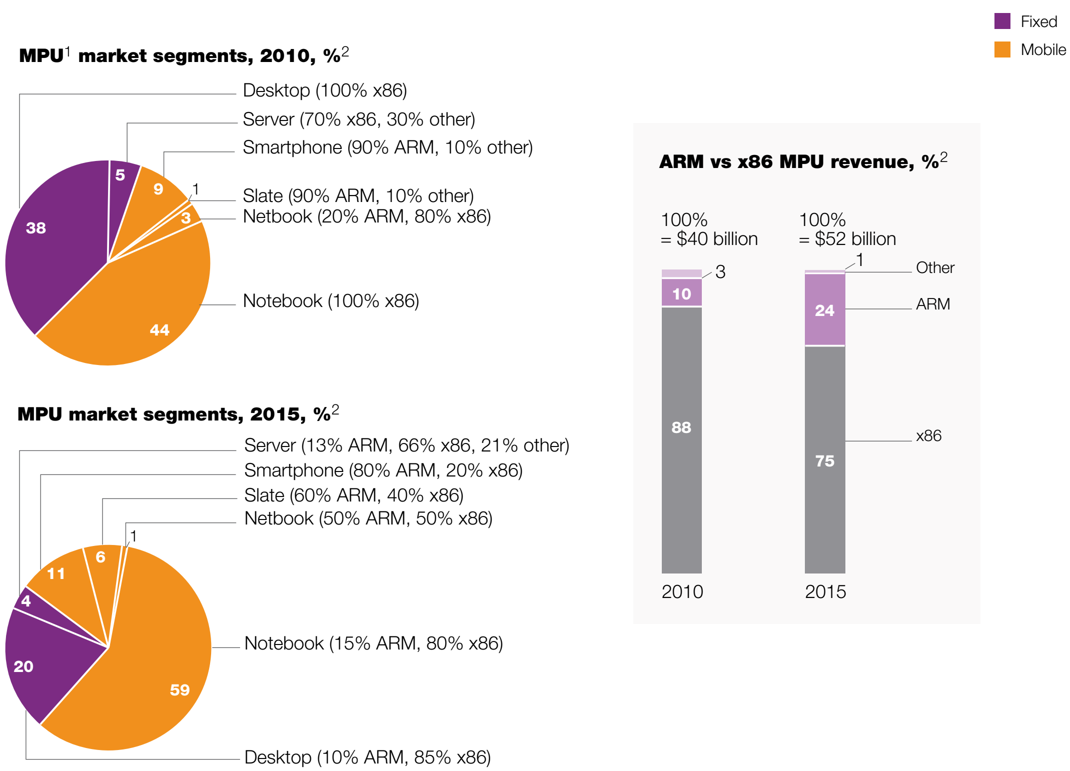
One caveat is that Intel, the dominant player in computing, wants to enter the smartphone market and may achieve suitably low power levels and competitive pricing for its x86 chips across most product categories by the end of 2013. That would lead to deeper competition in the mobile-processor market.

With regard to high-growth product segments, the best are chips that power midrange smartphones, with average selling prices in the range of $100 to $190. This category offers comfortable margins, and the overall segment is expected to grow at an 8 percent annual rate between now and 2014. The higher-growth, entry-level smartphone category will grow at a compound annual rate of 44 percent but is expected to be a competitive, relatively low-margin business, so scale is an important success factor. The battle in the high-end smartphone category is largely over, with Apple, Google, and Samsung expected to capture the lion's share of the value created in this segment through 2014. Profit margins for advanced phones are high, but the growth rate in the sector is expected to be a tepid 3 percent as volume shifts toward the categories noted above.

This trend also has implications for chip makers: the growth in smartphones and tablets will benefit flash-memory producers, especially those that build NAND flash chips. Logic application-specific standard products will also profit from

Exhibit 2

## Over the next five years, x86-based MPUs could lose >10% of market share to ARM.




Intel is the current dominant player in the mobile computing space; ARM is dominant in smartphones. Intel could achieve smartphone-suitable power levels (~500 mW) and price competitiveness for most use cases by 2013. Intel will continue to dominate the PC segments due to the optimized and well-penetrated Windows ecosystem, yet low-end PCs will adopt ARM-based processors as Microsoft starts supporting ARM for the next version of Windows. ARM is expected to penetrate in custom-built commodity servers for cloud-based processing, storage, and network.

[1]Microprocessing unit.
[2]Figures may not sum, because of rounding.

Source: Gartner; IDC; iSuppli; McKinsey analysis this surge, as will LEDs, since mobile devices need lighting sources that sip rather than guzzle power. The shift toward mobile devices should also produce an increase in the use of discrete components, except at the low end of the spectrum, where integrated components will be preferred. In all, we expect that mobile convergence will increase global semiconductor revenues by $21 billion over the next three years. It may, in fact, be the hottest corner of the semiconductor market over the near term.

### Next-generation wireless

From 2007 to 2010, global revenues from mobile broadband service grew at a 19 percent annual rate. Common sense would dictate that the rollout of 4G wireless around the world will only boost demand for rich media content. In fact, data traffic on mobile networks is already rising at a rate of roughly 80 percent a year. What is already a $100 billion opportunity for operators is expected to double by 2014, according to analysis from Yankee Group Research. Should it do so, mobile broadband would account for almost 20 percent of operator revenues.

Why is growth so robust? First, the smartphone category itself is growing at a 62 percent annual rate. The typical iPhone user consumes 250 MB of data a month. Second, the number of mobile broadband subscribers has grown at a 155 percent annual rate over the past four years—and these people tend to use between 500 MB and 1 GB of data in a typical month. Last, the number of data-hungry applications on phones and computers alike is driving a roughly 40 percent annual increase in data traffic per user.

In many markets, the current 3G networks are approaching the limits of their broadband capacity. As such, operators are working to implement 4G technologies, which will offer higher speeds and more stable connections. From a semiconductor point of view, this network upgrade should require upgraded memory as well as increased use of MIPS Technologies chips in both application processors and baseband systems. There will also be need for additional transport ports to support backhaul traffic. Logic chips will be in demand to support more sophisticated applications on next-wave smartphones and tablets. Power-management technology will also benefit, as these more sophisticated devices will support multitasking. Finally, additional features will be embedded in microprocessors, such as dedicated GPS modules. Taken together, we estimate the opportunity for semiconductor companies in the race to equip and implement next-generation wireless networks will add as much as $17 billion to industry revenues by 2015.

### The rise of immediacy

While the need for real-time data has largely been confined to niches such as the stock market or in corporate sales dashboards, the notion of dynamic data flows is spreading to other corners of the economy. Given the state of sensor technology, we feel there is a fundamental shift in modes of work coming. Among the industries to be revolutionized: health care, packaging and logistics, and consumer electronics (Exhibit 3).

Rising health care costs are driving demand for low-cost, home-based medical devices. We estimate this opportunity will be worth roughly $2 billion by 2015. Remote monitoring of blood pressure or glucose levels is another hot corner of the market. Our analysis indicates that the market for connected home-monitoring devices could be worth $2 billion to $3 billion in three years. Further down the line, a generation of smart

Exhibit 3

## Immediacy will change the way business is done.

| **Immediacy examples**[1] | **Description** |
|---|---|
| Health care | • Rising health care costs are driving the market for low-cost, home-based medical devices<br>• Intelligence will be incorporated in current "dumb" devices, as well as new devices, to enable better and new treatments |
| RFID[2] | • With technology maturity and active tags overcoming the limitations of passive tags, RFID will find increasing use in many applications |
| MCU[3] | • MCU will become the center of a smart-sensor device with integrated connectivity, memory, and low-end analog components |

[1]List is not exhaustive.
[2]Radio-frequency identification.
[3]Microcontroller.

Source: *RFID Journal*; McKinsey analysis

hospital devices will appear. Simple medical devices will increasingly incorporate computing power. An example of this might be digital monitoring of in vitro fertilization. It isn't easy to estimate the impact of these smart medical devices yet, but the broader medical-device market is large enough that semiconductor companies should monitor this developing opportunity. By 2020, there will be semiconductor-enabled devices for a range of products, such as artificial eyes or brain implants. Those two examples are, in fact, in clinical testing in Germany. The medical devices of the future will also employ LED lighting displays, making this a significant opportunity for companies in that subsector.

With regard to packaging and logistics, passive radio-frequency-identification (RFID) tags are already in wide use. But the next wave of so-called smart RFID tags will enable real-time location of products, trucks, and the like. It will also be the basis of patient treatment mapping in health care facilities. Over time, smart RFID technology should allow for development of analytics-driven retail operations in a range of categories. It should also permit sophisticated authentication of goods, from pharmaceuticals to apparel. This evolution will power additional growth in what is already expected to be a $16.5 billion sector this year.

The microcontroller (MCU) market is also expected to grow rapidly over the next three years. These low-power systems on a chip are already found in automobile engine-control systems, appliances, power tools, and toys. Recent advances in low-power radio circuits and core processors will enable a new wave of smarter smart devices, from cable set-top boxes to connected TV sets. These chips will also power over-the-top video and audio services and smart Blu-ray players. While 33 percent of today's MCU market is higher-end 32-bit ARM MCUs, we project that the chip's share will increase to 53 percent five years from now.

In total, we believe the immediacy trend will be worth about $16 billion to the industry over the next three years. That is only a little behind the $17 billion from next-generation wireless upgrades, meaning it is an important revenue opportunity for many types of chip makers.

### The cloud

By 2015, cloud computing is expected to account for nearly 20 percent of global IT and application spending. That figure may seem low. But with many companies pursuing the development of private clouds, and given the generally slow uptake of public offerings, the cloud is having less impact on IT spending than might be assumed. In the longer term, the shift from the corporate data center, enterprise storage, and the PC to thin-client computers running applications stored in the cloud offers a narrower opportunity for semiconductor companies than other trends.

Enterprise-server sales are forecast to decline, thanks to server virtualization and greater efficiency resulting from the implementation of multicore processors. Storage servers will decline more modestly because they are still needed to move data between workstations and the cloud. Obviously, there are fewer reasons to buy a PC when a tablet could effectively take its place.

There are other corners of the market that will face pressure given this migration. Analog and logic components are likely to see decreases in sales volume as virtualized servers shrink the data-center stacks.

As the trend plays out, we view it more as a reallocation than a disruption. Demand for flash memory will increase as companies move from PCs to thin-client machines. We also expect sales of networking gear to rise as both wired and wireless infrastructure are upgraded to take full advantage of the cloud. Other categories should benefit, too, such as 32-bit MCUs, optical and other sensors, discrete chips, disk-drive and network-storage controllers, radio-frequency components, Ethernet controllers, and attenuators; all are likely to see modest growth over the next three years. Our analysis indicates the cloud opportunity will be worth a net $6 billion in additional revenue for the semiconductor industry by 2015 (Exhibit 4).

## Bringing it all together

All four trends offer powerful opportunities for revenue growth. However, this is not the moment to rally the troops with a hearty “full speed ahead!” Instead, semiconductor companies will benefit from careful analysis of the microsegments that stand to benefit the most. Targeting the microsegments that present the deepest profit pools will require a proper strategy, as well as a granular understanding of the market and the competition.

Investigating opportunities in adjacent areas, such as software or services, is another priority. Distinctive software offerings can become a genuine competitive advantage; these are not simply table stakes. Such products also create a real opportunity for companies to differentiate themselves from competitors.

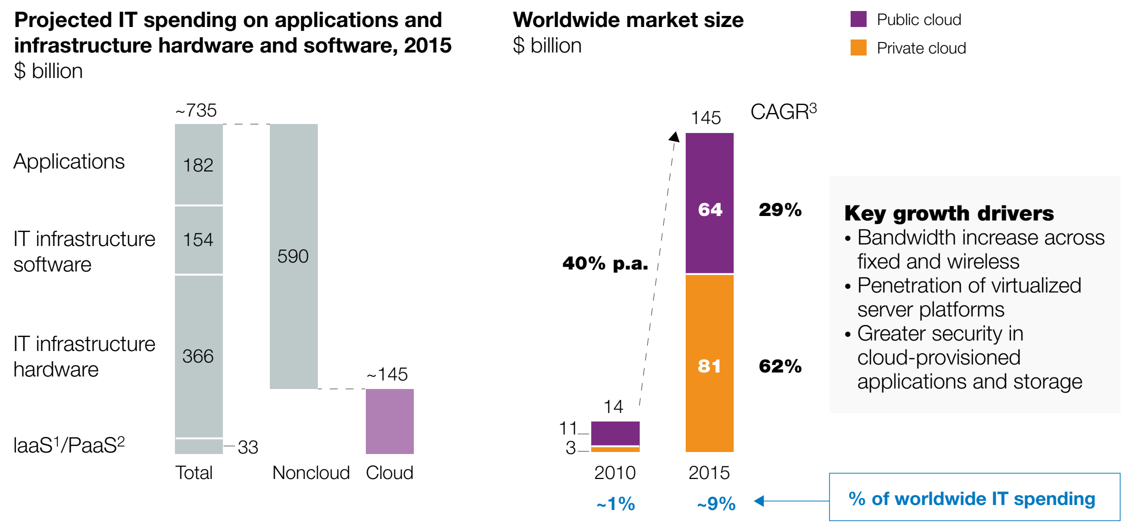
Questions of where to play are not the only concern; how to play is also vitally important. New capabilities may be required for a semiconductor company to take a leadership position in an attractive sector. For example, is the organization aligned with the new strategy? Are current sales capabilities enough to tap into new

Exhibit 4

## Cloud growth could yield $6 billion in additional revenue for the semiconductor industry.

Cloud makes up ~20% of 2015 infrastructure and application spending…

…and adoption is on the rise, with private clouds growing at twice the rate of public clouds




[1]Infrastructure as a service.
[2]Platform as a service.
[3]Compound annual growth rate.

Source: Bank of America Merrill Lynch; Forrester; Gartner; IDC; interviews of chief information officers (CIOs); McKinsey Cloud Initiative; McKinsey survey of CIOs and chief technology officers on cloud computing; McKinsey database on value migration

markets? It is also important to make sure that it is safe to pursue the selected opportunity and that doing so will not put large parts of the current business at risk. The proper marketing and sales strategy will continuously move a chip maker closer to its end customers. And the feedback from those customers must shape a new wave of products to increase the stickiness of the company's offerings. Last, getting the operational aspect of pursuing these opportunities right will be key. In many semiconductor markets, the winner takes all, so the difference between peak performance and second or third place can amount to significant amounts of money earned—or lost to competitors.

• • •

With almost $100 billion in new sales coming over the next three years, there is reason to pursue these trends with care and focus. Breaking the $300 billion barrier was a big achievement, but it is already time to set out for a higher peak. With the right R&D efforts, the right products, and the right strategy, the semiconductor industry's best days will be still ahead.

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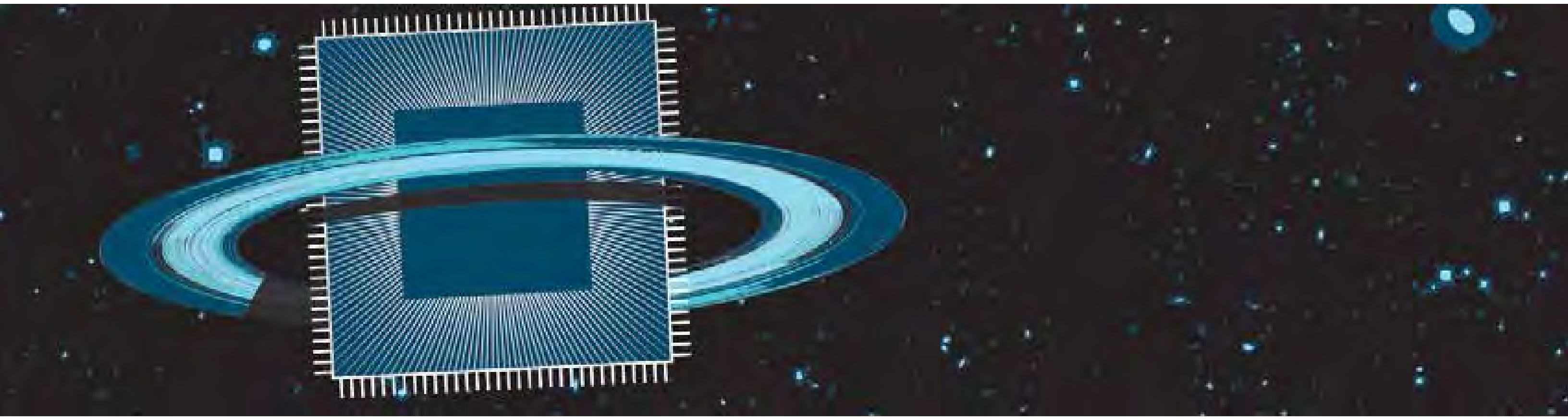


# The supercomputer in your pocket

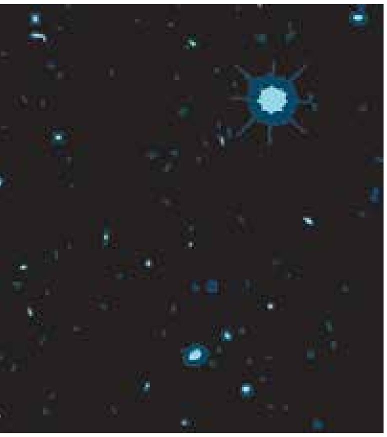
**Over the past decade, the computing landscape has shifted from beige boxes under desks to a mix of laptops, smartphones, tablets, and hybrid devices. This explosion of mobile CPUs is a profound shift for the semiconductor industry and will have a dramatic impact on its competitive intensity and structure.**

**Harald Bauer, Yetloong Goh, Joseph Park, Sebastian Schink, and Christopher Thomas**

The shift toward mobile computing, at the expense of tethered CPUs, is a major change that has raised the competitive metabolism of the semiconductor sector. Mobile, now the central battleground of the technology industry, is having an intense impact on the larger semiconductor landscape. Mobile-computing processor requirements now drive the industry, setting design requirements for transistor structures, process generations, and CPU architecture. It's the must-win arena for all the semiconductor sector's top companies. Over the next half decade, leading players will spend hundreds of billions of dollars on R&D.

Two major contests will play out for semiconductor vendors competing in the mobile arena: the clash between vertical-integration and horizontal-specialization business models, and the clash between the two dominant architectures and ecosystems, ARM and x86. Each of these battles will be explored in detail below.

More and more smartphones are as capable as the computers of yesteryear. Laptops have displaced desktops as the most popular form factor for PCs, and, thanks to the success of Apple's iPad, tablets have stormed into the



marketplace. PC original equipment manufacturers (OEMs) aren't waiting to lose consumer share of wallet to tablets. Instead, they are generating a wide range of new form factors. For example, hybrid computers—those with attributes of laptops and tablets in one device—are on store shelves across Asia. Combination machines are coming to market. Intel is pushing "ultrabooks," which combine aspects of both tablets and traditional PCs.

Over the next five years, we expect mobile phones, tablets, portable computers, and new hybrid devices to dramatically exceed overall industry growth. Adjacent technologies that feed these mobile CPUs are growing fast, too. Cisco reports that global 3G network rollouts have helped increase mobile traffic by a factor of 2.6 from 2010 to 2011, the third straight year of such rapid growth rates. Changes in the types of data transmitted over these networks, as well as an increase in wireless speeds, will drive additional demand for mobile processing. In 2011, mobile-video traffic accounted for more than 50 percent of all data traffic. The use of video, which is more processing intensive than static text or pictures, dramatically increases the level of sophistication required in mobile-device CPUs. What's next? Operators are now launching 4G technologies; Cisco says that the average early adopter of a 4G phone downloads 28 times more data than a 3G phone user.

Based on analysis of current trends, we expect fivefold growth in smartphone unit sales by the beginning of 2016. Tablets, another booming category, are expected to grow threefold, and the connected PC segments should see unit sales double in that time frame. If Moore's law, which assumes a doubling of processing power every 18 months, holds the same path for the next few years as it did for the last 40, the global, mobile CPU processing power of the installed base could grow 40- to 60-fold between 2011 and 2016 (Exhibit 1).

This massive growth provides a compelling opportunity for the semiconductor industry—but also leaves it facing two inflection points. Executives should take note because these types of transitions have again and again upset the competitive order, leading to new winners and losers.

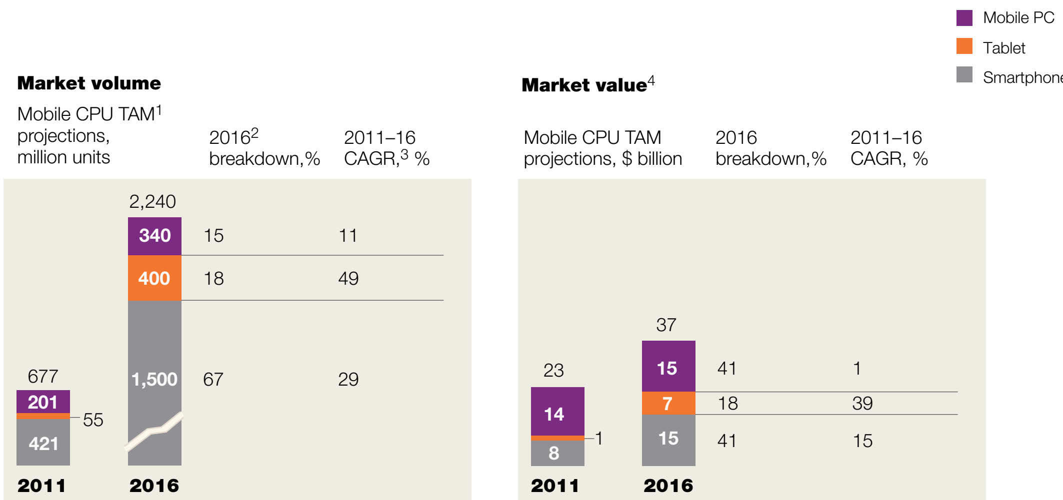
The first of these transitions is the serious challenge that Apple, Samsung, and others pose to the merchant silicon business model. An industry that has long accepted a horizontal business model is now revisiting vertical integration through the internal chip development occurring at some of its largest players.

At the same time, the two formerly separate worlds of the ARM and x86 architectures have grown into direct competition. Previously, these two CPU ecosystems largely moved in parallel, holding dominant positions in separate product lines with different customers. Further complexity is added as mobility changes the rules of traditional CPU technology competition. In small devices with limited battery density, mobile CPUs cannot fully benefit from the performance improvements of Moore's law; the power drain would be prohibitive.

Given this state of affairs, there are two issues that each semiconductor company should consider. The first is the competition between

Exhibit 1

**The growth rates for mobile devices with advanced CPU processing requirements are strong.**




[1]Total addressable market.
[2]Estimated.
[3]Compound annual growth rate.
[4]Includes value for application processor/CPU; wireless baseband (discrete or integrated) is excluded.

Source: ARM; DB Market Research; IC Insights; iSuppli; McKinsey analysis

two different models for industry structure, vertical or horizontal. Next, there is the battle between competing technical architectures, which pits x86 against ARM. The resolution to each of these debates will go a long way toward separating the winners from the losers in the years ahead.

## Competing industry structures

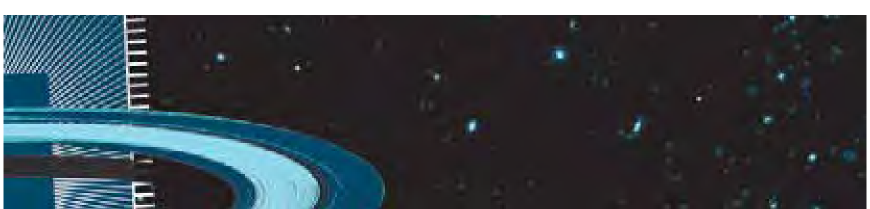
When smartphones first appeared in the market, each handset vendor had its own software stack and distinct sets of services, and players looked to differentiate themselves through hardware features. Different OEMs created distinct products, and proprietary technology created a barrier to entry for low-cost players.

Then Android emerged. As an open operating system, Android leveled the playing field, introducing both a standardized user experience and hardware specification. This allowed new low-cost players such as Chinese handset makers to develop products with a look, feel, and capabilities similar to those of the established players. The rules of the phone game changed—making it much more similar to the PC arena, where Intel and Microsoft drive the technology cadence and OEM differentiation is limited. The popularity and mass adoption of Android has required smartphone vendors to find new sources of differentiation. If they can't crack the code, these OEMs may be perceived as little more than product assemblers, with corresponding low margins.

Apple and Samsung, who collectively held over 50 percent share of the smartphone and tablet markets in 2012, have been winning with a different approach. They used their internal control of key CPU technology to provide differentiated customer experience to their device users. Apple assembled a silicon design team and began designing ARM-based custom CPUs for smartphones, with manufacturing performed by external foundries. Samsung, the world's number-two semiconductor vendor, expanded its design and manufacturing capabilities to smartphone and tablet CPUs. In today's system-on-a-chip (SOC) world, these two OEMs realized that the CPU *is* the system and thus they needed their own CPUs to truly differentiate their products.

This approach also gives the companies greater negotiating leverage with the leading merchant silicon vendors such as Intel, NVIDIA, Broadcom, MediaTek, and Qualcomm. Following this lead, others are increasingly looking to bring chip design back in-house. Both Microsoft and Google launched branded tablets in the second half of 2012. While both are powered by merchant silicon, these "software" companies are taking strict control of hardware specification and directly engaging CPU vendors for specific features.

This is a new and significant challenge to traditional merchant silicon vendors. First, it reduces their revenue opportunity. Second, and more important, it removes them from their traditional position of defining and driving the leading edge of product design; leading OEMs are pushing the envelope just as fast as the CPU vendors are.



Despite this shift toward internal design, the merchant markets are still robustly competitive. They maintain the greatest share of the chip market and the greatest concentration of technology capability. Merchant players are still providing complementary technologies beyond the CPU, such as baseband chips or analog silicon, that appear in top products from Samsung and Apple. In addition, merchant chip vendors still hold traditional advantages. First, their higher collective volume gives them scale advantages. They can develop technologies that extend into product lines and technologies far more diverse than any one OEM could support. They can push their technology cadence as fast as possible and provide that technology to multiple competing OEMs that iterate it and deploy it collectively across many devices. Vertical players, on the other hand, have stand-alone OEMs that must tackle all the technical and market hurdles individually. Merchant silicon vendors can also focus solely on making great silicon, rather than designing and manufacturing a full consumer end product. Finally, many mobile devices require CPUs to be integrated with other components such as digital-baseband chips—technologies that OEMs such as Apple, Samsung, ZTE, and others do not currently possess.

OEMs that attempt to control all aspects of their silicon may swim against the tide of history. All high-growth computing markets with rapid technology cadences have eventually adopted the horizontal silicon model; it has simply been too hard for integrated players to keep up. Apple, Samsung, and others will have expensive and technologically difficult challenges in aiming to win consistently against the merchant silicon players over the longer term.

## Competing architectures

All the growth in mobile computing over the last two decades has been driven by the x86 and ARM architectures. For more than 30 years, the x86 microprocessor instruction set architecture (ISA) has been the technical foundation of the personal-computing industry, and for the last 15 years, it has powered the Internet and server ecosystem. Intel, with about 80 percent market share of x86 CPU shipments, and Advanced Micro Devices (AMD) have been the drivers behind this architecture.

Recently, the ARM ISA, developed by ARM Holdings, has grown to match and, in some ways, exceed the scale and scope of the x86-based computing industry. Using a very different business model, the ARM ecosystem has shipped more than 15 billion ARM-based CPU and microcontroller chips in the last five years, and its sales are growing at a 25 percent annual rate. Traditionally, these two ISAs have not competed against each other directly as they served different end markets: x86 targeted personal computers, servers, and high-end embedded-computing applications, while ARM offered power-efficient chips for mobile phones, tablets, and microcontrollers.

Could ARM, a midsize company headquartered in the United Kingdom with fewer than 2,000 employees and a bit more than $700 million in annual revenue, actually thwart the ambitions of the company that has been the number-one semiconductor manufacturer for over 20 years? Or will the x86 architecture, the mainstay of personal computing since the Intel 8086 processor launched in 1978, conquer one more end market?

### Converging road maps

This architectural battle has been the subject of speculation and controversy for years in the semiconductor ecosystem. Yet 2012 may be a tipping point, the year a theoretical discussion becomes a real one (Exhibit 2).

In the past, economies of scale and learning effects—the fact that semiconductor design and manufacturing knowledge accumulates through previous generations and becomes a core asset required to make the next generation of designs—have tended to create winner-take-all dynamics for hardware architectures. In each market, one architecture has won, by far, the largest market and profit share.

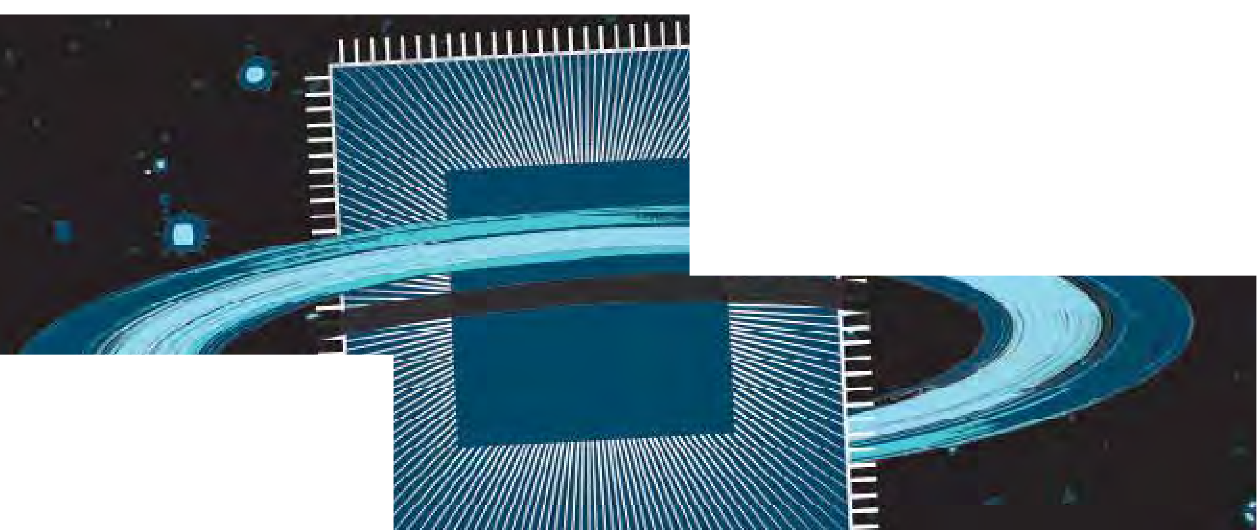


Exhibit 2

## In 2012 and beyond, the leading PC and smartphone operating systems will work on both x86 and ARM architectures.

Mobile-device shipment by operating system (OS), %[1]

x86 only
ARM only
Both x86 and ARM

| | | 2008 | 2011 | OS landscape beyond 2012 |
|---|---|---|---|---|
| **Portable computers** | Microsoft | 94 | 93 | Ported to ARM |
| | Mac OS X | 4 | 5 | No public announcements |
| **Tablets** | iOS | N/A | 70 | No public announcements |
| | Android | N/A | 26 | Ported to x86 |
| | Microsoft | N/A | <5 | Ported to ARM |
| **Smart-phones** | Android | N/A | 49 | Ported to x86 |
| | iOS | 9 | 18 | No public announcements |
| | Microsoft | 14 | 4 | No public announcements |
| | Symbian | 50 | 16 | No public announcements |
| | BlackBerry | 16 | 11 | No public announcements |

[1]Figures do not sum to 100% because "other" category has been excluded.

Source: Gartner; McKinsey analysis

### Clashing ecosystems

We believe the robustness and success of each architecture's ecosystem—the OEMs, original design manufacturers, and software vendors that build the device and services around a chip—will determine the outcome, rather than technical superiority. The robustness of the ecosystem hinges largely on the different business models of the two architectures.

There are three key criteria to assess the success of each business model. First, which architecture's technical ecosystem will have the greatest amount of engineering resources to drive the technology forward? Second, which will attract the most capital to fund increasingly expensive and difficult technology development? Third, which will be most successful in encouraging OEMs and software vendors to build innovative devices with the architecture?

It is ironic that in the current competition, ARM is now playing the role that the x86 architecture played in previous battles with proprietary mainframe and server CPUs. The x86 architecture built a foundation for standard hardware platforms. Many different OEMs and software providers then built industry-standard products around that ecosystem. This model has been successful, for the most part, displacing any vertically integrated system that challenged it.

However, as system architectures move from ones with discrete CPUs to SOCs, the CPU itself becomes the system (Exhibit 3). In a SOC model where a CPU core is surrounded by integrated peripherals such as switch fabrics, graphics processing, embedded flash memory, and multimedia processing, all on the same silicon die, the ARM CPU takes the role of a standard platform. Multiple chip-set vendors build SOCs on top of ARM cores, integrating their own and other vendors' intellectual-property (IP) "blocks" to make final products. Multiple wafer-fabrication facilities can then produce the final chip.

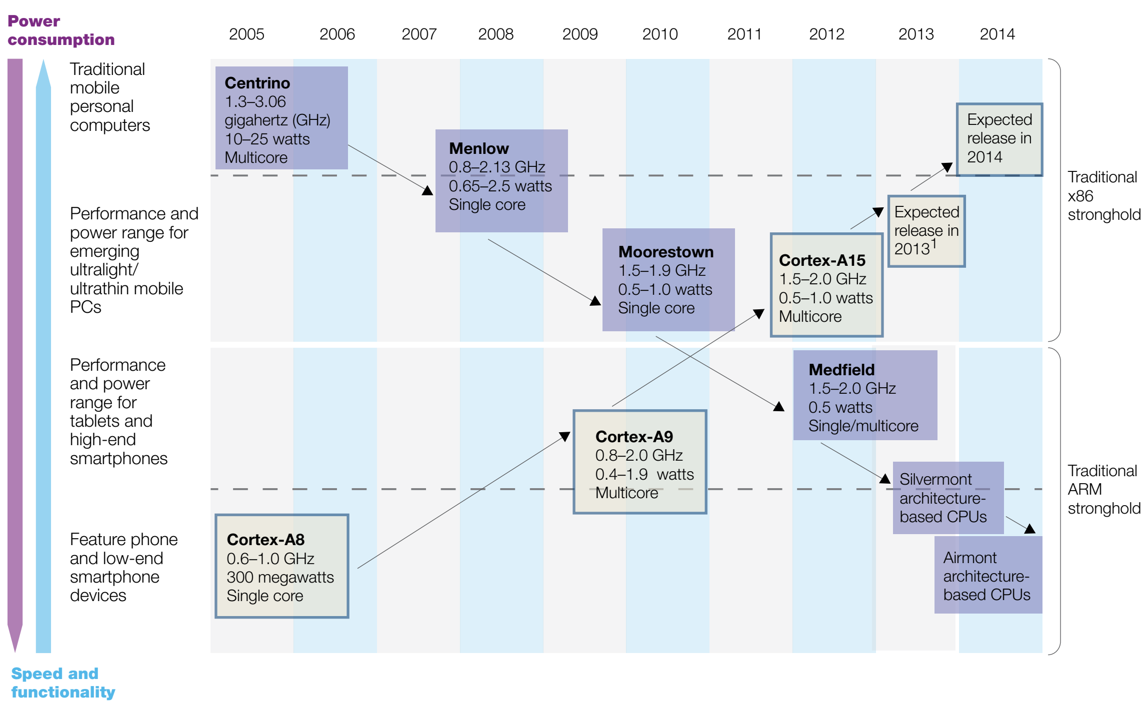
In x86, Intel and AMD are dependent primarily on their own engineers to develop these additional IP blocks. They must also integrate them into SOCs and develop the process technology to manufacture the chips containing those IP blocks. And they must depend solely on their own sales volume in mobile CPUs to fund process-technology development and manufacturing capacity.

## Clashing business models

The cost to develop the most advanced microprocessors has risen dramatically—from as much

Exhibit 3

## Intel and ARM are moving into each other's strongholds.




[1]ARM Holdings has not publicly announced its 2013 and 2014 product road map; Intel has announced it 2012–14 Atom product line microarchitecture road map, but no detailed product specifications.

Source: "A guide to mobile processors," The Linley Group, August 2012; Gartner ARM investor reports; product specifications as $4 billion to build one scale-capacity manufacturing facility with associated process development at 65 nanometers (2008–09 technology) to as much as $10 billion at 22 nanometers, the current leading edge. This figure will continue to grow through future technology generations. The increasing performance requirements of mobile devices will continue to demand the latest semiconductor technology. The technical and funding challenge is so large that, in 2012, the largest semiconductor players, including Intel and TSMC, began sharing some of the load via joint investments in the leading lithography tool vendor, ASML.

Despite a few instances of some joint cost sharing, under the current x86 business model, Intel and, to a lesser extent, AMD are required to fund the majority of these technologies internally. These two companies will be required to develop the process technology, build the factories, improve the microprocessor microarchitecture, develop complementary silicon IP to support the core CPU function, and figure out how to integrate all these elements. Intel certainly has the financial and technical capability to do this.

However, ARM will use a different model to approach this investment requirement. There are 15 ARM foundry licensees, and each can work to develop the best process technology to manufacture ARM-based CPUs. There are more than 275 ARM core licensees, and the design team for each can use diverse methods to solve technical problems. These licensees collectively have between 60,000 and 100,000 engineers driving forward ARM semiconductor technology, which is most likely more than the total number of engineers working at AMD and Intel directly on x86 technologies.

ARM licenses its technology using two primary mechanisms: the first is a set of microprocessor core/ISA licenses that enables chip designers to build application processors. The second is a physical IP license that enables third-party foundries to manufacture these cores and related IP blocks. The broad number of licensees enables ARM to be customized and sold into many different markets, whether large or niche, and it ensures vibrant competition among ARM chip vendors. That competition also enlarges the technology road map, as multiple design teams across the ARM ecosystem will try different implementations to solve end-customer problems.

License flexibility allows fabless semiconductor players to customize their own business model. Marvell and Qualcomm, for example, invested in architectural licenses by purchasing the ARM v7 ISA. This license has in turn enabled them to invest in custom ARM CPU cores. In one case, Qualcomm's Snapdragon product uses a customized and proprietary Krait CPU core, which the company claims has better performance than standard ARM Cortex-A8 CPUs. Other mobile CPU vendors make circuit-level modifications to the ARM standard core to improve performance without having to build a proprietary stand-alone core.

Each licensee's business-development and sales organization can experiment with a variety of business models and search for new customers. At the same time, the open model drives competition, advancing ARM technology and creating challenging dynamics for CPU vendors. There are often five to ten highly capable ARM-based CPU vendors competing for the same "socket" in a new OEM phone design.

ARM-based CPU designers have a wider range of CPU core IP from which to choose because ARM does not carry any manufacturing overhead when offering its legacy cores. ARM offers the higher-performance, higher-power dissipation A15 core as well as the much lower-power, smaller A7 companion core specifically for phones. (It should be noted that even older, general-purpose, lower-power cores can be used in these designs.) As a result, chip designers have a range of options for partitioning computing tasks. For instance, in an integrated CPU baseband chip, a legacy, low-power core can manage telephony (making and receiving calls), while a new, higher-performance core handles Internet access and video.

Intel's model may have less diversity, but the company believes this simplicity and focus on industry-standard platforms gives it unmatched agility and speed in technical development. Intel's chairman, Andy Bryant, has spoken often about how the company's integrated business model, in which "everybody works for the same owner," helps it move faster than the multi-headed ARM ecosystem and allows it to more thoroughly transfer knowledge while keeping the technology proprietary, thereby producing the unique benefit to those using Intel's products. The company can use its unmatched scale to transfer this technology leadership broadly and rapidly to the whole industry in a way a single, smaller ARM CPU vendor cannot. This scale allows technology innovation to diffuse much faster into the OEM ecosystem, and it creates a "level playing field" for OEMs with regard to raw hardware features, enabling them to compete on other factors such as branding, supply chain management, software, and device user experience (Exhibit 4).

## Clashing technologies: Convergence and competition

Beyond the rather stark differences in business models, each architecture brings different technical strengths to bear. Technology still matters, and CPUs are highly complex products—among the most difficult products in the world to design and manufacture. However, the technology competition between ARM and x86 will not only be about which architecture is technically "more efficient" or "better" for mobile computing. It will primarily involve what happens beyond the actual CPU architecture. We believe there are four key success factors required to build a better CPU chip; we can examine how each architecture currently stacks up in these dimensions.

*CPU microarchitecture.* Fundamental differences between x86 and ARM CPU cores remain, but those will lessen over time as each architecture works to adopt the best technical features of the other. ARM has always possessed less power than x86 because of its reduced ISA, which resulted in much lower performance. As ARM increases its processing capability to match the requirement of new mobile devices, it is adopting x86 core technologies such as multicore chips and deeper processing pipelines. Historically, ARM chips were much smaller than x86 CPUs. However, with the emergence of the low-end Atom architecture

## Exhibit 4

### The x86 mobile-device value chain is more integrated than that for ARM.

| | x86 ecosystem | ARM ecosystem | | OEMs[2] that use both x86 and ARM (announced products) |
|---|---|---|---|---|
| Instruction set and CPU core | Intel<br>Advanced Micro Devices (AMD) | ARM | | |
| Additional processing blocks and CPU core modifications | | Qualcomm<br>ARM<br>Texas Instruments<br>Mentor Graphics | Synopsys<br>CEVA<br>Imagination Technologies<br>Marvell | |
| System-on-a-chip integration | | Qualcomm<br>MediaTek<br>Texas Instruments<br>NVIDIA | ST-Ericsson<br>Broadcom<br>Samsung<br>Apple | |
| Chip fabrication[1] | Intel<br>AMD<br>GLOBALFOUNDRIES | Taiwan Semiconductor Manufacturing Company<br>United Microelectronics Corporation<br>SMIC<br>Samsung<br>GLOBALFOUNDRIES | | |
| Operating systems | Microsoft<br>Android | Android<br>iOS<br>Symbian<br>BlackBerry | Microsoft | |
| Other equipment manufacturers | Hewlett-Packard<br>Acer<br>Dell<br>ASUSTeK Computer | Nokia<br>HTC<br>ZTE<br>Samsung | Huawei<br>Sony Ericsson | Apple<br>Motorola<br>Lenovo |

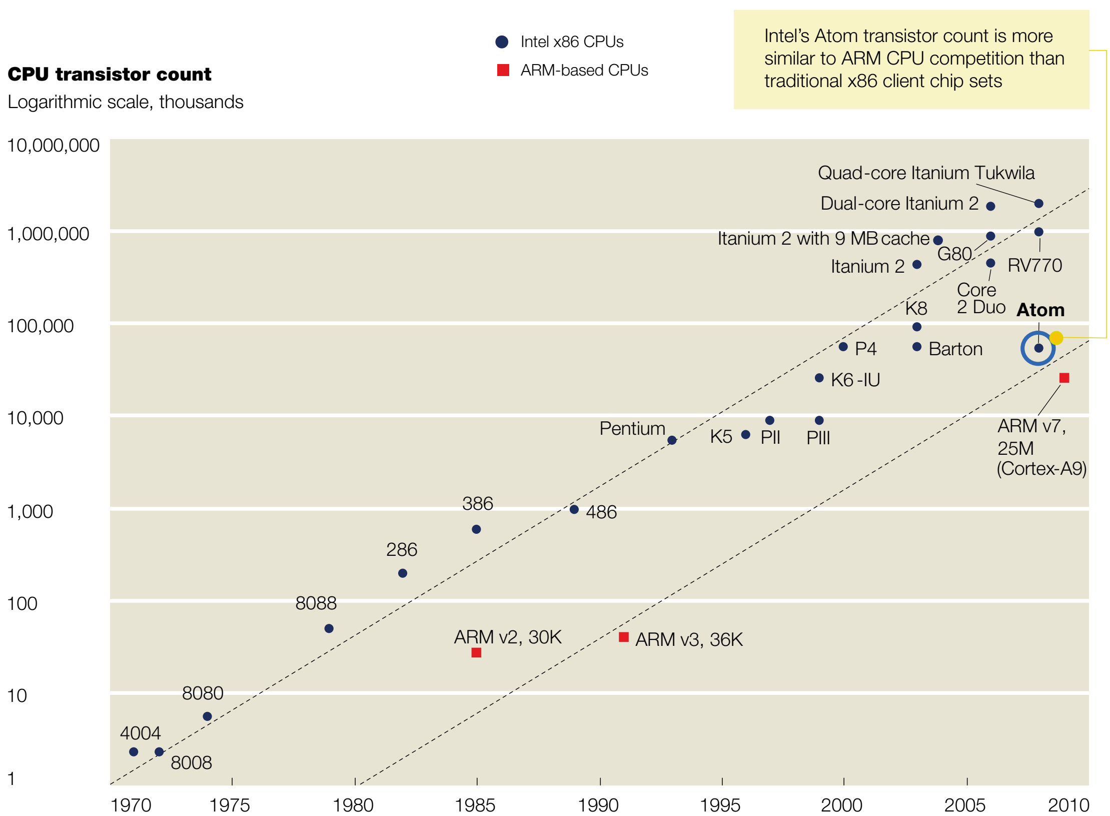
[1]Other ARM-licensed foundries include Chartered Semiconductor Manufacturing, Dongbu HiTek, IBM Microelectronics, TowerJazz, and Vanguard.
[2]Original equipment manufacturers.

from Intel and the increasing transistor count in ARM chips, the physical sizes of cores are converging, from the low end of x86 to the high end of ARM (Exhibit 5).

*Process technology.* By moving from one semiconductor manufacturing node to the next with smaller transistors, CPU products can gain 20 to 40 percent in performance, translating into lower power or lower cost than previous generations—or a combination of both. Intel has been the process leader for decades, traditionally holding a 12- to 18-month lead over major competitors in moving to a new generation of process technologies. It also ramps new technologies much faster than foundries, which maintain a significant amount of volume at lagging-edge lithographies. However, because there are more foundries pursuing the ARM business, they can offer a greater variety of process recipes (such as low-power processes focused specifically on maximizing battery life) than can Intel alone. The technology transition to smaller and smaller technologies will not be easy,

Exhibit 5

## The transistor count in ARM processors has increased, growing closer to that for traditional x86 CPUs.




Source: ARM; Intel; Sanford Bernstein; McKinsey analysis and it poses several hurdles. Intel began shipping 22-nanometer process products based on 3-D transistors in the second quarter of 2012, while the ARM ecosystem was only at 28 nanometers. If Intel can maintain or even extend this technology lead, its x86 products will possess greater processing or power-saving capabilities than ARM-based competition.

*CPU and wireless-baseband integration capability.* As mobile devices get smaller and price competition increases, there are size, power, and cost advantages to reducing the number of semiconductor chips. In basic and feature phones, all CPUs are integrated into wireless-baseband semiconductors that control the phone's communications. Personal computers and tablets have discrete semiconductors for CPUs and wireless basebands. Smartphones have both integrated and discrete configurations. ARM-based CPU vendors with discrete and integrated configurations can offer greater breadth in CPU products to OEMs competing in different categories across all mobile devices. The ARM-based CPU vendors can simplify the software-integration task that the device seller will have to undertake to make a radio work with a CPU. To that end, Intel purchased Infineon's baseband business in 2010 and has the option of integrating x86 CPUs and basebands. However, ARM-based vendors Qualcomm (which had 43 percent market share through the fourth quarter of 2011), MediaTek, Spreadtrum Communications, Broadcom, and Intel's Infineon division—the top five baseband suppliers—already sell a complete portfolio of integrated ARM CPU products. Intel's x86 product line will need to master the technically difficult task of logic and wireless integration to catch up to ARM. Qualcomm's 60 percent or more of 3G baseband share makes this an uphill climb. As such, Intel's integrated products have to take share from an ARM-based competitor with a highly defensible installed base.

*Application compatibility.* Consumers purchase a device because of the software and applications it can run. Application programmers write to an application environment or operating system—not an ISA. In the past, x86 and ARM have supported different operating environments for different applications. However, that distinction is fading, as both architectures are working to fully support all programming environments across all mobile devices. In fact, 2012 is proving to be the year in which cross-architecture operating-system compatibility becomes reality. By the end of 2012, all the major operating systems (for example, Android, Windows, and Windows Phone) and application environments (such as Flash, HTML5, and Webkit) will work on both architectures. Much like in the vertical-versus-horizontal debate, Apple could be a swing vote; it has been reported that Apple is also porting its iOS and Mac OS operating systems between the two architectures, but the company has made no public announcements on the matter.

Operating systems supporting both architectures use a "middleware" framework that abstracts the hardware from the software, making the end applications run on both architectures with minimal difference in performance. Android's system-development kit (SDK), for instance, allows developers to write applications that work on any Android system, regardless of the CPU. Certain high-performance applications for gaming or multimedia processing use native Android software code—not the SDK—to leverage application-programming-interface command sets to maximize processing performance. While we expect Android and other operating systems to provide supplementary middleware allowing developers to write one set of native code that will work on both architectures, software translation always involves processing overhead and reduces performance. If one architecture is able to gain the lion's share of natively developed applications, the other will be able to maintain application compatibility, but at a performance cost.

## Looking to the future

Where does this leave us? One view of the future sees Apple and Samsung extending their lead and deepening their investment in semiconductor capabilities that were once solely owned by merchant silicon vendors. Samsung could enter the wireless-baseband market through acquisition or internal development, or Apple could partner with a semiconductor foundry to develop proprietary access to new process technologies. Other OEMs may well follow these paths and the semiconductor industry could become primarily a vertically integrated, OEM-driven market. For this model to be successful, vertically integrated players would need to keep their market shares high to justify the technology investment, while driving the CPU technology as fast as the best merchant silicon vendors would.

Alternatively, the Chinese smartphone vendors, the smaller global OEMs and the global PC manufacturers could break this global smartphone-tablet duopoly with the strong support of Intel, Qualcomm, and other merchant silicon players, leaving the horizontal model supreme.

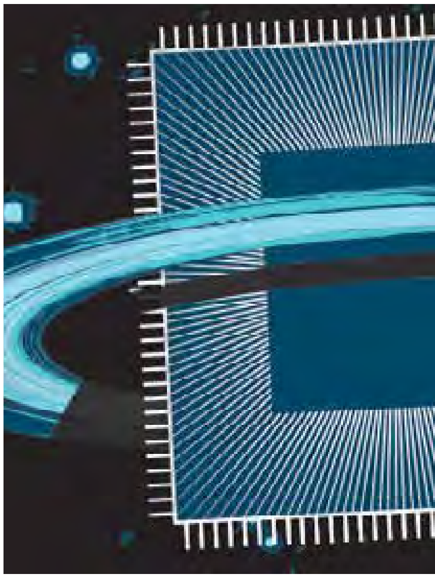
The x86-versus-ARM architectural battle is a multiround game. Both the ARM and x86 ecosystems have the financial model, the annuity cash flows, and the technology base to compete in the mobile-computing space for the next five years. Intel and AMD's revenue exceeds $50 billion, with about $15 billion in operating cash flow. ARM's annual revenue is modest, at about $700 million, but its partners generate $30 billion to $50 billion in silicon revenue—enough to drive multiple generations of process technology and new designs. Both architectures can fund investments to advance their design and process technologies for several years without prevailing over the other architecture in the battle to dominate the mobile-computing landscape. With such rapidly expanding consumer demand, even the "losing" architecture could still see revenue growth. ARM's best chance for success will not be achieved through displacing x86 from its traditional home, PCs, but rather through the expectation that ARM-based tablets and smartphones will cannibalize PCs. The x86 camp's best chance would be if Intel builds a sustainable lead in process technology to create products for its growth markets of smartphones and tablets with unmatched performance and power dissipation. These products would need to be so good that leading OEMs had to adopt them, despite the challenges of adopting a new architecture.

However, even if one architecture gains the upper hand, every new CPU product launch, every new version of Android or Windows, and every device-level transition is an opportunity for an OEM to choose a new architecture. For one architecture to truly triumph over the other, either ARM or x86 would need to string together an unbroken set of "transition wins" over many years to develop a permanent lead that convinces the other architecture and its ecosystem to accept a secondary role.

This increased competitive intensity in the semiconductor industry will drive an increase in the competitive metabolism of the device industry. The heightened competition will also drive consolidation along the ARM value chain, either by vendors exiting the market or shifting their design focus from mobile devices to other promising markets, such as Texas Instruments' recent announcement that it will focus its ARM-based CPU business on home networking and machine-to-machine communications.

• • •

Technology transitions have always created winners and losers. The mobile device industry is experiencing several changes right now, as the conversion from feature phones to smartphones reaches its apex, tablets move from a niche to a must have, and semiconductor industry participants face the most expensive and hardest-fought battle in their history. Semiconductor industry players need unmatched market insight, aggressive technology road maps, world-class business development, and operational excellence just to punch their entry ticket to compete in this arena, and the winners will need to combine all four elements (and perhaps a little luck) to emerge victorious. ○



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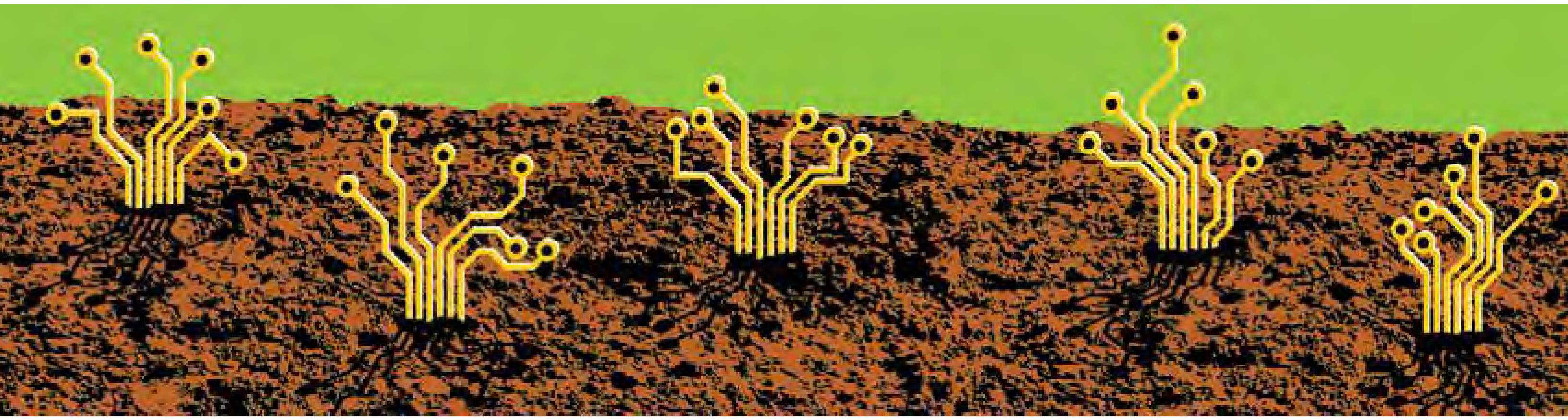


# What will enable alpha growth?

**A metric known as alpha growth measures a company's ability to grow faster than its market. Traditionally, semiconductor companies haven't stacked up well against players in other industries when it comes to this indicator—but there are ways to close the gap.**

**Aaron Aboagye, Sri Kaza, Rajat Mishra, and Nick Santhanam**

There are many ways to measure a company's performance, but few that are as powerful as alpha growth, which is a term used to describe a company's ability to grow faster than its market. After all, as the old saying notes, a rising tide lifts all boats. But there is real value in knowing which boats rise the fastest. As discussed in *The Granularity of Growth*,[1] we consider the portion of growth that doesn't come from portfolio momentum to be alpha growth. (The term is based on the definition of alpha in the investment world, that is, the risk-adjusted return of an investment above and beyond the return created by the market as a whole, known as beta. This sort of alpha is seen as a measure of manager skill in a hedge fund, mutual fund, or similar investment vehicle.) What are the ingredients of alpha growth? Essentially, three elements that require active leadership from the management team must be combined: gaining market share by defining new markets or expanding into related or adjacent markets, ensuring superior execution in sales and product development, and selectively deploying M&A skills to enhance revenue growth through targeted acquisitions.

In a wide range of industries, we have found the alpha-growth metric (measuring nonportfolio-based momentum) accounts for roughly 55 percent of long-term growth. The semiconductor industry, however, is a laggard, with only about

[1] In *The Granularity of Growth* (New York: Wiley, 2008), Mehrdad Baghai, Sven Smit, and Patrick Viguerie detailed a new, data-driven approach to formulating growth strategies. It allows companies to uncover, understand, and capture potential growth opportunities and then deploy them at scale.

27 percent of growth attributable to alpha growth over the last decade. High performers do exist, and they tend to be standouts because high levels of alpha growth correlate strongly with the creation of shareholder value and economic profit (Exhibit 1).

As core growth rates in the semiconductor industry decelerate in the years ahead, alpha growth will become ever more critical to sustaining long-term growth. A formal analysis of more than 700 large companies from a range of industries suggests there are definite steps a company can take to improve its share of alpha growth. The majority of this article will focus on four steps that semiconductor players can take to enhance the share of growth attributable to alpha growth.

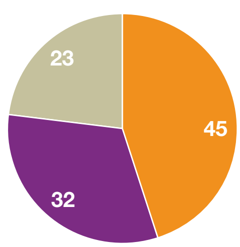
Exhibit 1

## Alpha growth accounts for about 55% of long-term growth throughout all industries.

Companies analyzed during the period 1999–2008, %

Portfolio momentum · M&A · Share gains

**Overall sample of companies**[1]




**Growth decomposition by industry**[2]

| | Portfolio momentum | M&A | Share gains | Number of companies |
|---|---|---|---|---|
| High tech | 42 | 25 | 33 | 70 |
| Travel and logistics | 42 | 26 | 31 | 29 |
| Financial institutions | 42 | 31 | 27 | 117 |
| Retail and wholesale | 48 | 27 | 25 | 46 |
| Health care | 41 | 34 | 25 | 64 |
| Media and entertainment | 36 | 41 | 23 | 36 |
| Consumer goods | 43 | 36 | 21 | 96 |
| Electric power and natural gas | 48 | 34 | 18 | 69 |
| Telecommunications | 57 | 25 | 18 | 55 |
| Chemicals | 49 | 36 | 16 | 30 |
| Basic materials | 50 | 35 | 15 | 40 |
| **Average** | **45** | **32** | **23** | |

Alpha growth = 55

[1]Based on multivariate regression; analysis excludes three outliers (also excluded from their respective sectors): Google, Virgin Blue, and Wynn Resorts.
[2]Figures may not add up to 100%, because of rounding.

Source: McKinsey growth-decomposition database of information from 720 large companies

At the highest level, those steps include expanding beyond the company's comfort zone to explore related markets, creating wholly new markets, developing a strong focus on product innovation and sales excellence, and leveraging M&A selectively to build scale or add needed capabilities. Before we discuss these steps in detail, though, we present more evidence of the efficacy of alpha growth as a metric and put it into proper context vis-à-vis other measures of business performance.

## How alpha growth drives value

When we set out to analyze growth across the semiconductor industry, we leveraged McKinsey's proprietary databases and we discovered that over a five-year period, from 2003 to 2008, 73 percent of growth was attributable to choice of market—in other words, the rising tide. However, revenue growth due to successful M&A was responsible for a healthy 18 percent of growth. The rarest form of growth was due to increases in market share; such growth accounted for 9 percent of gains during this period. Both M&A-derived growth and gains from increasing market share result in alpha growth.

As mentioned earlier, high levels of alpha growth are evident in semiconductor companies with high levels of shareholder value creation and economic profits. However, just as umbrellas don't cause rain to fall, companies can have respectable levels of alpha growth without generating economic profits or shareholder value. The difference is that those with positive alpha growth may be poised for growth (and negative economic profits in the near term), whereas other companies might be ahead of the pack at the moment but have already run out of gas (manifested in negative shareholder value creation).

Ultimately, any high-performing semiconductor company should aspire to generate profitable alpha growth. To do so is to join the industry's elite and to ensure that the organization has tapped into a long-term source of quality growth. We believe there are four levers that will allow companies to develop profitable alpha growth; each is explored in detail in the following section.

## Actively pursuing alpha growth

Quality growth is not necessarily easy to come by in an industry as cutthroat as the semiconductor sector. After all, a company may make rapid gains with one runaway success—but that scenario is not one that can be banked on. Instead, we prefer to look for more sustainable platforms for growth, such as alpha growth.

At a high level, there are two main inputs into alpha growth: a dedicated focus on finding the right expansion opportunities and flawless execution with regard to product innovation, sales strategies, and targeted M&A capabilities.

### Terra incognita

The first lever involves tapping latent growth opportunities—in essence, going where no one has gone before. Our analysis of companies with a distinctive ability to create new markets surfaced five notable traits that they share. First, they tend to adopt an expansive—or even creative—view of market opportunities worth assessing. They also place bold bets when entering new markets. They share a culture of informed risk taking, with no pulled punches or half measures. These companies also work to encourage rapid decision making and avoid so-called analysis paralysis, which could prevent them from making any significant moves at all. They work to predefine the elements that make for successful expansion and enforce discipline to ensure that projects that are not meeting targets are abandoned. The final characteristic these companies have in common is that they leverage their core capabilities to prioritize the markets to play in. By blending current talent with future markets, these companies can develop distinctive concepts and products that will set them apart from rivals (Exhibit 2).

A good example of this lever in action would be the bold bet Texas Instruments made on the digital-signal-processor (DSP) market in the early 1980s. At the time, the United States was just beginning to emerge from a double-dip recession, and semiconductor demand was at a low ebb. At the worst of this downturn, a company executive became convinced that a dedicated signal-processing chip had the potential to become a substantial success. The programmable-products division tasked its design team to build a processor for a market that did not exist yet. By early 1982, a prototype single-chip DSP achieved an operating speed of five million instructions per second, putting it on par with many mainframe computers of the era.

Similarly, in the mid-2000s, Cypress Semiconductor adopted a new strategy, focusing on programmable products. The strategy built on an existing business line, which produced USB microcontrollers but expanded its remit to include programmable-system-on-a-chip (PSOC) products. It should be noted that PSOCs do not require leading-edge fabs, thus helping the company's margins. As this business gained momentum in 2007, with Cypress's PSOC powering the clickwheel for Apple's popular iPod music player, the company was able to sell off six noncore businesses. Now, that same PSOC product line is scaling into new applications, such as mobile handsets and portable medical devices.

### Expanded focus

In addition to placing bets on wholly new markets, a second lever for driving alpha growth involves expanding into adjacent markets, located one or two steps from current products or services. Qualcomm, for example, parlayed its

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Exhibit 2

## Companies with a distinctive ability to create new markets exhibit several characteristics.

- **Adopt an expansive view** of which market to play in—and think creatively
- **Make bold bets** when entering a new market—do not take a 50/50 approach—and foster a culture of informed risk taking
- **Avoid analysis paralysis,** which could prevent the company from entering a new space even if it presents a real growth opportunity
- **Be ready to move on** by predefining what success looks like and be willing to abandon projects when necessary
- **Leverage core capabilities** to prioritize which markets to play in, as they can be a source of distinctiveness

expertise in nanoscale chip fabrication into the launch of its mirasol display technology, which is powered by microelectromechanical systems. SanDisk followed a similar approach, leveraging its core competencies related to production of flash memory and channeling it into the design of the Sansa line of MP3 players.

SunPower Corporation designs and manufactures high-efficiency crystalline silicon photovoltaic cells, roof tiles, and solar panels based on a silicon all-back-contact solar cell invented at Stanford University. In 2002, Cypress Semiconductor spent $150 million to buy a stake in the company, giving it access to the solar-panel market. By 2005, SunPower's revenues had grown significantly; it was then spun off from Cypress in a public offering. Cypress's $150 million stake was worth $1.1 billion on transaction day.

Whether looking inside your existing product portfolio or considering complementary products outside it, these examples serve to illustrate the opportunities in services or new product categories that often can be uncovered.

### Maniacal focus on execution

A maniacal focus on execution is a no-regret move and can have significant impact when supplemented by business-model disruption and distinctive capability building. While 40 percent of market-share growth is driven by business-model disruption (being an attacker or being attacked), another 40 percent is driven by a truly distinctive capability that leads to competitive advantage. An example of this would be Toyota's quality system. The remaining 20 percent is driven by relentless execution, or performing day-to-day tasks a bit better every day.

There are two functions within each semiconductor company that can add to the overall company's alpha growth meaningfully if they are focused tightly on best-in-class performance. These are the product-development and sales teams.

As part of our research effort, we studied a broad range of corporations that excel in these two areas, and from that we discovered five characteristics that top performers share. First, they leverage existing core capabilities in product innovation and brainstorm unique ways to combine their abilities with external sources of intellectual property. Atmel, for example, acquired Quantum Research Group in 2008. Quantum was a supplier of capacitive-sensing solutions. By leveraging its existing microcontroller expertise and blending this with Quantum's know-how, the combined company developed its line of maXTouch controllers, which was worth $140 million for Atmel within two years due to its inclusion in a broad range of Android-based smartphones.

Successful companies also cultivate close collaboration between their R&D and marketing functions to ensure that cross-functional teams make all important product-development decisions. A third trait is having in place a robust, consistent framework for evaluating ideas, examining potential financial impact, and assessing the strategic fit of the idea, as well as its feasibility and the positives or negatives of the timing of any potential launch.

Leaders also go to great lengths to engage customers early in the product-development cycle. Research and qualitative comments from key customers are used to shape initial concepts, as well as specific elements of early and midstage prototypes.

Last, these companies nurture a formal innovation culture, setting a foundation to welcome new thinking and support the development of new ideas, while also underlining the importance of continually improving ideas throughout the development cycle. Taken together, these five traits represent best-in-class capabilities for introducing new products.

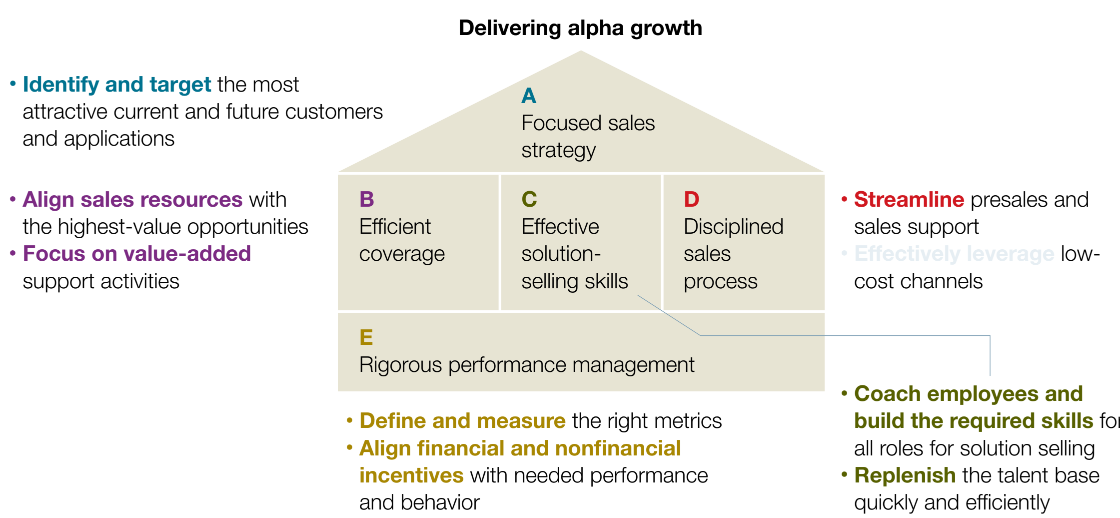
Turning to sales—the engine that transforms those new products or services into revenues—there is a five-pronged approach to developing alpha growth (Exhibit 3). A focused sales strategy is the first element. Such a strategy must identify and target the most attractive customers. Many companies identify key accounts and gear investments toward them, but best-in-class companies develop account-level perspectives on where the company can expect to find near-term profits.

The second element is an efficient coverage model. By efficient, we mean that the right sales resources must be devoted to the highest-value opportunities at each point in the account's life cycle (for example, with regard to "hunter" and "farmer" sales coverage). In addition, top performers need to develop the solution-selling skills of the sales force. It is not enough to roll out training in, say, value pricing. The pool of talent must be replenished regularly. Sales campaigns should focus on building mind share among distributors and include the company's products in a broader set of IT systems—a genuine solution for customers.

The fourth element is a truly efficient sales process. While some are content to streamline quoting or simplify distributor sales models, the best companies take things further. They define a crisp set of processes with clarity and coordination among the internal teams involved in the sale. They also develop automated tools and resources to minimize the administrative burden on sales teams.

Exhibit 3

## A sales strategy aligned to create alpha growth has five key elements.



The final building block is a robust performance-management system. Peak performers track metrics such as design wins and share gain in addition to traditional sales data. They also fit these metrics into a real-time dashboard that generates live updates from the field, instead of at day's end. With all five of these upgrades in place, semiconductor companies can expect to see genuine improvement in sales conversion, revenues, and profits—as well as in alpha growth.

### Selective M&A

The fourth lever involves developing a targeted approach to both M&A and business-development activity. From our study of top-performing institutions, we determined that these leaders share four attributes. They develop two or three M&A archetypes, such as buying scale versus buying in related markets or in specific geographies. The archetypes should align with the company's overall strategy, and the aim should be building platforms rather than becoming a conglomerate. Cisco Systems provides a good example of a programmatic approach to M&A. Between January 2005 and June 2008, Cisco acquired 48 companies, and 55 percent of them were companies in related markets. Its overall strategy is to create a lineup of standard, scalable products it can drive through its strong channel network. Seventy-nine percent of those 48 deals were worth less than $250 million. These smaller acquisitions generally focused on tuck-in technologies that built out Cisco's existing market positions. Twenty-one percent of the deals came at prices above $250 million, and here the company was largely purchasing new platforms.

IBM, on the other hand, prefers to buy scope. During the same period, it made 63 acquisitions, and fully 80 percent of those deals brought a new technology or service into the company's portfolio. And approximately 80 percent of those deals came in under $250 million. More rarely, IBM will purchase scale; 16 percent of the deals in this period gave it substantial reach into a new market. Company executives have noted that they found software deals in the range of $100 million to $400 million provide it with an outsize internal rate of return. Given the company's formidable global footprint, only 4 percent of its deals brought entrée into a new geography.

What are the ingredients of a world-class M&A process? First, companies that excel develop a proactive and systematic set of processes to screen for and assess M&A opportunities. Next, they develop a formalized M&A playbook, covering every aspect of the company's M&A strategy, governance structure, deal-team staffing and other organizational elements of the M&A system, and key documents such as detailed process descriptions, due-diligence checklists, valuation tools, and go/no-go criteria. The final element is a rigorous approach to merger management, with a focus on value creation.

To ensure that things progress according to plan, the M&A team should rigorously track post-merger activities and operating metrics in addition to traditional financial metrics. That said, it's not purely about numbers. Culture is crucial to successful merger integration, as are lines of communication. Based on extensive postmerger-integration work with clients, we advise that M&A teams plan three times as much communication as they might initially expect. Teams should risk overcommunicating with all relevant stakeholders. As a final thought, M&A teams should work to leverage the integration to build skills among line leaders and more junior team members that will be useful in future deals.

## Putting the pieces together

With all of the elements listed above, semiconductor companies can move from their current idea of growth to one that will prove more sustainable over the long term. Many opportunities exist to make the types of changes that lead to alpha growth. As part of our research, we identified two categories of opportunities that seem perfectly suited to semiconductor companies seeking this kind of growth; they exist in both software and services. Just as Apple acquired Siri in 2010, other leading technology companies have begun leveraging software acquisitions to launch distinctive products. Service-based companies, such as Netflix or Mint.com, are another area we believe might interest semiconductor companies.

However, before running off after a shiny new acquisition, semiconductor players must know where they stand. We believe it is critical for companies to understand their position with regard to shareholder value creation, economic profits, and alpha growth. Furthermore, it is crucial to know whether existing growth is by design or default. It is also useful to know where your corporation stands vis-à-vis competitors across these three financial metrics. With those facts in hand, it is possible to develop the right strategic posture for various markets.

In addition, it is important to identify the specific levers that will allow your company to attain the ideal mix of alpha growth, economic profit, and shareholder value creation. That is as much a matter of having the right capabilities in place as of excelling in execution.

However, distinctive execution is a key ingredient. Companies must set proper targets, track the right metrics, and deploy appropriate resources to achieve peak performance.

The last piece of the puzzle is having the right M&A strategy in place before M&A becomes mainstream in the semiconductor industry. Now is the time to begin building M&A muscle; once the right M&A plan is in place, it can contribute strongly to an enterprise's alpha growth.

• • •

Given the intense competition in the semiconductor industry, it is no surprise that companies count on innovative products and services in order to grow. But over the longer term, that means a company is only as successful as its most recent product launch. Alpha growth, on the other hand, is the key to quality, sustainable increases in revenues and profits. It blends organic improvements with strategic acquisitions—and it ultimately separates the leaders from the rest of the pack.

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# Creating value through M&A and divestiture

**M&A has long been an important contributor to the growth of semiconductor companies. In this article, we review the industry's record, forecast the most effective M&A models, and highlight capabilities required to get the process right.**

**Anders Nielsen, Robert Uhlaner, and Bill Wiseman**

Mergers and acquisitions are an important lever in the pursuit of growth for semiconductor companies, but few industry players have experience doing more than small, tactical deals. At the same time, the pool of such targets is shrinking, while pressure to grow through M&A is increasing. A big question for semiconductor companies is where to focus their M&A efforts to maximize growth opportunities.

McKinsey research has identified five models that characterize the M&A programs of the world's biggest companies. Many semiconductor companies have successfully pursued what we term a tactical model, characterized by the completion of numerous small deals over the course of a year that, when combined, make up less than 20 percent in aggregate over the past decade of the acquirer's market capitalization. But we don't see much potential left in this approach, and we expect semiconductor companies to pursue what we call a programmatic M&A model, where companies complete a similar number of larger deals that together represent a significant share (that is, greater than 20 percent over the past decade) of the acquirer's market capitalization. Put another way, as small deals become harder to come by, we believe industry players will need to be willing to spend more per acquisition in the hunt for growth. In this article, we'll offer an overview of M&A in the semiconductor industry, present the approaches that may generate the most value, and offer a perspective on how to get M&A right.

## A bias toward small deals

The source of inorganic growth for semiconductor companies has historically been the acquisition of small industry players, in deals generally valued at less than $500 million. From 2000 to 2010, there were 221 deals in the semiconductor industry, and 83 percent of them fell into the sub-$500 million category, according to McKinsey research. Many, in fact, were much less expensive: 22 percent of those deals were under $25 million, 13 percent were valued between $25 million and $50 million, and another 23 percent came in between $50 million and $100 million.

An informal poll of 34 industry leaders at McKinsey's annual semiconductor CEO event in 2012 showed that roughly a third of them will look to small acquisitions as a source of inorganic growth in the years ahead. Why the preference for smaller deals? Most attendees cited the low capital requirements and noted that smaller deals entail less risk than larger deals.

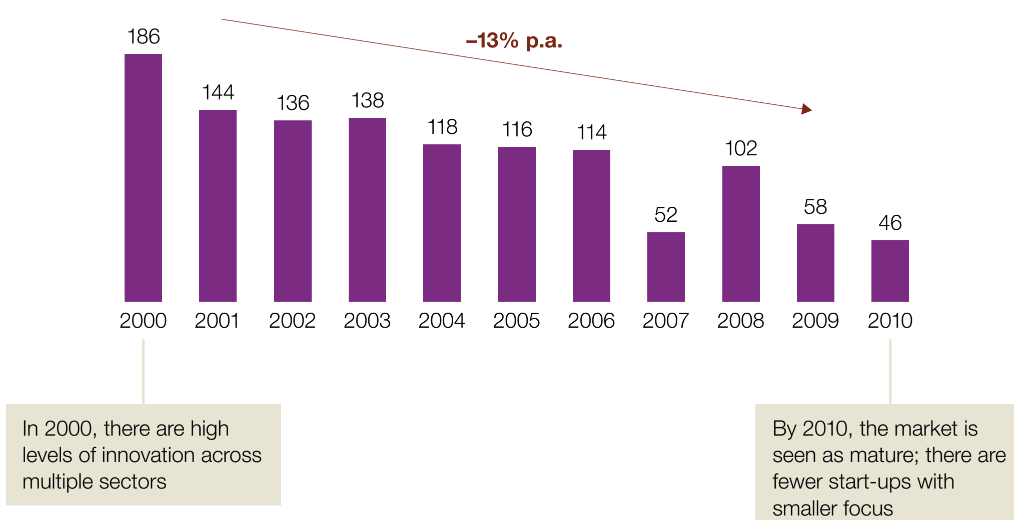
But the days of small deal after small deal seem numbered, offering a strong reason for semiconductor companies to reexamine their M&A approach. The pool of new semiconductor start-ups shrank at a 13 percent annual rate from 2000 to 2010 (Exhibit 1).

Moreover, the pipeline of new start-ups is not being refilled, largely as a result of venture-capital firms looking to other industries and cutting back on money they are investing in the sector. Overall venture-capital deals with semiconductor players sank at a 6 percent annual rate, and the crucial Series A investments dropped at an 18 percent annual rate between 2000 and 2010 (Exhibit 2).

Exhibit 1

**The pool of new semiconductor start-ups is shrinking.**

New semiconductor start-ups founded



Complicating matters is that bidders from adjacent industries have begun competing with semiconductor companies for the remaining smaller-scale chip companies. Apple paid $280 million in 2008 to acquire P.A. Semi, a fabless design company specializing in power-efficient chips. Two years later, to enhance its A5 processors, Apple paid $121 million for Intrinsity, a Texas-based fabless company specializing in high-speed, low-power processor cores. And in 2011, Apple paid a reported $390 million to buy Anobit, an Israeli manufacturer of flash-memory products.

## Identifying the most effective M&A strategy

McKinsey's corporate-finance practice analyzed more than 15,000 M&A deals executed by the world's top 1,000 nonbanking companies over the past decade. The study found that semiconductor companies have largely stuck to the two most successful strategies—tactical and programmatic—out of the five identified, as measured by excess shareholder returns.[1] In fact, the tactical and programmatic M&A programs combined were employed by 40 percent of the semiconductor companies in the global top 1,000 and 66 percent in the global top 500 (Exhibit 3).

The other three strategies are not ideal for semiconductor companies, for a variety of reasons:

Large deals. Large-deal strategies—those where at least one deal is 30 percent of the acquirer's market capitalization—are pursued successfully by companies operating in more mature industries

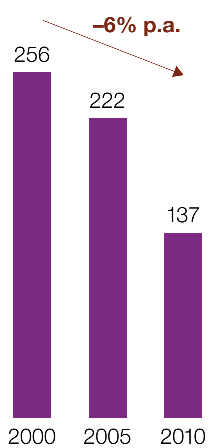
[1] This analysis corrects for a bias in traditional measures of M&A value, which understate the value of deals too small to affect share prices by relying on short-term investor reactions to deal announcements, focusing instead on the impact of M&A programs rather than individual deals. For more information, see Werner Rehm, Robert Uhlaner, and Andy West, "Taking a longer-term look at M&A value creation," mckinseyquarterly.com, January 2012.

Exhibit 2

## The pipeline is not being refilled, as venture-capital funding is declining for semiconductor start-ups.

**Fewer venture-capital (VC) deals are being done**

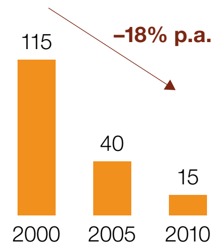
VC deals in semiconductor start-ups, number of deals




**New funding for semiconductor start-ups is also on the decline**

Series A funding of semiconductor start-ups, number of start-ups

*"I can count on one hand the VCs who are bullish about semi start-ups . . . there are so many other investment opportunities out there"*
–Venture capitalist in Silicon Valley

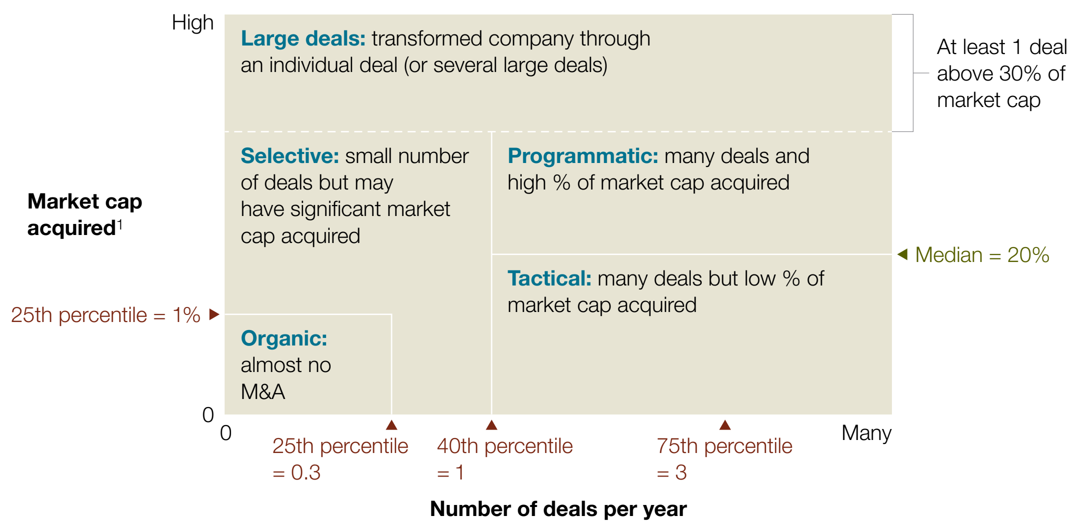



Source: Capital IQ; National Venture Capital Association; interviews; McKinsey analysis

Exhibit 3

## We segmented companies into five different M&A strategies.

World's top 1,000 nonbanks in 1999 with data until 2010, n = 639




[1] We calculate market cap acquired based on the sum of deal value as a percent of market cap in each year.
Source: Corporate Performance Analysis Tool; Dealogic; TPSi database v73

with excess capacity or where scale is a competitive factor. Similarly, we found that large deals in faster-growing or rapidly evolving industries—such as the semiconductor industry—were less successful. Why? Large deals often consumed critical organizational resources over a lengthy period following a deal, resulting in critical product or upgrade cycles being missed. In the technology sector in particular, large deals were generally completed when valuations were high, "at the top of the cycle," and often those companies overpaid for the acquisitions.

Selective deals. Companies with selective strategies engage in M&A opportunistically, even though they don't seem to be pursuing a proactive strategy. As a result, they spend less than 2 percent of market capitalization on the deals. This was a category from which it was difficult to draw conclusions. Often, the sources of these companies' growth were organic rather than enabled by M&A.

Organic growth. The organic segment represents companies that did no, or practically no, M&A over the past decade. They averaged about three deals over the course of the decade, and those acquisitions were worth less than 1 percent of the company's market capitalization.

Of the two remaining segments, much of semiconductor deal making has fallen into the tactical bucket, where companies completed numerous small deals that, combined, made up less than

20 percent of the acquirer's market capitalization but usually were part of a broader innovation or capability-building strategy. Most of these deals were to acquire small, niche companies that would fill gaps in intellectual property, product portfolios, or channel lineups. These acquisitions frequently involved early-stage technology companies with promising intellectual property. The median semiconductor company in this category did 28 deals over the last decade, and the median deal was equivalent to 8 percent of the acquirer's market capitalization (Exhibit 4). While this approach certainly worked for the period between 1999 and 2010, we believe the market has changed in profound ways.

In our view, the conditions in today's semiconductor industry will require semiconductor companies to transition from tactical tuck-in deals to a larger-scale series of business-building deals. While this programmatic approach to M&A produced negative returns for shareholders, we believe it will be the most effective path to growth in the future. Semiconductor companies pursuing a programmatic approach have historically conducted 25 deals on average over the last decade, compared with 28 deals for companies pursuing a tactical M&A strategy.[2] As a result, we think the key for semiconductor companies will be to increase the size of the deals they are willing to do. Companies will also need to build their M&A capabilities before shifting to a programmatic approach. Perhaps the most essential capability will be the companies' ability to integrate larger, more complex organizations into their own organizations. (We will address this topic in greater depth later in this article.)

In addition, semiconductor companies shifting to a programmatic model will also need to expand their capabilities to identify and evaluate targets. In the tactical approach, targets are often evaluated purely based on their technology, and the main due-diligence capabilities therefore reside within the R&D groups. In the

[2] Our analysis draws on data from McKinsey's Corporate Performance Analysis Tool, Dealogic, and a TPSi database.

Exhibit 4

## Tactical has been the most reliable M&A strategy for semiconductor companies through upturns and downturns.

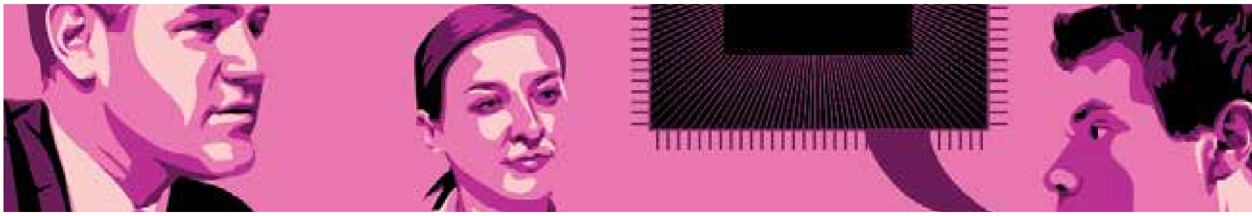
Semiconductor companies in global top 1,000, median excess total return to shareholders (TRS),[1] %, n = 33

% with excess TRS >0

| | Dec 1999–Dec 2002 | | Dec 2002–Dec 2007 | | Dec 2007–Dec 2010 | | Dec 1999–Dec 2010 | |
|---|---|---|---|---|---|---|---|---|
| | Median excess TRS | % with excess TRS >0 | Median excess TRS | % with excess TRS >0 | Median excess TRS | % with excess TRS >0 | Median excess TRS | % with excess TRS >0 |
| Programmatic | 3.9 | 50 | –12.6 | 25 | 3.3 | 50 | –2.3 | 50 |
| Selective | 7.1 | 69 | –11.0 | 31 | 10.9 | 77 | 4.5 | 62 |
| Organic | –4.9 | 40 | –7.4 | 20 | –4.1 | 40 | –8.2 | 20 |
| **Tactical** | 10.0 | 100 | –0.1 | 50 | 2.2 | 50 | 4.0 | 100 |
| Large deal | –7.9 | 14 | –14.8 | 29 | 13.6 | 86 | –5.5 | 29 |

[1] Program definition is based on M&A activity from Jan 1, 2000, to Dec 31, 2010; excess TRS is for the specified period.

Source: Corporate Performance Analysis Tool; Dealogic; TPSi database v73



programmatic model, a more holistic approach may be warranted, requiring due diligence of go-to-market potential, cost and operational synergies, and overall strategic fit, in addition to an evaluation of the technology. Capabilities in due diligence and target evaluation therefore must be built across the organization.

Relying mostly on organic growth will no longer cut it in the semiconductor industry. By extension, the organic path described above becomes irrelevant for companies that seek industry leadership, as does the selective model, given how few deals are executed and their overall impact on the acquirer. As noted, many companies apply a tactical approach today, but the number of small-target candidates is falling. In the large-deal category, the shareholder returns do not seem to justify the execution risks.

In fact, some semiconductor companies have already applied the programmatic approach, where companies complete many deals that together represent a significant share of the acquirer's market capitalization.[3] This was one of the top two M&A strategies in most industries as measured by excess total returns to shareholders (TRS), and among semiconductor companies it was employed to acquire midsize companies with established customer bases. This flow of business was used to increase revenues and build new platforms. Much of the value creation stemmed from either the acquirers gaining access to new sales channels or from operational synergies.

Across industries, companies that pursue programmatic M&A typically have explicitly defined deal strategies in place and have built up the strong internal M&A capabilities needed to implement them. The median programmatic semiconductor company completed 25 acquisitions over the course of the decade, adding the equivalent of 37 percent of its market capitalization. In contrast to tactical M&A strategies that focus on reinforcing current businesses by acquiring intellectual property, programmatic M&A identifies deals against a business case to build new revenue streams. Often these programs target acquiring new capabilities, products, and regional coverage in addition to intellectual property.

One example is Broadcom, which has successfully applied a programmatic M&A strategy—acquiring 37 companies since 1999—to enable excess TRS growth of greater than 5 percent.[4] The key to Broadcom's success has been the alignment of its M&A strategy with the company's overall strategy, consistently acquiring complementary technologies to grow into a full-service provider of solutions for wired and wireless communication. The result is that today, Broadcom has grown to become the third-largest

[3] A median of 36 percent of market cap acquired with 33 deals over the time frame.
[4] Our analysis draws on data from McKinsey's Corporate Performance Analysis Tool, Dealogic, and a TPSi database.

semiconductor company among the Fortune 500.[5] The key here is not the pursuit of complementary technologies in and of itself but rather the integration of the M&A strategy with the technology road map, overall corporate strategy, and specific go-to-market strategies enabling both revenue and cost synergies. While the model may not work for all semiconductor companies, the disciplined approach the company applies to M&A may offer lessons for other players (Exhibit 5).

## Merger integration

To build a successful programmatic M&A program, semiconductor companies should focus on developing two organizational capabilities: structured approaches to target selection and deal sourcing, and postmerger integration. How might a company prospect for target companies? It takes significant effort to develop an overview of all relevant players in the semiconductor space. Players can consult databases of early-stage technology companies relevant to the semiconductor industry, including one created by McKinsey's semiconductor practice. These kinds of databases can be used to form growth strategies or to narrow the field of potential acquisition candidates.

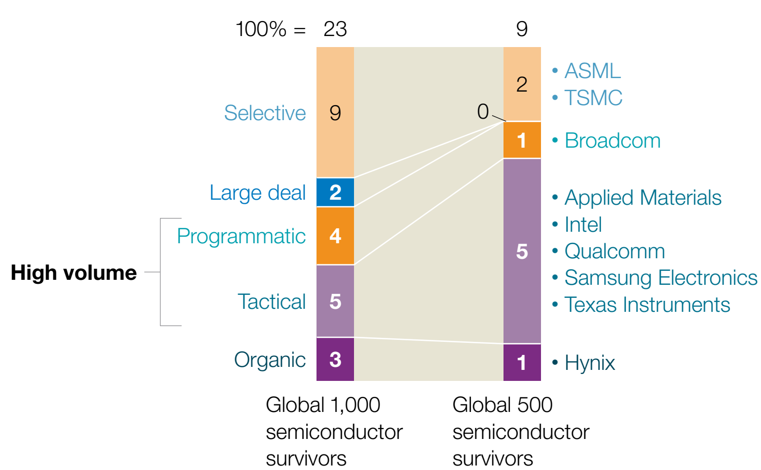
The second key organizational capability is M&A integration management. In recent research, McKinsey's corporate-finance practice reviewed the performance of the largest deals that took place between 2000 and 2006. In case studies of nine of the best-performing deals and six of the worst in our data set, McKinsey found that

[5] Broadcom analyst presentation, December 14, 2011.

Exhibit 5

**The largest semiconductor companies rely on high-volume M&A programs.**

Distribution of semiconductor survivors[1] by M&A program, %




[1] Survivors are companies that were in the global 1,000 or 500 in both 1999 and 2010.

Source: Corporate Performance Analysis Tool; Dealogic; TPSi database v73 successful acquirers employ several approaches to merger execution and postmerger integration that differ from those used by the unsuccessful.[6]

In the hectic pace of integration after the announcement of a deal, merging companies often focus too heavily on regulatory compliance and on organizational alignment. Moreover, they may limit themselves to going after only the immediate opportunities identified during the due-diligence process. Although these are important considerations, such narrow focus may shift attention from the original point of the deal.

Instead, we found that successful acquirers did three things differently:

Aiming high. They look beyond the due-diligence phase and set their ambitions more broadly than they would when doing smaller deals. Companies should identify a broad range of opportunities across both organizations and build a fact base to support them. This may require companies to think beyond the deal and consider selectively transforming parts of the business. The key is to uncover and focus on sources of value creation apart from those identified during the busy due-diligence period, and then to set stretch targets and align the organizations around these goals.

Managing integration. They recognize that control over the cultural integration of the two companies is critical, and they rigorously plan that part of the postmerger program. As the merging companies move beyond due diligence into the preclose phase, preparing well becomes essential. To do so, they should acknowledge that a "merger of equals" approach likely will not create the right outcome. We find this approach often leads to confusion and lack of accountability. Instead, the acquirer needs to take the lead in postmerger integration while being sensitive to the cultural differences of both companies. Successful acquirers take cultural differences into account when establishing value-capture goals. Through careful planning, the staff from both the acquirer and the acquired company can work together to maximize the value of the combined entity.

Engaging leadership. They involve their CEOs where it counts the most. Demands on the CEO's time can be overwhelming in the days immediately before and after the close of a merger, so making sure he or she is involved in the right decisions—at the right time—becomes critical. To permit focus on the most important issues, some CEOs delegate day-to-day merger-management responsibilities to an integration-management office led by a senior executive.

Based on McKinsey research, as well as on experience from more than 1,000 merger-integration client engagements, we've identified 12 best practices that facilitate successful integration and value creation (Exhibit 6).

For semiconductor companies, the integration challenge often resides in aligning and integrating technology road maps and product development, as well as complex manufacturing environments and sales organizations that typically have concentrated customer bases. The implications are threefold. First, semiconductor companies need to focus on the underlying cultural practices, which become even more critical in areas such as R&D and manufacturing, as well as on the account-management side. Second, they should identify synergies in technology road maps and determine early in the process what

[6] See Ankur Agrawal, Cristina Ferrer, and Andy West, "When big acquisitions pay off," *McKinsey on Finance*, Number 39, Spring 2011.

Exhibit 6

## There are 12 best practices in merger integration.

| | |
|---|---|
| **Focus on value creation** | **1** Anchor integration architecture and approach in deal rationale |
| | **2** Look beyond due diligence and open the aperture to exceed traditional synergies |
| | **3** Selectively transform parts of the business |
| | **4** Protect business momentum to avoid typical loss of revenue |
| **Prepare well** | **5** Define a comprehensive, tailored integration approach—and stick to it |
| | **6** Empower a value-added integration-management office that attracts top performers and line leaders |
| | **7** Don't underestimate culture; use a scientific approach to identify issues and intervene as needed |
| | **8** Build momentum by making critical decisions well before close and completing key activities within 100 days |
| **Execute rigorously** | **9** Don't make day one bigger than it needs to be |
| | **10** Track activities and operating metrics in addition to traditional financial measures |
| | **11** Overcommunicate, with messages tailored to every stakeholder group |
| | **12** Build capabilities for future deals |

that means for manufacturing footprints. This is frequently a significant driver of the overall deal value. Lastly, restrictive customer non-disclosure agreements arising from integrated customer technology road maps may limit pre-close planning. Some companies address this issue by using "clean teams," which sit between the two organizations and make objective, fact-based decisions about the proper path for all parties.

### The potential role of divestitures

While we have spent most of this article addressing acquisitions, divestiture is an equally important—and often overlooked—aspect of corporate and M&A strategy. As enterprises grow, their portfolio of businesses tends to become more diverse. McKinsey's corporate-finance practice recently examined the factors that distinguish strong-performing conglomerates from weaker ones. The goal was to understand the defining characteristics of successful companies as their portfolios grow.[7]

When companies reach a certain size and maturity, or when the growth potential of the overall industry segment diminishes, companies may become tempted by diversification. While few Western companies today qualify as true conglomerates, there were a significant number of them in the United States in the 1960s and 1970s. Many executives believe that diversifying into unrelated industries reduces risks for investors. Furthermore, executives believe that they can allocate capital across businesses better than the market can.[8] In analyzing the drivers

[7] Joseph Cyriac, Tim Koller, and Jannick Thomsen, "Testing the limits of diversification," mckinseyquarterly.com, February 2012.
[8] Ibid.

of excess TRS, three distinct features of successful conglomerates emerged, even though more than a few did not succeed:

They are disciplined investors. They continually rebalance their portfolios, purchasing companies that they believe are undervalued by the market and whose performance they believe they can improve. Similarly, they divest themselves of a business unit when market conditions are favorable or when their ability to further improve the performance of the unit diminishes.

They are aggressive capital managers. They transfer all cash beyond what is needed for day-to-day operations to the parent company for reallocation based on stringent return requirements.

They employ lean corporate centers. High-performing conglomerates often operate like private-equity firms, with a small corporate center that restricts its role to selecting top managers, allocating capital, vetting strategies, setting performance targets, and monitoring performance. Equally important, these companies restrain themselves from extensive use of corporate-wide shared-service centers, as this may lead to each business becoming dependent on the corporate center, making divestures more difficult and thus limiting the conglomerate's ability to rebalance its business portfolio.[9]

No major semiconductor company qualifies as a conglomerate, but we think these lessons are still relevant to the industry. As certain types of chips fall from favor at the leading edge, for example, there may be value to unlock by selling a business or spinning it off as a freestanding entity serving the lagging edge.

• • •

The semiconductor industry is entering a period of consolidation, and our research indicates that few industry players are embracing mergers and acquisitions, let alone divestiture of underperforming business units, in a strategic way. So there is no time to lose to develop a robust M&A program. Using a winning M&A formula and identifying the right pockets of growth will position bolder companies to leapfrog rivals.

[9] Ibid.

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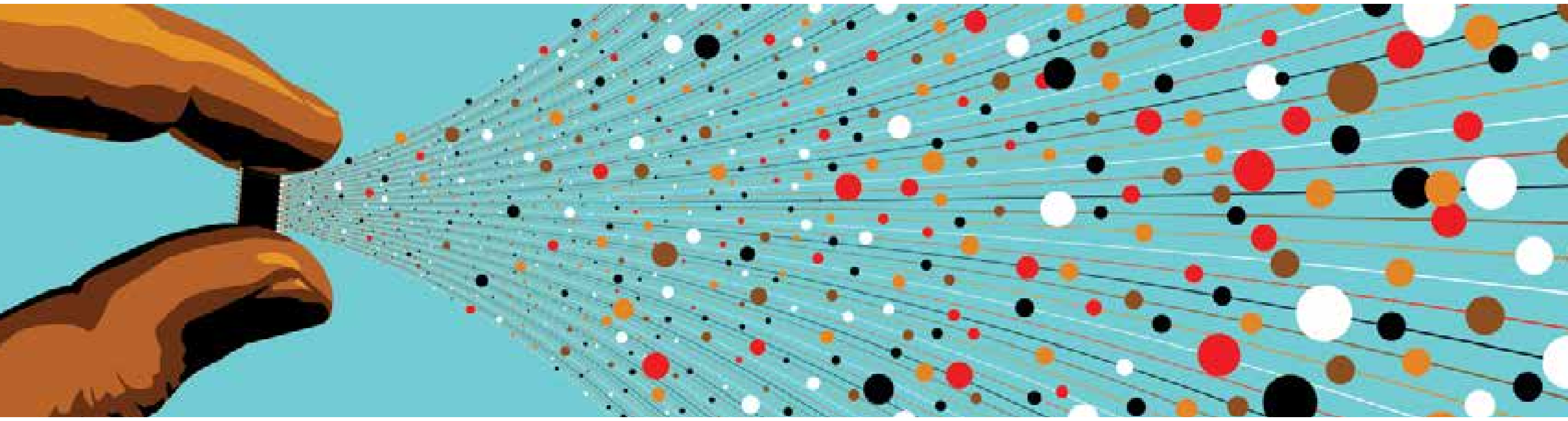


# Big data and the opportunities it creates for semiconductor players

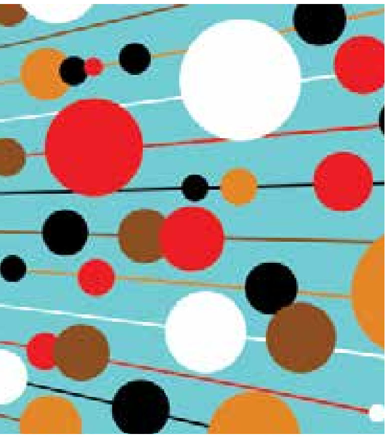
**The wave of big data is likely to reshape not only how business gets done but also the pockets of opportunity for semiconductor players. In this article, we explain the nuts and bolts of big data and present a semiconductor-centric view on segments likely to grow most rapidly.**

**Harald Bauer,**
**Pratap Ranade,**
**and Sid Tandon**

The era of big data is upon us. A deluge of business data flows into corporate data centers each day, faster, it seems, than anyone can sort through it. At the same time, consumers going about their day—communicating, browsing, buying, sharing, searching—create their own enormous trails of data. And the volume of data generated by a wide range of sensors, such as those in pipelines, throughout power plants, and on machinery around the factory floor, as well as in smartphones, GPS systems, and connected consumer-electronics devices, presents an entirely new category of "machine data"—generated without explicit human intervention.

The question, then, is what this phenomenon means. Is the proliferation of data simply evidence of an increasingly intrusive world? Or can big data play a useful economic role? While most research into big data thus far has focused on the question of its volume, McKinsey's detailed study of the topic makes the case that the business and economic possibilities of big data and its wider implications are important issues that business leaders and policy makers must tackle.

Before digging into those issues, we define what we consider to be big data and discuss its



growth rates. We then offer an analysis of the challenges and opportunities that big-data and advanced-analytics technologies will present for semiconductor companies, and we conclude with a look at the strategic impact of big data for these companies.

### What is big data?

Big data is the confluence of Internet data, business data, and sensor data that together requires a new generation of technical architectures and analytics to process. Such data, if analyzed properly, will help companies large and small unlock new sources of value.

Of course, businesses have tracked performance data for ages, so we must develop a more crisp definition of big data in order to illustrate the difference between it and garden-variety data. Big data has five defining characteristics; any data set that embodies at least the first three characteristics could be considered big data.

First, the scale is significantly larger than traditional data sets. Big data is normally massive. It is usually measured in petabytes, and the databases that house it are designed to scale, ingesting additional classes of information over time. Second, big data is characterized by high dimensionality (thousands or even millions of dimensions for each data element), creating unique challenges for analysis. A third characteristic is the sheer diversity of data. Big data is usually semistructured or even unstructured (for example, tweets from users around the world), and it is often amalgamated across various sources. Frequently, it is a blend of several types of data, which would gum up traditional analytical tools. Big data also flows at a rapid rate, forcing analytical engines to be able to capture, process, and analyze a rushing river of information to enable real-time decision making. The final characteristic of big data is that companies typically use adaptive or machine learning–based analytics that generate better results as the size of the total data set increases.

### How big is the wave?

Sizing big data presents a challenge, as the sheer volume of information becomes difficult for humans to interpret. We estimate, for example, that the amount of data stored in enterprise systems, on a global basis, exceeded seven exabytes in 2010. New data stored by consumers that year added another six exabytes to the total. To put these very large numbers in context, the data that companies and individuals are producing and storing is equivalent to filling more than 60,000 US Libraries of Congress. If all words spoken by humans were digitized as text, they would total about five exabytes—less than the new data stored by consumers in a year.

How fast is this data pile growing? Various estimates put the rate of growth at between 23 and 40 percent a year. Recently, Martin Hilbert and Priscila López published a paper in *Science* that analyzed total global storage and computing capacity from 1986 to 2007.[1] Their analysis showed that global storage capacity grew at an annual rate of 23 percent over that period (to more than 290 exabytes in 2007 for all analog and digital media) and that general-purpose computing capacity grew at a much higher annual rate, 58 percent.

IDC estimates that the total amount of data created and replicated in 2009 was 800 exabytes—

[1] Martin Hilbert and Priscila López, "The world's technological capacity to store, communicate, and compute information," *Science*, April 2011, Volume 332, Number 6025, pp. 60–5.

enough to fill two stacks of DVDs that would reach all the way to the moon. The research firm projected that this volume would grow by 44 times to 2020, an implied annual growth rate of 40 percent.

All sources agree that the growth trend in the generation of data has been accelerating at a healthy clip. That will only complicate the challenge of extracting insight from the building mountain of data.

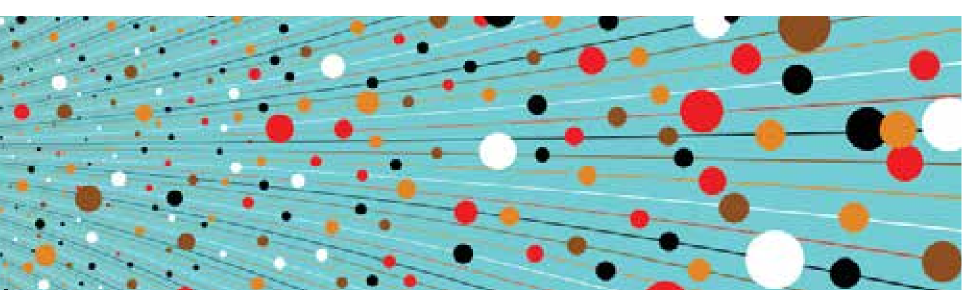
## Big data's impact on semiconductor companies

To assess the challenges and opportunities that this trend poses for the semiconductor industry, it makes sense to look at the sorts of demands that data and advanced analytics will put on computer hardware. We will look at four elements involved in creating value from big data: collecting distributed data, extracting meaningful patterns from noisy data, refreshing insights in real time from flowing data, and determining the architecture for chips of the future.

### I. Collecting distributed data

To start, you must understand what type of data needs to be collected and how you can go about collecting it. The type of data collected is critical to the impact that the data can have. For example, a retailer used to need to know the name, address, and zip code of each customer to do business. Now, that barely captures the outermost layer of the information available about each customer. Tweets, Facebook posts, user-generated video, GPS modules, and accelerometers in mobile phones are just a few examples of sources for such information. In addition, there is a wide range of structured and unstructured data available that could help modern retailers deliver targeted sales pitches through the most relevant medium at the perfect moment. As data are collected for individuals across other dimensions, more interesting patterns may emerge. Nike+ FuelBands, for example, track a user's motion throughout the day, and iPhone applications such as SleepCycle monitor the quality of their sleep at night. Even more powerful are the sensors for industrial applications. They are being embedded to track information from all aspects of a complex operation such as an oil refinery, a power station, or a mine.

To understand how data are collected from the viewpoint of semiconductor companies, it helps to break the overarching task into three elements: field nodes, network infrastructure, and back-end analytics. Field nodes are the millions of networked sensors that are being embedded in the world around us, whether in mobile phones, smart energy meters, automobiles, or industrial machines. They are engineered to communicate with other electronics, making up the "Internet of Things," also referred to as machine-to-machine communications. Sales of these types of devices—comprising an analog front end, an embedded microcontroller unit, and a radio-frequency chip—are currently increasing at a compound annual growth rate of 35 percent. In all, we expect there will be a global field-node installed base of



## Analysis is the key to turning the multitude of data into useful insights.

200 million units by 2015, representing a market worth between $3 billion and $5 billion. These field nodes are, by design, low consumers of power, and as such, they are popular as a tool to drive efficiencies in industries ranging from retail to health care, from manufacturing environments to oil and gas processing.

"Digital oil fields," for example, are emerging as a key technology to optimize production costs for oil fields. (Typically, the production phase accounts for about 42 percent of the cost of producing a barrel of oil.) Digital fields aggregate data from arrays of field nodes, including seismic sensors, flow monitors, and oil-rig and tanker GPS and telemetry. The data are aggregated and managed in real time at operations and decision centers, relying heavily on automated pattern recognition and decision making, significantly lowering the cost of production.

In health care, remote health-monitoring nodes allow physicians to monitor patients' vital signs via low-power wireless signals. This data stream enables preventive medicine and therefore reduces medical costs, since it is frequently cheaper to treat a patient before the condition deteriorates and becomes an emergency. In the public sector, this technology is being deployed to reduce traffic congestion by coordinating data from sensors embedded in the road surface with smart parking meters and even water-supply-management systems. Policing is another application. Over the last 15 years, New York City experienced a 60 percent drop in crime by adopting predictive policing efforts that integrate data from closed-circuit TV cameras, real-time news feeds, and mining of CompStat data to assess the real-time likelihood of crimes by type and by location.

Once data are collected, information can be transmitted over wireless or wireline data networks. Telecommunications carriers such as AT&T and Sprint have launched services aimed at facilitating the transport of data collected from field nodes. These services are being tailored for enterprises in different industries, including health care, transportation, and energy generation and distribution. The focus of the network is to ensure that the data collected by field nodes are transported back to central clusters of computers for analysis in a fast, reliable, and secure manner.

Analysis is the key to turning the multitude of data into useful insights. With the right tools in place, businesses can uncover patterns and connections within the data that would not be obvious to human analysts. Combining data from the Web, field nodes, and other sources in an effort to capture multiple attributes of a target (which could be a customer, a location, or a product) is the first step. As you sift through billions of data points across hundreds or even millions of dimensions for patterns, you encounter what is known as the "curse of dimensionality"—data analysis gets exponentially harder as the dimensionality of the information increases. Big data sets have very high dimensionality. A general rule of thumb, used by several start-ups dedicated to machine learning (Exhibit 1), is that once you have more than 15 dimensions in a group of data, you start to see significant benefits from applying machine-learning techniques instead of classical methods to analyze the data. This brings us to the second task for semiconductors in the age of big data: extracting meaning from the mountain of data through advanced analytics.

## II. Extracting signal from noise

IT professionals tend to think of big data primarily as a database-management challenge. After all, it does involve large numbers of data points. But handling the high dimensionality in the data is as much, if not more, of a challenge. If Facebook wanted to track an individual user, for instance, it would know right off the bat where the user lived, what his or her e-mail address was, who that person's friends are, how often they communicate with each other, and perhaps where they bank or shop. Each of those aspects is a dimension. In all, the count of dimensions for any one customer or user could easily reach 1,000. Now, if Facebook wanted to use this data to segment its user base, the task would quickly become too much for any human mind to easily comprehend.

One of the techniques used by machine learning practitioners to crunch this geyser of data is to find the "natural dimensionality" of the data they wish to analyze (Exhibit 2). A support-vector machine (SVM) is a well-established, powerful

Exhibit 1

## Machine learning seeks to automate understanding.

Machine learning is the science (or art) of building algorithms that can recognize patterns in data and improve as they learn

**It uses a bottom-up approach:**
- Learn model structure from the data
- Separate training and testing

**It includes two types of learning:**
- Supervised (classification, regression)
- Unsupervised (clustering, structuring, detection)

**It has broad applications:**
- Speech and gesture recognition (Kinect)
- Natural language processing (Siri)
- Vision (iPhoto facial recognition)
- Recommendation (Netflix, Amazon)
- Time-series prediction (Rebellion)
- Medicine (Equinox Pharma)

Over the past few years,[1] machine learning has exploded, but it is still at the knee of an S-curve

| 1957 | 1980–1990s | 2004 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| Perceptrons invented | Novel algorithms SVMs, HMMs[2] created | Google MapReduce published | Netflix prize offered[3] | Start-ups emerge (eg, Cloudera, Kaggle, Tresata) | Watson won Jeopardy; Siri released for iPhone 4 | First major industry conference, Strata 2011, held | Companies build in-house machine-learning capability (eg, Facebook, LinkedIn, Twitter) |

[1]Dates are approximate.
[2]SVMs: support-vector machines; HMMs: hidden Markov models.
[3]Progress prize awarded in 2008.

Exhibit 2

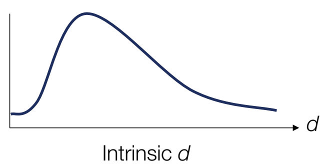
## Machine learning seeks to discover intrinsic structures embedded in high-dimensional observations.

EXAMPLE: UNSUPERVISED LEARNING

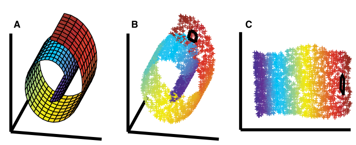
**Linear methods are insensitive to higher-order nonlinear structures**

The "curse of dimensionality" motivates the need to reduce the complexity of data

Classification performance



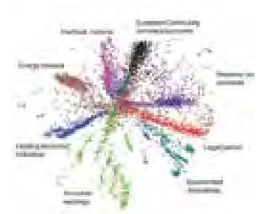

Linear methods cannot unroll the Swiss roll




**More sophisticated methods are necessary to uncover patterns in high-*d* data**

Linear method applied to ~800,000 news stories

Autoencoder network applied to same data



Source: G. E. Hinton and R. R. Salakhutdinov, "Reducing the dimensionality of data with neural networks," *Science*, July 2006, Volume 313, Number 5786, pp. 504–7; Sam T. Roweis and Lawrence K. Saul, "Nonlinear dimensionality reduction by locally linear embedding," *Science*, December 2000, Volume 290, Number 5500, pp. 2323–6

machine-learning algorithm often used for classification of large data sets. It transforms data into a higher-dimensional feature space where the data are sorted and separated by a "hyperplane." Feature-space transformations are leveraged not only by SVMs but also by many leading machine-learning algorithms. Such types of linear-algebra transformations require matrix operations in high-dimensional spaces, which resemble the transformations that graphics processors use to quickly render beautiful images for video games. This is a class of operation known in Flynn's taxonomy (a classification of computer architectures) as SIMD or MIMD—that is, single instruction or multiple instructions on multiple data. The phrase "multiple data" in this case refers to the multiple elements of one vector data point. SISD, on the other hand, represents single instruction on single data—a more traditional workload.

These machine-learning algorithms, such as SVMs, tend to outperform traditional statistical methods for classifying complex data sets. Furthermore, the task of combing through large data sets is actually quite similar to the types of operations found in modern graphics processing. After all, a computer monitor or high-definition TV screen is essentially a matrix, and an individual vector is similar to the number of pixels in one row on a screen.

Graphics processing units (GPUs) have been optimized to do the massively parallel linear algebra and matrix math that is behind the sorts of high-powered animations found in home game systems such as Microsoft's Xbox LIVE or Sony's PlayStation 3. A new class of GPUs sold for general-purpose computing, known as GPGPUs, is already catching on. In fact, as workload shifts to the cloud, GPGPU clusters could present an important opportunity area for semiconductor players in the server space. Amazon.com was the first major cloud player to launch a GPGPU instance of its popular Elastic Compute Cloud (EC2) offering; it did so in November 2010.

Optimizing code for the GPGPU, however, remains one of the primary barriers to adoption. The upper bound with regard to how fast code can run in a massively parallelized environment is described by Amdahl's law, which states that the degree of speed increase is inversely proportional to the share of sequential code, measured by run time. That said, the observed speed increases for a range of machine-learning algorithms have varied from 43 to 800 times the normal speed when run on GPGPUs rather than CPUs. Researchers at the Toyota Technological Institute (a joint effort with the University of Chicago), for example, demonstrated speed increases of 40 to 80 times on GPUs in 2011 for the multiclass SVM—a core machine-learning algorithm (Exhibit 3).

However, parallelizing code to enable programs to run on GPGPUs presents significant challenges. First, having multiple threads operating at the same time, with a few shared variables across

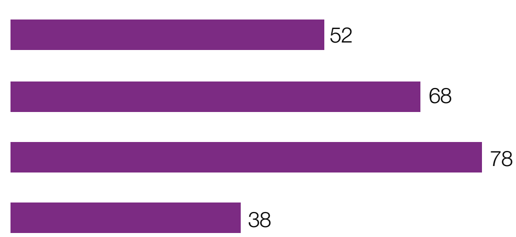
Exhibit 3

## Binary and multiclass kernel-based SVMs, a core set of machine-learning algorithms, can operate 40 to 80 times faster on GPUs.

Multiclass SVM run time[1]
Seconds

| Training data set | CPU | GPU[2] |
|---|---|---|
| ADULT | 61 | 1.2 |
| MNIST | 264 | 3.9 |
| **TIMIT** | 276 | 3.5 |
| COV1 | 16,200 | 432 |

Speed increase on GPU vs CPU
Ratio of CPU to GPU implementation run times

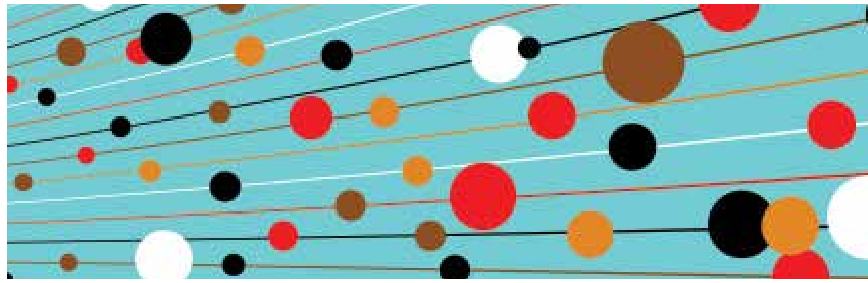



**TIMIT**, a typical machine-learning data set, is a phonetically transcribed corpus of words spoken by North American speakers

**Testing system specs:**
- Intel Core i7 920 CPU; 12G memory
- 2x NVIDIA Tesla C1060 graphics cards (4G memory each): only 1 card used for GPU implementation

[1]SVM: support-vector machine; run times do not include time spent during initialization (or clustering).
[2]Graphics processing unit.

Source: A. Cotter, J. Keshet, and N. Srebro, "Proceedings of the 17th ACM SIGKDD," an international conference on knowledge discovery and data mining, 2011; K. Crammer and Y. Singer, "On the algorithmic implementation of multiclass kernel-based vector machines." *Journal of Machine Learning Research*, March 2002, pp. 2265–92



them, can create an entirely new class of software bugs. The most common example would be “race conditions,” which arise from errors in “locking” shared variables while a particular thread is operating on the program. While that is bad enough, race conditions can also create a condition known as “parallel slowdown,” where the entire program actually functions slower when parallelized than when run in a linear fashion.

A second challenge comes from the human mind. Academics and IT professionals with experience in parallel programming have highlighted repeatedly that the human brain thinks sequentially, not in parallel, which makes parallel programming conceptually less intuitive and more challenging. Last, parallelization requires programming in a new language. The two most popular are CUDA and OpenCL; these are not considered easy to learn, nor are they easy to use.

Now that we understand a bit more about the nature of the new analytical workloads and their implications for processing horsepower, we shift to the third important task that chips will encounter in their efforts to make big data powerful: generating insights in real time.

### III. Making decisions in real time

Putting together the pieces of insight from big-data harvests overnight is good. But putting them together to inform business decisions in real time is even better. Here we encounter the third task that semiconductor companies must accomplish in order to participate in the big-data revolution: real-time analytics.

Depending on the business and its specific context, a given company may refresh its customer data several times a day, or even several times an hour. And if it wants to track customers in real time, the company will need to know when, for example, you begin to shut down your PC at work and head for the subway or commuter-rail service in the evening. To target you with an advertisement that appears on the screen of your mobile phone in time for you to walk by a branch location, that company will need a system optimized to make marketing decisions in real time. The GPGPUs discussed in the previous section help reduce the raw computation times needed to run machine-learning pattern-recognition algorithms, but the biggest bottleneck for real-time analytics is the speed of memory access. The roadblock is the time it takes a CPU or GPGPU to read and write information from cache, random-access memory (RAM), and the hard-disk drives or flash memory where the data are stored.

Data flows from storage, such as hard disks, to RAM and then to cache memory, getting physically close to the processor at each step, With the rise of big data and the Internet of Things, the trend toward integration of more functions onto a single piece of silicon is likely to continue.

enabling increasingly fast access. More memory, closer to the processor, is essential for speed. More and more companies are therefore looking to shift toward in-memory computing. The elements that make this possible are larger caches, above 512 megabytes, and faster interconnects. These pieces allow even a robust business to store in memory, say, the last minute of customer data across a large retail network. That gives the cache one minute to refresh its data, and because the processor is not involved in that refresh, it can concentrate on the decision-making end of the process, thereby speeding up the decision-making engine.

### IV. Moving toward the elegant, all-in-one smart chip of the future

The microchip is evolving at a brisk clip. More and more functions that used to reside on discrete chips are being integrated into a single chip. With the rise of big data and the Internet of Things, the trend toward integration of more functions onto a single piece of silicon is likely to continue.

According to James Jian-Qiang Lu and Ken Rose of Rensselaer Polytechnic Institute and Susan Vitkavage of Sematech, the next generation of devices will likely be 3-D integrated circuits (ICs) with an array of sensors (GPS, accelerometers, microelectromechanical systems components, and biosensors, to name a few) deposited on one layer and large, ultra-high-density cache memory on another layer. These two layers will be integrated both vertically and horizontally, forming a single circuit. Those multilayered circuits could usher in an era of smart, integrated devices, constantly collecting and transmitting data about the world around us.

## A bright future is just around the corner

The types of innovations discussed in the last section are at the forefront of laboratory research today, but given a few years' time, these sorts of innovations will be appearing in fabs and foundries around the globe. This presents a range of opportunities for semiconductor companies, whether in the development of sensors or in the field of integration, which takes both engineering prowess and manufacturing skill to flourish.

All semiconductor companies must adapt to the era of big data and the Internet of Things.

Fortunately, there are many, many ways semiconductors—whether they are CPUs, GPGPUs, chip-based sensors, integrated field nodes, 3-D ICs, or optical chip interconnects—will power the core of the machines that drive the next S-curve in productivity and insight generation. Big data presents a huge opportunity for semiconductor companies to power this next phase of growth.

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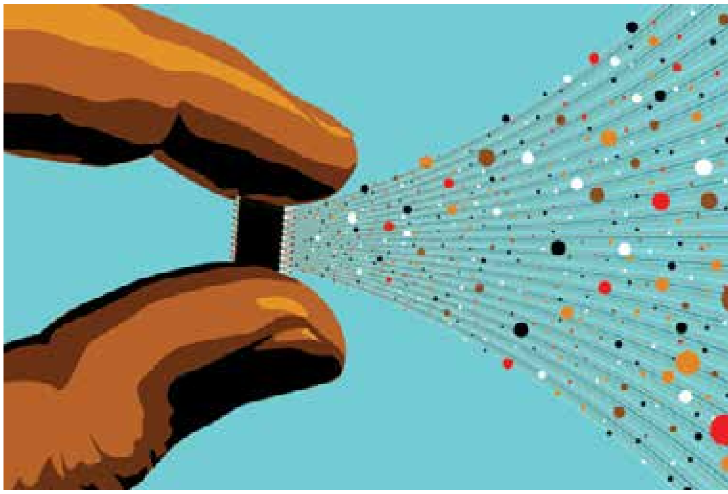
Given the context of the broad big-data revolution, it will be important for chip players to acknowledge that software analytics will be as important as their precious semiconductors are. To tackle the challenges of deploying advanced analytics for the big-data world, semiconductor companies will benefit from alliances with or even acquisitions of the software and middleware players also working on their pieces of the big-data puzzle. Additional collaborations with systems original equipment manufacturers, specifically those that are working to design solutions for big-data analytics, could also prove helpful for semiconductor companies. These sorts of collaborations will benefit both parties as they work to uncover the right approach to real-time, large-scale data processing. New ideas for hardware and software elements will occur during testing, and that leads to new market opportunities for both partners. While the technical challenges are significant, the opportunity for semiconductor players in the age of big data is substantial.



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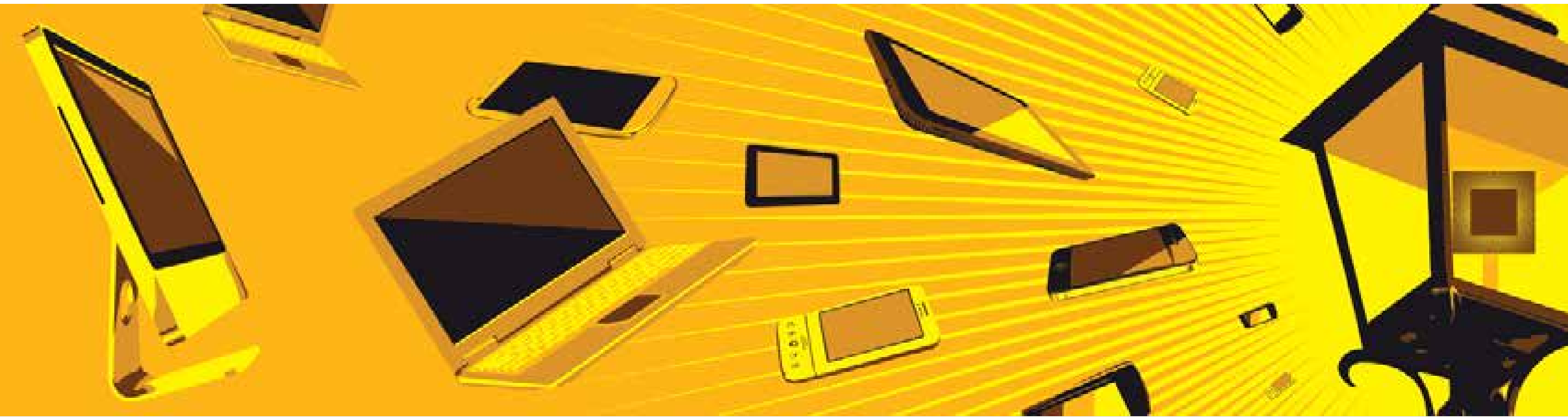


# Semiconductors for wireless communications: Growth engine of the industry

**Over the last three years, the market for wireless semiconductors has undergone tectonic shifts, with new operating systems and high-performance smartphones taking the stage. The disruption creates opportunities for new players and changes the game within the industry.**

**Harald Bauer, Felix Grawert, and Sebastian Schink**

The market for the semiconductors that power wireless communications is undergoing dramatic changes. Based on data from Strategy Analytics, the estimated overall industry growth rate will average 6 percent from 2011 to 2015. A large share of that growth will be attributable to two categories: smartphones and connected devices such as iPads. These account for more than half of total units shipped, and each category is growing at more than 25 percent per year. Today, mobile application processors operate at 5 to 10 percent of a typical laptop's computing power, yet that gap is rapidly narrowing as smartphones run applications from mobile video to mobile games, and their energy consumption is lower than a laptop's by a factor of 10 to 30 times. Despite the clear opportunity, the increased performance and the rapid shift from traditional handsets to mobile computing devices pose a number of challenges for chip makers (Exhibit 1).

### Challenge 1: Tectonic shifts in market share

The shift to smartphones and connected devices comes with significant market-share gains for players that have offered devices in these categories from early on. Apple and Samsung were able to increase their market share to a combined 27 percent in 2011—and to capture more than 80 percent of industry profits at the

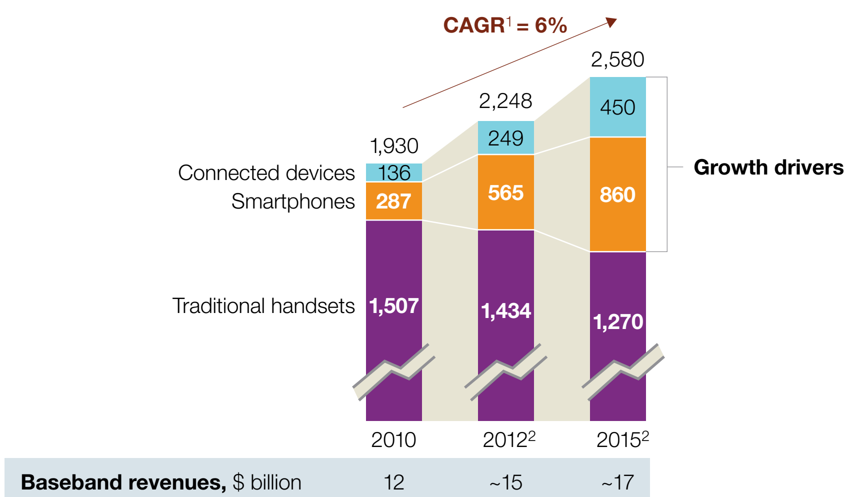
same time. Apple in particular profits from its leading position as an innovator in the mobile space. Nokia, on the other hand, steadily lost ground, and its attempts to catch up in smart-phones have not yet yielded the desired results (Exhibit 2).

The shift in market share of handset makers also has led to discontinuities in the market for operating systems. Symbian, once the leading mobile operating system, with more than 50 percent market share, claimed only 17 percent in 2012. Google's Android (with 49 percent share in 2011) and Apple's iOS (with 19 percent share) have taken the lead. Both Apple and Google have created open platforms for third-party application developers, resulting in an unrivaled breadth of apps—more than 850,000 for iOS and 500,000 for Android. Indeed, mobile operating systems are increasingly becoming differentiators in their own right, apart from the device hardware for various handsets. It would be difficult for Blackberry OS and Windows Mobile to catch up; their combined market share has fallen to 13 percent. However, the new HTML5 standard, which is still under development, aims to provide an alternative to today's downloadable apps that are written for a single, specific platform. HTML5 will provide a platform that shows the content of Web sites

Exhibit 1

## The wireless industry is growing rapidly, creating an opportunity for leading semiconductor suppliers.

Growth of baseband sales, million units



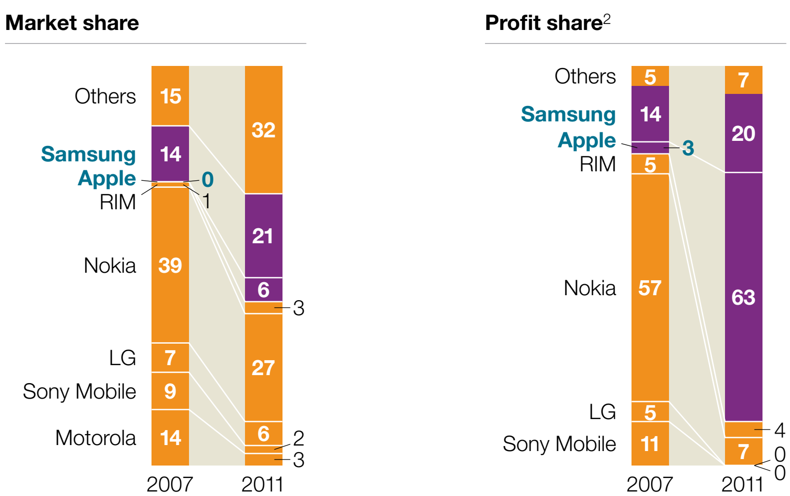

[1]Compound annual growth rate.
[2]Estimated.

Source: Strategy Analytics; McKinsey analysis

Exhibit 2

## The mobile handset market has seen sizable shifts in market and profit share.

%[1]




[1]Figures may not sum to 100%, because of rounding.
[2]Losses considered as 0 in calculation of totals.

Source: Strategy Analytics; McKinsey analysis

independent of hardware and operating system. This shift is likely to once again shake up market shares within the industry.

A new battle comes with the advent of low-end and midrange smartphones. While first-generation smartphones competed head-on with Apple's iPhone, lower-end smartphones, with retail prices under $300, are now being developed to cater to the needs (and pockets) of broader customer groups. These segments will grow annually by more than 20 percent, and they are expected to take the largest share of the smartphone market by 2014 (Exhibit 3). With silicon content typically running at 6 percent of handset price, this type of smartphone requires different chip architecture in order to meet a price point of $7 to $20 (compared with $25 to $40 for high-end smartphones). And top-tier smartphones typically have discrete chips for application processor (AP), radio frequency, and baseband (cellular modem) tasks. This functionality must be integrated in midrange and low-end smartphones in one-or two-chip designs. For chip makers, the emergence of lower-end smartphones has three major implications.

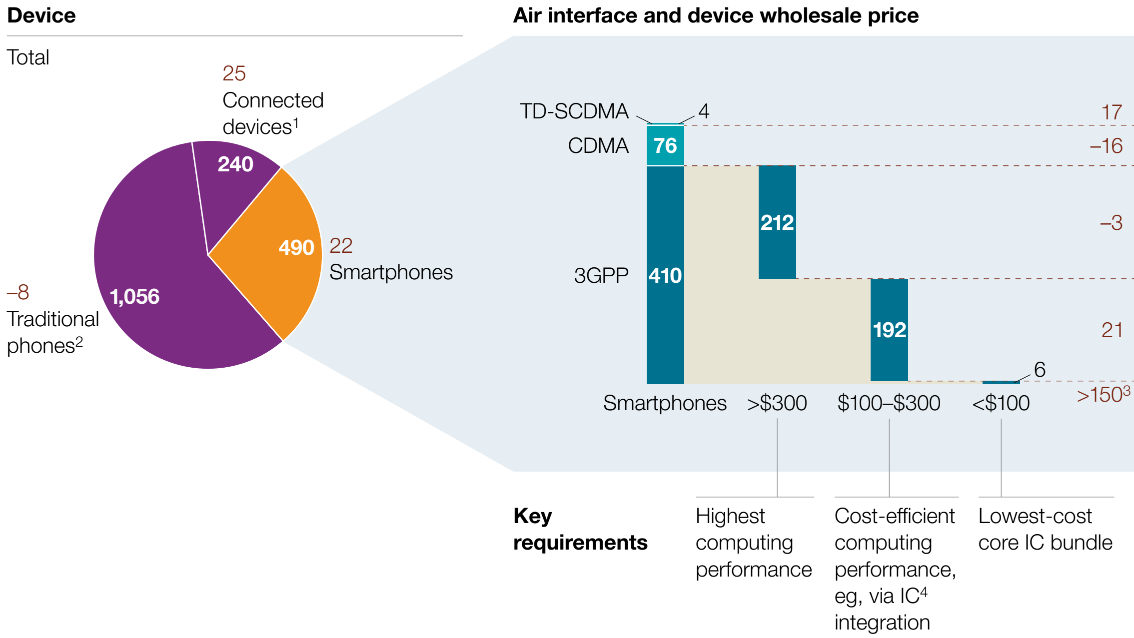
First, players need to develop an integration strategy that allows them to offer a powerful AP at a reasonable cost. Given the speed of the handset market, APs need to keep pace with short innovation cycles of 9 to 12 months. However, due

Exhibit 3

## The low-end and midrange smartphone segments will grow rapidly.

Mobile-device market, million units, 2011

% Compound annual growth rate, 2011–15




[1]Including iPad, machine-to-machine communications, 3G/4G cards, dongles, and so on.
[2]Real-time operating system.
[3]~220 million units by 2015.
[4]Integrated circuit.

Source: Strategy Analytics; McKinsey analysis

to integration with the analog baseband on a single chip, some chip partitioning is needed to allow for frequent upgrades to the high-speed digital part of the AP, while permitting for reuse of the analog baseband. This approach should keep the development cost within limits.

Second, chip makers must broaden their customer base beyond the established smartphone players such as Apple, LG, and Samsung to capture the growth opportunity of low-end smartphones, especially in the Asia-Pacific region. In this part of the world, MediaTek is emerging as an aggressive "local hero"; its revenues climbed from $1.43 billion in 2005 to $2.95 billion in 2011. The company recently announced a bid for Taiwanese chip maker Mstar worth $3.8 billion. MediaTek's low-cost strategy and its focus on lagging-edge mobile standards, as well as its stringent standardization and low-cost local development, make it difficult for incumbent players to match its price points.

Handset and chip makers can now choose between two ecosystems that are expected to be of equal power in the near term; they must carefully decide which is right for their portfolio.

Third, players need to offer integration support to local handset makers in China that do not have the integration capabilities of incumbents. These manufacturers need ready-to-use reference designs and extensive engineering support. Both factors were essential for MediaTek in its early years. In this market segment, we believe that turnkey designs will be offered eventually; these will provide white-label phone makers with fully functional phones on a printed circuit board that only needs to be customized and surrounded by a case.

### Challenge 2: ARM versus Atom

Today, the fabless vendor ARM Holdings is the de facto standard and the dominant provider of CPUs for mobile handsets. ARM's business model is tailored to the needs of mobile communications: it offers chips with the lowest power consumption and highest design flexibility in the industry. ARM develops CPU blocks of different sizes and speeds and then licenses its technology to chip vendors that can either incorporate the ARM CPU as is or customize it to their needs. This way, chip makers have design flexibility and can, for example, use a smaller, lower-power ARM A7 chip as the CPU for the digital baseband, while building the application processor on a more powerful ARM A15 core. Customers can also tailor ARM CPUs as necessary—Qualcomm, for instance, has customized an ARM core for use in its Snapdragon system-on-a-chip series.

Intel recently entered the market for mobile APs with its Atom series. Coming from the land of PCs, which have higher computing power as well as higher power consumption, Intel has released an aggressive road map to match the needs of mobile customers. The Atom series reduces power consumption with a broad range of power-saving techniques. The company is also working on low-power process technology, and it acquired a wireless business unit from Infineon Technologies to complete its wireless portfolio. As a result, all mobile operating systems (such as Android and Windows Phone) and application environments (such as Flash and HTML5) are expected to be ported to the x86 architecture by the end of 2012. This gives handset and chip makers the option to choose between two ecosystems that are expected to be of equal power in the near term. Consequently, chip makers must carefully decide which ecosystem is right for their portfolio. Because of the high switching costs that result from the significant differences between the ARM and x86 architectures, most chip makers will need to choose a single architecture for their products.

### Challenge 3: Rapid introduction of LTE

The next-generation mobile-communications standard, LTE—or 4G, as it is also called—is being rapidly introduced to the marketplace by telecommunications operators. This comes as a surprise to many players in the semiconductor industry, who still remember the slow introduction of the prior mobile-communications standard, 3G. When 3G debuted, there were no killer applications ready, power consumption was initially too high, and actual performance fell short of expectations. With LTE, things are quite different, as the use case for mobile Internet creates strong pull: from an operator's perspective, LTE technology offers much-needed transmission bandwidth for mobile data. Furthermore, the higher data rates cater to the consumer need for fast connectivity on tablets, high-end smartphones, and netbooks. As a result, both handset original equipment manufacturers and telecommunications operators are expected to migrate to LTE as early as possible to take advantage of its greater speed and data capacity. However, LTE brings three challenges for chip makers, and these will contribute to the industry's shake-up.

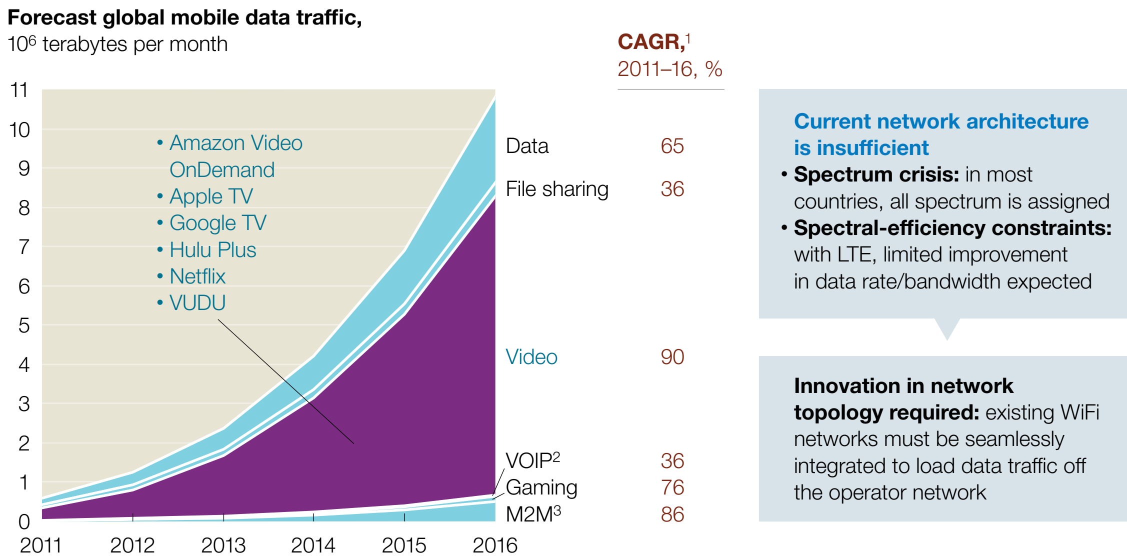
First, research and development costs with LTE will be roughly twice what they were for 3G technologies. This is because LTE, for the first time, unites the two separate mobile-communications standards, GSM (as well as its successors) and CDMA (and its derivatives). For each LTE standard release, updates to the majority of previous standards, such as W-CDMA, UMTS, HSPA, and HSPA+, are included. All these features must be developed and tested—not only in the laboratory but also in field tests with operators—and this drives up the effort required for verification. As a result, the engineering effort and R&D costs grow by an estimated factor of two, because both 3G and LTE are being updated significantly throughout release 11.

Second, the time-to-market gap between players is widening. The LTE standard is still in the development phase, and new features are being introduced rapidly. Qualcomm is one to two years ahead of its peers with regard to time to market, and the company introduces products on each version of the LTE standard roughly a year after the release date. This first-mover benefit gives Qualcomm multiple lead customers, lead operators, and equipment partners. It also creates opportunities for Qualcomm to shape the standard itself. In contrast, players that are one cycle late have to offer discounts of more than 20 percent to secure a lead customer. Players that are more than one cycle late find it hard to win lead customers and cannot offer a competitive, leading-edge feature set.

Third, with LTE, critical intellectual property is becoming more and more of a competitive weapon. Royalties have become a stronger value-redistribution lever, increasing from an average of only 3 percent of a phone's average selling price in the 2G era to 12 percent of an LTE smartphone's average selling price. Royalty

Exhibit 4

## Mobile data traffic will grow tremendously.




[1]Compound annual growth rate.
[2]Voice over Internet protocol.
[3]Machine-to-machine communications.

Source: Cisco Systems, Feb 2012; McKinsey analysis

payments can be as much as twice as high for new entrants without any intellectual-property rights (IPR). For smartphones, those payments are divided roughly evenly between the wireless-communications stack and other areas.

IPR is unevenly distributed, putting new entrants at a real disadvantage against established players like Ericsson, Motorola, Nokia, and Qualcomm. Recent lawsuits, such as the fight between Apple and Samsung, demonstrate the threat of products being banned from specific markets, and of long and costly court battles in general. This has motivated players to invest in IPR purchases; for instance, the Nortel IPR auction yielded roughly $4 billion in revenue, Google acquired Motorola Mobility for $12.5 billion, and Intel acquired a group of InterDigital patents for $375 million. The need for a strong IPR portfolio will drive further consolidation throughout the industry, and it will also create entry barriers for players that are not active in the market today.

As a result of the challenges regarding the cost of R&D for LTE chips and the time-to-market and IPR battles that are likely to be fought, we expect that at most two players other than Qualcomm can make profits at the leading edge of the base-band chip market.

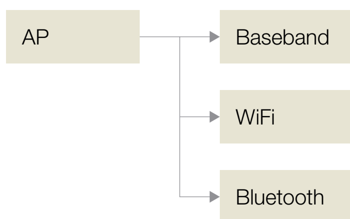
### Challenge 4: Emergence of 'multicom' solutions

Mobile data traffic is projected to double each year between now and 2015, according to Cisco

Exhibit 5

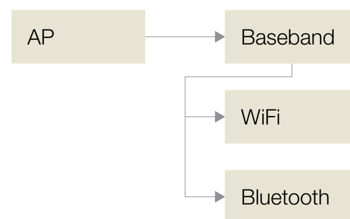
## Changes in partitioning of building blocks will likely allow for 'multicom' offerings.

**Today: application processor (AP) controls WiFi**




- (+) Preferred by app vendors: apps can access WiFi directly
- (+) Different component vendors possible—original equipment manufacturer integrates
- (−) Coordination of cellular and WiFi usage difficult
- (−) Operator cannot control WiFi

**Future: baseband processor handles all communication**




- (+) Seamless handover and synchronous use of WiFi and cellular possible
- (+) Preferred by operator: network can control WiFi offload
- (−) Requires baseband vendor to integrate connectivity components
- (−) Baseband processor active, even in WiFi-only mode

Systems—a trend largely attributable to the rapid growth in mobile video (Exhibit 4). In consequence, mobile operators will find it increasingly difficult to provide the bandwidth requested by customers. In most countries, there is no additional spectrum that can be assigned. Furthermore, the spectral efficiency of mobile networks is reaching its physical limits. A solution lies in the seamless integration of existing WiFi networks into the mobile ecosystem. The chips designed to accomplish this integration are known as "multicom" chips.

WiFi and baseband communications are expected to converge in three steps. Today, the applications running on the mobile device decide which data are handled via 3G network and which are routed over the WiFi network. In the next step, LTE release eight calls for seamless movement of all IP traffic between 3G and WiFi connections. In the final step, with LTE release ten, traffic is supposed to be routed simultaneously over 3G and WiFi networks.

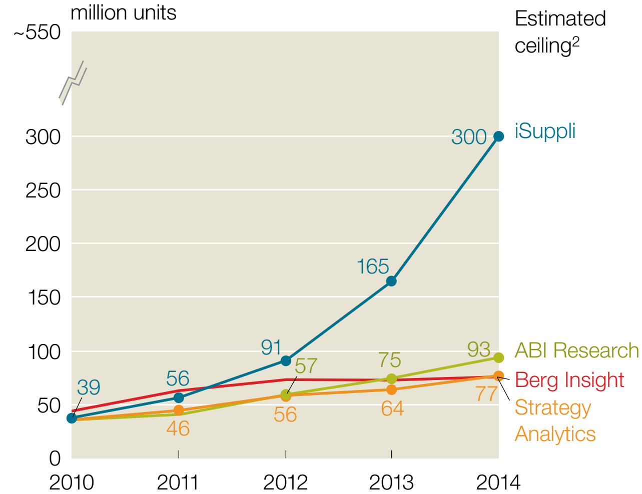
To allow for such seamless handovers between network types, the architecture of mobile devices is likely to change. Today, the AP is connected to baseband, Bluetooth, and WiFi chips directly. In the future, the baseband chip is expected to take control of the routing (Exhibit 5). Thus, the connectivity components are connected to the baseband or integrated in a single silicon package. As a result of this architecture change, an increasing share of the integration work is likely done by

## Exhibit 6

### Strong growth in machine-to-machine communications is expected, though estimates vary considerably.

| Drivers | CAGR,[1] 2010–14, % |
|---|---|
| **Automotive**<br>• E-call<br>• Tracking (theft)<br>• Insurance by actual mileage | ~55 |
| **Smart grid**<br>• Cellular smart meters<br>• Cellular connectivity to network infrastructure | ~90 |
| **Remote monitoring**<br>• Monitoring of power plants and machines | ~70 |

**Machine-to-machine forecast,** million units




[1]Compound annual growth rate.
[2]Based on rough calculations.

Source: ABI Research; Berg Insight; Strategy Analytics; McKinsey analysis

baseband manufacturers rather than by handset makers. Baseband makers need to quickly define their connectivity strategy; in particular, they must decide whether to make or buy the relevant intellectual property. As a reaction to the increasing need for on-chip connectivity, Samsung recently acquired Swedish fabless company Nanoradio, which is well-known for its ultra-low-power WiFi capabilities in the mobile arena.

### Challenge 5: Mobile-to-mobile communications

Another longer-term opportunity for wireless-communications chip makers is the rise of machine-to-machine (M2M) computing, also known as the Internet of Things, which spans a broad range of applications. In the automotive industry, tracking features might allow for the reduction of insurance premiums via innovative business models, such as car insurance that only bills for miles actually driven. In the smart-grid arena, cellular communications will allow sensors to report power outages and let utilities read meters without sending meter readers into homes or buildings.

While there is consensus that M2M is a promising pocket of growth, analyst estimates on the size of the opportunity diverge by a factor of four (Exhibit 6). Conservative estimates assume roughly 80 million to 90 million M2M units will be sold in 2014, whereas more optimistic projections forecast sales of 300 million units. Based on historical analyses of adoption curves for similar disruptive technologies, such as portable MP3 players and antilock braking systems for cars, we believe unit sales in M2M could rise by as much as a factor of ten over the next five years.

At the moment, the M2M value chain is fragmented, with a wide range of semiconductor players, as well as traditional machinery and electronics manufacturers, vying for a slice of the market. So far, no player has attempted to integrate the sector vertically by forming an alliance of, say, an automaker and chip-set makers, modularization specialists, system integrators, and application developers. Once a few such alliances have formed, we expect additional growth will be driven by standardization. Chip makers must determine how to best address this potentially very large market. They need to decide how much to invest up front in the development of M2M chips, given that current sales volumes are comparatively small. Finally, they have to define which steps in the M2M value chain they want to address to be in a good position once the market takes off.

• • •

The market for wireless communications is one of the fastest-growing segments in the integrated-circuit industry. Breathtakingly fast innovation, rapid changes in communications standards, the entry of new players, and the evolution of new market subsegments will lead to disruptions across the industry. LTE and multicom solutions increase the pressure for industry consolidation, while the choice between the ARM and x86 architectures forces players to make big bets that may or may not pay off. Companies in this industry need to carefully craft, and periodically review, their strategy in order to make the right choices in an unforgiving environment.

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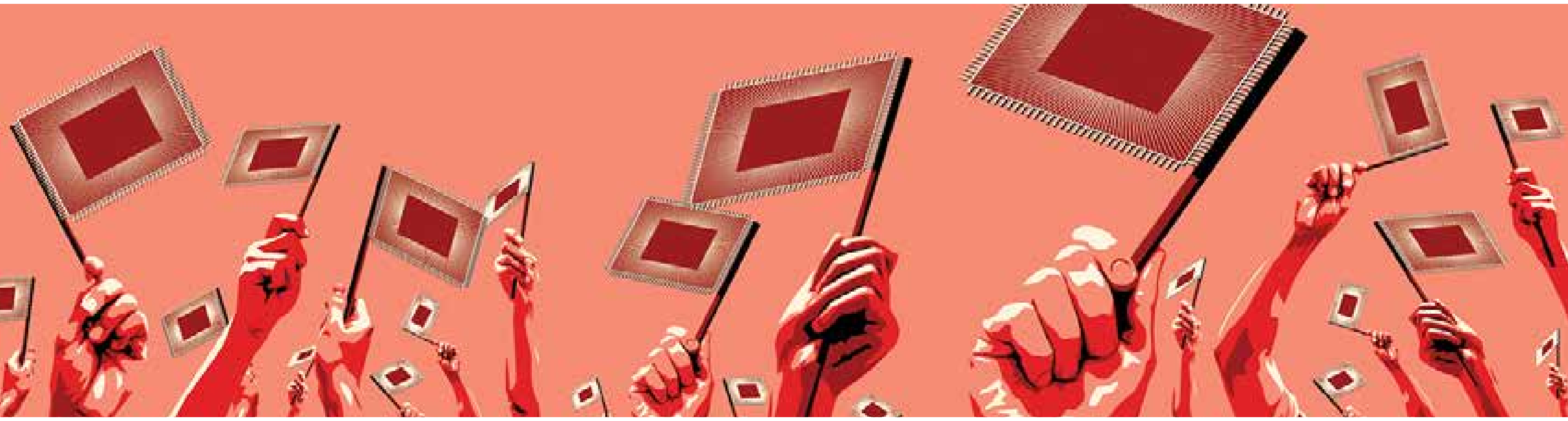


# Unlocking sales-force potential in the semiconductor industry

**Many semiconductor companies are struggling to find growth, and yet significant potential is sitting right in front of them, overlooked. A rigorous rethinking of sales and marketing processes can uncover hidden opportunities and convert them into real revenue.**

**Gaurav Batra and Sri Kaza**

Even as semiconductors increasingly saturate so many aspects of modern life, industry growth rates have been decelerating. In such an atmosphere, can a company afford to overlook part of its market or fail to ponder how well it serves its existing markets? Certainly not. As noted elsewhere in this issue, the compound annual growth rate of the semiconductor industry is slowing, to the point where it is beginning to mirror GDP growth rates. The industry's annual growth rate was 7 percent in the 2000s, and it is expected to average 5 to 6 percent in the current decade. That's significantly slower than the 13 percent annual growth rate the industry enjoyed in the 1990s. As a result, semiconductor companies need to squeeze every last drop of juice from the fruit.

Even a relatively simple metric like cost of sales as a percent of revenue shows that leading semiconductor players' sales organizations vary significantly in their effectiveness in generating revenues (Exhibit 1).

With these benchmarks as the foundation, we isolated the factors that hold semiconductor players' sales performance back and identified what they can do to unlock the full potential of their sales teams.

### Assessing sales effectiveness for semiconductor companies

To isolate the issues that hold back many semiconductor players, we analyzed the sector, using both industry information and sanitized results from client work. We were able to identify five questions that will help companies understand their strengths and highlight any weaknesses in the effectiveness of their marketing and sales teams.

#### What forms the foundation of your company's sales strategy?

In our experience, the majority of semiconductor companies frame their sales strategy around the supplier-addressable market (SAM)—the subset of the total addressable market that is left once they back out of the sectors they can't sell into due to lack of qualifications. A formal analysis of one client's account data showed that it had SAM of 55 percent of the total addressable market, yet after subtracting the opportunities it didn't pursue and the loss rate with regard to sales in the competitive marketplace, this company closed less than 7 percent of all potential sales—a sobering picture (Exhibit 2).

By focusing on SAM, semiconductor companies are overlooking improvements in sales effectiveness that could materially increase that market share. For example, the corners of the market that this company declined to pursue amount to 45 percent of total addressable market. Another complication: semiconductor companies classify accounts as key accounts or focus accounts based purely on the supplier-addressable spend. As a result, they align

Exhibit 1

**Wide variability in cost of sales across semiconductor companies.**

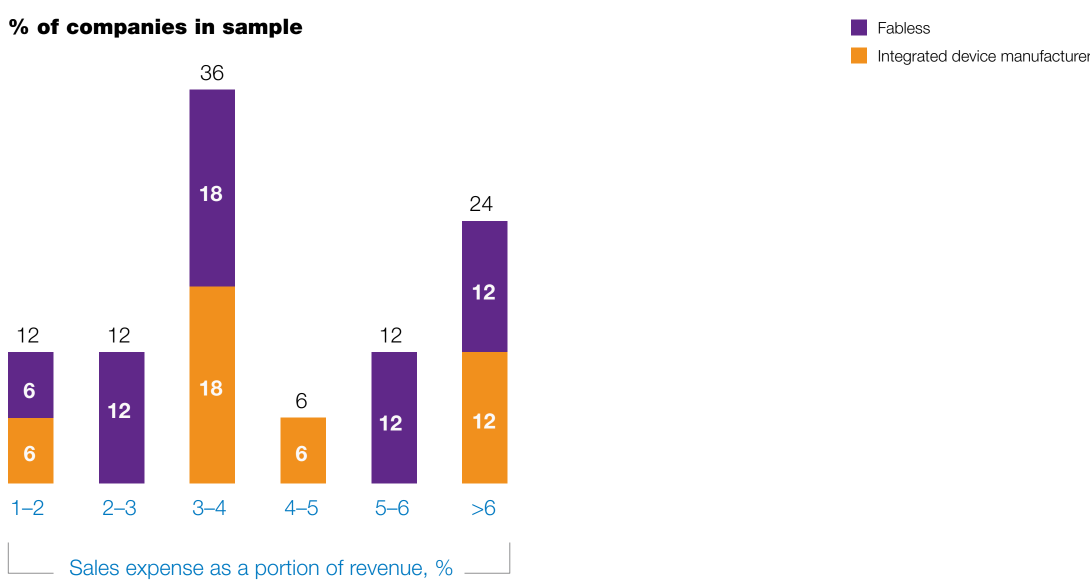
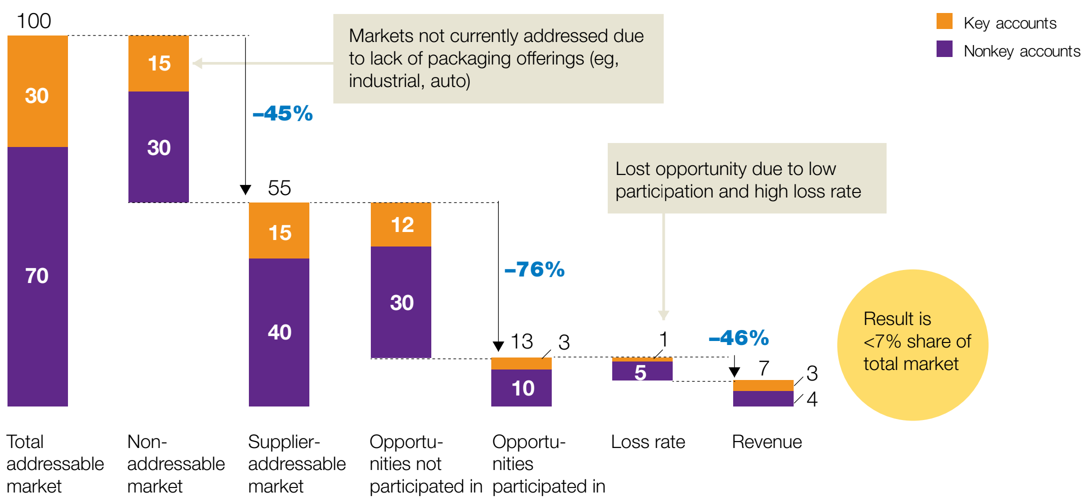


Exhibit 2

## Semiconductor players often miss out on a large portion of their addressable market by not identifying and participating in relevant opportunities.

**Sales pipeline**
**Revenue indexed to total addressable market, %**




Source: McKinsey sales and marketing semiconductor database

resources to increase calls and contacts with the key accounts and then the focus accounts, overlooking opportunities that lay beyond the current customer list. This leads to our second question.

### How efficient is the sales teams' coverage of both existing and prospective customers?

A common stumbling block for semiconductor players involves overinvesting their sales resources in "farming" current customers rather than "hunting" new design wins that will find a place in upcoming customer sockets. An analysis of sales-force time usage at one client showed that that there was three to five times the focus on existing customers as compared with new customers (Exhibit 3). Taking a deeper look, we also observed that, even with existing customers, the internal sales force has about 20 percent fewer touch points than external reps—primarily because too much time was invested in internal processes.

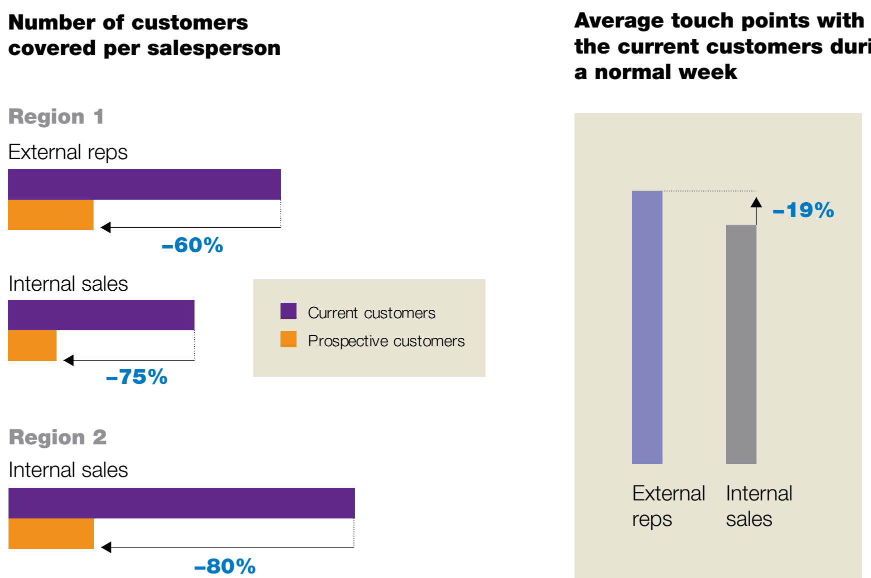
### Does the sales force have the right solution-selling skills to be effective?

While sales is regarded more as an art than a science, during our work with sales teams in the semiconductor sector, we have tried to identify what separates a good salesperson from an average one. We have found four qualities that separate the two categories:

- Opportunity identification. In our recent work with a client, we noticed that even within the supplier-addressable market, the sales team was participating in fewer than one in four new

Exhibit 3

**Semiconductor players often overinvest in 'farming' current customers instead of 'hunting' for new ones—even with current customers, their external reps outperform internal sales.**




opportunities. Sales leaders need to keep an eye open for gaps in this category, as they are not easily evident based on internal, self-reported SAM numbers.

- Understanding of customer needs. Our extensive survey of semiconductor sales forces reveals a gap in understanding customer needs. While most sales teams are well versed in their own company's products, they struggle to articulate the needs of the customer. As one regional sales manager put it, "[We need to] alter [our] approach from a product-centric to a segment- or customer-centric approach. Different customer segments need different intellectual property, different product features, and the like."

- Ability to communicate a unique value proposition. A universal theme in our work with semiconductor sales teams is the inability to communicate the company's or indeed the product's unique value proposition to the customer. The lack of a methodical approach to identifying and then communicating a product's unique attributes—and the dollar value of those attributes—to the customers is a key roadblock to unlocking true sales effectiveness.

- Multilevel selling. Strong sales teams usually cultivate a web of relationships with their customers, going beyond procurement mangers to R&D, engineering, and business unit managers. Having such deep access to customers is a key success factor when it comes to knowing

where the next opportunity for a design win will arise. It also helps sales teams define the attributes of the product that will truly add value for the customer.

## Is the sales process efficient enough to enable your sales team to be effective?

A common obstacle to sales effectiveness in the semiconductor sector is non-customer-facing activities that eat up the sales force's time. Examples include time spent preparing materials for internal meetings, time devoted to working with the product group to review new products, and gathering and entering information into demand-forecasting systems. According to our semiconductor-industry benchmarks, the average player's sales force spends only 26 percent of its time on customer-facing sales tasks, such as planning account strategy, planning sales calls, and traveling to meet with customers. Slightly more time, 28 percent, is devoted to internal tasks related to sales, such as campaign planning. Eighteen percent of the sales force's time is devoted to service and support activities. The remaining 28 percent of its time is eaten up by purely internal activities (for example, team meetings, management duties, and training sessions).

A lack of proper sales tools and marketing materials also drags down sales effectiveness. During client interviews, one field application engineer told us, "The field needs to be provided with quality updated competitive information, updated product guides, collateral, road maps, and clear messaging to sell more effectively." Others noted the lack of streamlined reports in their SAP system and the lack of a centralized product database. Without these resources, the sales force constantly has to reinvent the wheel, running up the tally of non-customer-facing time.

## How are sales teams managed and provided incentives?

Semiconductor sales teams are usually managed and provided incentives with an eye on quarterly and full-year sales targets. While the use of a single metric is simple—and ensures a tight focus on driving the top line—in our experience, it also has two critical downsides. First, a short-term focus on revenue results in decisions that favor quick progress over the types of longer-term investments that can significantly improve the revenue trajectory of the company, and second, a sole focus on revenue may not translate into appropriate levels of profitability. Unless the sales team feels it needs to protect certain profit margins, this focus on selling at any cost can quickly erode sales effectiveness.

Given the crucial importance of the marketing and sales functions in semiconductor companies, it is surprising that so many companies let these shortfalls bedevil the sales process. But it does not have to be this way. Over the course of our benchmarking effort, we found a number of high-performing semiconductor companies, and from our analysis of this group, we were able to synthesize a road map for any player looking to elevate its sales performance.

### Journey to best-in-class sales performance

In our research, we found that high-performing semiconductor companies invest in each of the five distinct areas discussed earlier to ensure that sales excellence becomes a reality. To make this investment pay off, they rely on five key success factors.

#### Establish a focused sales strategy

The first essential element involves setting revenue and gross-margin targets for each customer. This will allow proper prioritization and, ultimately, segmentation of customers into three categories: high priority, maintain, and lower focus. As for key accounts, they should be prioritized based on current and potential share-of-market expectations for the various divisions of the customer organization. The goal is to apply the same segmentation to divisions within top customers and to double down on those with the largest product spending and largest revenues. Divisions that have already been solidly penetrated would fall into the maintain category. Laggards fall into the lower-focus category and are only covered lightly (Exhibit 4).

Exhibit 4

## The focus for key accounts should be refined based on current and potential share expectations.

ILLUSTRATIVE EXAMPLE OF GO-TO-MARKET PLAN

□ Current SOM[1] ■ ▶ Double down
▷ Future SOM[1] ■ ▶ Maintain
■ ▶ Lower focus

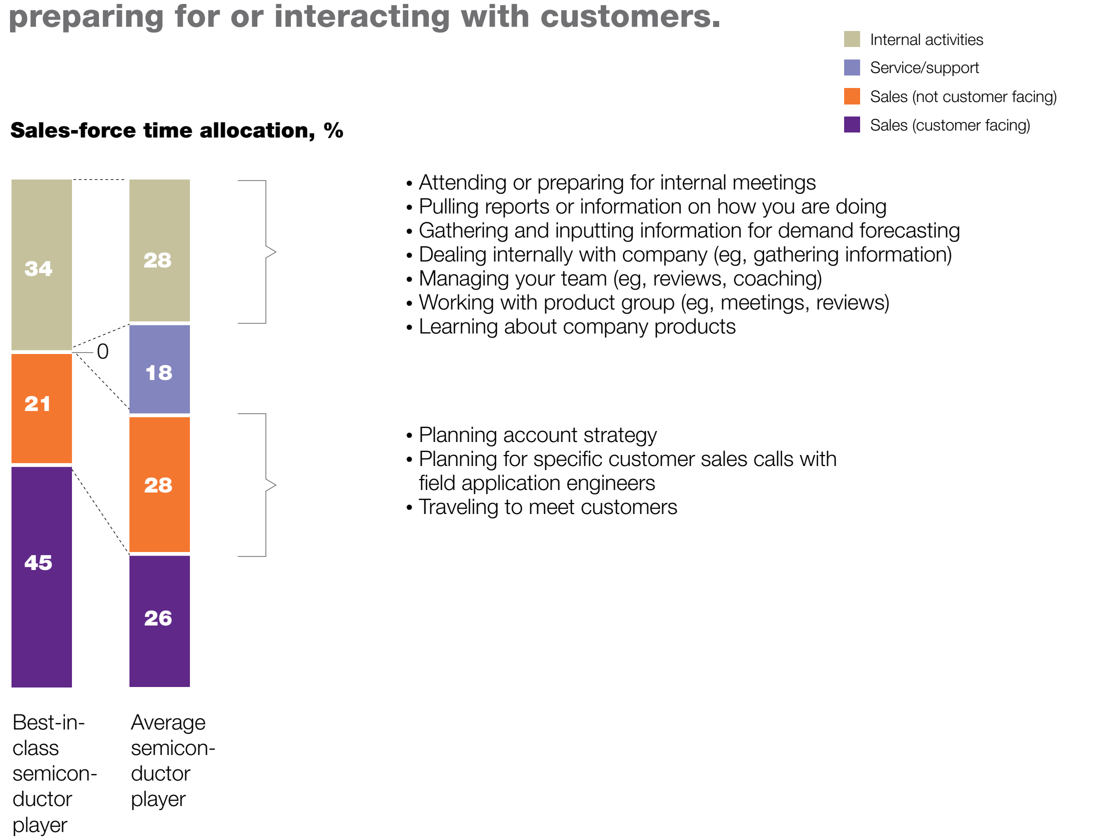
Customer lens by division

| Customer | Division 1 | | Division 2 | | Division 3 | | Division 4 | |
|---|---|---|---|---|---|---|---|---|
| Product A spend | $15 million | | $8 million | | $10 million | | $1 million | |
| Product B spend | $5 million | | $25 million | | $3 million | | $1 million | |
| Product A SOM[1] (%) | 5% ■ | 10% ▶ | 10% ■ | 20% ▶ | 60% ■ | 60% ▶ | 1% ■ | 2% ▶ |
| Product B SOM[1] (%) | 2% ■ | 6% ▶ | 2% ■ | 7% ▶ | 10% ■ | 11% ▶ | NA ■ | NA ▶ |
| Need to close loop with product marketing and engineering to drive design wins | • Largest product spend; small market share<br>• Will benefit from putting more resources into securing design wins, as products have long life cycles | | • Largest division by revenues<br>• New design wins are largely in a space of relative weakness for the company with regard to technology and time to market | | • Good account penetration, achieved through design wins on key platforms<br>• Need to maintain account | | • Has not been a focus due to small total addressable market | |

[1]Share of market.

Exhibit 5

## Best-in-class sales performers spend about two-thirds of their time preparing for or interacting with customers.




### Develop an efficient coverage model for both existing and prospective customers

Next, semiconductor sales resources should be mapped to coverage needs, with an eye toward maximizing efficiency. By that we mean ensuring that the sales team ends up spending the bulk of its time in front of customers. In addition, within that time, the sales agents are balancing farming existing customers with hunting for prospective customers. Based on the best-in-class benchmarks from leading semiconductor players, we expect that about two-thirds of the time should be spent in customer-facing or preparatory activities ahead of sales calls (Exhibit 5).

These changes require organizational support, such as building up customer-service teams, clarifying the roles and responsibilities of the field team (including field application engineers and other technical staff), and establishing efficient processes and stringent performance-management systems. The latter two enablers will be discussed in detail below.

### Develop effective solution-selling skills

The third success factor covers targeted training programs aimed at remediating any areas in the current sales approach that are weak. We recommend conducting a quick survey of customers, asking them to rate performance across a number of key dimensions (for example, understanding of customer needs, negotiation skills, and coordination among sales, business units, and field application engineers) on a scale from zero to five. Next, ask the customers to rate the importance of each of those factors in driving direct sales. The results can be fed into a two-by-two matrix that will highlight the skills that are both important to the customer and lacking in the organization at present. These are the skills that need to be addressed promptly with formal training programs.

As noted above, in our experience, sales teams across the industry need to do a better job of understanding customers' needs and articulating value propositions to the customer. Structured negotiation exercises and formal sales playbooks have been employed to bridge this gap in certain semiconductor companies.

Semiconductor sales resources should be mapped to coverage needs...ensuring that the sales team ends up spending the bulk of its time in front of customers.

### Develop efficient sales processes

Fourth, we recommend that companies run a detailed activity analysis of sales staff to determine precisely how it is spending its time. Depending on the allocations that come in, it is possible to make process adjustments, such as automating certain reports, that lighten the administrative burden on sales agents. Other issues will require organizational realignment, such as transferring certain activities from sales staff to a call center or to the customer-service team. By bulking up these other teams and sending entire categories of requests their way, the sales force will have a significant time dividend that it can put toward sales activities. With these types of changes in place, the entire sales process will become much more disciplined, and this will, in turn, benefit the entire organization (Exhibit 6).

### Establish rigorous performance management

The final element of a best-practice sales approach involves a reworked performance-management system that will not only track sales revenue but will also track key business metrics throughout the sales pipeline, from the sizing of the total addressable market to the assessment of the revenue quality of each segment—and indeed each key account. These carefully chosen metrics will inform the choice of which segments

Exhibit 6

**A detailed activity analysis drives process and organizational fixes that increase the customer-facing time for the sales force.**

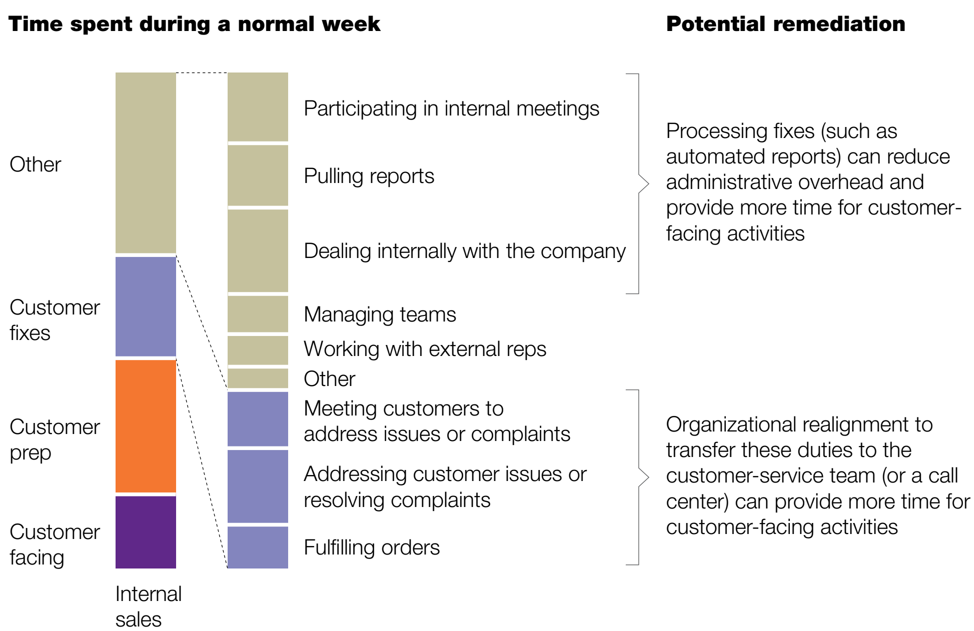
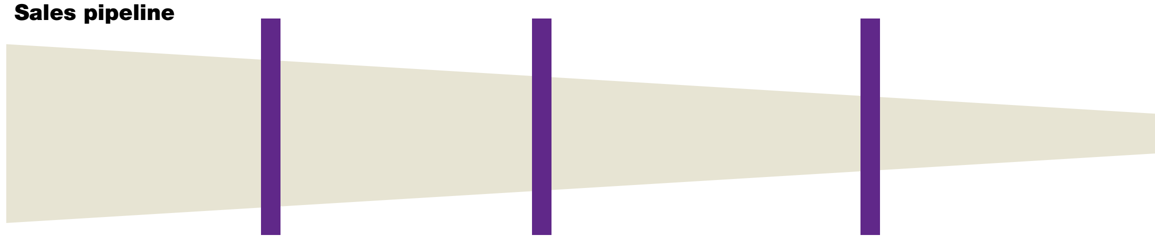


Exhibit 7

## Key metrics help track progress across the sales pipeline.

**Sales pipeline**



| **Total addressable market** | **Supplier-addressable market** | **Opportunities participated in** | **Opportunities won** |
|---|---|---|---|
| Key metrics to monitor sales effectiveness | 1 Targeting right segments (eg, those growing) | 2 Targeting right segment customers<br>3 Call frequency (touch points per employee per week by segments/accounts)<br>4 Pipeline key performance indicators | 5 Design win rate by segment or marquee wins by segment<br>6 New-win fraction (alpha growth in key segments/ share of market by segment)<br>7 Customer-loyalty index in key accounts<br>8 Revenue quality by key segments or accounts |

to pursue, as well as the tactical approach to employ. These metrics should drive the cadence and targeting of all sales activities, providing a data-driven basis for all major business decisions (Exhibit 7).

• • •

These ideas offer a glimpse of the tactics and vision that make up a larger sales-transformation program. However, many of the elements discussed above can be put in place within a few weeks. In a product cycle or two, the company will have profited significantly from the transformation, which will have freed up critical resources and aligned them against the largest accounts in key segments. In all, leaders will see a step change in sales performance. In an environment characterized by slowing sales growth, this could be a crucial differentiator in the years to come. ○

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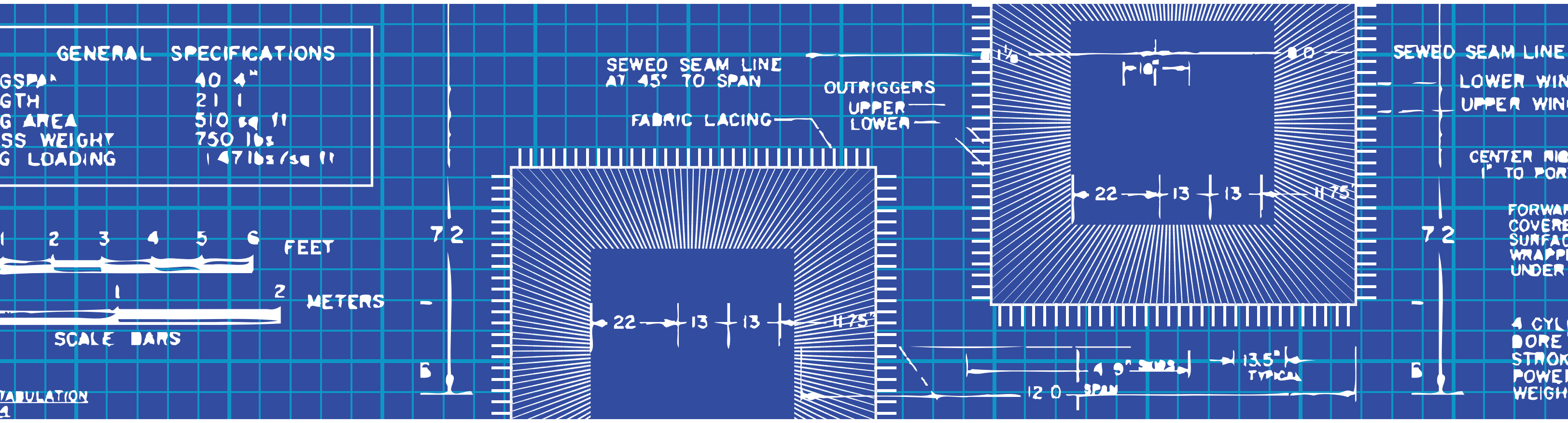



# At the core of communications: An interview with Broadcom's Scott McGregor

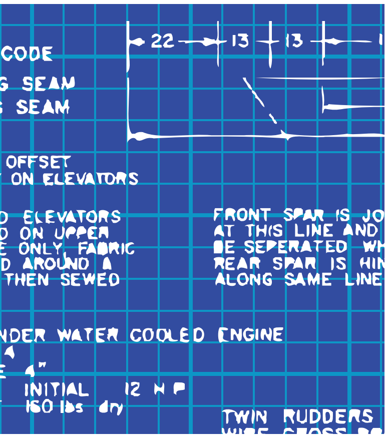
**Scott McGregor, president and CEO of Broadcom, talks about the roles that M&A and talent management play in shaping the strategy-development process. He also discusses his vision for the future of the semiconductor industry and Broadcom.**

**Rajat Mishra and Nick Santhanam**

Broadcom is the world's largest fabless semiconductor company. It offers the broadest range of system-on-a-chip (SOC) and software solutions in the industry and in just more than 20 years of existence, it has grown to be one of the top ten semiconductor companies in the world, as measured by revenues. The core of its portfolio is communications products, ranging from the guts of cable set-top boxes to femtocells, from cellular baseband chips to GPS processors and radio-frequency identification chips. Broadcom's offerings can also be found in corporate data centers and in cloud infrastructure. The company's intellectual property and product portfolio has attracted as customers some of the world's biggest names in computing and consumer electronics.

Broadcom's strategy has greatly contributed to the development of its impressive technology portfolio. Over the years, it has acquired nearly 50 companies, expanding its market footprint while soaking up technical expertise and innovative products along the way.

But as industry growth rates slow and the number of semiconductor start-ups dwindles, there are plenty of challenges that Broadcom's seasoned management team will face in the years ahead. McKinsey's Rajat Mishra and Nick Santhanam sat down with the CEO and president of Broadcom, Scott McGregor, to discuss the roles that strategy development and talent management play in today's business environment.




**McKinsey on Semiconductors:** *Let's start with a discussion of how you think about corporate strategy at Broadcom.*

**Scott McGregor:** We have a one-page corporate strategy at Broadcom. It helps us articulate what we are doing as a company, and it includes our goals, our competencies, and key metrics.

The philosophy at Broadcom is that everyone should have a voice in the company. We post the one-pager on the company's intranet and everyone in the company can comment on it. And we do get all sorts of suggestions—ranging from text edits to major shifts in company strategy. This level of participation gets everyone involved in the strategy-development process, and the finished strategy gets embedded deeply in the company's culture. The result isn't something a competitor can just copy—it's custom tailored to work well for Broadcom. At the same time, one must remember it is not a democracy. I hold the final pen when it comes to corporate strategy.

After the corporate strategy one-pager is finished, the individual business units use it to build their own one-pagers, and that is how the strategy gets percolated down through the organization.

**McKinsey on Semiconductors:** *Given all the groups providing input, from frontline employees to executive staff, how do you balance long-term vision with the strategy being actionable for the front line?*

**Scott McGregor:** The test is this: the one-pager should be useful in the boardroom and in small groups. We have lots of debates on how specific should it be. We have certain financial goals that help there. For example, we have specific targets such as 20 to 22 percent operating income and a 50 to 52 percent gross margin. At the end of the day, the metrics we set become the core of our corporate annual bonus plan, which means that execution becomes an even greater responsibility.

**McKinsey on Semiconductors:** *Mergers and acquisitions seem to be a big part of your strategy. Furthermore, the company has been successful in this area. Can you say a few things about how Broadcom views and approaches M&A?*

**Scott McGregor:** We decided to build M&A as a core competency at Broadcom. It is not about how big the M&A team is; it is more about ownership and accountability in the M&A function. At Broadcom, I would say about two-thirds of the acquisitions we've done have created value. About 15 to 20 percent have been a push, financially, and the rest have destroyed value. That's a better track record than almost anyone else we're aware of, but it underscores the point that M&A isn't risk free.

**McKinsey on Semiconductors:** *That is a pretty good record for M&A in general and for the semiconductor industry in particular. How does Broadcom go about M&A?*

**Scott McGregor:** One of the things we do is to integrate rapidly. The day the deal is done, we parachute in. We almost always replace the old IT system with a new one. It takes too much time and energy in the long run to migrate IT, so we just replace it. We also move quickly on things like signage and accounting. And we put a lot of energy into welcoming the people of the acquired company to Broadcom.

Most of our deals focus on early-revenue companies that are too mature for the venture-capital model. We focus on three questions when we look at potential targets. Are they accretive to growth? Is the team high quality, with a similar approach to engineering, innovation, and culture? And are the financials sound?

**McKinsey on Semiconductors:** *As the number of start-ups has been declining in the industry, don't you find this stance increasingly difficult?*

**Scott McGregor:** I agree that the number of companies has been decreasing as the costs to get them up and running have rapidly increased. But this is more of a phenomenon in the United States, as start-ups in the rest of the world have increased. So, the start-up decline is not broad based. And good talent is always around. For us, acquisitions are a way of acquiring talent.

**McKinsey on Semiconductors:** *Can you give us an example of how you thought through, and acted upon, an acquisition?*

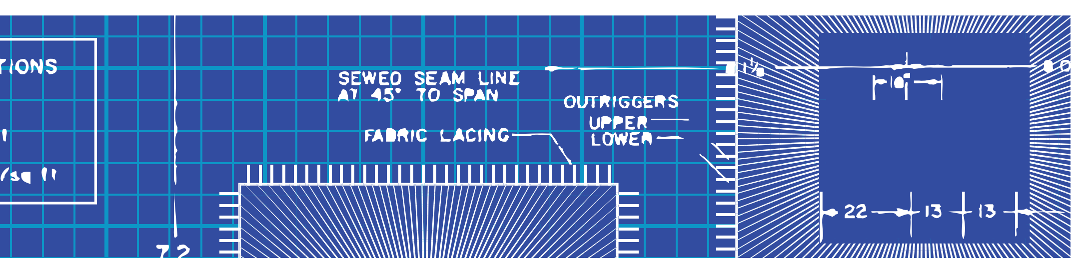
**Scott McGregor:** Well, long ago we realized that GPS would be an important growth space to get into for various reasons. So we started looking at a number of start-ups in this space, internationally. In parallel, we started our own GPS group within Broadcom, the rationale being that we wanted to know what we were getting into; we also wanted to be able to test the start-ups when it came time for evaluation.

We did not go with the industry leader. When we looked at its business plan, we saw that the company had faulty assumptions on average-selling-price trends, which led to unrealistic revenue targets and hence unrealistic valuation. After our search, we acquired Global Locate. It was not the largest or most successful start-up around, but we felt it had the best technology, the best team, and a robust and realistic business plan, in comparison with others. We acquired it, and as you know, GPS is integrated into our chips and we're now a leader in the space.

**McKinsey on Semiconductors:** *Do you think other semiconductor companies will do more M&A in the future?*

**Scott McGregor:** Either you have M&A in your DNA or you don't. I think most companies make few bids because if one doesn't work out, it creates a sense of hesitation to do another one, and yet that's the only way to build M&A capability.

We pick some of our best people to run M&A projects. We also look for people who have done it



If we find talented individuals, we help them do what they are good at and customize the role for them.

before. In fact, the talent of our teams eventually makes a lot of these bids successful.

**McKinsey on Semiconductors:** *This is a good segue into the talent discussion. Talent has been a thorny issue in the semiconductor industry lately. Can you tell us about the talent-management system at Broadcom?*

**Scott McGregor:** We have a 4 to 6 percent attrition rate at Broadcom. And, of the acquired companies, roughly 85 percent of the talent has been retained over the last five years.

On the M&A side, we find people that fit with our culture and give them important roles. If we don't think there is a fit, we don't pick them up. With acquired start-ups, we give them the incremental resources they need to be successful. We also give them access to our intellectual property. Broadcom is an "R&D candy store" for the companies we acquire.

We give engineers all the tools they need, but then we hold them accountable. There is a lot of false economics when it comes to cost cutting for engineers. I believe we need to give them the best equipment and resources and then hold them accountable. A few years ago, we hired consultants to tell us how to reduce our sales, general, and administrative expenses, and all they could tell us was that we needed to buy cheaper laptops for our engineers. I am not going to save a few hundred dollars (at best) and let my engineers wait five minutes every time they need to turn the computer on.

One way to think of Broadcom is that on the continuum of military regime to artists' colony we are more on the artists' colony side. More freedom, fewer rules. We tend to create jobs around individuals. If we find talented individuals, we help them do what they are good at and customize the role for them. The downside is that Broadcom can be a hard-to-navigate organization, and if you don't know people, it is tough to get things done. One of the things I tell new employees is get to know the organization, get to know the people, and create your own network.

**McKinsey on Semiconductors:** *Building on the people theme, how do you measure and reward employees at Broadcom?*

**Scott McGregor:** Alpha is a big part of our bonus plan. Our target alpha is 35 percent more or faster than the overall market-growth rates. So, we have to go faster than our peers in order to get rewarded. It does not matter how fast or slow the market grows—our metric is relative. If the market grows at 10 percent, our target is at least 13.5 percent.

# The coming war for talent in semiconductors

**Aaron Aboagye, Rajat Mishra, and Mohan Rajagopalan**

Research and development is the lifeblood of the semiconductor industry. R&D spending as a percentage of overall industry revenue has grown significantly, from 8 percent at the 1971 debut of the Intel 4004 microprocessor, through the bursting of the Internet bubble in 2001–02, to reach 16 percent today. The increase in the productivity and capabilities of semiconductor chips, measured by transistor count, has been noteworthy. The number of transistors in a DRAM chip has risen 45 percent a year since the mid-1970s; Intel's microprocessors increased 40 percent a year over the same period, and those on flash chips rose at a 74 percent rate. A deep well of engineering talent has made these achievements possible. However, in 2012, the pool of available semiconductor talent is shrinking.

We believe that the competition for talent will intensify in the coming years, yet most semiconductor companies seem ill prepared for that battle. And the vicious development cycles in the industry leave little time for optimizing talent management. Furthermore, skill in talent management correlates strongly with the overall performance of a company (exhibit), so executives will need to explore strategies that cover all aspects of talent management, from attraction and utilization to motivation and cultivation of the workforce.

As we see it, there are three major challenges that cloud the talent picture for semiconductor companies. First, the industry offers limited "step-out" innovation, focusing instead on incremental improvements to products and services. Next, the industry's growth rate is slowing as the market for semiconductors matures. And last, the supply of incoming semiconductor workers is insufficient, leading to a battle for finite talent resources. These three factors together create a perfect storm for semiconductor companies.

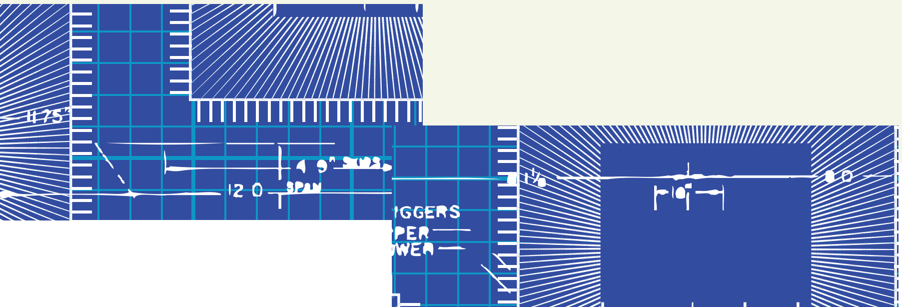
To start, most recent innovations in the semiconductor sector have been incremental. They involve upgrading products, adding new features, or enhancing end-user experiences rather than developing breakthroughs in, say, process technology. The most highly funded semiconductor start-up since 2000, INSIDE Secure, for instance, has developed a range of contact and contactless chips, near-field-communications chips, and reader solutions—all based on open standards. The second most highly funded start-up was Tabula, which makes 3-D programmable logic devices. These are cheaper, smaller, and a bit faster than existing field-programmable-gate-array chips, but they are still an incremental improvement. As a result, fewer engineering graduates are looking to work for major semiconductor companies.

To complicate matters, the compound annual growth rate of the semiconductor industry is slowing and beginning to mirror GDP growth rates. The industry's annual growth rate was 7 percent in the 2000s, and it is expected to average 5 to 6 percent a year in the current decade. That's significantly slower than the 13 percent annual growth rate the industry enjoyed in the 1990s.

Venture-capital funding for semiconductor start-ups is slowing as well. The number of semiconductor investments as a share of overall venture-capital activity fell to 1.7 percent in 2009 from 4.8 percent in 2004. A total of 48 semiconductor start-up investments were made in 2009, compared with 151 in 2005. With regard to public offerings, the deal value of semiconductor-company IPOs in comparison with the broader IPO pool has fallen by 12 percent each year since 2003.

Making matters worse, the number of graduates who pursue degrees in electrical engineering has been shrinking at a rate of roughly 7 percent a year since 2005. They made up only 0.73 percent of graduates in 2009, whereas they accounted for 0.99 percent four years earlier.

Of those who do graduate with relevant skills, fewer are choosing to work for semiconductor companies. Social-media and other Web 2.0 companies—such as Facebook,

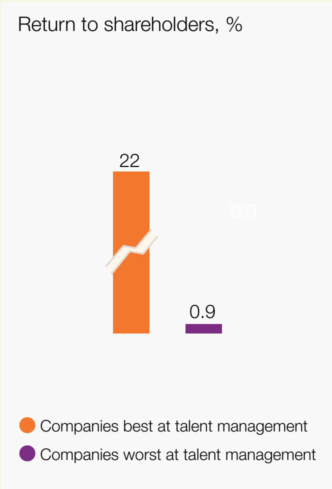


Exhibit

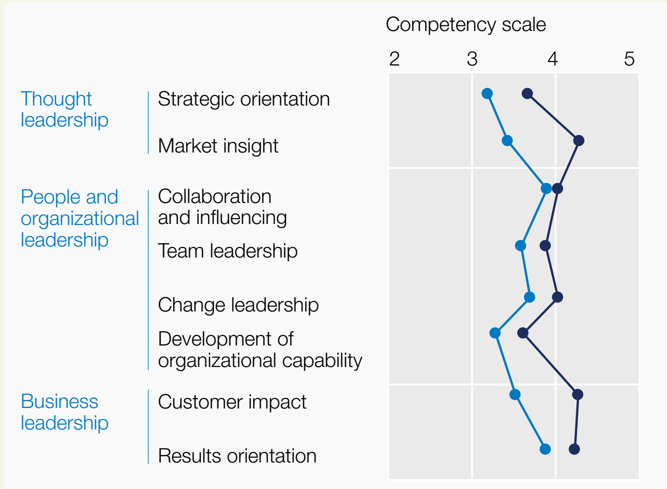
## Across industries, talent is a key driver of performance.

● Bottom-quartile companies (revenue, n = 494 appraisals)
● Top-quartile companies (revenue, n = 343 appraisals)

Talent management correlates with performance




Talent in top-performing companies scored higher in all competencies




Source: Global-forces executive opinion survey, 2005; next-generation talent research, 2006

Twitter, and Zynga—attract top engineering talent the way Google and Yahoo! did years ago. The shift can also be seen in *Fortune* magazine's "100 Best Companies to Work For" list. The number of semiconductor companies in that ranking went from eight in 2004 to just three in 2010.

The shortage of engineering talent will remain a cloud on the semiconductor industry's horizon for the foreseeable future. But industry players can use an enhanced talent strategy to expand the search for talent and to extend the tenure of the engineers they do attract. Companies that look after the lifestyle and the longevity of their engineers will find themselves better placed to win in the competitive years ahead.

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## Scott McGregor

**Vital statistics**
Married, with 3 children
Lives in Orange County, California

**Education**
Graduated from Stanford University with a BA in psychology and an MS in computer science and computer engineering

**Career highlights**
**Broadcom**
(2005–present)
CEO

**Philips Semiconductors**
(1998–2004)
Served as president and CEO after joining Philips as head of its emerging-business unit

**Microsoft**
(1983–85)
Led the original Microsoft Windows group

**Xerox PARC**
(1977–83)
Worked on research programs

**Fast facts**
Is responsible for guiding the vision and direction for Broadcom's growth strategy

Enjoys electric cars and drives a Tesla

People sometimes ask me to forecast the market. But it is impossible to do. My view is, no matter what, we will grow at least 35 percent more or higher than the market. And when that happens, we gain share, even if the overall market is slowing down.

**McKinsey on Semiconductors:** *Let's talk about the semiconductor industry a little bit. There are smaller players with valuations in the $1 billion to $2 billion range, and then there are Intel and the others. How do you view these different parts of the industry?*

**Scott McGregor:** I feel that companies in the $1 billion to $2 billion range are stuck. There is an R&D arms race in semiconductors, and the smaller companies chronically underinvest in R&D. There is a game of Pac-Man under way in the industry. As companies gobble up niches on the socket where you play, you might just disappear.

As for Intel, I don't think people will overvalue processor speed in the future. People will buy SOCs. The processor is good enough now, and having the best of one piece is not enough anymore. The processor of tomorrow will be just a component, like a resistor or capacitor of today.

**McKinsey on Semiconductors:** *Where do you expect growth for the industry to come from?*

**Scott McGregor:** I am bullish about the industry and think value capture will increase. As the industry consolidates, it will rise from its current flatline performance.

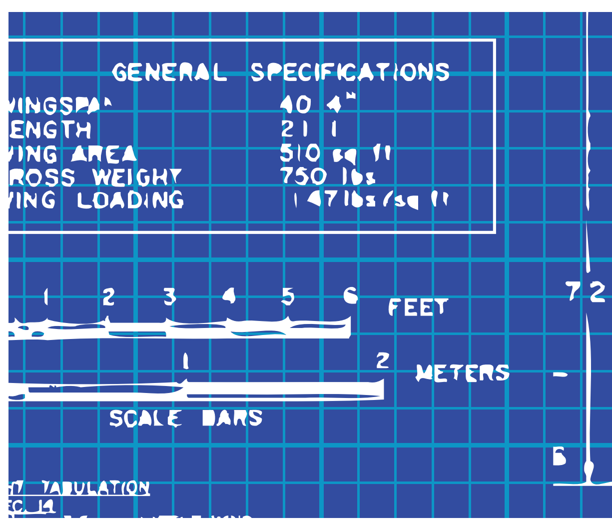
Software will be one of the vectors of growth. It will no longer be given away for free, or as a percent of the silicon's price, as the bill of materials grows. Software is one thing that will bring value to the industry. I also think the industry will move to charging for value. Switching costs for our customers are increasing, and the industry should use this trend to capture a bigger portion of value.

**McKinsey on Semiconductors:** *Let's talk about your personal aspirations and the things that keep you up at night.*

**Scott McGregor:** I am not happy with our shareholder returns, and I think we have pumped a lot more dollars into the long run and areas that have yet to come to market, rather than having a short-term focus on earnings. I think we will outpace the market and grow, and Wall Street will eventually recognize that.

Five years from now, I would like to see Broadcom recognized as the clear leader in both wired and wireless communications. We are in the business of encoding, transmitting, and decoding data, and that translates into both wired and wireless.

It is a privilege to work at Broadcom. I think a lot of technologies—for example, locational intelligence and user interfaces—are still in their infancy. And I look forward to the future with excitement.

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# **Solar power:** Darkest before dawn

**Those who believe the potential of the solar industry has dimmed may be surprised. Companies that take the right steps now can position themselves for a bright future in the coming years.**

**Krister Aanesen, Stefan Heck, and Dickon Pinner**

In less than a decade, the solar-photovoltaic (PV) sector has transformed from a cottage industry centered in Germany to a $100 billion business with global reach. Among the factors contributing to its growth were government subsidies, significant capacity additions from existing and new entrants, and continual innovation. PV prices have fallen dramatically, and by 2011, global installed capacity exceeded 65 gigawatts (GW).

PV prices are expected to continue to fall—even though subsidies are expected to dry up—as manufacturing capacity doubles over the next three to five years and underlying costs drop by as much as 10 percent annually until 2020. Indeed, our analysis suggests that by the end of the decade, costs could decline to $1 per watt peak (Wp)[1] for a fully installed residential system. But even if costs only fall to $2 per Wp, the industry is still likely to install an additional 400 to 600 GW of PV capacity between now and 2020.

Such a scenario could bring dramatic changes across the globe. Rapid growth of distributed generation could disrupt the regulated utility industry in countries that belong to the Organisation for Economic Co-operation and

[1] In photovoltaics, the output of a solar generator operating under standard conditions is defined as its peak output, which is measured in watts or kilowatts and expressed as either watt peak or kilowatt peak, respectively.

Development (OECD). In non-OECD countries, distributed generation (in combination with inexpensive storage solutions) could bring electricity to millions of poor people living in rural areas, greatly improving their standard of living.

Given the potential economic benefits, competition—already fierce—would intensify under such circumstances. Manufacturing is likely to become more standardized and commoditized as the industry matures, reducing opportunities for upstream players to differentiate themselves. Our research suggests that the industry may consolidate across the solar value chain as participants compete for capital and access to customers.

Downstream players will have the greatest potential to generate value, particularly when demand for distributed generation hits an inflection point after 2015. The biggest winners are likely to be those that target the highest-value customers in the distributed-generation segment, delivering quality products and services in multiple regions at scale while keeping their customer-acquisition and operational costs low.

In this article, we highlight five customer segments that could be particularly attractive over the next 20 years, excluding subsidized sources of demand such as feed-in tariffs, renewable-portfolio mandates, and tax credits that constitute the majority of today's installed capacity. We also outline a number of steps upstream and downstream players could take to position themselves for success in this new environment.

## Market evolution

Over the past seven years, the solar industry experienced unprecedented growth. The price of solar-PV modules dropped from more than $4 per Wp in 2008 to just under $1 per Wp by January 2012, and global installed capacity increased from 4.5 GW in 2005 to more than 65 GW today.

The subsidies that made solar PV economically attractive for many consumers set the conditions for the boom. Demand rose, new entrants flocked to the industry, and the pace of innovation accelerated. But the boom also laid the foundations for a bust. Manufacturing capacity increased dramatically—particularly after large-scale, low-cost Chinese manufacturers entered the space—and the market became oversupplied. Prices dropped precipitously, which fueled demand but put pressure on margins. In the near term, demand may not keep up with supply growth; governments are continuing to reduce subsidies due to the effects of the economic crisis, and the shale-gas boom is beginning to take hold in the United States. (See the sidebar "The global boom-bust cycle in solar PV" for more on how the market evolved from 2005 to 2011.)

It may therefore appear that the solar industry has run its course. A number of solar companies have already declared bankruptcy, many more are hovering on the brink, and the MAC Global Solar Energy Index fell 65 percent in 2011. Moreover, there is little doubt in the near term that existing players will face difficulties. Several global technology and manufacturing companies—including Samsung and Hanwha from Korea, TSMC from Taiwan, and GE from the

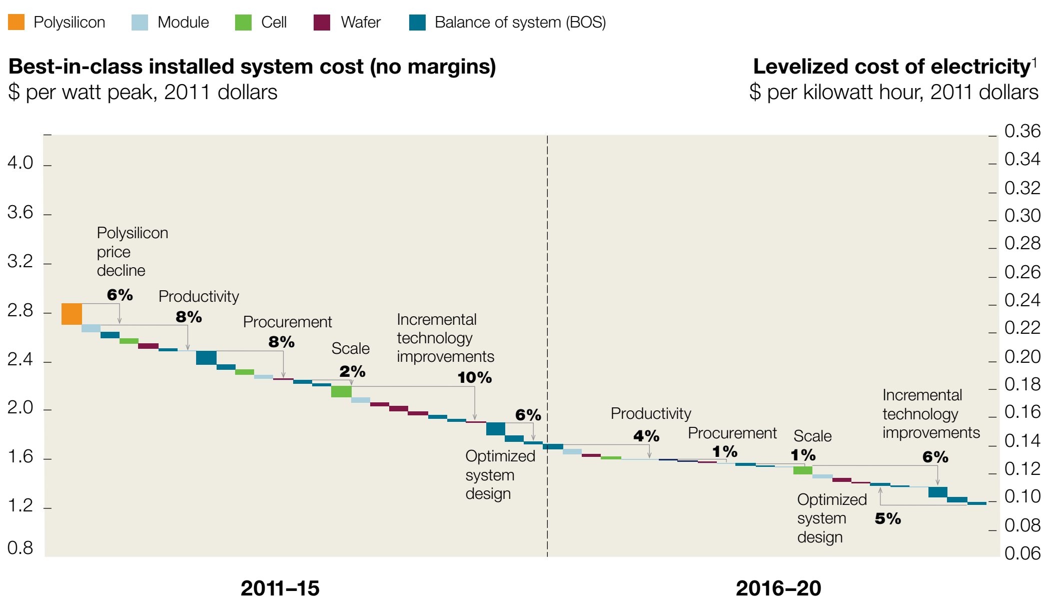
United States—have recently entered or announced their intention to enter the manufacturing segments of the solar value chain. Their efforts, combined with those of existing Chinese companies, could considerably increase global manufacturing capacity in the next three to five years, even as subsidies continue to shrink.

But these are natural growing pains, not death throes. The industry is entering a period of maturation that is likely to set the conditions for more stable and expansive growth after 2015. To succeed in this environment, companies must turn their attention to the relatively prosaic objective of reducing costs without giving up on the imperative to innovate, which has been critical to success thus far. Indeed, companies have an opportunity to reduce their costs dramatically by adopting approaches widely used in more mature industries to optimize areas such as procurement, supply-chain management, and manufacturing. For example, our analysis suggests that the cost of a commercial-scale rooftop system could be reduced by 40 percent by 2015, to $1.70 per Wp from roughly $2.90 per Wp, and by approximately another 30 percent by 2020—to nearly $1.20 per Wp (Exhibit 1). Thus companies could position themselves to capture attractive margins even as prices for PV modules decline.

Exhibit 1

## Industrialization will yield significant cost reductions.

c-Si multicrystalline solar-photovoltaic system




[1] Levelized cost of energy; assumptions: 7% weighted average cost of capital, annual operations and maintenance equivalent to 1% of system cost, 0.9% degradation per year, constant 2011 dollars, 15% margin at module level (engineering, procurement, and construction margin included in BOS costs).

Source: Industry experts; Photon; GTM Research; National Renewable Energy Laboratory; US Energy Information Administration; Enerdata; press search; company Web sites; McKinsey analysis

## Potential evolution of solar-PV capacity in the United States

The unsubsidized economic potential for distributed residential and commercial solar photovoltaic (PV) in the United States is likely to reach 10 to 12 gigawatts (GW) by the end of 2012. This is not the amount of PV capacity that will be installed, but the amount that producers could sell at a profit because it is competitive with other options (such as purchasing electricity via the grid from a traditional utility) on total cost of ownership.

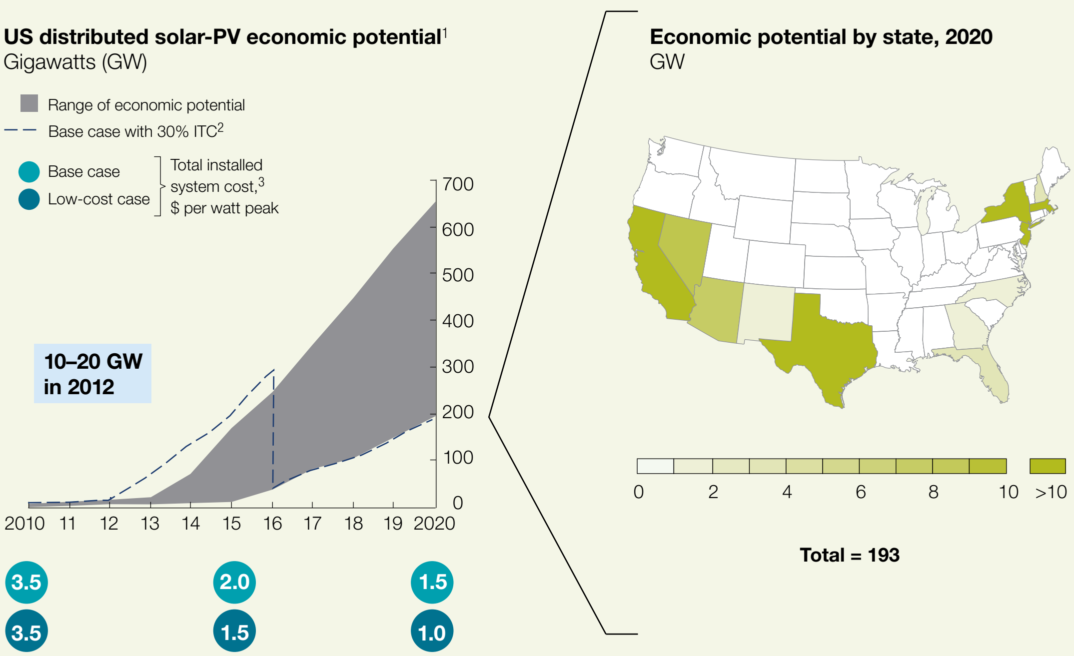
Growth is likely to continue in these segments after 2012, potentially reaching a tipping point in 2014 or 2016 that could enable unsubsidized demand for solar PV to grow to between 200 and 700 GW by 2020. Demand is likely to be concentrated in ten states. Indeed, 50 percent of the available power delivered to the residential and commercial segments in some of these states may be generated by solar PV in 2020.

Our estimates increase dramatically when we include the effects of subsidies from the federal government's investment tax credit,[1] which could enable installed capacity of solar PV to climb as high as 70 GW by 2013 (exhibit).

[1]The investment tax credit, which is in effect through December 31, 2016, provides a reduction in the overall tax liability for individuals or businesses that make investments in solar-energy-generation technology.

Exhibit

### Solar PV for distributed generation is approaching an inflection point in the United States.




[1]PV = photovoltaic; economic potential assumes 20-year lifetime and 8% cost of capital, computed separately for residential and commercial segments using actual retail rates, schedules, and tiers.
[2]Investment tax credit.
[3]Numbers quoted are for a best-in-class commercial rooftop system; residential systems modeled with 30% higher price to account for higher installment costs.

Source: US Energy Information Administration; Ventyx; utility filings; National Renewable Energy Laboratory; McKinsey US low-carbon economics toolkit

## The prize: Distributed generation

Our analysis suggests that the global economic potential for total installed solar PV—that is, the amount of PV that could be operated at a lower levelized cost of energy (LCOE)[2] than competing sources—could exceed a terawatt (1,000 GW) by 2020. However, given the barriers to implementation, such as possible changes to the regulatory environment and access to finance, we expect installed capacity to increase to between 400 and 600 GW by 2020.[3]

At this level of demand, annual capacity additions would increase by a factor of three to four, climbing to 75 to 100 GW in 2020 from 26 GW in 2011. Price declines mean that the annual revenue generated across the value chain will probably remain flat, about $75 billion to $100 billion per year, despite the fact that margins may begin to rise around 2015. Nevertheless, our analysis suggests annual installations of solar PV could increase 50-fold by 2020 compared with 2005, achieving installation rates that could rival those of gas, wind, and hydro and that might outpace nuclear.

This growth will stem largely from demand in five customer segments over the next 20 years. Four of these segments are likely to grow significantly by 2020; the fifth is likely to grow significantly from 2020 to 2030 (Exhibit 2).

1. Off-grid areas. Solar power is ideal in places without access to an electric grid. Applications include delivering power to agricultural irrigation systems, telecommunications towers, remote industrial sites such as mines, and military field sites. Within this segment, the most significant potential resides in areas that use diesel generators to provide uninterrupted power supply for remote infrastructure, such as telecommunications towers in India. Off-grid applications have been economically viable in some locations for several years, but the lack of low-cost financing for remote sites—where credit risk is often relatively high—has made it difficult for companies and customers to afford the up-front costs of installation. The dearth of local distribution partners has also impeded growth. Nevertheless, our research indicates that demand in this segment could reach 15 to 20 GW by 2020.

2a. Residential and commercial retail customers in sunny areas where power prices rise steeply at times of peak demand. Many businesses in places like California, Hawaii, Italy, and Spain already generate their own power using solar applications. In the near term, this segment's growth will depend on the availability of low-cost financing, customer-acquisition costs, and reactions from regulated utilities. For example, in the United States and Europe, there is a risk that utilities could request to modify their rate structures to make switching to distributed generation less attractive for customers. In Hawaii, regulations require anyone located in a region where distributed generation represents 50 percent of peak demand to undergo a lengthy and costly review process before adding distributed solar capacity.[4] In India, companies such as SunEdison (now part of MEMC) have partnered with organizations like the World Bank's International Finance Corporation and the Export-Import Bank of the United States to establish programs that enable preapproved financing. Our analysis suggests that the demand in this segment is likely to be between 150 and 250 GW by 2020.

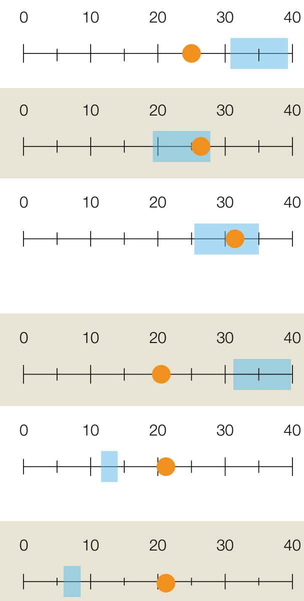
[2] Levelized cost of energy is the price at which electricity must be generated from a specific source to break even.
[3] At these levels, solar power would represent about 2 to 3 percent of power generated globally in 2020, which would nearly equal the projected total demand for power in Africa in 2020.
[4] The rule is designed to mitigate the risk that distributed generation might pose to the stability of the power grid. In 2011, the threshold was increased to 50 percent from its earlier level of 15 percent.

Exhibit 2

## Solar power is approaching a tipping point in a number of customer segments.

**Photovoltaic solar power**

Cost comparison, 2011, ¢ per kilowatt hour
● Solar ■ Other energy sources[1]




| | Customer segment | Cumulative market potential,[2] 2012–20, GWp (gigawatt peak) | Timing of viability |
|---|---|---|---|
| 1 | **Off-grid:** applications in areas with no grids (eg, Africa, India, Southeast Asia, and parts of Middle East) | 15–20 | Now |
| 2a | **Commercial and residential, good sunlight:** developed markets in sunbelts (eg, Australia, California, Italy, and Spain) | 150–250 | Now |
| 2b | **Commercial and residential, moderate sunlight:** developed markets with moderate solar yields (eg, Canada, Denmark, Germany, Netherlands, and United Kingdom) | 65–120 | 2012–13 and beyond |
| 3 | **Isolated grids:** small local grids primarily fueled by small diesel generators; large latent demand (eg, Africa) | 25–30 | Now |
| 4 | **Peak capacity in growth markets:** growth markets; large power investments (eg, Africa, China, India, and the Middle East) | 150–170 | 2013–14 and beyond |
| 5 | **New large-scale power plants:** growth markets; large power investments (eg, China, India, and the Middle East) | Marginal | 2025 and beyond |

**Total market potential = 400–600 gigawatts**
(compared with 2011 installed base of 65 gigawatts)

[1]Alternative to solar power in given segment—eg, for residential customers, price for power from grid.
[2]Adjusted for implementation time.

Source: US Energy Information Administration; McKinsey analysis

2b. Residential and commercial retail customers in areas with moderate sun conditions but high retail electricity prices. A wide range of countries and regions fall into this segment, including parts of Europe and the United States, Japan, Canada, and some countries in Latin America. As in segment 2a, barriers to growth include access to low-cost financing and the ability to dramatically reduce customer-acquisition costs. New entrants from the security, cable, or broadband industries could leverage their existing customer relationships to acquire customers at a significantly lower cost than existing players. If the barriers are addressed, potential demand in this segment could range from 65 to 120 GW by 2020. (See the sidebar "Potential evolution of solar-PV capacity in the United States" for details about likely PV penetration in the country through 2020.)

3. Isolated grids. Small grids fueled by diesel generators require an LCOE of between $0.32 and $0.40 per kilowatt hour (kWh) to be economically attractive. These primarily provide power to remote villages in Africa,[5] India, Southeast Asia, and parts of the Middle East. We estimate that demand in this segment is already 25 to 30 GW. The current barrier to deployment is the limited availability of low-cost financing in non-OECD regions.

4. Peak capacity in growth markets. To be economically attractive, new solar-power plants used at periods of peak capacity require an LCOE of $0.12 to $0.14 per kWh. The largest potential for this segment lies in markets where substantial new electric-power infrastructure is set to be built (for instance, India, Brazil, the Middle East, and China) or in countries that rely heavily on imports of liquefied natural gas (such as Japan). Greater access to inexpensive natural gas from shale could erode solar economics, but demand may reach 150 to 170 GW by 2020.

5. New, large-scale power plants. New solar-power plants must reach an LCOE of $0.06 to $0.08 per kWh to be competitive with new-build conventional generation such as coal, natural gas, and nuclear. As with smaller peak-capacity plants, large-scale solar plants are most likely to be built in emerging markets that are expanding their infrastructure aggressively, where the cost of solar will be compared with the cost of a new coal, natural-gas, or nuclear plant. Companies must still achieve breakthroughs in manufacturing techniques to reach this cost threshold in solar; once they do, it will take time to implement the advances at scale. Extensive use of solar as an alternative to traditional base-load generation is not likely before 2020, but the segment could reach 110 to 130 GW by 2030, representing only 15 percent of the cumulative new solar build in the same period.[6] Margins will probably be set by the wholesale power price, however, and may be slim as a result.

Across these five segments, distributed rooftop generation is likely to be the dominant source of solar demand in OECD countries; distributed ground-mounted generation is likely to dominate non-OECD countries (Exhibit 3).

In addition to these segments, many entrepreneurial opportunities will arise for new players and investors seeking to develop tailored business models in different markets and customer segments. Sets of companies focused on serving specific segments could emerge, and these players might become regional or even global champions in their chosen niches. For

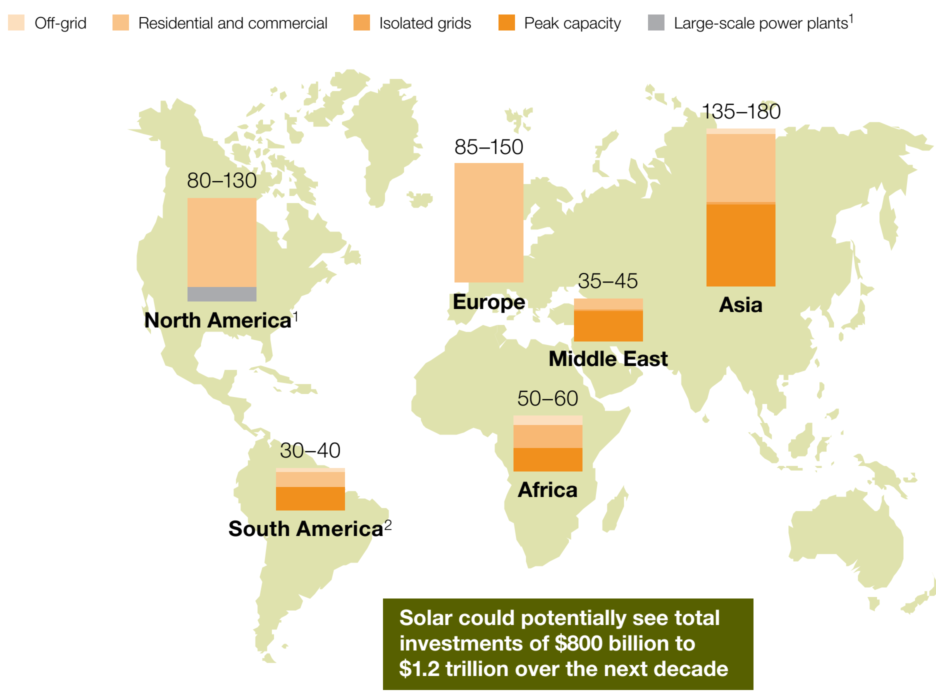
[5] According to the International Energy Agency, there are almost 590 million people with no access to power in Africa alone.

[6] Costs at this level could support the building of new power plants in the United States and some European countries in order to meet carbon-emission targets between 2020 and 2030. However, much will depend on the extent to which low-cost natural gas becomes available in these markets. The analysis therefore heavily discounts the potential in developed markets.

Exhibit 3

## Growth in solar PV may transform power markets.

Cumulative capacity additions, 2012–20, gigawatts




[1] Includes 10–20 gigawatts of regulated utility pipeline in the United States.
[2] Includes Mexico.

Source: Enerdata; McKinsey Global Solar Initiative

example, a phone company could make a play to provide solar power and water pumping in Africa. A global developer could help big retailers such as Wal-Mart and Staples to deploy solar and energy-efficiency approaches in their stores. Home-security companies such as ADT could add solar-power packages on to their existing value propositions.

Given the emergence of these pools of demand, we believe that leading solar companies could have healthier margins by 2015. Prices paid for solar are likely to continue to fall, but sales should rise as solar power becomes economically viable for an increasing number of customers. Additionally, because prices for solar-based power are likely to be set by prices for fossil fuels instead of subsidies (which have been falling annually), margins for leading solar players should increase even as their costs continue to decline.

### How to win

Against this backdrop, competition among manufacturers is likely to intensify, but our analysis suggests that downstream segments of the value

## The global boom-bust cycle in solar PV

### Boom: 2005 to 2008

The solar industry was initially nurtured in Germany, Japan, and the United States, then gained strength in countries such as Italy, where government support designed to boost demand helped photovoltaic (PV) manufacturers increase capacity, reduce costs, and advance their technologies.

These subsidies helped spur demand that outpaced supply, which brought about shortages that underwrote bumper profits for the sector until 2008. The focus during this period was developing better cell and module technologies; many Silicon Valley–based venture-capital firms entered the space around this time, often by investing in companies in thin-film solar-cell manufacturing. Valuations for some of the more promising solar-cell start-ups at that time exceeded $1 billion.

The price to residential customers of installing PV systems fell from more than $100 per watt peak (Wp) in 1975 to $8 per Wp by the end of 2007—although from 2005 to 2008, prices declined at the comparatively modest rate of 4 percent per year. German subsidies drove value creation, with the lion's share of the value going to polysilicon, cell, and module-manufacturing companies in countries that are part of the Organisation for Economic Co-operation and Development.

### Bust: 2009 to 2011

Encouraged by the growth of the industry, other countries—including France, Canada, South Korea, Australia, South Africa, India, and China—began to offer support programs to foster the development of solar sectors within their borders.

Chinese manufacturers began to build a solar-manufacturing sector targeting foreign countries where demand was driven by subsidies, particularly Germany. Armed with inexpensive labor and equipment, Chinese players triggered a race to expand capacity that drove PV prices down by 40 percent per year; prices fell from more than $4 per Wp in 2008 to about $1 per Wp in January 2012. We estimate that balance-of-system (BOS) costs declined by about 16 percent per year in this period, from about $4 per Wp in 2008 to approximately $2 per Wp in 2012 (these are more difficult to track, in part because BOS costs vary more than module costs).

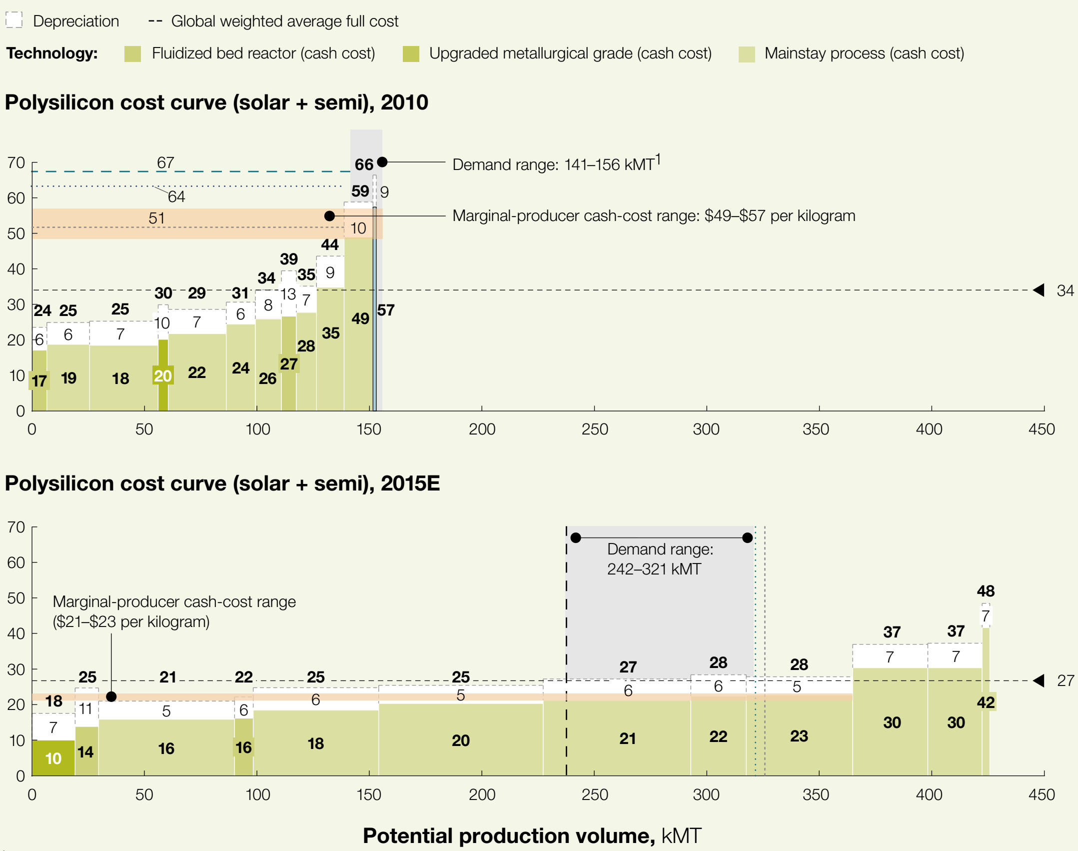
The cost curve flattened for many upstream segments of the value chain during this period. For example, costs converged for many polysilicon manufacturers from 2010 to 2012; one force that drove this trend was the entry of players such as South Korea's OCI Company Ltd. and China's GCL Solar, which contributed to polysilicon spot prices declining from about $50 per kilogram in 2010 to between $20 and $25 per kilogram today (exhibit). Solar-cell and module cost curves have flattened to similar degrees. As a result, value has migrated downstream to players that develop and finance solar projects and install capacity.

By 2009, venture-capital firms began to shift their new solar investments from capital-intensive solar-cell manufacturers to companies focused on developing innovative downstream business models, such as Solar City, SunRun, and Sungevity.

Exhibit

## The polysilicon cost curve illustrates how upstream cost curves are flattening.

Production cost (cash cost and full cost), $ per kilogram




[1]Kilo metric tons.

Source: Expert interviews; literature search; iSuppli; Photon; Bernreuter Research; Solar & Energy; McKinsey analysis

## Scale will be crucial for solar manufacturers; to achieve scale, they will also need strong balance sheets.

chain will become increasingly attractive. Both upstream and downstream players will have to reduce costs dramatically to succeed, but they will also need to deliver distinctive products and services. Manufacturers can distinguish themselves by developing proprietary technologies; downstream players should focus on meeting the needs of particular customer segments.

### Key success factors for upstream players

Scale will be crucial for solar manufacturers. A few years ago, manufacturers needed to have 50 to 100 MW of solar capacity to compete in the PV market; today they need 2 to 3 GW of capacity to compete. To achieve scale, they will also need strong balance sheets. We have identified three steps that manufacturers can take to get there.

*Develop or own differentiated and scalable technologies.* Companies can capture significant cost advantages by developing proprietary technologies. This is particularly important in manufacturing, where cost curves that were historically quite steep have already flattened significantly and will continue to do so. For example, MEMC and REC have commercialized the fluidized-bed-reactor (FBR) process to reduce the energy intensity of manufacturing polysilicon relative to today's mainstay polysilicon manufacturing process. As a result, the cost of polysilicon is expected to drop significantly by 2015, with the leading players that use the FBR process achieving cash costs of $14 to $16 per kilogram, compared with $16 to $18 per kilogram for leading players that do not use it. Others have developed cell technologies using copper indium gallium selenide that require much less photovoltaic material to harvest the solar energy than crystalline silicon technologies; these new technologies could therefore be less expensive.

*Drive operational excellence in manufacturing.* Manufacturers should examine every operational step to identify opportunities to reduce costs. They should consider adopting lean production approaches, implementing category-based procurement processes, developing strategic relationships with suppliers, and streamlining their supply chains. To drive operational excellence, leading players often recruit experienced managers from highly competitive industries such as automotives, electronics, or semiconductors. Manufacturers can increase productivity by 30 to 40 percent by pursuing these types of initiatives. They can also develop advantages by adopting practices from other industries to increase their productivity. For example, Taiwanese and Korean companies are applying low-cost approaches for manufacturing solar technologies that were originally developed for manufacturing semiconductors and liquid crystal displays.

*Address balance-of-system costs.* Solar components excluding PV panels—such as wires, switches, inverters, and labor for installing solar modules—represent more than half the cost of a solar system. These components are collectively referred to as the "balance of system" (BOS), and BOS manufacturers could significantly reduce their costs (and thus lower costs for the whole industry) by implementing techniques—such as modularization, pre-assembly, standardization, and automation—that are common in mature industries. BOS manufacturers could also reduce industry costs by increasing the durability of the components—for example, by developing technologies that significantly extend the lifetime of inverters relative to the seven to ten years typical today.

Large manufacturing companies may have the scale to excel at reducing costs and improving product performance, but they sometimes lack the capabilities needed to understand and fulfill customer needs. Incumbent manufacturers could seek to strengthen their positions by acquiring or partnering with companies that are closer to customers and that can support the development of tailored solutions.

## Key success factors for downstream players

Since the bulk of the market in the next five to ten years is expected to be in distributed generation, we focus here on downstream distributed-generation companies. These companies should focus on serving high-value customers at low cost. To do so, companies must know their customers well: they need to understand the solar conditions in the areas in which customers are located, the space customers have available for solar applications, the level of power they consume at different times of day and throughout the year, the amount they pay for power, and their ability to finance purchases. These companies must also reduce the cost of acquiring and serving customers.

*Develop targeted customer offerings.* Large commercial customers are likely to prefer suppliers that can install and operate solar systems across a global network of sites. Providers will also increasingly be asked to develop specialist solar applications—for example, direct-

current water pumps and mobile-charging units, or applications that combine solar with LED lighting. IBM uses solar applications to power its high-voltage, direct-current data center in Bangalore. Off-grid applications in emerging markets need robust equipment that is easy to install without sophisticated engineering and construction equipment. Companies could partner with local project developers to gain access to reliable distribution channels and secure access to finance for projects that carry risks specific to emerging markets. They could also partner with companies that already deliver products and services. For example, Eight19, a solar-PV start-up, partnered with SolarAid, a nonprofit, to provide Kenyans with bundled products and services that include solar-powered LED lighting and phone-charging options. Customers pay for the services as they use them via scratchcards validated through a text-message service. These products are inexpensive to manufacture, and the innovative pay-as-you-go approach enables partners to address some of the financing challenges that might otherwise stymie their efforts to serve poor communities.

*Minimize customer-acquisition and installation costs.* In the residential segment, acquisition costs for pure-play solar installers in places such as California vary from about $2,000 to more than $4,000 per customer. Acquisition costs are significantly lower in Germany, but best practices that have enabled German companies to reduce costs are not always transferrable given the regulatory environment and the lack of feed-in tariffs in the United States. For players in the United States to sufficiently reduce acquisition cost per customer, companies should minimize door-to-door sales efforts and prescreen potential customers for creditworthiness. Digital channels provide opportunities to meet marketing goals at a lower cost than traditional approaches allow. Companies may also be able to reduce acquisition costs by striking partnerships with companies in other sectors: for example, home builders, security companies, broadband providers, or retail power providers. They can reduce installation costs by optimizing logistics, predesigning systems, training employees to improve their capabilities, and clearly defining standards.

*Secure low-cost financing.* Many companies are partnering with other organizations to gain access to low-cost financing. MEMC's SunEdison joined with First Reserve, a financial provider, to secure a large pool of project equity. SolarCity secured funding from Google to finance residential solar projects, enabling Google to receive tax benefits in exchange for owning electricity-producing solar assets. Other potential innovative approaches include solar real-estate investment trusts,[7] which allow retail investors to provide funding for solar projects or offer options that let distributed-generation customers pay for their solar investments via their monthly utility bill. The cost of capital is often the most crucial factor determining returns on solar projects. To succeed in downstream markets, companies need strong capabilities in project finance—indeed, the entities that structure solar investments often achieve better returns than the companies that manufacture or install modules. Companies are increasingly likely to turn to institutional investors, asset-management firms, private-equity firms, and even the retail capital markets to raise the

[7] In general, a real-estate investment trust (REIT) is a company that owns (and typically operates) income-producing real estate or real estate–related assets. REITs provide a way for individual investors to earn a share of the income produced through commercial-real-estate ownership without actually going out and buying commercial real estate. Solar REITs rent roof space to companies and utilities that can install and manage solar panels on top of buildings.

sums required to finance expected demand for solar, which could add up to more than $1 trillion over the next decade.

As the solar investment pool swells, financial institutions, professional investors, and asset managers are likely to be drawn to the sector, since solar projects that are capital-heavy up front but rely on stable contracts will become attractive in comparison with traditional financial products. New types of downstream developers and investment products will emerge to aggregate low-cost equity and debt and to structure financial products with risk-return profiles aligned with the specific needs of institutional investors.

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The solar industry is undergoing a critical transition. The rules of the game are changing, and many current players could face significant challenges as the industry restructures. But those who believe the solar industry has run its course may be surprised. Solar companies that reduce their costs, develop value propositions to target the needs of particular segments, and strategically navigate the evolving regulatory landscape can position themselves to reap significant rewards in the coming years.

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