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Silicon Alchemists & AI: 2023 Semiconductors Outlook

Semiconductors have emerged as a lynchpin of modern electronic technology, used in almost every device today, from cell phones to automobiles. Looking ahead, the next evolution of artificial intelligence (AI) hinges on developing new semiconductor chips, a dynamic we believe will create a tremendous growth opportunity for investors.

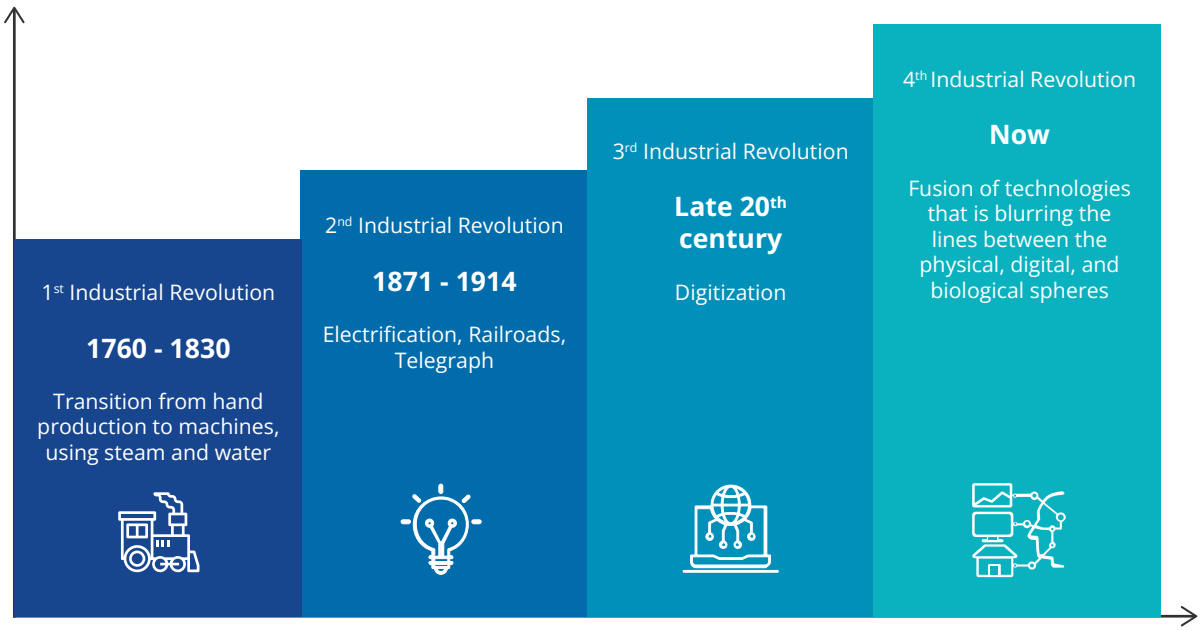
The ubiquitous use of semiconductors, along with the dynamic characteristics of the industry, help make this industry a compelling investment opportunity, in our view. In this whitepaper, we provide an in-depth breakdown of the industry to help investors better understand what's driving the long-term potential of this space.

Key takeaways:

- Semiconductors are a crucial component for many of the innovative technologies that are driving the global economy
- Semiconductor processing power has continued to increase exponentially over time, allowing for faster and better technology to be produced
- As technology has improved, demand has risen, alongside a number of secular growth trends, most notably artificial intelligence (AI)
- Semiconductor companies enjoy several different economic moats
- The rapid adoption of AI is ushering in a new era of growth for semiconductors, setting up the potential for the sector to deliver outsized long-term returns

A technological revolution is underway, potentially bringing us to the brink of the fourth industrial revolution. Lines between the physical, digital, and biological spheres that were once clear are now blurred.

The Evolution of Industrial Revolutions



Source: World Economic Forum as of 2022.

The first Industrial Revolution started in Britain around 1760. It was powered by a significant invention: the steam engine. The steam engine enabled new manufacturing processes, leading to the creation of factories.

The second Industrial Revolution came roughly one century later and was characterized by mass production in new industries like steel, oil, and electricity. The light bulb, telephone, and internal combustion engine were some of the critical inventions of this era.

The inventions of the semiconductor, the personal computer, and the internet marked the third Industrial Revolution starting in the 1960s, also commonly referred to as the "Digital Revolution."

The third Industrial Revolution refers to how technologies like AI, autonomous vehicles, and the Internet of Things merge with humans' physical lives. Think of voice-activated assistants, facial ID recognition, or digital healthcare sensors.

The fourth Industrial Revolution is different from the third revolution for two reasons: the gaps between the digital, physical and biological worlds are shrinking, and secondly, technology is changing faster than ever, thanks in large part to advances in Artificial Intelligence.

The Fourth Industrial Revolution Is Underway

Semiconductors play a crucial role in the development of each of these disruptive industries

ADVANTAGE

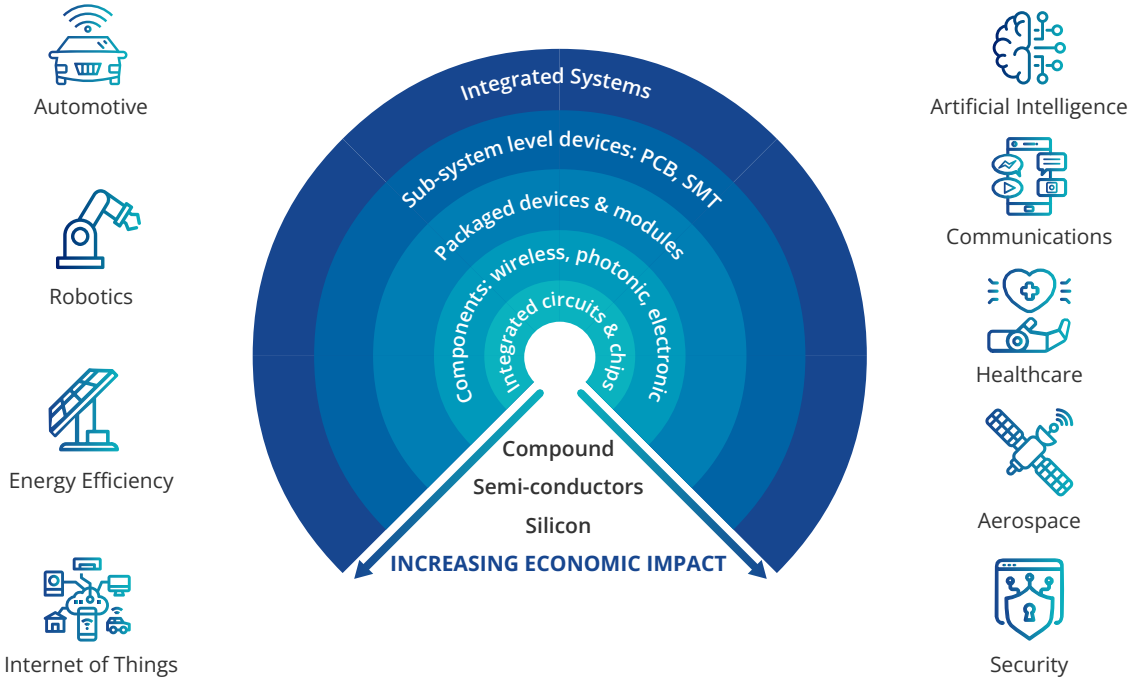
Autonomous Driving	Artificial Intelligence (AI)	Robotization	5G	Internet of Things
				
▪ Drastically reducing traffic casualties, thanks to machines making decisions ▪ Reducing transport costs ▪ Increasing usage of automatically rechargeable electric cars ▪ Low-cost taxi services	▪ The rapid adoption of generative AI and chatbots across industries ▪ Improving artificial analysis and customer support services ▪ Voice-controlled personal assistants ▪ Intelligent camera systems reduce the risk of burglary	▪ Household assistance ▪ Improving quality and reducing cost in manufacturing ▪ Increasing agricultural efficiency	▪ Remaining in contact with others ▪ Immersive gaming and virtual reality ▪ Mobile artificial intelligence and remote working	▪ Energy usage reduction through smart thermostats and electrical devices ▪ Automatic refrigerator replenishment

Source: CDIC, Deloitte as of 2022.

Semiconductors Are All Around Us.

The so-called "brains of modern electronics" semiconductors enable tremendous computing power through small devices.

Technology Powered by Semiconductors



Source: VanEck as of 2023.

Semiconductors are essential technology enablers that power many of the cutting-edge digital devices today.

They control the computers, and mobile devices we use to communicate, the cars and planes we rely on to travel, the machines that diagnose and treat illnesses, the military systems that protect us, and the electronic gadgets we use to listen to music, watch movies, and play games, just to name a few.

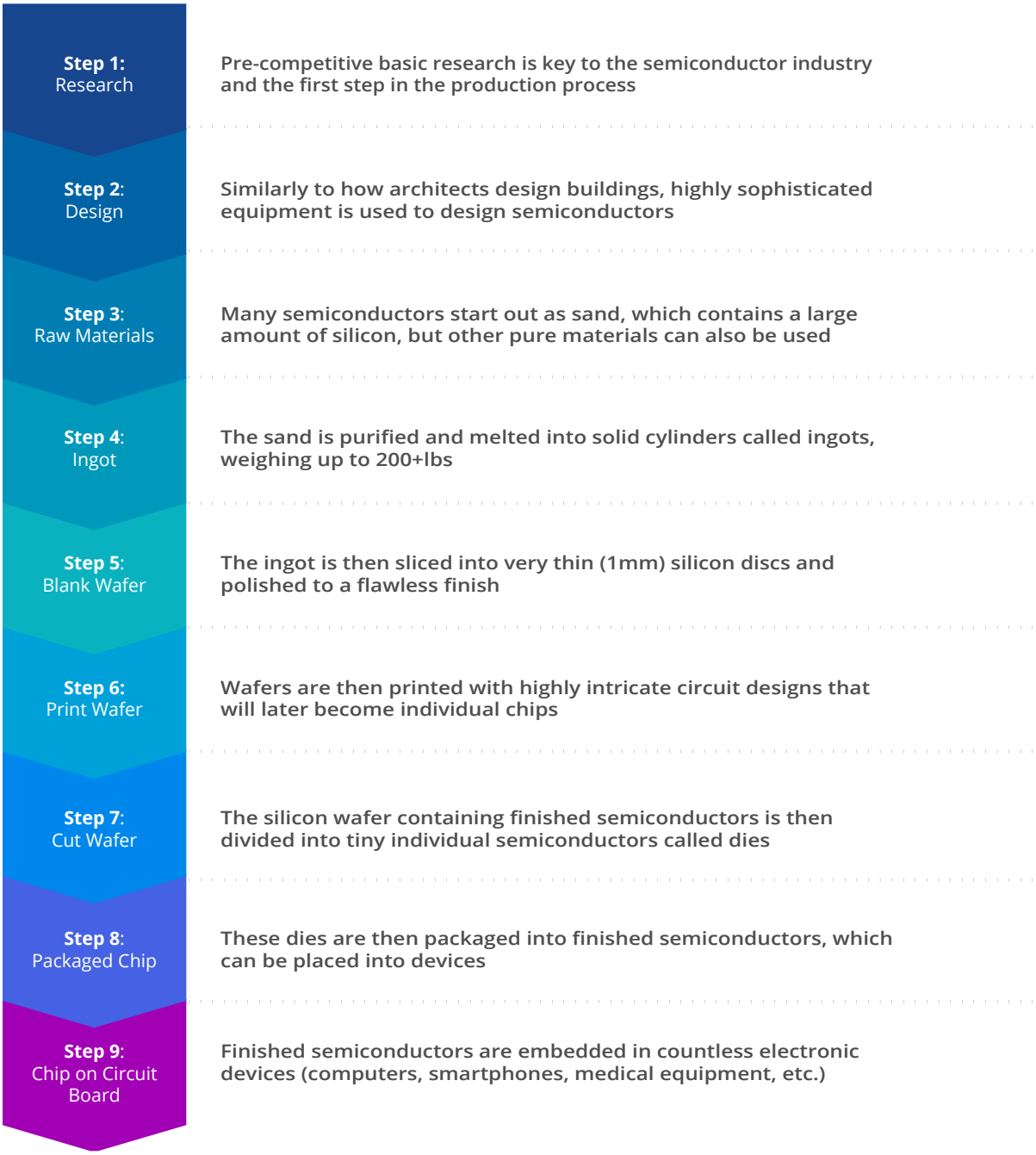
And not only does semiconductor technology make these devices possible, but it also makes them more compact, less expensive and more powerful.

How Are Semiconductors Made?

Semiconductors are created through a complicated, multi-step process as illustrated below. First, the semiconductor company must conduct competitive basic research to determine market fit and opportunity. Highly sophisticated equipment is used to design semiconductors, similar to how architects design buildings. Many semiconductors start out as sand, which contains a large amount of silicon, but other pure materials can also be used. The sand is purified and melted into solid cylinders called ingots, weighing up to two hundred pounds.

The ingot is then sliced into very thin (1mm) silicon discs and polished to a flawless finish. Wafers are printed with highly intricate circuit designs that will later become individual chips. The silicon wafer containing finished semiconductors is divided into tiny individual semiconductors called dies. These dies are packaged into finished semiconductors, which can be placed into devices. Finished semiconductors are embedded into the specific electronic device.

Semiconductor Production Stages

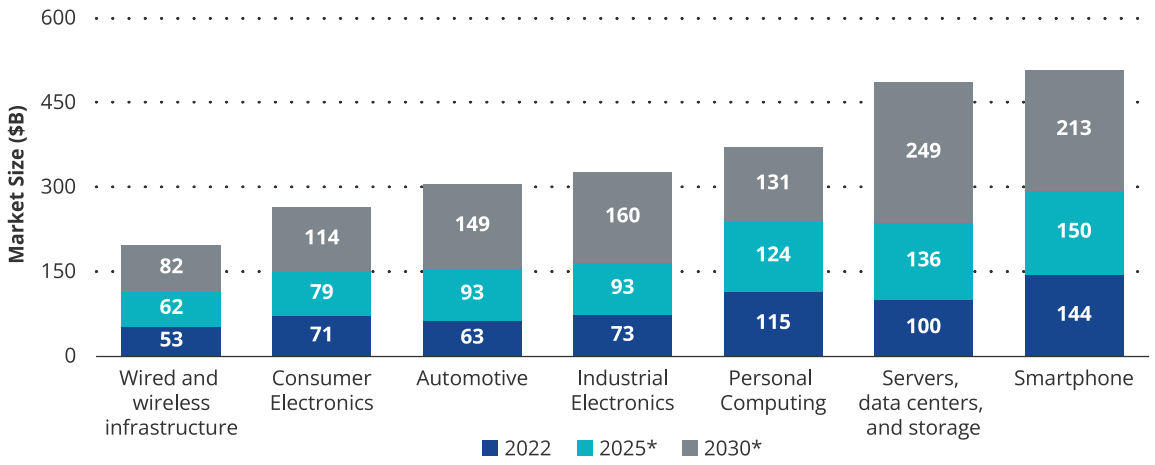


Source: VanEck as of 2022.

Semiconductor Industry Revenue Growth

Semiconductors are used in various sectors such as data processing, communications, industrial, automotive, consumer, and military/civil aerospace electronics.

Projected Global Semiconductor Market Cap by Application

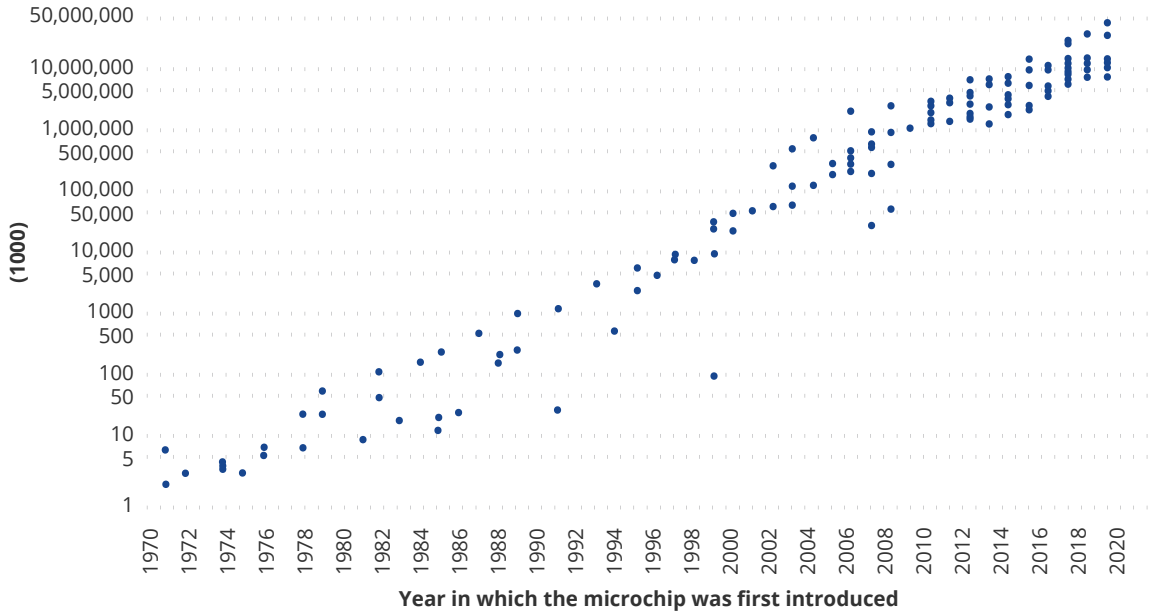


Source: ASML, Data as of 03/2023. Past performance is no guarantee of future results. Not intended as a recommendation to buy or sell any securities mentioned herein, or as any call to action. For illustrative purposes only. Not intended as a forecast or prediction of future results. Actual future semiconductor market growth is unknown.
* Figures are estimated projections

Semiconductor Computing Power Rises Exponentially

During the past 50 years, semiconductor technology developments have made electronic devices smaller, faster, and more reliable. Think of all the encounters you have with electronic devices; each, has essential components that have been manufactured with electronic materials.

Transistor Count



Source: Wikipedia, as of 2020.

A single semiconductor chip has as many transistors as all of the stones in the Great Pyramids of Giza, and today, there are more than 100 billion integrated circuits in daily use around the world—that's equal to the number of stars in our corner of the Milky Way galaxy.

Economic Moats in the Semiconductor Industry

Economic moats are competitive advantages that are expected to allow companies to fend off competition and sustain profitability into the future. Semiconductor companies can position themselves favorably, by creating and maintaining economic moats.

ECONOMIC MOATS

Competitive advantages are expected to allow companies to fend off competition and sustain profitability in the future.

Switching Costs	Intangible Assets	Network Effects	Efficient Scale
			
Changing semiconductor type can be expensive because of the need to rewrite software	**Patents protect semiconductors**	**Semiconductors require software. Software houses will prefer to write software for well-established semiconductors**	**Developing a new chip can costs over 100 million USD and requires involvement of hundreds of engineers**

Source: CDIC, Deloitte as of 2022.

The AI Revolution Ushers in a New Phase of Growth for Semiconductors

Machine learning thrives on vast data sets for its training and operational processes. To be harnessed effectively, this data demands speedy and efficient processing and storage, a role filled perfectly by semiconductors. These chips are found in everything—from the smartphone in your pocket to sprawling data centers—and are vital for powering AI applications.

As the applications grow increasingly complex, the demand for advanced semiconductors escalates. This expanding need represents a golden opportunity for semiconductor companies. For example, graphic processing units (GPUs) are instrumental in powering companies like OpenAI and its applications, including ChatGPT. GPUs are also used in a variety of other AI applications, including:

- Self-driving cars: GPUs are used to process the data from the car's sensors, such as cameras and radar, to help the car navigate safely.
- Facial recognition: GPUs are used to identify people in images and videos. This technology is used in variety of applications, such as security and marketing.
- Natural language processing: GPUs are used to understand human language. This technology is used in various applications, such as voice assistants, machine translation, and spam filtering.

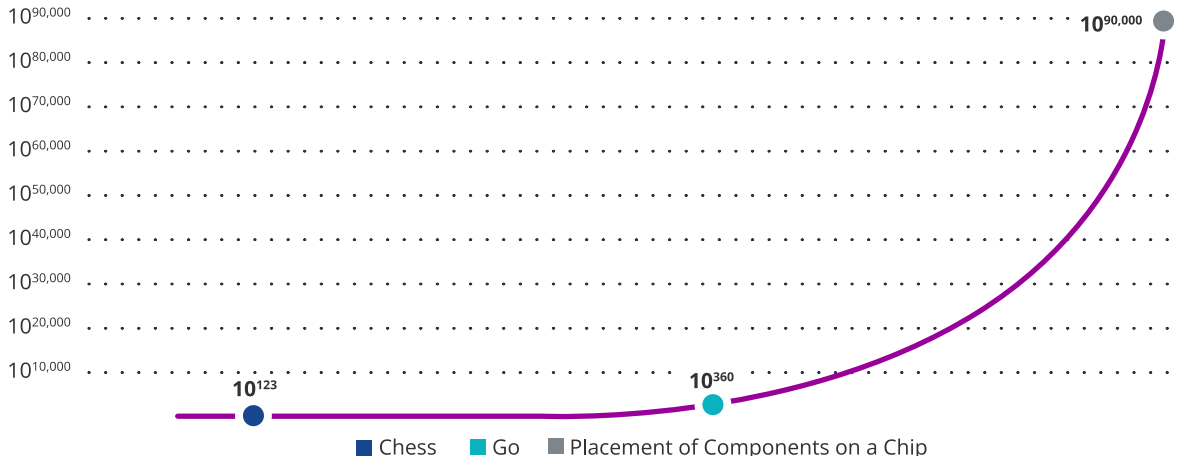
The GPUs' ability to efficiently handle parallel tasks makes them perfect for the heavy-duty processing required in machine learning. These high-speed GPUs manage the large volumes of data needed to train AI models like GPT. By doing so, they enable quicker responses and better language understanding. Simply put, semiconductor technology is vital in smoothly operating applications such as ChatGPT.

AI's Role in Accelerating Semiconductor Design and Manufacturing

AI is not just benefiting from semiconductor power; it has emerged as a significant driving force in the evolution of the semiconductor industry. AI is enhancing efficiency and profitability within the sector by redefining chip designs, identifying defects, optimizing processes, and predicting chip failures. And there's more to the story—AI is catalyzing the creation of a new lineage of chips tailor-made for AI's distinctive requirements and needs. These aren't your regular chips, but one's tailor-made for AI's unique demands. Think of Intel (NASDAQ: INTC) and its pioneering work crafting AI-optimized chips that excel in speed, efficiency, and power management.

AI Beats a Human at Chess and Go, Now Watch It Design Chips

Chips have exponentially more configurations than chess or Go[1]

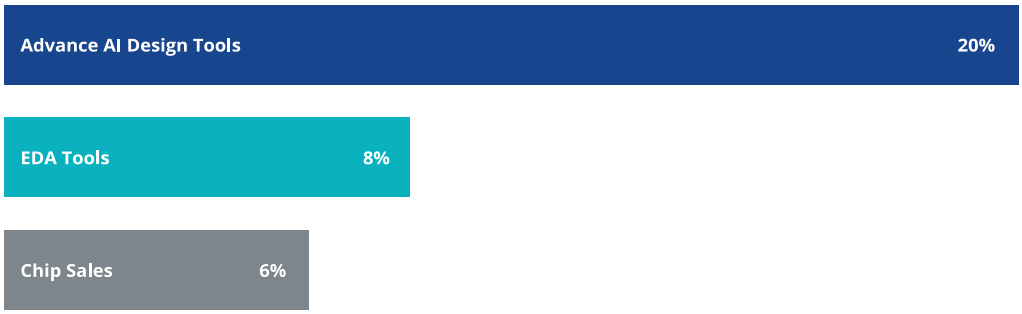


Source: Deloitte Insights adapted from Synopsys, "What is Design Space Optimization?" as of July 2020.

AI has previously proven its capability by outperforming humans in complex board games like Chess and Go, but now it's stepping into an even more intricate field: chip design. With an astronomical number of potential configurations far surpassing those in Chess or Go, the ability to optimize and innovate in chip design could be a game-changing application of AI technology. As the relationship between AI and semiconductors deepens, they're paving the way for a fresh surge of technological innovation. The forthcoming progression of AI is heavily dependent on the creation of new semiconductor chips that are specifically designed for AI applications. We believe this trend will likely fuel significant growth in the next five years.

Long-Term Outlook for Semiconductor Demand Continues to Grow

5-year CAGR for chips, EDA tools, and advanced AI design tools (2023-2028)[2]



Sources: WSTS; Global Markets Insights; and Deloitte Global as of November 2022.

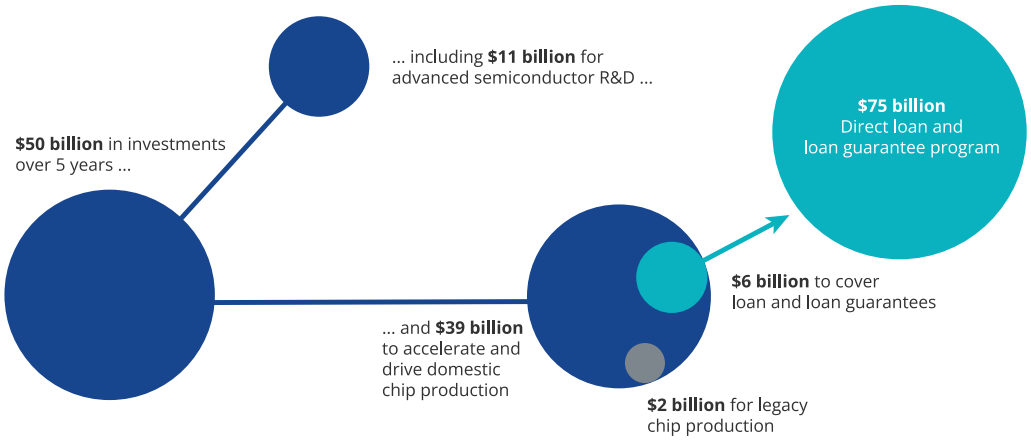
AI's imminent growth largely hinges on the development of semiconductor chips optimized explicitly for AI functionality. According to Deloitte, it is very plausible that this factor can trigger substantial growth over the next half-decade.

United States CHIPS Act Aimed at Re-Shoring Advanced Chip Manufacturing

Illustrating just how critical semiconductors have become for economic prosperity, Europe and the U.S. are pushing to become self-sufficient in semiconductors, aiming to curb dependence on foreign supply chains. This drive follows the Covid-19 pandemic exposing the vulnerabilities in supply. The typical semiconductor production process could involve steps in more than five countries and three or more shipments across the globe. Regional bottlenecks exist at nearly every step in the value chain because of industry consolidation, labor cost dynamics, and technical complexity.

Shortages of semiconductors dented U.S. economic growth by nearly a quarter-trillion dollars in 2021, according to the US Department of Commerce. To expand domestic manufacturing of mature and advanced semiconductors, the US Chips and Science Act will channel $50 billion in investments into the industry over five years, including $11 billion for advanced semiconductor research and development, and $39 billion to accelerate and drive domestic chip production ($6 billion of which can cover direct loans and loan guarantees). The country's large semiconductor producers are among the primary beneficiaries of the US CHIPS Act.

Budget to expand domestic manufacturing of mature and advanced semiconductors



Source: McKinsey[3] as of October 2022.

Among the main beneficiaries of the US CHIPS Act are the U.S.'s large semiconductor producers. Instead of trying to pick individual stock winners in the sector, investors can gain exposure to the 25 largest most liquid, U.S. listed semiconductor companies in the **VanEck Semiconductor ETF (SMH)**.

In closing, we believe semiconductors are the 'picks and shovels' way to play the AI landscape and present a compelling way to capitalize on the growing AI sector, particularly when direct access to private AI companies is limited for many investors. The **VanEck Semiconductor ETF (SMH)** provides a way to invest in the entire value chain of the semiconductor industry, from chip design and fabrication to the machinery used in the manufacturing process. As semiconductors are the essential components that power AI innovation, we believe they are poised to gain value amid the potential deflationary impact of AI's efficiency—they also provide a unique opportunity to ride the wave of AI's transformative impact.

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Important Disclosures:

Intel Corp is 4.76 of SMH net assets as of 6/20/23.

1 https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2023/ai-in-chip-design.html

2 https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2023/ai-in-chip-design.html

3 https://www.mckinsey.com/industries/public-and-social-sector/our-insights/the-chips-and-science-act-heres-whats-in-it

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