2024 GLOBAL SEMICONDUCTOR MARKET OUTLOOK

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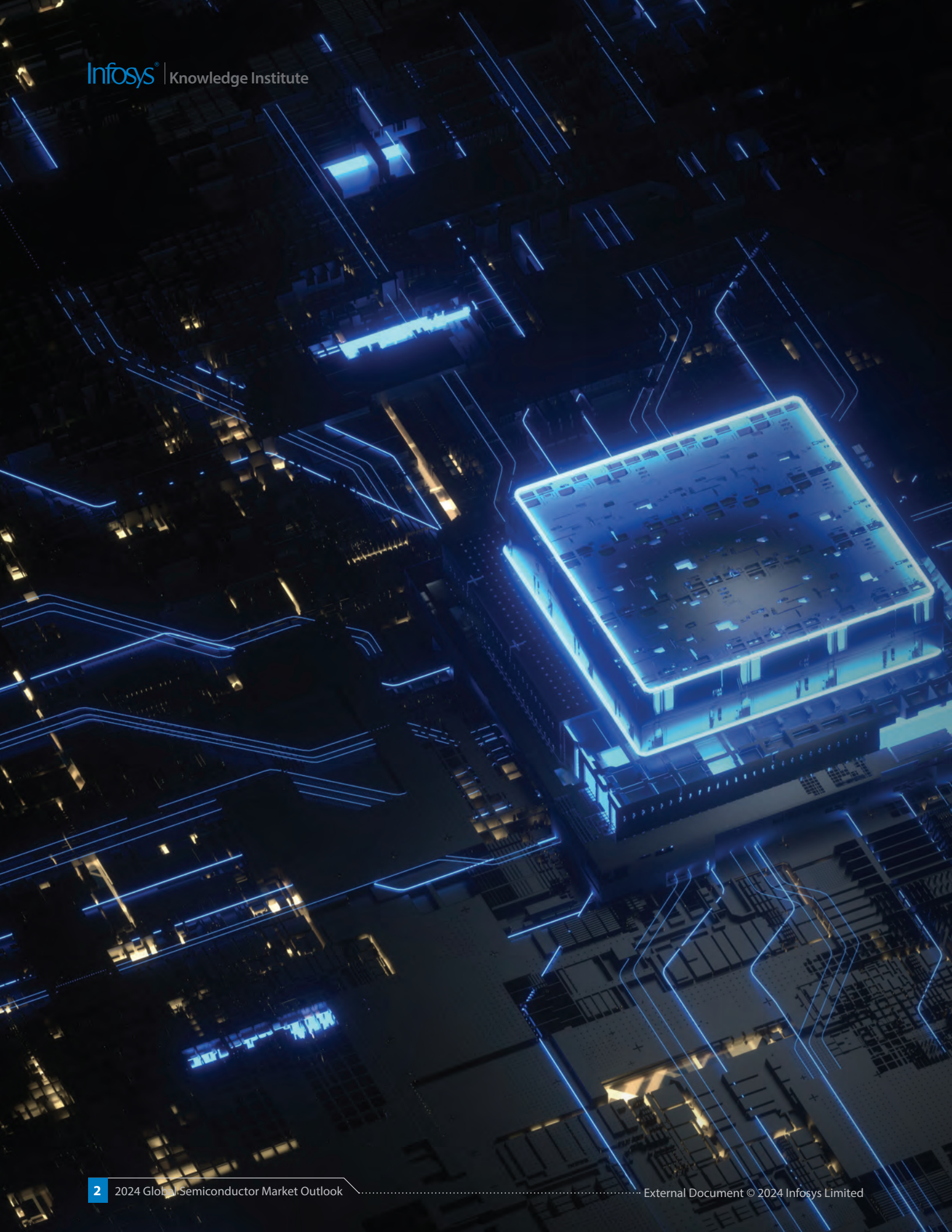

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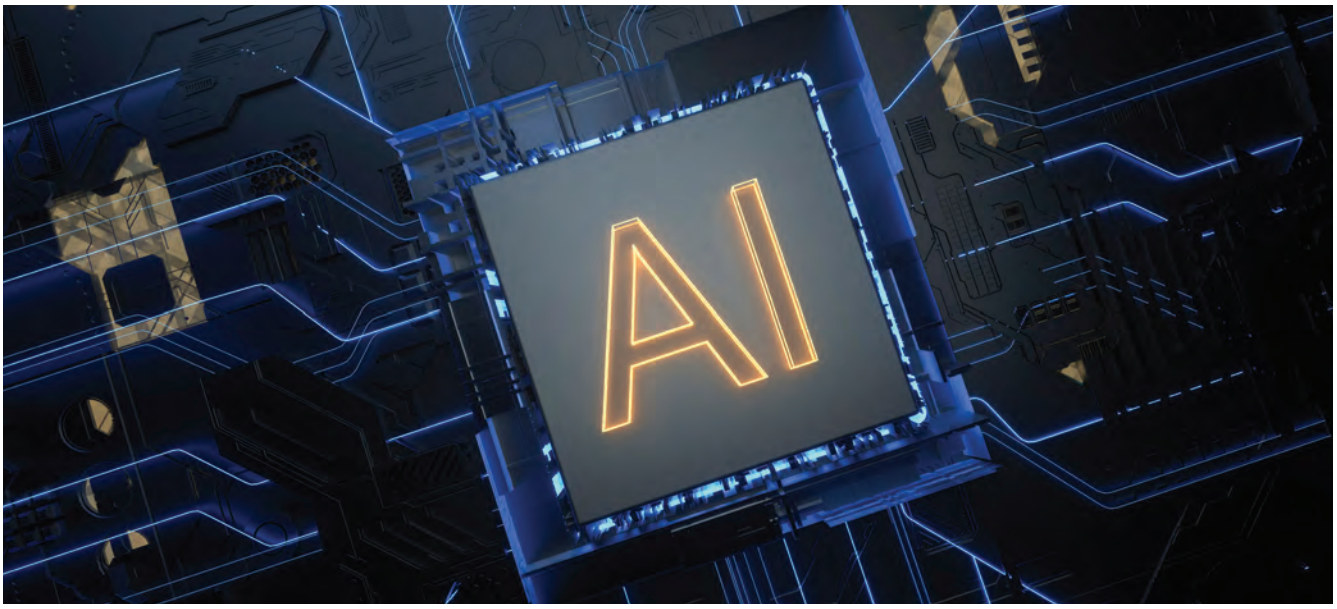
Executive summary

Semiconductor demand is experiencing a surge, fueled by several global trends. These include the widespread adoption of artificial intelligence, shift toward vehicle electrification, advancement of autonomous driving, rollout of 5G networks, and proliferation of internet of things (IoT). These transformative forces are poised to elevate semiconductor demand to greater heights in the coming decade. This increased demand is driving innovations from alternative chip materials to newer packaging technologies. Established giants are investing heavily in this projected trillion-dollar chip market, while nimble startups are also making their mark.

The increased demand for chips is excellent news for the semiconductor industry, but comes with a variety of challenges and risks. While the industry grapples with increased demand, it also must battle geopolitical tensions, with manufacturing confined to certain geographies, supply chain disruptions, recycling, sustainability issues, and governmental decisions that affect self-sufficiency measures, among other things. Semiconductor firms must balance innovation, adaptability, and resilience to thrive in this dynamic landscape.

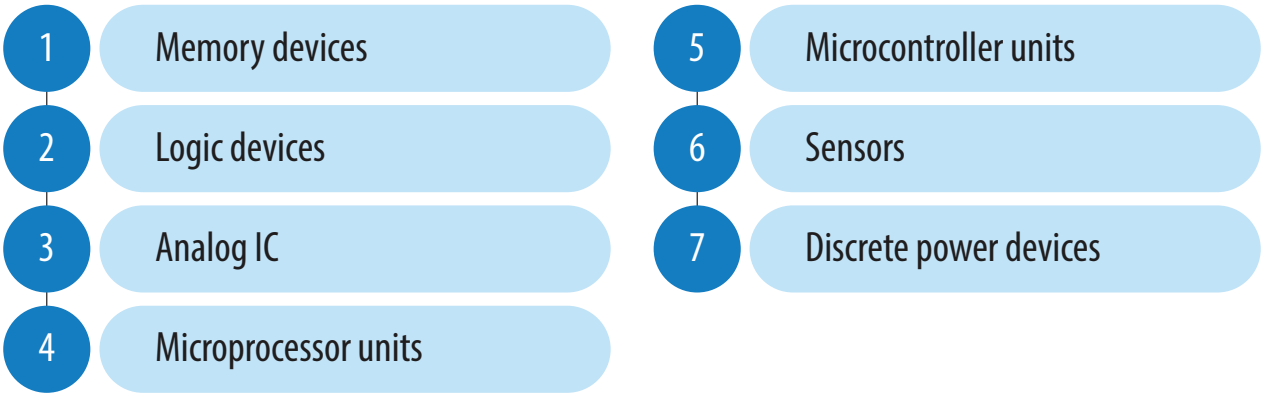


Overall state of the semiconductor industry

The semiconductor market has faced stiff challenges in recent years, including a stunning 38.8% decline in the memory market in 2023 due to oversupply. However, market revenue is expected to grow briskly in 2024, with 83% of executives predicting their firm's revenue to increase, and 85% expecting the industry revenue as a whole to increase. An additional 115,000 semiconductor jobs are expected to be created by 2030. Even though semiconductor industry executives are focused on talent development and retention, 67,000 of these jobs could go unfilled. The industry is projected to achieve $1 trillion in global revenue by 2030, with 70% of growth being driven by automotive, computation and data storage, and wireless industries. The AI chip boom is set to continue, with billions of dollars invested to develop AI chips for data centers, edge computing, training, and inferencing. The semiconductor industry is also exploring the potential of generative AI for operational efficiencies.

Among semiconductor components, microprocessors are expected to have the highest growth rate in the upcoming year. Experts attribute this growth to the increasing demand for processing power required by AI applications, high-performance devices, and the automotive industry. A recent survey ranked microprocessors as the top growth area, followed by sensors/MEMS and optoelectronics. Memory, which has been experiencing a prolonged downturn, ranked the lowest in the previous year's survey but rose to the fourth position in the current year's survey.

Figure 1. Top growth areas for semiconductor components



Source: Infosys Knowledge Institute

Short-term outlook

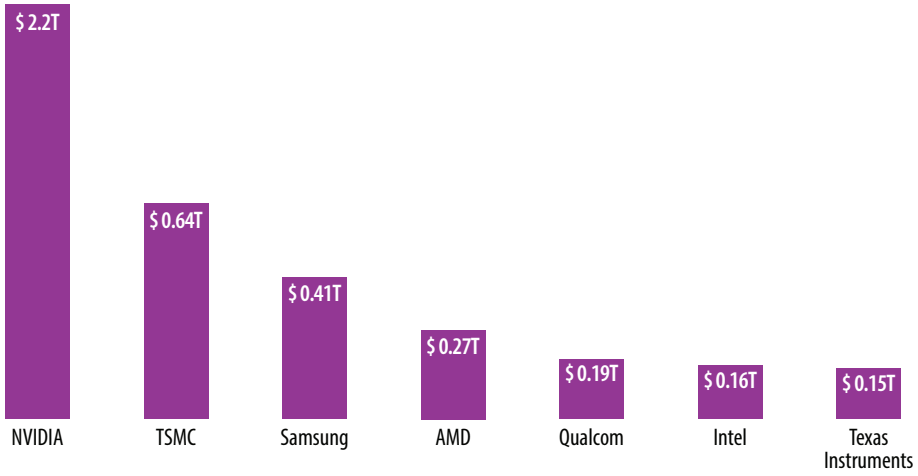
Revenue growth. Expectations are high for revenue growth in 2024. Global semiconductor revenue is projected to grow by 16.8% in 2024, reaching a total of $624 billion.

This follows a decline of 10.9% in 2023, when the market reached $534 billion. Factors propelling the industry's growth include the following:

- Positive trends in generative artificial intelligence (AI), cloud computing, data centers, wireless technologies, namely 5G and IoT and semiconductors in automobiles.
- Strong demand for chips to support AI workloads, such as graphics processing units (GPUs).
- Worldwide market rebound for the memory market. NAND flash revenue, which had declined 38.8% to $35.4 billion in 2023, is set to rebound in 2024, growing 66.3% to $53 billion. DRAM revenue is expected to grow 88% to $87.4 billion.

Industry leaders. The semiconductor industry is home to some of the world's most prominent publicly listed market players, many valued at over $100 billion. Alongside these big players are private companies that have raised significant funding. In Q3 2023, for instance, the largest equity deal in any sector was a $1.9 billion round for China-based GTA Semiconductor.

Figure 2. Market capitalization of top semiconductor companies



Source: Google finance, Infosys Knowledge Institute

Fabless revolution acceleration. NVIDIA's Q3 revenue in 2023 reached $18.1 billion, surpassing TSMC's $17.3 billion, Intel's $14.2 billion, and Samsung Semiconductor's $12.5 billion for the same quarter. This growth was fueled by generative AI frenzy, data center hardware sales, and cutting-edge architectures like Hopper and Ampere. NVIDIA's data center earnings soared by 105%, making it the highest-earning fabless chip designer.

Fabless companies are expected to grow by around 10%, and IDMs by only 4% in the next five years. TSMC's Chairman Mark Liu emphasized that semiconductor technology advances threefold every two years, projecting an exponential 242-fold improvement over a decade.

Amid increasing competition in the fabless industry, it is worth noting that Intel has also set up its foundry to support AI chip designs for its partners. In fact, Intel has recently announced a big win for its foundry, with Microsoft CEO Satya Nadella revealing that Microsoft has chosen a chip design that it plans to produce on the Intel 18A process.

AI for operational efficiency. The semiconductor industry is prioritizing AI adoption in the following areas:

1. Increasing semiconductor supply chain resiliency, especially with integration of data analytics.
2. Generative AI implementation in research and development (R&D), engineering, marketing and sales, design and manufacturing, and operations.
3. Sustainability.
4. Digital twin technology.
5. Meeting growing needs in automotives.
6. More local (onshore) production to handle geopolitical tensions.
7. Increased cybersecurity efforts (cyberthreats on the rise due to geopolitical conflicts).

According to Gartner, B2B sales organizations using generative AI-embedded sales technologies will expect substantial gains. By 2026, these organizations are projected to reduce prospecting and customer meeting preparation time by over 50%. Generative AI will streamline workflows, enabling sales teams to focus on high-value activities. This increased efficiency will have a positive impact on revenue outcomes.

R&D and CapEx. In 2024, R&D spending projections indicate a slight decrease in R&D spending from the previous year. According to the Global Semiconductor Industry Outlook Survey 2024, despite this decrease, R&D spending will remain robust, with 69% of the companies anticipating an increase. However, interest rates and government subsidies are expected to negatively impact CapEx. The industry is evenly split on whether CapEx will increase.

Workforce expansion. Semiconductor companies face challenges to attract and retain qualified workers. Despite a massive shortfall of qualified workers, few companies and regions have taken necessary action to address the issue. Due to the lack of graduates, an aging workforce, and poor industry perception among candidates, the planned capital projects could face delays or may not operate at full capacity if urgent and coordinated action is not taken. A few points to note:

- Job postings for technical roles in semiconductors rose at a CAGR of over 75% from 2018 to 2022 in the EU and the US.
- The talent gap for engineers could be massive, with over 100,000 in the US and Europe each, and upward of 200,000 in Asia-Pacific (excluding China).
- India may potentially be a net exporter of engineering talent, while Japan and South Korea face severe shortages.
- In advanced electronics and semiconductors, 53% of employees expressed their likelihood to leave their current jobs in the next three to six months in 2023, compared to 40% in 2021. The top reasons cited for seeking opportunities elsewhere include the absence of career development and advancement (34%) and lack of workplace flexibility (33%).

Long-term outlook

Revenue growth. The industry is projected to achieve $1 trillion in global revenue by 2030, according to many market researchers, including McKinsey and KPMG. Data storage, driven by the proliferation of data centers, cloud computing, edge computing, and wireless communications, powered by 5G and IoT, will significantly boost revenue growth. Automotive advancements, including advanced driver-assisted systems and electric vehicles, and rising demand for specialized AI chips such as GPUs and application-specific integrated circuits, will drive long-term growth. Long-term automotive demand for semiconductor units will only continue to increase, with microprocessors showing the highest growth opportunity over the next year. Another big mover will be memory, which suffered a downturn in 2022 due to oversupply and reduced demand.

AI accelerators. The surge in AI applications has sparked a revolution in specialized integrated circuits (ICs) designed to accelerate AI tasks. These chips, which go beyond traditional CPUs, have become essential for processing vast amounts of data efficiently. It is expected that there will be different types of chips for data centers, edge computing, training, and inferencing. It is estimated that billions of dollars will be invested in the development of these multiple types of AI chips that range from graphics processing units (GPUs), tensor processing units (TPUs), field-programmable gate arrays (FPGAs), and application-specific integrated circuits (ASICs).

Figure 3. Top applications driving the semiconductor market

Source: Infosys Knowledge Institute

Generative AI across the industry. While the semiconductor industry has been using AI for chip design, research on generative AI in semiconductors shows that AI will further transform the industry in areas such as supply chain forecasts, R&D, defect detection, manufacturing process simulation, and sales and marketing. Although challenges such as high costs and the need for human validation remain, the benefits of AI in the semiconductor industry are significant and will improve efficiency and productivity.

Market challenges and responses for sustainable growth

Talent development. The burgeoning need for chips comes with its challenges. The US economy faces a significant shortage of qualified workers, which could hinder the country's economic growth, technology leadership, and national security. The shortage creates significant impact, spanning the semiconductor industry and other technology-reliant industries. A report commissioned by the Semiconductor Industry Association (SIA) suggests that by 2030, the industry's workforce will grow by nearly 115,000 jobs. Still, about 67,000 jobs could go unfilled due to the current degree completion rates.

Semiconductor companies now make talent development and retention the top strategic priorities across sectors. The US Chamber of Commerce has suggested taking measures to broaden the talent pool, such as allocating resources towards K-12 education. In addition, they emphasized the importance of immigration reform to address the current and future talent demands of the semiconductor sector.

Supply chain diversification. Disruptions due to the pandemic and geopolitical tensions have made companies increase geographical diversity in their supply chains. Forty-six percent of automotive leaders are concerned about the supply of semiconductor components in the next five years. To mitigate the risk of silicon components availability, several major automotive companies are creating their own chip divisions and/or entering into long-term supply agreements with semiconductor companies. In the latest news, Toyota joined hands with TSMC in February 2024.

Geopolitical tensions. Globally governments continue to take proactive steps to build domestic chip ecosystems and increase market competitiveness. Governments are increasing market competitiveness through subsidies and tax incentives for regional semiconductor R&D and manufacturing. Governments in Asia, Europe, and the Americas are continuing to advance their versions of the CHIPS (Creating Helpful Incentives to Produce Semiconductors for America) and Science Act.

According to Z2Data's analysis, 73 new semiconductor fabs are being built worldwide. Of these, 35 are coming up in the West, with 27 of those being built in the US. The other 38 fabs are in East and Southeast Asia, most notably China, Taiwan, South Korea, and Japan.

The US CHIPS and Science Act. This 2022 act has a budget of $280 billion, with $200 billion allotted for scientific research in AI, robotics, quantum computing, and other cutting-edge fields. Notably, the budget includes $52 billion allocated to the CHIPS for America program, which aims to support semiconductor manufacturing, R&D, and workforce development. Additionally, there is $24 billion in tax credits provided for chip production. In response to the CHIPS initiative, companies are investing heavily in research, workforce development, and manufacturing.

There are now two significant developments in the implementation of the CHIPS Act:

1. In the latest news, the US Department of Commerce has reached a preliminary agreement with Intel to provide up to $8.5 billion in direct funding along with $11 billion in loans under the CHIPS and Science Act. The funding will help offset costs for Intel's chipmaking facilities in Arizona, New Mexico, Ohio, and Oregon. Intel plans to invest more than $100 billion in the U.S. over five years to expand U.S. chipmaking capacity. Intel's investments are expected to create more than 10,000 company jobs and nearly 20,000 construction jobs, and to support more than 50,000 indirect jobs with suppliers and supporting industries.
2. The Biden administration has announced another major deal out of the CHIPS program: a preliminary agreement for up to $6.6 billion in grants, plus up to $5 billion in loans, for TSMC. In response to the CHIPS Act, companies have announced over $231 billion in commitments in semiconductor and electronics investments in the US.

Emerging revolutionary trends

The semiconductor industry is constantly working to create smaller, more powerful, and efficient semiconductors. This work is guided by the principles of Moore's Law, which focuses on increasing transistor density on microchips, as well as More than Moore and Beyond Moore. These emphasize innovation in chip design and emerging technologies beyond silicon-based semiconductors.

Together, these principles drive the industry's journey toward exploring new ways to improve efficiency and innovation beyond simply shrinking transistors. The following paragraphs explore these evolving technologies, key players, and potential impact on the semiconductor industry.

Figure 4. Next-generation semiconductor technologies

Advanced materials

- Wide bandgap semiconductors — SiC GaN
- Spintronics semiconductors — carbon nanotubes, graphene, and magnetic materials
- Quantum dots semiconductors — Qubits

Beyond Moore's law

- Chiplets
- Advanced packaging
- EUV lithography

Source: Infosys Knowledge Institute

Advanced materials: Beyond silicon semiconductors

WBG semiconductors. As silicon faces physical constraints in high-power and high-temperature applications, the industry seeks more efficient power systems. Wide bandgap (WBG) semiconductors have emerged as an alternative. The global WBG semiconductor market reached $1.6 billion in 2022. These semiconductors, made up of materials such as silicon carbide (SiC) and gallium nitride (GaN), are now revolutionizing power systems.

Major suppliers of SiC semiconductors include STMicroelectronics, Cree/Wolfspeed, Rohm, Infineon Technologies, ON Semiconductor, and Mitsubishi Electric. For GaN, Power Integrations and Infineon are the main players, and startups such as Navitas Semiconductor, Efficient Power Conversion (EPC), GaN Systems, and Transphorm.

Spintronics semiconductors. Spin electronics, once confined to academic research, has now gained significant attention from major manufacturing companies like Intel, AMS, and IBM. Spintronics devices, which utilize alternative materials such as carbon nanotubes, graphene, and magnetic materials, are becoming popular in AI applications due to their advantages: lower power consumption and faster data processing.

Quantum dots semiconductors. Quantum dots, also known as semiconductor nanocrystals, are tiny semiconductor particles measuring just a few nanometers in size. These particles play a pivotal role in various nanotechnology-based applications from solar cells and LEDs to biomedical imaging and quantum computing. Currently, Intel and Nanosys are the two prominent leaders in quantum dots research.

In early 2024 researchers and engineers from QuTech and Intel delivered the first qubit (quantum dot) made in the same industrial manufacturing facilities that mass-produce conventional computer chips.

With the increasing interest in quantum computers to aid critical research on cancer cure, climate change, and AI/ML, mass production of quantum dots are predicted to be the next big step.

Beyond Moore's law

Chiplets. As it became almost impossible to shrink the size of transistors any further, manufacturers started turning to chiplets that could be packaged together to build a system. Companies such as Advanced Micro Devices and Intel have marketed chiplet-based systems for years. However, the industry is still working out the best way to balance cost with performance. The CHIPS Act, a 2022 US legislation, directs $11 billion toward "advanced semiconductor" research and creates a National Advanced Packaging Manufacturing Program to foster collaboration between academia and industry. Now the industry has embraced an open-source standard called Universal Chiplet Interconnect Express, which will aid the plug-and-play between different companies. This could give chipmakers more freedom

in fast-moving fields like AI, aerospace, and automaking.

Advanced packaging. Semiconductor wafers are the foundation of integrated circuits, and their packaging is crucial to protect them from damage and chemical contamination. Advanced packaging is now gaining significant momentum as the next breakthrough in semiconductor technology to create more compact, efficient, and flexible chip designs. Three major advanced packaging technologies have become commercially available since 2000 and are now being further developed: 2.5-D packaging, 3-D packaging, and fan-out packaging.

Advanced packaging creates new opportunities for manufacturers to meet the demand for high-performance, low-power chips that process massive amounts of data. Currently many major semiconductor manufacturers are investing in advanced packaging, including Intel, TSMC, Amkor, and ASE. The advanced packaging market size is estimated at $32.6 billion in 2024, and is expected to reach $45 billion by 2029.

EUV lithography systems. Complementing the chiplet technology and the advanced packaging are extreme ultraviolet (EUV) lithography systems. These cutting-edge technologies used for manufacturing integrated circuits propel the mass production of leading-edge microchips (chips with node sizes of 7 nanometers and below). This unique technology, pioneered by ASML, is revolutionizing microchip manufacturing.

While ASML is the only company globally to manufacture the EUV lithography machines, many semiconductor manufacturers are investing in applying the technology for chip manufacturing. Intel, Samsung, TSMC, and Toppan are the leading companies investing in the EUV lithography.

Mordor Intelligence predicts the EUV lithography market to grow with an estimated size of $10.3 billion by 2024, and further expanding to $17.8 billion by 2029. Another study predicts even more aggressive growth at 30% CAGR from 2022 to 2029, reaching $49.8 billion by 2029.

Growth applications and products

The semiconductor industry is experiencing significant growth, with automotive and AI as the top revenue drivers. Microprocessors, including GPUs, have the highest growth potential.

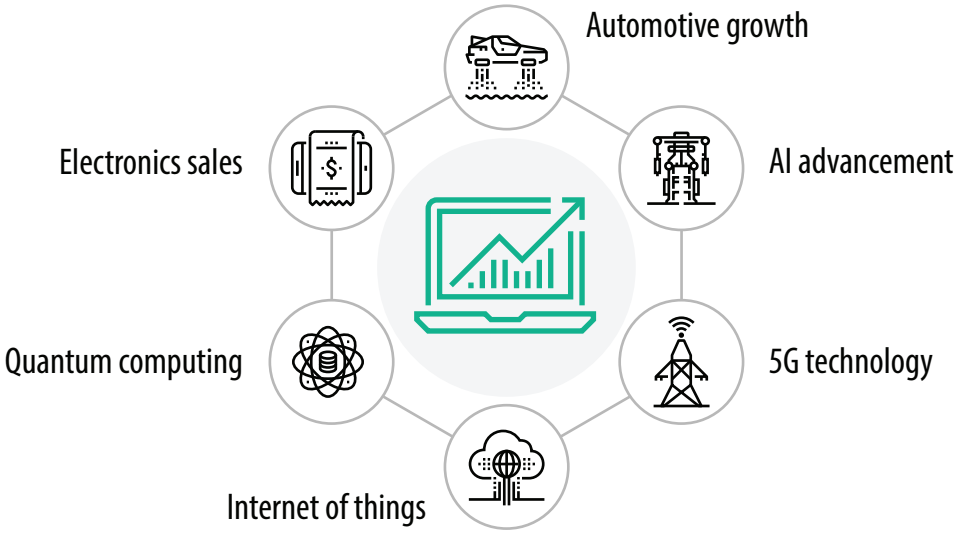
Automotive growth. Automotive remains the top revenue driver, with the auto semiconductor market projected to exceed $250 billion by 2040.

AI advancements. AI has risen to the second most important revenue growth driver, with microprocessors (including GPUs for AI) as the top growth opportunity.

5G technology. By providing lightning-fast data transfer, minimal latency, and the ability to connect a multitude of devices, 5G is revolutionizing communication networks. The demand for this technology spans various industries, ranging from mobile devices, edge computing, and smart cities to industrial automation. This demand drives the need for advanced semiconductor chips that power 5G base stations, modems, devices, and IoT sensors. As the adoption of 5G technology continues to grow, semiconductor manufacturers are constantly innovating to meet the industry's ever-evolving requirements.

IoT. This technology is driving a surge in semiconductor demand across industries. As active IoT devices grow, specialized components become essential for efficient operation. These components include microcontrollers, which serve as the brains of IoT devices; connectivity chipsets for wireless communication; AI chipsets that bring intelligence to edge devices; and security chipsets to protect data. As IoT adoption expands, semiconductor companies invest in tailored solutions to meet the unique

Figure 5. Growth applications and products



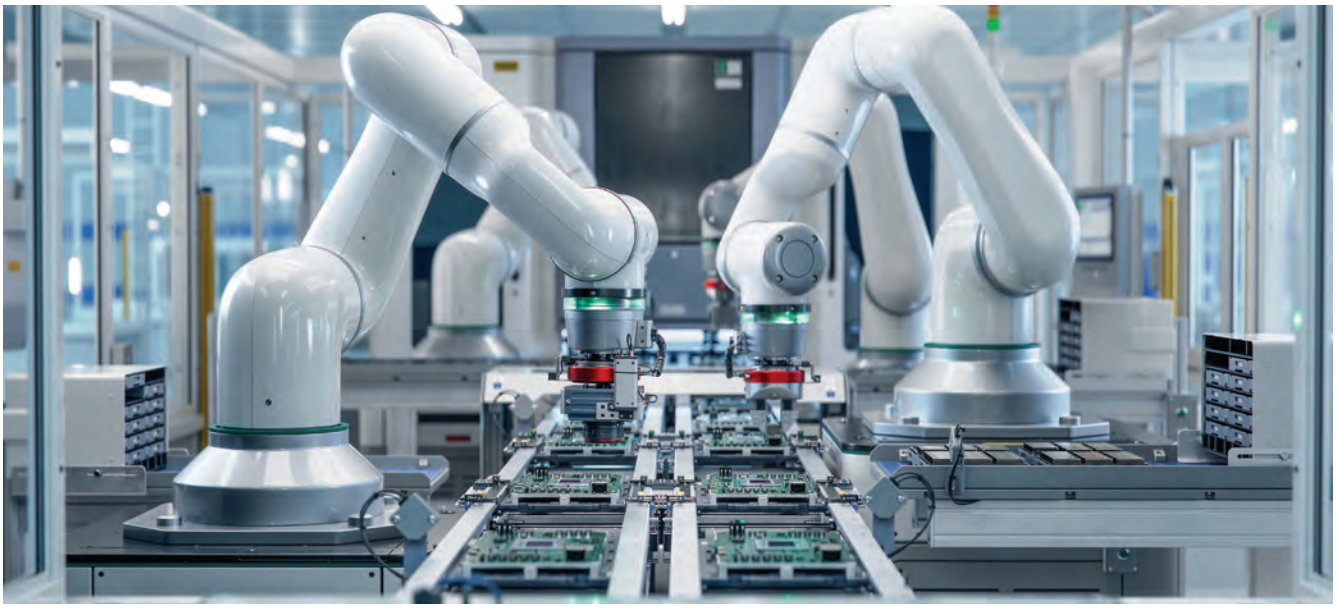
Source: Infosys Knowledge Institute

requirements of ultra-connected, intelligent devices.

Quantum computing. Holding immense promise in revolutionizing various fields, quantum computing has unprecedented computational power. It has the potential to impact ranging from drug discovery and supply chain optimization to financial modeling. Quantum technologies will propel chip design innovations, redefining the world of electronics.

Electronics sales. SEMI reports that electronics sales in 2024 will surpass its 2022 peak. PC and smartphone sales are expected to grow 4% in 2024, after declines of 14% and 3.5% in 2023.

A recent article in Forbes states that import tariffs, chip dumping, laws preventing technology transfers, and supply chain disruptions from trade wars could wreak havoc in the semiconductor market.



Conclusion

The future of the semiconductor industry is deeply intertwined with emerging technologies like AI, IoT, and advanced manufacturing techniques. Industry revenue is expected to grow in 2024, with automotive and AI being the top revenue drivers.
The memory industry is also expected to rebound. Top industry priorities include talent development and retention, supply chain flexibility, and generative AI implementation. Microprocessors, including GPUs used for AI, offer the greatest growth potential.

The functions in which semiconductor companies expect to implement generative AI are R&D, engineering, marketing and sales, and manufacturing and operations. Additionally, the CHIPS Act aims to bolster domestic semiconductor manufacturing and research, emphasizing the industry's strategic importance in national security and economic resilience.

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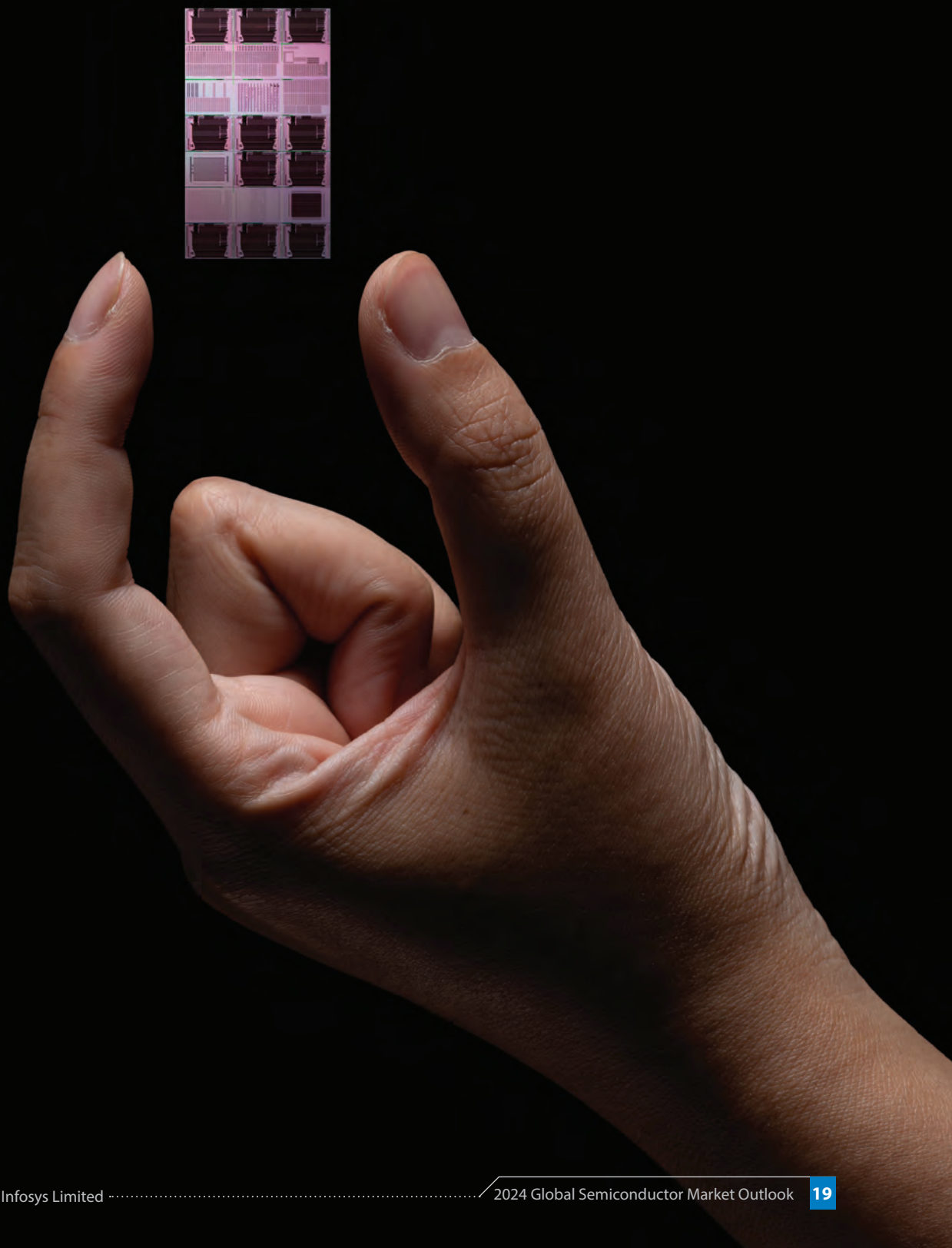

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