

Powering Everything

ChatGPT has practically turned chipmaker NVIDIA into a household name. We believe NVIDIA and other companies along the semiconductor value chain should grow more than expected, benefiting not only from AI adoption but also from other new technologies that demand more powerful and more complex chips.

July 2023

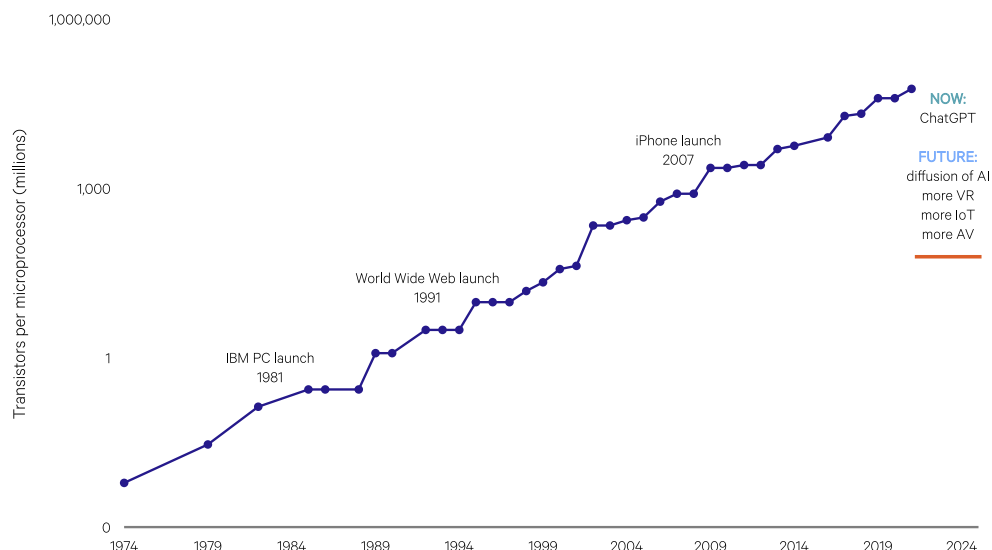
NVIDIA’s recent rise to prominence on the back of the generative artificial intelligence (AI) explosion underlines the potential not only for this chipmaker but also for other select companies across the semiconductor value chain. Over the last several decades, we have seen how chips became a necessary component to power all the pieces of our modern lives—from setting the brew time on our Keurig coffeemakers to the automated clearing of trillions of foreign-exchange transactions. Newer technologies, such as AI, the Internet of Things, virtual reality, autonomous driving, and enormous investments from cloud infrastructure providers, often referred to as hyperscalers (i.e., Microsoft, Alphabet, and Amazon) are driving the need for compute power up about 50 percent each year.

Continued innovation across sectors and industries, with AI text chatbot ChatGPT as the most prominent

recent example, will require enormous amounts of compute power—processing power, memory, networking, storage, and other resources required for the computational success of any program. We don’t believe the market fully appreciates the magnitude or duration of the higher levels of revenue and earnings per share growth across the semiconductor value chain that we see coming.

Overall semiconductor industry revenue was estimated to be \$600 billion in 2022, and we think it has the potential to double or triple over the next eight to 10 years. In addition to NVIDIA, we expect other critical enablers—such as ASML, Taiwan Semiconductor, Lam Research, and Entegris—to capture much of this growth as in some cases they are among the sole providers of machines and services needed to create chips that are powerful and complex enough to run advanced technologies.

EXHIBIT 1
MOORE’S LAW IN ACTION: THE DIFFUSION OF INNOVATION THROUGH IMPROVEMENTS IN TRANSISTOR TECHNOLOGY



Source: Sands Capital research based on Karl Rupp’s 2022 microprocessor trend data in “Moore’s Law: The Number of Transistors per Microprocessor,” Our World in Data <https://ourworldindata.org/grapher/transistors-per-microprocessor?time=1971..latest>.”

All the Pieces That Matter

The semiconductor industry has transformed our lives since its inception in the 1960s. Moore's Law, the observation that the number of transistors on every integrated circuit doubles about every two years, has driven the transistor count for leading-edge chips to increase by over 25 million times over the past 50 years. The steady improvement of microprocessor technology has led to the continuous innovation and diffusion of technology, unleashing a powerful flywheel, driving even more demand for computing power (see iPhone example below). The advances have enabled personal computing, the internet, smartphones, and, more recently, ChatGPT and generative AI. We expect this diffusion to continue with ramifications for compute demand as we start harnessing AI everywhere.

An Increasingly Specialized Supply Chain

Over the past 40 years, the semiconductor industry has consolidated as only a few businesses have been able to afford the tremendous capital investment and research and development (R&D) needed.¹ Over this time, the cost to build a semiconductor foundry, for instance, has exploded. The increasing complexity has required a level of capital intensity that has

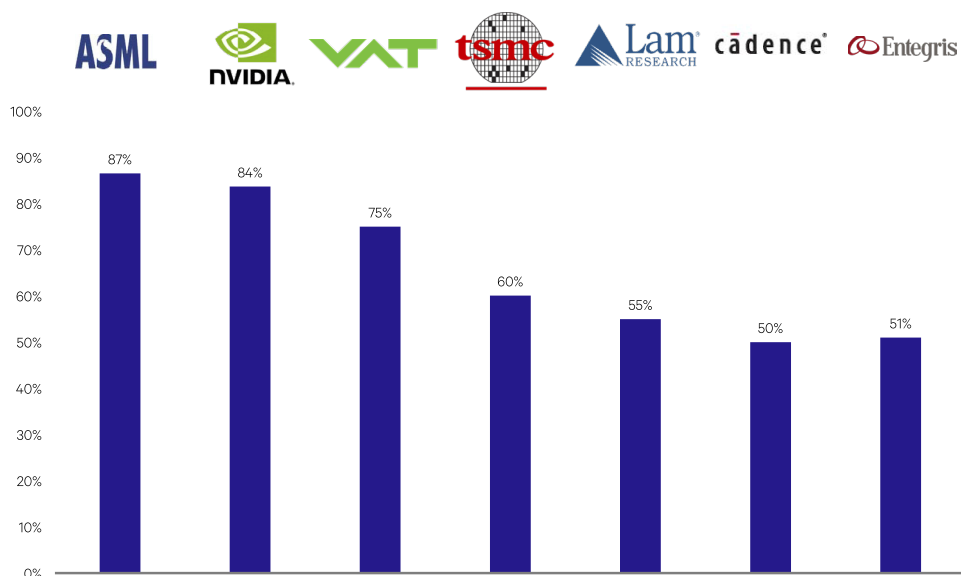
pushed costs, which once ran in the 10s of millions of dollars, into the 10s of billions of dollars. In the foundry space, for instance, Taiwan Semiconductor was able to build its near monopoly position as the world's largest outsourced provider of logic chips because it could afford such outlays due to its scale economies. It now sits at a critical chokepoint in the semiconductor value chain, capturing the business of chip design companies that benefit from its high-quality manufacturing process and the economies of scale that only large outsourcers are able to provide.

We have seen this dynamic play out across the value chain, among select chip designers, and suppliers to chipmakers as well. In fact, many of the businesses that we have invested in over the past 15 years sit at critical chokepoints. We tend to favor businesses, like Taiwan Semiconductor, that are oligopolistic, highly specialized, and boast competitive advantages that should allow them to benefit from increased compute demand. Other holdings, including ASML, Lam Research, Entegris, are businesses that supply advanced machinery and materials and stand to generate additional revenue from increased compute demand regardless of the end market.

In Exhibit 2, we show the market share (in terms of revenue) of many of our semiconductor businesses.

EXHIBIT 2

THE INDUSTRY HAS CONSOLIDATED AMID RISING R&D EXPENSE



Source: Estimates as of June 2023. Market share estimates sourced from Semi.org, Sands Capital, Trendforce. Chart illustrates the market share held by the share leader within different semiconductor industry sub-categories. Sub-categories for each business are as follows: ASML (lithography), Lam Research (dry etch), NVIDIA (AI chips), Taiwan Semiconductor (foundry), VAT (semi vacuum valves), Entegris (semi filters). For illustrative purposes only. The specific securities identified and described do not represent all of the securities purchased, sold, or recommended for advisory clients. The reader should not assume that investments in the securities identified and discussed were or will be profitable. The securities identified represent a subset of current holdings in Sands Capital public equity strategies. They represent all holdings in the semiconductor industry. Other Sands Capital holdings, Lastertec, ASMI, and Texas Instruments are also market leaders in terms of revenue.

Dutch semiconductor capital equipment vendor ASML is another critical enabler whose lithography equipment requires intense amounts of R&D and is fundamental to the fabrication of any integrated circuit. It puts together some of the most sophisticated pieces of equipment manufactured by humankind to create a complex optical system that harnesses the light necessary to print tiny patterns on silicon. It is the only company in the world capable of building these lithography machines that can achieve the level of accuracy needed for advanced chipmaking. This specialization persists across the supply chain. Lam creates equipment used to etch and deposit transistor structures—the patterns created by ASML’s lithography equipment—onto silicon wafers. Increasingly advanced semiconductors will require more process steps to manufacture, driving increased usage of chemicals and filters. Here we see Entegris, the largest pure-play producer of consumables used in the chip manufacturing process, benefitting from increased demand for its filters and chemicals.

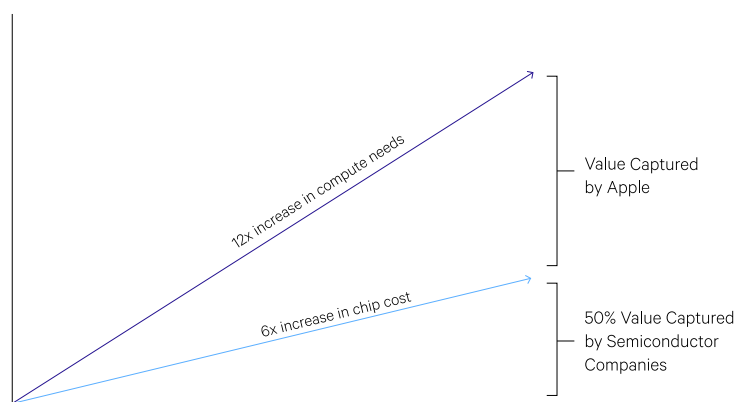
And of course, at the beginning and the end of this supply chain are the chip designers, which draw on the advanced equipment and manufacturing process of the various verticals in the semiconductor supply chain. NVIDIA is the key provider of the hardware and software ecosystem necessary to support more AI adoption. The company originally focused on graphic processing units (GPUs) used in computer gaming, where each pixel area on a screen can be computed in a parallel manner, with its many cores accelerating the computational process. That same parallel system of accelerated calculations is critical to train algorithms to learn and extrapolate from data and has put NVIDIA in the lead of creating GPUs that are optimized for AI capabilities, like OpenAI and its applications. We believe NVIDIA’s competitive moat will be difficult to penetrate. None of the leading chip designers or cloud infrastructure companies has been able to achieve the same advanced capabilities as NVIDIA. In addition, AI computing requires tremendous networking and system know-how given that the workloads require hundreds of GPUs be connected within one system. To date, only NVIDIA has been able to solve this issue. Lastly, NVIDIA’s software ecosystem, comprised of CUDA (software that makes compute parallel) along with hundreds of software development kits that cater to industry specific use-cases, allow developers to

utilize its hardware efficiently—no other business has come close to replicating that.

Seeking Guidance from the Past

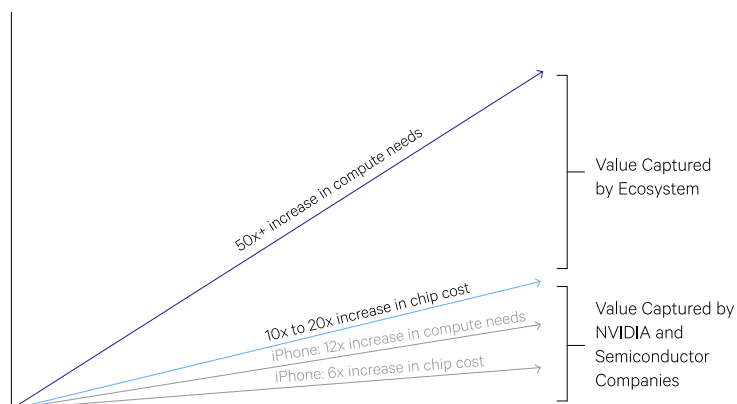
There is no certainty in predicting the future or in knowing which technologies will take off next. By looking at the diffusion of technology that has occurred in line with Moore’s law, we expect new and advanced use cases for semiconductors will emerge and drive levels of demand that could be exponentially greater than the market expects.

EXHIBIT 3
VALUE CAPTURED THROUGH IPHONE’S EVOLUTION
COULD MODEL FUTURE GROWTH



Source: Based on Sands Capital research, with data from Geekbench performance benchmarks, IHS Markit Teardown Analysis Service, Taiwan Semiconductor wafer cost estimates, and Nikkei Asia/Fomalhaut Techno Solutions.

EXHIBIT 4
NVIDIA COULD EXPERIENCE SIGNIFICANT BENEFITS
FROM INCREASED COMPUTE DEMAND



Source: Sands Capital research.

History tends to be a good gauge, in our view, for what might happen with the iPhone as an example. Over the past 10 years, the iPhone has become about 12 times more powerful, enabling users to take better pictures and play more graphically intensive games (Exhibit 3). Developers were able to take advantage of these hardware improvements by creating millions of apps for the iPhone. This has created a virtuous cycle where better hardware opens up new use cases, which in turn drives revenue growth for the Apple App store while creating the world’s largest market cap in Apple. Semiconductors benefited at the same time as the cost of the brain of an iPhone went up about six-fold in the past decade for a theoretical semiconductor take-rate of about 50 percent (chip cost divided by compute growth).

In Exhibit 4, we are making an educated guess that over the next 10 years, we will see AI compute needs increase by 50 times—which would correspond to a 50 percent annual growth rate versus the iPhone annual improvement of about 30 percent over the past decade. Given the oligopolistic nature of the semiconductor industry, we can assume that select businesses along the semiconductor value chain will enjoy a meaningful take rate. In Exhibit 4, we assume a 20 percent to 40 percent take rate which at the

midpoint would equate to a 15 times growth rate for NVIDIA’s datacenter business, which would imply NVIDIA’s datacenter business growing from about \$15 billion to \$235 billion from 2023 to 2030.

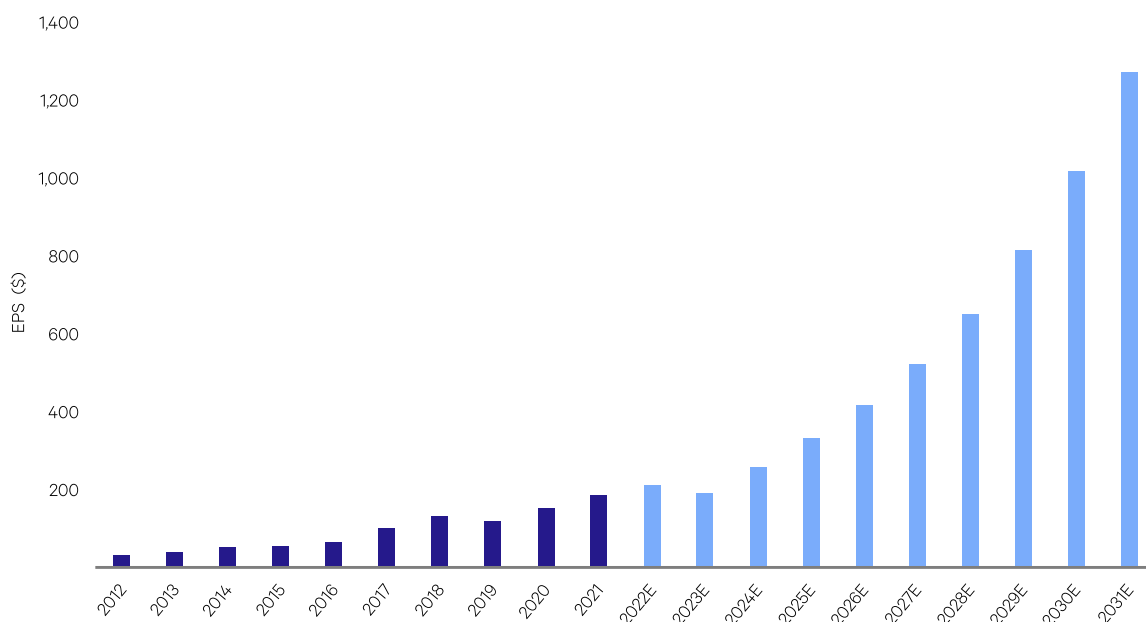
AI will likely need more powerful and complex chips than were needed by the iPhone. Better hardware, GPUs in this case, are enabling better AI capabilities which in turn is driving the use-case explosion that we are witnessing today.

Creating Value Through Sustained Earnings Growth

With the global need for computing power expected to continue its 50 percent compound annual growth rate, we expect earnings per share of the semiconductor industry to compound over 20 percent annually. Increased adoption of generative AI and other new technologies could cause that demand to increase even further, and benefit select businesses along the semiconductor value chain. We believe industry valuations, currently at six times 2030 projected earnings per share (on average), offer an attractive entry point for a space that we believe can sustain high earnings-per-share growth for the long term.

EXHIBIT 5

THE COST TO DEVELOP CHIPS AND THE DEMAND FOR THESE CHIPS IS RISING AT THE SAME TIME, WHICH LEADS TO ACCELERATING INDUSTRY GROWTH



Source: Semiconductor Industry EPS shows earnings per share for the PHLX Semiconductor Sector, a modified market capitalization-weighted index comprised of companies primarily involved in the design, distribution, manufacture, and sale of semiconductors. EPS in years 2026 through 2031 is based on a 25 percent expected growth rate.

Over the past 15 years, we have seen how many of our portfolio companies have been able to seize market share and cement their competitive advantage by creating the most specialized and precise technologies needed to power the expected technological advances. While we may not know exactly where innovation will lead us or how much compute power they will require, we are confident that innovations will continue and that many of our businesses will lead the way forward. To that end, we believe it is far more important to get the trends directionally accurate than to agonize over exactly when they will happen, how long they will last, and how powerful they will be.

The rapid adoption of generative AI technology shows us just how fast the world and our expectations can change. We are living through a moment when “gradually” turns to “suddenly.” And as investors in innovative growth companies, many of which are disrupting the status quo and creating the future, we need to prepare for an even greater momentum of change. We have seen it happen several times throughout the past 100 years. It’s a bit of a variation on Moore’s Law. For example, in the 90s, a small number of people had cellphones. Today, we can’t live without them. The same pattern repeated with the internet, cloud computing, online shopping, and food delivery, and we are now seeing it in the growing adoption of generative AI.

We believe the ability to recognize the inflection point between nice-to-have and must-have is critical in building portfolios that can help enable long-term wealth creation for our clients. As students of innovation, we will continue to explore possibilities that are changing not just the future of computing but the future of the world. Our in-house research team continuously talks to leading thinkers, creators, and entrepreneurs who are exploring possibilities for smarter future mobility solutions, key hardware and software technologies, big data analytics, AI, and machine learning.

Being able to draw insight from patterns of the past to anticipate the course of the future is how we aim to find businesses that we expect to generate long-term earnings growth. Making these discoveries before the inflection point—when gradually becomes suddenly—is how we believe we can provide the exponential long-term wealth creation that we seek for our clients.

¹ <https://www.kearney.com/communications-media-technology/article/?/a/why-a-resilient-semiconductor-supply-chain-is-imperative-and-how-to-create-one>

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Unless otherwise noted, the companies identified represent a subset of current holdings in Sands Capital portfolios and were selected on an objective basis to illustrate examples of the range of companies involved in the production and design of semiconductors across public markets.

They were selected to reflect holdings with varied business models across multiple geographies. This article is part of a larger series on digitalization and features businesses and related companies that were selected to illustrate current underlying macroeconomic and sectoral trends.

As of June 30, 2023, Alphabet was held in Global Growth, Technology Innovators, and Global Shariah. Amazon was held in Select Growth, Global Growth, Technology Innovators, and Global Shariah. ASM International was held in Global Leaders and International Leaders, ASML was held in Global Growth, International Growth, and Technology Innovators. Cadence Design Systems was held in Select Leaders and Global Shariah. Entegris was held in Select Growth, Global Growth, Global Leaders, and Select Leaders. Lam Research was held in Select Growth, Global Growth, Emerging Markets Growth, Technology Innovators, Global Shariah, and Emerging Markets ex China. Lasertec was held in International Growth. Microsoft was held in Select Growth, Global Leaders, Select Leaders, Technology Innovators, and Global Shariah. NVIDIA was held in Select Growth, Global Growth, Technology Innovators, and Global Shariah. Taiwan Semiconductor was held in Emerging Market Growth, International Growth, Technology Innovators, Global Shariah, and Emerging Markets ex China. Texas Instruments was held in Global Leaders, Select Leaders, and Technology Innovators. VAT Group was held in International Growth and International Leaders.

AMD, Intel, and Keurig were not held in any Sands Capital portfolios. Apple was not held in any Sands Capital portfolios.

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