Deloitte.

2023 semiconductor industry outlook

Contents

Onshoring, reshoring, nearshoring, friendshoring, and still some offshoring: Getting the mix right 4

Diversifying with intent and taking a guarded approach 6

Digital transformation and data-driven supply chain networks 7

Addressing the semi talent shortage and the need for specialized skills 8

Building a sustainable semiconductor industry 9

Signposts for the future 10

About Deloitte's outlooks

Deloitte's 2023 semiconductor industry outlook seeks to identify the strategic issues and opportunities for semiconductor companies and other parts of the semi supply chain to consider in the coming year, including their impacts, key actions to take, and critical questions to ask. The goal is to equip semiconductor companies across the semiconductor supply chain with the information and foresight they need to position themselves for a robust and resilient future.

Executive summary

It turns out that there may be something worse for the global chip industry than shortage or oversupply: having both at once.

Heading into 2023, global macroeconomic and geopolitical factors are emerging as the dominant forces shaping the semiconductor industry. Rising interest rates, high inflation, lower consumer confidence, and tech-led stock market retreats have led to a dramatic loss in market capitalization: the top 10 global chip companies' combined market cap is down 34% from US$2.9 trillion in November 2021 to US$1.9 trillion in November 2022.[1] At one point in October 2022, the Philadelphia Semiconductor index was down 45% since January and ended the year down 37%.[2]

High-end memory prices are down 50% in the past year, and most of the phone, personal computer, and data center chip supply chain has returned to normal lead times. But average lead times for the overall industry as of October 2022 were still elevated at about 25.5 weeks, compared to a more normal 10–14 weeks.[3] Moreover, certain kinds of chips (power management and microcontrollers, vital for the auto industry and others) are still in severe shortage.[4]

If all that weren't enough, the war in Ukraine is disrupting supply chains, access to important raw materials, and energy prices worldwide—and especially in Europe. These disruptions are expected to continue into 2023. Additionally, the US government's steps in October 2022 to tighten the rules around the export of advanced semiconductor technologies to China will likely shape the entire industry (including the downstream customers) for 2023.[5]

In response to the higher cost of capital, inventory drawdowns from customers and the supply chain, and decline in earnings, many chip companies are cutting costs, reducing employee headcount, and pushing out (but not cancelling) capital expenditures (capex) for additional capacity. To be clear, capex spending for 2023 will still likely be higher than it was in 2020 but will be lower than previous expectations for the year.[6]

There could be a bright side: A downturn may provide an opportunity for the industry to focus on things other than just trying to catch up during a shortage. As the sections that follow will show, Deloitte anticipates that 2023 could act as the pause that refreshes and allows the semi industry to consider five big things:

1. Bring manufacturing closer to home with both entirely new fabs and the expansion of existing facilities—with extensive use of friendshoring, as the industry and governments recognize that no country or region can truly be self-sufficient but also needs to rely on trusted friends and allies for parts of its semi supply chain.[7]
2. Manage the diversification risks and challenges that come with localization and friendshoring.
3. Digitally transform and digitize many parts of the process: financial planning and operations, order management, and supply chain.
4. Address and balance the semiconductor talent equation: shortages in some roles, but layoffs in others.
5. Establish and accelerate the path toward achieving environmental, social, and governance (ESG) goals, particularly around sustainability.

Onshoring, reshoring, nearshoring, friendshoring, and still some offshoring: Getting the mix right

In the United States and Europe, the goal for both chipmakers and policymakers is likely to make their domestic industrial capacity appropriately more self-sufficient, while recognizing that self-sufficiency may be unattainable. As Ursula von der Leyen, president of the European Commission, said in her remarks introducing the EU Chips Act: "It should be clear that no country—and even no continent—can be entirely self-sufficient."[8]

After all, "chips" are not a monolithic category: Many kinds of chips (memory, logic, mixed signal, power semis, etc.) are manufactured for many different end markets (smartphone chips and PC chips are different than chips for cars). Each type of chip may require different wafer sizes and process technologies, and require different materials, facilities, equipment and design tools, radiation tolerance, and so on. There are two dominant but different models: the fabless/foundry/OSAT (outsourced semiconductor assembly and test) ecosystem, and the integrated device manufacturing model (IDM), which usually combines all three roles.

Manufacturing processes are also diverse, calling on multiple semiconducting materials and relying on numerous other inputs (such as specialized epoxies) and a vast array of fabrication, testing, and assembly equipment. Sometimes, there is only a single manufacturer or source for a critical part. And concentrating facilities can increase risks: any given plant or cluster can be shut down by drought, earthquake, fire, flood, military conflict, pandemic, power shortage, or typhoon, among other causes.

Finally, given the realignment of leading-edge manufacturing in North America and Europe, the US and European semiconductor makers may have to locate more back-end assembly and testing (AT) nearby, as they are equally essential parts of the process as the large fabs. This is because leaving almost all AT in Asia will do little to mitigate supply chain risk. At the same time, it doesn't mean that AT must be in the same state, country, or even region as the fabrication plants: a chip plant in Arizona might rely on AT in Latin America, while a German fab could rely on AT in Turkey.

At a high level, policymakers in almost all countries and regions understand that the new supply chain will likely feature a mix of solutions, and countries should consider rethinking their footprint based on ongoing developments with trade restrictions. Some parts may be in our country or region (onshoring); some parts could be in geographies very close to our country or region (nearshoring); and some could be in countries that we consider friends and allies (friendshoring). Those countries may be relatively nearby, or they might be on the other side of the world. As an example, given current US views, having certain parts of the semi supply chain in Japan or Singapore may be just as far away as China… but still likely preferable.

Deciding what mix of onshoring, nearshoring, and friendshoring (while almost certainly still relying on offshoring as well) may be best for each manufacturer or country/region will make 2023 an interesting year. These decisions could resonate for years to come: New or expanded facilities started in 2023 will likely still be in operation in 2030 and beyond, and so will their supply chain linkages. And the trade-offs involved could reach far beyond just governments or chipmakers: As an example, the auto industry relies on different chips than smartphone companies—and usually employs many more workers, with consequent political implications. Moreover, buyers of chips are beginning to express preferences for where chips are made, not just what they do and how much they cost.[9]

Strategic questions to consider, by region or country:

1. The United States and its chipmakers are likely to attempt maximum self-sufficiency in fabs: advanced node, trailing node, specialized chips relevant for defense, chips for auto industry—all of it. They are also likely to dominate in the advanced tools needed but will also friendshore with leading companies in Europe and Asia. AT will remain a challenge: Though there are US-headquartered companies, almost all the high-volume facilities are outside of the United States. Will US labor costs and the focus on higher margin aspects of the value chain keep AT offshore? Is nearshoring in Mexico and Latin America—especially for some specialty chip assembly, test, and module assembly—a viable option? What should be the fab versus foundry mix to help support the US-based fabless companies that have strong design competencies?

2. European chipmakers and governments have seemingly more difficult choices. They currently lag the United States in semi share, and as they scale up, they will need to weigh onshoring versus friendshoring. Should Europe rely more heavily on friendshoring? How much advanced node chipmaking does Europe really need, given that the auto and other industries in Europe rely much more on trailing nodes? In terms of AT, can Europe turn to Eastern Europe? Given the other big gap is in chip design (fabless semi companies), where Europe trails badly at present,[10] what should it do to address this issue?

3. Meanwhile, Taiwan, China, Japan, and South Korea, already dominant in many parts of the semi ecosystem, are fighting hard to keep their preeminent positions and market share, or even grow them. It isn't happenstance that so much semi manufacturing occurs in those countries, as well as in other parts of Southeast Asia (mainly in Malaysia, Singapore): They have educated workforces, infrastructures and short supply chains, and anchor companies. For these regions, what factors—including threats and challenges—might adversely affect their positions in the near term?

4. Many other countries are making similar choices, although usually at a smaller scale—India, Canada, Saudi Arabia, others. What key parts of the semi supply chain do they really want in their country? What can they afford—and what is realistic?

Diversifying with intent and taking a guarded approach

The US and Europe chip industries are looking at diversifying not just fabs but all parts of the semi supply chain, including AT. They would move chipmaking out of the traditional strongholds in the Asia/Pacific region into North America (both the United States and Canada) and Europe[11] (e.g., in EU countries such as Italy, Germany, Netherlands, and Spain; as well as the non-EU states, notably, the United Kingdom, Ukraine, and Norway). The United States and Europe have set ambitious targets to grow their domestic chip manufacturing capacity: The United States intends to grow its domestic capacity share from 11% in 2020 to 30% in 2030, and Europe is aiming to expand its share from 9% to 20% over the same period. Over the same time span, the global chip industry is expected to roughly double in size.[12] However, making these shifts requires semiconductor companies to consider certain nuances related to potential risks and challenges that they need to plan for.

Replicating the capabilities of Asian manufacturing locations won't be easy. Until the supply chain, pandemic, and trade issues surfaced, Asia had secured supply of raw and manufactured materials to make hundreds of components. It still has leading-edge chip production facilities, owns the most advanced AT services, and can even ship final products to the end customers—all in a highly efficient and reliable manner. Replicating and building that model in multiple, geographically unconcentrated new locations could likely take years or even decades. Nonetheless, starting in 2023, the chip companies need to plan and prepare for potential risks involved in diversification.

One of the crucial starting steps is expected to be identifying new sourcing and trade routes. The ongoing war in Ukraine and US-China technology restrictions introduce additional complications and risks and will likely require new air corridors, sea routes, and export-control compliance. These new pathways are likely to increase freight, transportation, and logistics costs, and in turn, pricing of the end products—which are already elevated due to higher energy costs.[13] In an extreme scenario, there are concerns about the ongoing Ukraine crisis ballooning into a possible global war, with an even greater probability of affecting semiconductor manufacturing and supply chains.[14]

As trade restrictions and sanctions intensify further, countries that hold semiconductor manufacturing and design intellectual property (IP) will likely restrict sharing their IP and may even demand more stringent cataloging and tracking. China, in particular, could seek IP from other Asian countries, as its trade tensions with the United States continue to escalate. Semi companies that have R&D and manufacturing operations in these regions should consider being better prepared to deal with the fluid nature of the hi-tech industry's cross-border trade situation. An important additional factor is extraterritoriality (US laws affecting non-US companies). As an example, the United States isn't just forbidding the export of certain technologies to China; it is also attempting to forbid non-US companies (that have extensive US operations or rely on US intellectual property) from exporting those technologies.[15]

Semi companies should consider assessing the various ecosystem players that are available in new locations. Those include suppliers of raw materials and components, access to equipment and tools, availability and cost of talent, and the presence of channel partners and distributors: These all likely need to be considered at once during the planning and location process. Large-volume AT plants could tend to require lower-cost labor. Depending on key materials and services that they need to develop, the chip companies may need to evaluate what type of business relationship would work best: For instance, strategic acquisitions or alliances with local or nearshore commodity suppliers and manufacturers to secure availability; exclusive partnerships or joint ventures (JVs) with critical suppliers of specialized equipment and components. These actions—when put in place in 2023—could help ensure uninterrupted supply of materials and reduce operating costs in the long term.

Moreover, expanding to new locations could present environmental and climate-related risk factors that are probably unique or inherent to those locations. Semi companies should consider aspects such as natural disasters, water crises, and energy shortages, and devise strategies to mitigate those unforeseeable risks. Equally, a lack of these risks is also an important factor: For instance, many companies are looking to build new plants in places with abundant water and reliable power.

With supply chains most likely to fan out to dozens of new locations within the next two to three years, semi companies may need to invest in advanced software and analytics in 2023, to track their products and solutions at any given point in time across the supply chain and facilitate timely decisions.

Strategic questions to consider:

1. While diversifying the manufacturing base and supply chain, what factors should be considered related to building their own facilities, buying existing ones, partnering with other companies or peers, or friendshoring? (See the earlier section on friendshoring.)
2. When commencing operations in new regions and fostering new alliances and partnerships, what types of IP, technological, trade restrictions, and cyber risks could emerge?
3. Given the current downturn and falling profits, how can companies preserve cash while expanding into new geographic regions, pursuing strategic M&A, investing in new JVs or alliances, and divesting select non-core assets?

Digital transformation and data-driven supply chain networks

The global semiconductor industry is anticipated to grow to US$1 trillion in revenues by 2030, doubling in the decade.[16] This growth is expected to require investment in high-end advanced wafer manufacturing materials, equipment, and services—but also in the back-end AT solutions and services.

Currently, more than 90% of the AT base is in Asia, either in foundries or outsourced semiconductor assembly and test (OSAT) providers.[17] With around US$100 billion pledged to support localization of semi capacity, several companies in the semi industry are adding new AT capacity in Europe, North America, and Southeast Asia.[18] And that could exacerbate the existing challenge of disparate and siloed supply chain tech and systems, rendering it even more difficult to predict potential supply chain disruptions. This is where integrated data platforms, next-generation ERP, planning, and supplier collaboration systems along with artificial intelligence (AI) and cognitive technologies are expected to make OSAT processes more efficient and help sense and preemptively plan for future supply chain shocks.

Beyond OSATs, data analytics platforms which are integrated into ERP, planning, and procurement systems can help semi companies predict unexpected events that could disrupt the supply chain: unexpected weather events, transport bottlenecks, logistics challenges that require re-routing shipments, and labor-related issues.[19] Sharing real-time data and intelligence across the ecosystem—encompassing the equipment and tool suppliers, chip design companies, wafer fab facilities, AT facilities, distributors, OEM and ODM customers, and more—is likely essential to build a digitally connected supply chain. A connected network of supply chain partners can help allow chip companies to address multiple issues across their sales and partner organizations and proactively manage their logistics and warehouse planning. This can improve working capital management and delivery estimates and even contain operating costs.[20]

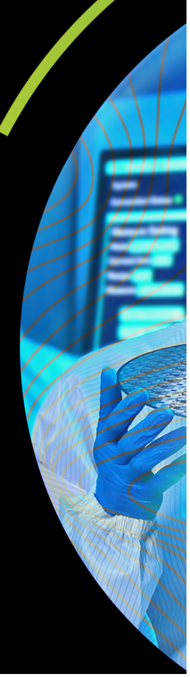
Solutions such as smart databases can help facilitate proactive data-sharing between key players and can help supply chain executives make timely and informed decisions.[21] Chip companies can use advanced analytics solutions to improve bill of materials (BOM) tracking and analyze delivery timelines of machines and components. These digitization efforts will likely help the industry not only to get a better view of suppliers' production schedules and changes, but also to present granular insights into customer demand expectations across tiers.[22] Besides improving production processes, AI and analytics solutions can help shorten calibration time required to develop and design chips, and even improve yield.[23]

By adopting Industry 4.0 solutions—such as digital twins—in their smart factory operations, chip manufacturers and foundries can produce electronics parts and components on demand and ship to customers in an agile way. This could mitigate disruptions due to supply chain vulnerabilities such as sourcing delays or component shortages.[24]

To realize maximum benefit from advanced analytics, AI tech, and data-driven solutions, data quality matters. Industry leaders and executives will make crucial decisions on the supply chain and adjustments based on data-based insights and outputs—and data is the building block in those analytics and AI processes.[25] So, in 2023, semi companies need to modernize their ERP systems and integrate diverse data sources such as customer data, manufacturing data, financial and operational data. And they should consider investing in data management and data analytics modernization solutions, and establish the required data governance and fixing data quality issues.

Strategic questions to consider:

1. Given the current economic and industry trends (rising interest rates, falling demand in some important chip sectors, high inventories), how can companies best revamp and accelerate digital transformation in the face of the adverse trends?
2. When deploying digital technology and AI tools to digitize supply chain management, what entities and variables should be considered as part of the advanced and predictive analytics data-driven decision model?
3. As localization accelerates through the next year, how much of a negative impact will there be on the supply chain and data modernization efforts? How do companies effectively interconnect new and existing entities (e.g., a fab or site) into an increasingly complex global network?
4. How can companies deploy resources to modernize and integrate their IT systems when budgets are getting tighter? And how can they balance near-term IT implementations with strategic long-term investments in next-generation digital technologies?



Addressing the semi talent shortage and the need for specialized skills

Semi talent was in short supply in 2022[26]—and the shortage is expected to get even worse in 2023 for parts of the industry and be a challenge for the rest of the decade. The race to localize semiconductor manufacturing is intensifying globally and is exacerbating the chip talent and skill shortage issues.[27] Deloitte predicts that the semiconductor workforce—estimated at more than 2 million direct semiconductor employees worldwide in 2021—will need to grow by more than 1 million additional skilled workers by 2030; roughly adding more than 100,000 workers annually.[28] In Asia, each country faces a unique set of challenges to grow their talent pool even as they're trying to establish their own domestic chip production capabilities.[29]

Chip manufacturing and the back-end AT are highly clustered—four countries in East Asia produce roughly 80% of all chips, and more than 90% of the AT occurs in or near those countries.[30] A less concentrated chip industry, both in manufacturing and AT, could help US and European industries that rely on chips.[31] But an industry that operates in more locations will need more talent, and more dispersed talent, to make trillions of dollars' worth of chips.[32]

In 2023, chip companies should consider expediting hiring diverse skills for both building and automating their manufacturing facilities, and to design chips and tools. Their talent challenges are compounded by the urgent need to build large-scale fab facilities in multiple regions. Therefore, they need to accelerate hiring for a range of skills: electricians, pipefitters, and welders; technical engineers, maintenance personnel, and smart factory automation specialists; and graduate electrical engineers to design chips and the tools and manufacturing processes that make the chips.[33] With the drive to overhaul supply chains, chipmakers in Europe and the Americas are also expected to need a similar mix of specialized workforce to build out back-end AT facilities.

These job groups have distinct training and educational needs, and skills within these job groups are evolving due to automation, digitization, and semiconductor technology advancements. The chip industry thus likely needs to partner with universities and engineering schools; work more closely with local tech schools, vocational schools, and community colleges; and support national institutions specialized in STEM fields.[34]

Besides skill development, the chip industry may need to join hands with various local governments to enhance fungibility and mobility of skills between regions, secure support in the form of favorable talent immigration policies, and seek assistance for local recruitment and skills-based training. Further, after years of M&A activity and consolidation, many companies may need to find a better way to integrate the various talent workforces.

From an organization's standpoint, chip companies should aim to develop strong and diverse talent pools across their ranks. To achieve this, they need to continue to adopt a diversity, equity, and inclusion (DEI) mindset and include women and other underrepresented demographic categories in both their technical and leadership areas.[35] And they likely need to figure out ways to retain talent and show long-term career growth pathways for professionals.

Going forward, the technical skills needed by the industry are becoming less purely hardware focused (where the industry traditionally has been strong) and are increasingly more about software, which requires new talent recruitment and training approaches. The good news is that new advances in AI tools for chip design, especially physical layout, are allowing companies to produce better chips, faster, and using fewer people, which allows scarce talent to concentrate on the most pressing issues.[36]

Strategic questions to consider:

1. What specific efforts and programs are required to identify, access, and develop future skills across the engineering and manufacturing workforce and drive superior performance and value? And how can semi companies plan and prioritize hiring in key roles and expand their workforce, while dealing with hiring freezes and limited budgets?
2. How can semi companies redesign the way humans and technology interact to develop solutions and deliver services and value for customers? Does that need to be about advanced tools such as AI, automation, robots, and cobots, or can the industry benefit from simpler solutions?
3. What should the organization talent design model look like to ensure that it not only addresses the immediate talent-related issues, but also allows the organization to capitalize on new or greenfield areas that offer long-term growth opportunities?

Building a sustainable semiconductor industry

The global semiconductor industry has experienced the impact of climate-driven adverse events in 2021 and 2022. Extreme heat and drought conditions affected power supply in China's Sichuan province, leading to factory closures at several electronics component makers.[37] Drought in Taiwan caused water restrictions to some chipmaking plants.[38] Intense winter storms triggered power outages in Texas affecting three major semi plants' operations.[39]

But the chip industry is not just facing climate issues: It is likely contributing to climate change. The production process for every new generation of chips uses more energy, water, and greenhouse gases (GHGs)—especially process gases with high Global Warming Potential (GWP) that are difficult to mitigate[40]—than the generation before. And by 2030, the information and communications technology industry is likely to account for 20% of global electricity demand.[41] As a result, investors, customers, board members, and regulators are requiring more transparent and comprehensive disclosures on GHG emissions, environmental risks, and mitigation actions.[42]

Some semi companies have been proactive in their approach to sustainability. For instance, one large IDM and one major fabless chip company have set net-zero targets. They aim to use more renewable energy to power their factories and office buildings, as well as to minimize energy emissions from their supply chain operations.[43] But not all chip companies are doing the same: Five semi companies with a combined market cap of more than US$900 billion had not yet committed to net-zero targets until mid-2022.[44] 2023 could be the year when more of the large players set bold targets and take specific actions beyond the basic carbon offsets—for example, evaluating the various aspects outlined in the United Nations Environment Programme's (UNEP's) Sustainable Development Goals program and figuring out specific ways to foster sustainable terrestrial ecosystems.[45]

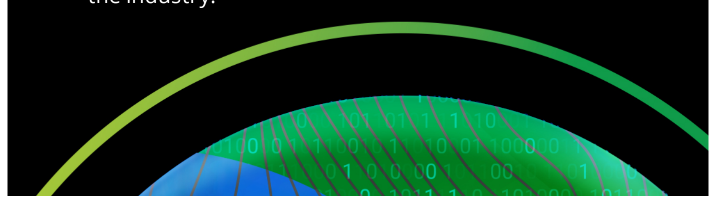
Some chip manufacturers and foundries have already implemented technologies that are enabling them to recycle and reuse water.[46] Additionally, companies have increased renewable energy used to generate power for their office buildings and manufacturing facilities.[47] These efforts address Scope 1 and 2 emissions.[48] The industry is also looking at Scope 3 emissions, which are those coming from upstream and downstream in the supply chain. Besides, using less water and energy not only reduces the ESG footprint but could also reduce operating costs because of lowered spending on resources consumption, potentially benefitting the bottom line.

In 2023, the chip industry can form strategic alliances with all parts of the supply chain and work more cohesively to explore and develop new technologies and methods to help accelerate decarbonization efforts, although there is some skepticism that the industry can achieve net-zero. Besides reducing carbon emissions from their own operations, companies in the chip industry have the potential to reduce others' carbon footprints. Compound power semiconductors, such as silicon carbide and gallium nitride, can help enhance energy efficiency and improve the green carbon footprint of sectors such as automotive (electric vehicles), industrial automation, rail transportation, and renewable installations.[49]

Semi companies likely need to consider a more elaborate and comprehensive ESG and financial reporting mechanism. These additional disclosures are vital because they could help provide increased operational transparency to local communities regarding what steps companies have taken to address environmental impact and how they are incorporating sustainable practices into their local manufacturing and office facilities. And they don't have to settle for being victims of climate change, nor must they worsen it. Instead, they can make 2023 an inflection to come together, define starting steps (including setting net-zero targets), and start contributing to the solution.

Strategic questions to consider:

1. What broader sustainability and net-zero strategy will likely be necessary as companies build out new fabs at an unprecedented pace and in new regions?
2. When defining sustainability and net-zero goals, what specific parts of the upstream and downstream supply chain should be prioritized over the next two to three years, based on what would be feasible?
3. Will governments, regulators, stock exchanges, or shareholders demand semiconductor companies move significantly faster on sustainability during 2023?
4. Are irreplaceable and difficult to mitigate essential process gases (which have high GWP) the biggest sustainability challenge for the industry?



Signposts for the future

For 2023, we recommend semiconductor industry executives be mindful of the following signposts:

- Macroeconomic indicators: Reduction in inflation, hard or soft economic landing, central banks slowing or stopping increasing interest rates, signs of renewed consumer demand for smartphones and PCs, and a rise in the market capitalization of the sector.
- Inventory levels for end customers and distributors, plus manufacturing cutbacks: Inventories are almost certain to be reduced in H1 2023, but will we see orders begin to flow in the second half, and will we see reductions in wafer starts being reversed?
- Memory prices can often be leading indicators for the chip cycle. Prices bottoming or even rising will be an important bellwether.
- Capex plans are being reduced or deferred—a key signpost may be companies publicly raising guidance.
- Regulatory/political issues can change quickly: US attitudes on semi technologies and China could change (we are still waiting to see how China responds), the war in Ukraine could shift toward diplomatic solutions or could escalate, and environmental regulators could announce new rules.
- As the war for talent continues (plus high inflation, plus low unemployment, plus the need to ramp up new plants in the United States and Europe but also in Southeast Asia), will chipmakers see costs rise much faster than usual?

Contacts

Christie Simons
Global Semiconductor and
US TMT Industry
Audit & Assurance Leader
csimons@deloitte.com

Brandon Kulik
US Semiconductor Leader and
Consulting Principal
bkulik@deloitte.com

Jan Nicholas
APAC Semiconductor Leader
jnicholas@deloitte.com

Jordan Bish
EMEA Semiconductor Leader
jbish@deloitte.nl

Christie Simons, Brandon Kulik, Jan Nicholas, and Jordan Bish would like to thank Duncan Stewart and Karthik Ramachandran from Deloitte's Center for Technology, Media & Telecommunications (TMT Center) along with Dan Hamling, Uwe Lambrette, and Jeroen Kusters for their contributions to the research and writing of this outlook.

About the TMT Center

Deloitte's Center for Technology, Media & Telecommunications (TMT Center) conducts research and develops insights to help business leaders see their options more clearly. Beneath the surface of new technologies and trends, the TMT Center's research can help executives simplify complex business issues and frame smart questions. The TMT Center can help executives better discern risk and reward, capture opportunities, and solve tough challenges amid the rapidly evolving TMT landscape.

Endnotes

1. Deloitte analysis of publicly available stock market data.
2. Ibid.
3. James Morra, "The chip boom? It's over. The chip shortage? Not yet.," *Electronic Design*, December 1, 2022.
4. Ian King, "Chip delivery times shrank in August, but some shortages drag on," Bloomberg, September 8, 2022.
5. Laura He, "US curbs on microchips could throttle China's ambitions and escalate the tech war," CNN Business, October 31, 2022.
6. Deloitte analysis of publicly available large semiconductor capital expenditure forecasts.
7. Sarah Kessler, "What is 'Friendshoring', the buzzword in global supply chains?," *Economic Times*, November 19, 2022.
8. European Commission, "Statement by President von der Leyen on the European Chips Act," February 8, 2022.
9. Mark Gurman, "Apple prepares to get made-in-US chips in pivot from Asia," Bloomberg, November 15, 2022.
10. European Chips Act: Staff Working document, figure 24, p. 29. See also: European Commission, "Statement by President von der Leyen on the European Chips Act."
11. Jordan Bish et al., "A new dawn for European chips," Deloitte Insights, November 3, 2022.
12. Analysis based on information gathered from publicly available third-party sources. 2030 data reflects US and Europe numbers based on stated goals of the respective regional Chips Acts.
13. Philip Barrett, "How food and energy are driving the global inflation surge," IMF, September 12, 2022.
14. Guy Faulconbridge and Lidia Kelly, "Russian official warns of World War Three if Ukraine joins NATO," Reuters, October 13, 2022.
15. Steven F. Hill et al., "U.S. government imposes significant new export controls on semiconductor, semiconductor manufacturing equipment, and supercomputer-related transactions involving China and Chinese entities," K&L Gates, October 21, 2022.
16. Michael Hall, "ISS 2022: Semiconductor industry market outlook and prospects for reaching $1 trillion by 2030," SEMI, May 9, 2022.
17. Karen Weisz et al., *The global semiconductor talent shortage: How to solve semiconductor workforce challenges*, Deloitte, 2022.
18. Ibid.
19. Bob Violino, "How using analytics and AI can help companies manage the semiconductor supply chain," CNBC, October 19, 2022.
20. Ibid.
21. Intelligent supply chains would mean self-adjusting and automated, which can make quick decisions and reduce turnaround time with the help of deployment of AI and ML through a control tower. It helps to manage service levels in an effective and efficient way. It will help ensure that no demand is left unmet, and idle inventory is only to take care of supply chain and environmental risks. The most cost-effective interconnected supply chain must necessarily be a cloud solution. See further on: Anjani Mandal, "Building a cloud-driven foundation for supply chain management," DATAQUEST, August 2, 2022.
22. Barbara Jorgensen, "Building a better supply chain: 5 trends to watch," *EE Times*, September 22, 2022.
23. Jeff Loucks et al., "AI in chip design: Semiconductor companies are using AI to design better chips faster, cheaper, and more efficiently," Deloitte Insights (Global TMT Predictions 2023), November 30, 2022.
24. Digitization also provides new toolsets for the supply chain, such as AI and digital twins. In factories, the Internet of Things provides autonomous condition monitoring for critical equipment plus machine-to-machine communication throughout a facility. Today, that includes robots performing operations, configurable material handling equipment, and automated inspection stations. Defects can be spotted early in the production process and quickly corrected. See further on: Jorgensen, "Building a better supply chain: 5 trends to watch."
25. Violino, "How using analytics and AI can help companies manage the semiconductor supply chain."
26. Deloitte, *2022 semiconductor industry outlook*, January 2022.
27. Deloitte predicts that the global chip industry will need more than 1 million additional skilled workers by 2030, translating into at least 100,000 annually from 2023 through 2030. Further, a study shows that the United States alone needs to add a total of 90,000 skilled and most-critical workforce between 2020 and 2025, in order to meet its fab manufacturing expansion plans. To read further, see: Weisz et al., *The global semiconductor talent shortage: How to solve semiconductor workforce challenges*.
28. For context, there are fewer than 100,000 graduate students enrolled in electrical engineering and computer science in the United States annually. To read further: Weisz et al., "The global semiconductor talent shortage," Deloitte, 2022.
29. Insights developed based on Deloitte's research and conversations with experts across regions worldwide. Malaysia and Thailand are reasonably well-developed domestic electronics and chip manufacturing hubs, but they need more engineering and hi-tech talent than what they have now. Singapore has a highly developed chip and electronics workforce, but it's expensive. In Vietnam, semiconductor skill levels commensurate with the rest of Southeast Asia, but there are some infrastructure-related issues. And it's dealing with scaling talent to meet the continued growing demand for additional semiconductor capacity in the country. India has strong design and engineering talent, though it lacks domestic chip manufacturing capabilities.
30. Back-end capabilities are still a critical and necessary part of the process and about 15% of the global semi workforce. Making more chips in the United States or Europe is a good thing in terms of self-sufficiency. But if those chips need to be sent to Asia for AT after manufacture and then sent back for consumption, the supply chains just doubled in length.
31. The United States and Europe also need to start augmenting their domestic AT workforce in 2023—because having AT capabilities is vital to improve a region's self-reliance and reduce exposure to risk-centric APAC locations via outsourced AT, and make the global supply chain more resilient.
32. With the longer-term trend showing prospects for the chip industry to grow more than 80% by 2030, there is a corresponding talent boost required to enable, achieve, and support that growth.
33. Weisz et al., *The global semiconductor talent shortage: How to solve semiconductor workforce challenges*.
34. From an academic and STEM skill development perspective, introducing semiconductor-specific curriculum and training programs at the higher education level will enable countries and regions to produce industry-ready workforce and help address the skill gap. For instance, efforts are already in full swing in China to set up specialized schools, training centers, and colleges focused on semiconductors and AI. In Taiwan and Malaysia, universities are joining hands with domestic chip companies to introduce specialized semiconductor curricula. To read further, see: Stephanie Yang, "Chip makers contend for talent as industry faces labor shortage," *Wall Street Journal*, January 2, 2022; Aaron Raj, "The world needs more skilled semiconductor workers," *Techwire Asia*, January 26, 2022.
35. Kathryn Moody, "With demand for semiconductors rising, can training and DEI attract more workers to the industry?," *HR Dive*, July 18, 2022.
36. Jeff Loucks et al., "AI in chip design: Semiconductor companies are using AI to design better chips faster, cheaper, and more efficiently," Deloitte Insights (Global TMT Predictions 2023), November 2022.
37. Laura He, "China's worst heatwave in 60 years is forcing factories to close," CNN Business, August 17, 2022.
38. Emanuela Barbiroglio, "No water no microchips: What is happening in Taiwan?," *Forbes*, May 31, 2021.
39. Jacques Leslie, "How climate change is disrupting the global supply chain," *Yale Environment 360*, March 10, 2022.
40. US Environmental Protection Agency (EPA), F-Gas Partnership Program – Semiconductor industry, accessed December 7, 2022.
41. Alan Crawford, Ian King, and Debby Wu, "The chip industry has a problem with its giant carbon footprint," *Bloomberg*, April 8, 2021.
42. Susanne Hupfer et al., "Tech's climate commitment: Organizational and personal impacts are pushing tech leaders toward faster climate action," Deloitte Insights (Global TMT Predictions 2023), November 30, 2022.
43. Deloitte analysis based on information available from multiple sources.
44. Data and analysis based on publicly available sources as of November 11, 2022.
45. UNEP, Sustainable Development Goals, Goal 15: Life on land, accessed December 2, 2022.
46. Dexter Johnson, "Scarcity drives fabs to wastewater recycling: Boosting water recycling at fabs by up to 98 percent keeps chip production on target," *IEEE Spectrum*, January 25, 2022.
47. Sarah Barry James, Stefan Modrich, and Sydney Price, "Path to net-zero: US chipmakers balance growth vs. going green," S&P Global Market Intelligence, June 13, 2022.
48. Scopes 1, 2, and 3 are a way of categorizing the different kinds of carbon emissions a company creates in its own operations and in its wider value chain. Scope 1 emissions cover GHG emissions that a company makes directly (e.g., while running its boilers and vehicles). Scope 2 emissions are the ones it makes indirectly (e.g., electricity that a company procures for heating and cooling buildings). Scope 3 emissions include all emissions that the company is indirectly responsible for, up and down its value chain (e.g., emissions generated when buying products from its suppliers, and emissions from its own products when customers use them). Emissions-wise, Scope 3 is nearly always the big one. To read further, see Deloitte's perspective on Scope 1, 2 and 3 emissions.
49. Duncan Stewart et al., "Supercharged semiconductors: Chips made of newer materials surge ahead, handling the volts that would fry silicon chips," Deloitte Insights (Global TMT Predictions 2023), November 30, 2022.

Deloitte.