SEMICONDUCTOR INDUSTRY ASSOCIATION + BCG

ATTRACTING CHIPS INVESTMENT: INDUSTRY RECOMMENDATIONS FOR POLICYMAKERS

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The Semiconductor Industry Association (SIA) is the voice of the semiconductor industry in the US, one of America's top export industries and a key driver of America's economic strength, national security, and global competitiveness. The semiconductor industry directly employs more than 300,000 workers in the United States, and US semiconductor company sales totaled $264 billion in 2023. SIA represents 99 percent of the US semiconductor industry by revenue and nearly two-thirds of non-US chip firms. Through this coalition, SIA seeks to strengthen leadership of semiconductor manufacturing, design, and research by working with Congress, the Administration, and key industry stakeholders around the world to encourage policies that fuel innovation, propel business, and drive international competition.

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BCG's contribution to this document was limited to research, and analysis and the policy recommendations contained herein are entirely the product of SIA. BCG does not necessarily agree with or support any such recommendations or conclusions.

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Executive Summary

Chips are integral to the 21st century economy, from electric vehicles, AI data centers, and medical technologies to mobile devices, energy grids, and streaming platforms. Historically, semiconductor supply chain production activities have concentrated in a handful of regions. But as global chips demand increases, and the industry responds to geopolitical uncertainty and other disruptions, companies are diversifying their global investment footprint to improve supply chain resilience. In our new SIA-BCG report, *Attracting Chips Investment: Industry Recommendations for Policymakers*, we recommend policy actions governments can undertake to better attract investment, based on the following five key factors that semiconductor companies evaluate when making investment decisions:

1 Investment and Operational Costs

Semiconductor development, both design and manufacturing, is expensive. In 2023, the industry's R&D and capital expenditure represented over 40% of global semiconductor sales. In evaluating site options, companies thoroughly analyze site specific costs, including land, utilities, equipment, materials, labor, and taxes.

Recommendations:

- Design simple and flexible incentive programs
- Prioritize incentives that offset construction and equipment costs

2 Workforce and Talent

The semiconductor industry requires skilled workers, including engineers, technicians, and computer scientists, with an interdisciplinary skillset grounded in STEM fields. They seek countries where the education system and public-private partnerships coalesce to generate a rich talent pipeline. When evaluating new sites, companies consider a range of factors, including the labor pool, costs, the education system, and opportunities to apprentice future workers.

Recommendations:

- Develop skills roadmaps, update curricula, and develop "micro-steps" certification
- Upskill faculty to teach relevant curricula
- Incentivize STEM education
- Permit flexible work shifts
- Increase flexibility

3 Infrastructure

Infrastructure is paramount for semiconductor facilities that run 24 hours a day, 365 days a year. Even a "micro power outage" can cause substantial operational losses. Key investment criteria include site construction conditions, utility infrastructure, transportation and logistics networks, and disaster risk.

Recommendations:

- Support efficient utilities infrastructure
- Ensure stable power supplies
- Develop green energy
- Optimize communications and transportation logistics

4 Regulatory Environment

Semiconductor investments concentrate in countries with market-friendly trade policies. Barriers and delays at the border significantly impact operational efficiency. By the same token, onerous permitting can delay timelines for multi-billion-dollar projects. IP protection is also critical in an industry with high R&D-to-revenue ratios. Moreover, companies now face a more complex geopolitical environment, with attendant trade compliance and data requirements.

Recommendations:

- **Trade:** Liberalize tariffs; optimize trade facilitation; and leverage free trade zones
- **IP:** Promote a "culture" of IP protection in regulatory and business practices; enforce criminal penalties; and adopt clear conformity assessments
- **Permitting:** Establish a "single window"; eliminate redundant requirements; and harmonize environmental standards
- **Trade controls compliance:** Implement a transparent export control regime; educate local companies on how to support trade compliance work
- **Data regulations:** Ensure free movement of semiconductor data; avoid unnecessary data localization rules

5 Integrated Ecosystems

Semiconductor companies prefer locations with vibrant ecosystems of suppliers, customers, R&D partners, innovation hubs and, ideally, downstream industries, such as electronics and automotive. These clustered locations can benefit from talent, know-how, and the presence of major downstream industries such as electronics and automotive.

Recommendations:

- Develop clusters that concentrate suppliers
- Link semiconductors to downstream industries
- Seek deliberate evolution, focusing first on supply chain segments with lower barriers to entry

To take advantage of the current window of opportunity, policymakers seeking to win semiconductor ecosystem investments should move quickly and deliberately, mindful that other governments are likewise competing for such projects. By implementing these policy actions, governments can better attract and facilitate chips investments, and in turn drive greater security, resilience, and diversification in global semiconductor supply chains.

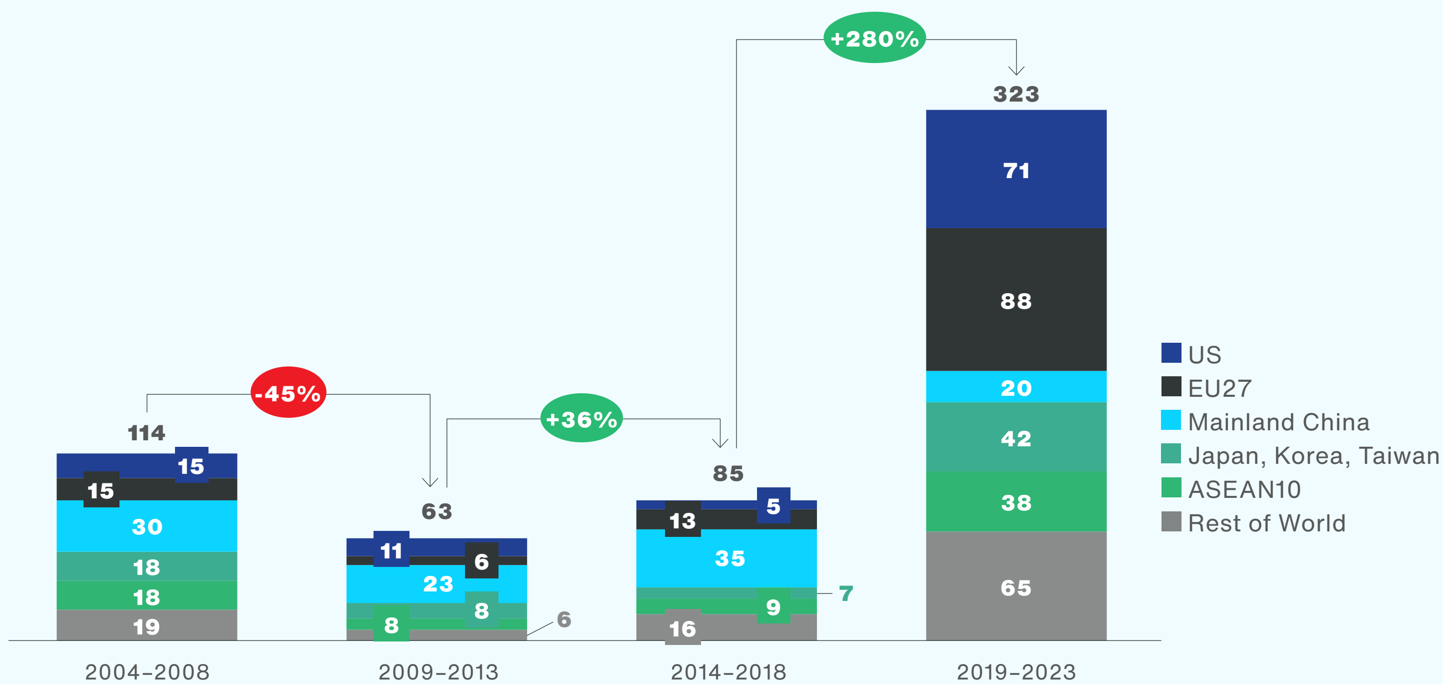
The Opportunity and the Challenge

Semiconductors are integral to the 21st century economy. To meet rising demand, the semiconductor industry is experiencing a worldwide investment boom. In our SIA-BCG report, *Emerging Resilience in the Semiconductor Supply Chain*, we project $2.3 trillion investment in wafer fabrication capacity alone in 2024–2032. This fab investment will exert both a “pull effect” on the supply chain, with assembly, test, and packaging (ATP) capacity expanding to keep pace with wafer fabrication, and rising investment in other areas, from design to materials sites and equipment-related training centers. This is already becoming evident in the boom of cross-border investment **(see Exhibit 1)**.

Historically, the semiconductor supply chain has been concentrated in few regions—East Asia, Western Europe, and the United States—and indeed, in specific clusters within those regions. But semiconductor companies are rethinking how to diversify risk and are seeking opportunities to broaden their operational footprint, with a renewed focus on supply chain resilience. They are making investments outside their HQ regions **(see Exhibit 1)** and taking advantage of advances in education and infrastructure as well as commitments by governments to improve the investment and operating environments in their countries. The United States and likeminded countries, in turn, are forging partnerships to expand capacity and strengthen supply chain resilience for semiconductors **(see Textbox 1 for the United States)**.

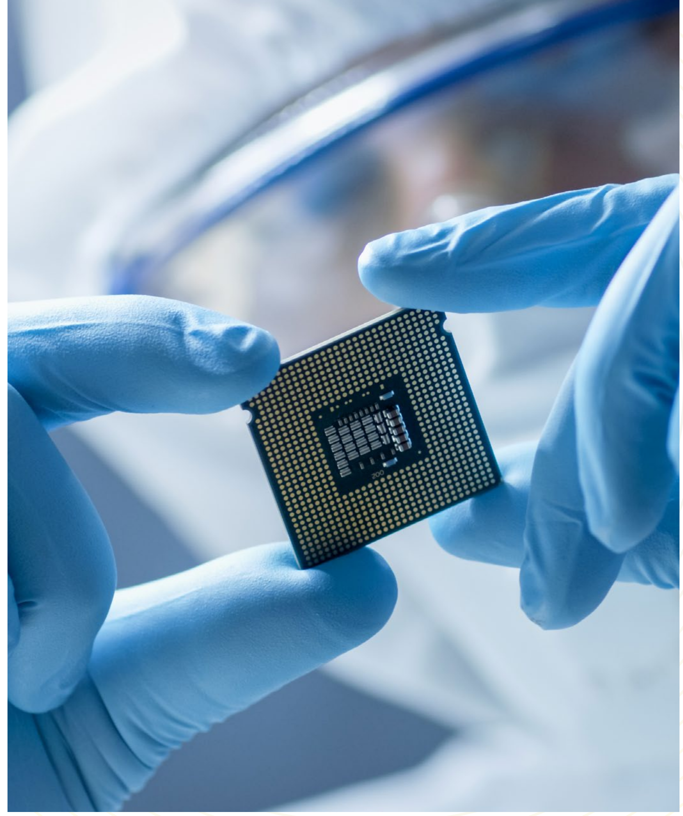
EXHIBIT 1

New Semiconductor Sector Cross-Border Investment ($B), by Five-Year Period, 2004–2023



Note: Cross-border investment in a new physical project or expansion of an existing investment which creates new jobs and capital investment. Joint ventures are only included where they lead to a new physical operation. Mergers & acquisitions (M&A) and other equity investments are not tracked. There is no minimum size for a project to be included. Includes semiconductor-related investment in manufacturing as well as other activities, including R&D, education & training, sales & marketing, among others.
Source: fDi Markets

And yet, when semiconductor companies invest overseas, they face formidable planning challenges. For example, a semiconductor manufacturing site is capital-intensive to construct and equip. Planning for operations requires identifying large and reliable supplies of power and water, an ecosystem of specialized suppliers, and efficient logistics networks. In both manufacturing and design, semiconductor companies rely on a highly qualified workforce, robust protection of intellectual property (IP), and a regulatory environment that is both transparent and easily navigable. Unsurprisingly, companies prefer locations where they have suppliers and customer bases to minimize risk and leverage trusted networks. Companies strive to ensure new projects meet these criteria—while also generating an attractive return on investment.



Textbox 1: U.S. Partnerships to Strengthen the Semiconductor Supply Chain

The International Technology Security and Innovation (ITSI) Fund, established under the U.S. CHIPS Act, provides the U.S. Department of State with $500 million over five years to promote semiconductor supply chain security and diversification. To date, ITSI partnerships have been announced with Mexico, Costa Rica, and Panama in the Americas and with Indonesia, the Philippines, and Vietnam in Asia.[1]

The U.S. government is also working to strengthen the semiconductor supply chain with partner countries through other initiatives. For example, during Indian Prime Minister Modi's state visit to the United States in June 2023, the White House established a framework (iCET) to forge deeper ties in critical and emerging technology supply chains, including semiconductors.[2]

In this report, we explore the factors semiconductor companies consider when making new investments, which should inform the strategies, policies, and programs governments are developing to attract these investments. Based on interviews with a number of SIA member companies, as well as industry and regional experts, we examine five key factors that impact investment decisions: (1) investment and operational costs, (2) workforce and talent, (3) infrastructure, (4) regulatory environment, and (5) integrated ecosystems. For each factor, we identify emerging trends, common pain points, and recipes for success. We also develop a set of recommendations for each key factor regarding what governments can do to improve the attractiveness of their country or sub-region as a destination for semiconductor companies.

We find policymakers have multiple levers to attract semiconductor ecosystem investments. Contrary to what some may think, incentives alone are insufficient. Companies value locations that act on a long-term, holistic strategy, tailored to the semiconductor industry, involving talent development, infrastructure improvements, and ease of doing business. Ultimately, success is measured in the emergence of a viable semiconductor ecosystem, a building block for a broader technology ecosystem.

A Framework for Investment Decision-Making

The semiconductor supply chain spans diverse activities, from R&D and chip design to wafer fabrication, ATP, and materials and equipment **(see Exhibit 2)**.[3] Investment requirements differ, for example, between a manufacturing site and an R&D facility. This report focuses less on "front-end" wafer fabrication, a segment in which investments are highly capital-intensive and technically challenging. That being said, our findings and recommendations aim to be agnostic to semiconductor segments.

When semiconductor companies evaluate a potential investment, they first identify operationally viable candidate locations. They then calculate and compare detailed cost estimates for constructing and operating a facility in those locations. Those estimates assess a range of factors that will ultimately influence site selection—ranging from human resources, infrastructure, and logistics to regulatory permitting, legal compliance, and taxes. By one estimate, hundreds of discrete factors are considered.[4] Site-specific factors—such as proximity to a company's key suppliers and customers—also play a role.

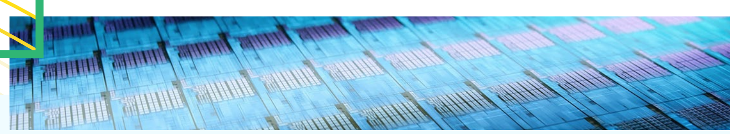
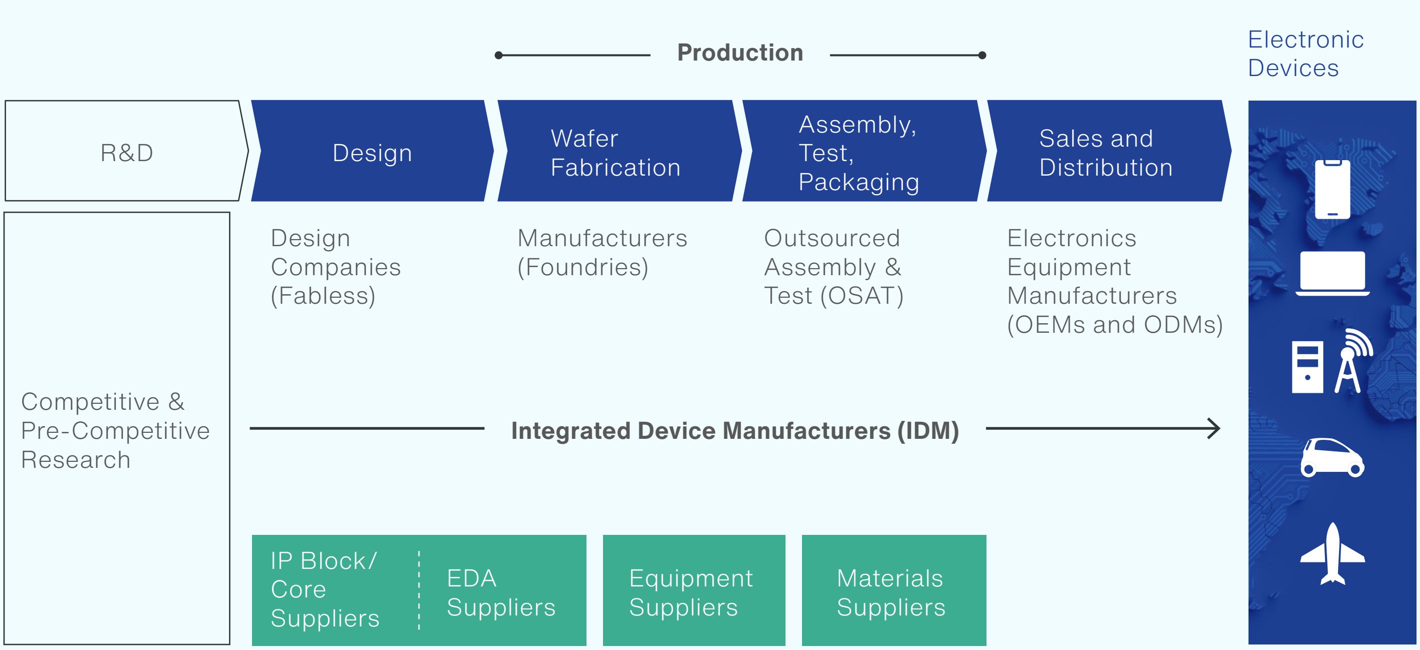
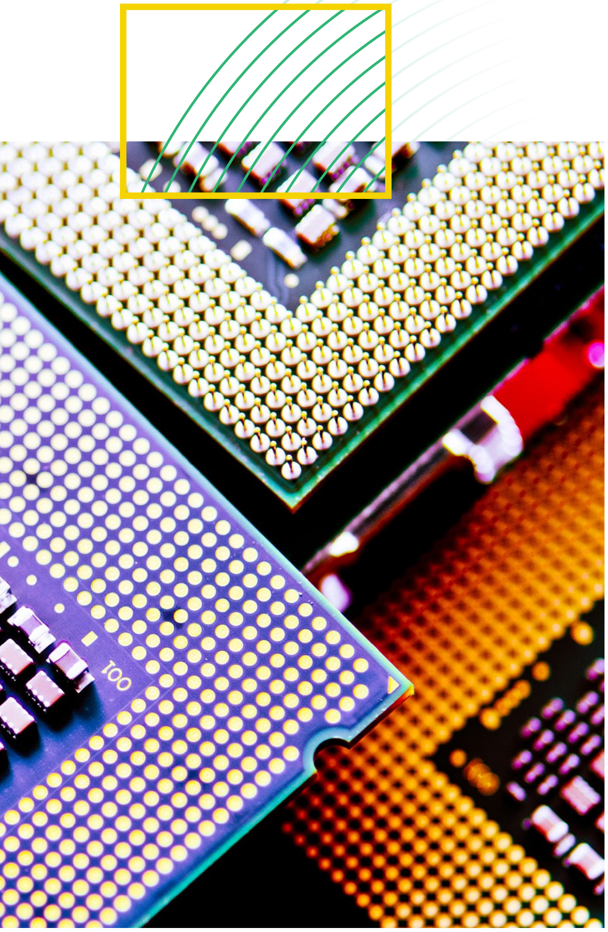


EXHIBIT 2

The Semiconductor Supply Chain



The following five factors are key to semiconductor investment decisions:



1. **Investment and Operational Costs.** Semiconductor development, in both design and manufacturing, is expensive. In 2023, the industry's R&D and capital expenditure represented over 40% of global semiconductor sales. In evaluating site options, companies thoroughly analyze site-specific costs, including land, utilities, equipment, materials, labor, and taxes.

2. **Workforce.** Semiconductor companies require access to a large technical workforce. They seek countries where the education system and public-private partnerships coalesce to generate a rich talent pipeline—from technicians and skilled trades to PhD-level engineers and scientists. Key criteria include the total pool of technicians and engineers, relative labor costs, labor regulations, and the quality and scale of STEM education programs.

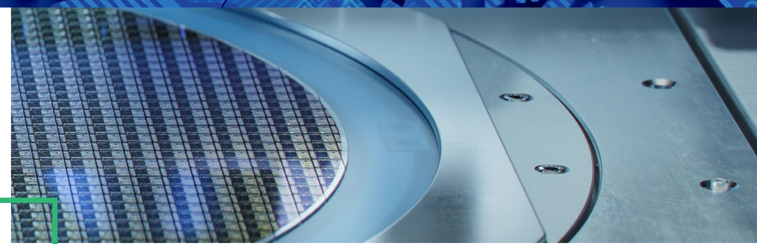
3. **Infrastructure.** Since chipmaking relies on continuous, resource-intensive production to make complex products, safe and reliable infrastructure is critical. Even small interruptions in operations can lead to massive costs. Key investment criteria include site construction conditions, utility infrastructure, transportation and logistics networks, and disaster risk.

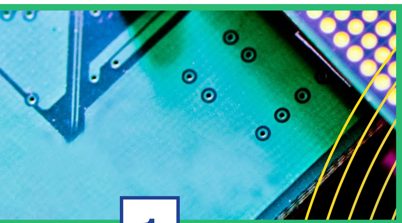
4. **Regulatory Environment.** Given the importance of global supply chains to the industry, semiconductor investment concentrates in countries with market-friendly policies and low border costs. Delays in permitting and customs clearance, for example, impact operational efficiency. At the same time, companies must safeguard sensitive IP across their global sites. Key investment criteria include IP protection, regulatory permitting, trade costs and procedures, trade compliance, and data regulations.

5. **Integrated Ecosystems.** Semiconductor companies thrive on vibrant ecosystems that cluster suppliers, customers, R&D partners, educational partners, and innovative talent. Key investment criteria include the density of supplier clusters, the presence of local innovation hubs, and the presence of major downstream industries such as electronics and automotive.

Below, we explore each key factor in detail.

Key Factors Enabling Semiconductor Investment





1

Investment and Operational Costs

Given the high degree of capital intensity in the semiconductor industry, semiconductor companies pay close attention to large-cost items that could impact long-term returns on capital, including energy, water, transportation, labor, and materials. Because they make complex products on tight schedules, with little margin for error, they tend to prioritize operating stability over operating costs. This tendency is evident in three areas:

Utilities and water. Semiconductor companies cite utilities as a major cost driver. But they view the reliability and sustainability of power and water resources as paramount **(see discussion on Infrastructure below)**. Where feasible, they also seek to incorporate renewable energy sources and to negotiate with authorities and/or utility providers to find fair, sustainable rates.

Labor. Semiconductor companies require a highly qualified workforce to conduct complex operations in manufacturing, design, equipment, and other segments of the supply chain **(see Workforce and Talent section below)**. Compared with securing talent, labor costs can be a secondary consideration. As one company explained, during greenfield site selection, unit labor costs helped narrow country choices, but proved less pivotal in the final selection than did the caliber of local talent. Another company made clear that even if wage rates rose substantially at its ATP site in one country, it would be reluctant to move to lower-wage neighboring countries on that basis alone.

Materials. Specialty gases, chemicals, metals, and other materials are a top cost item. But materials suppliers tend to develop specialized technology, products, and customer relationships and are typically clustered in certain geographies. This limits opportunities for semiconductor companies to optimize costs by sourcing locally. Nonetheless, because companies import many materials for use at their sites, a decisive factor is border costs, such as tariffs, fees, customs clearance, and regulatory approvals **(see discussion on Regulatory Environment below)**.

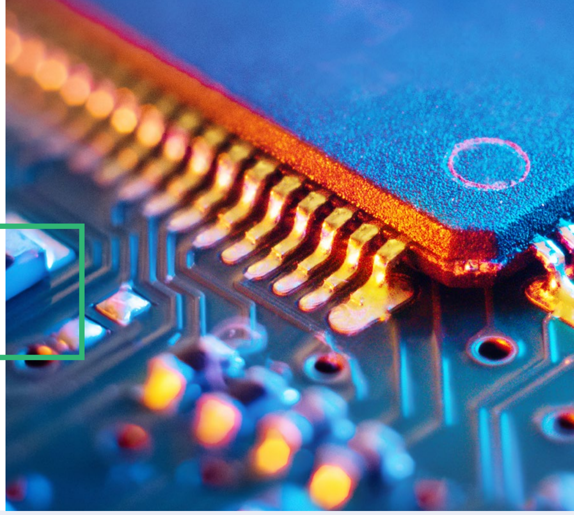
Location-specific construction and equipment costs, as much as operational costs, drive investment decisions. Constructing a new, state-of-the-art facility not only is expensive, but also incurs costs associated with permitting processes and utilities connections. To reduce construction costs for a large greenfield facility, a company might realize savings by repurposing warehouses or office facilities into manufacturing sites, or by building adjacent to an existing facility.

Facilities equipment—including for testing and manufacturing—is expensive to acquire and depreciates in value. Several trends are elevating equipment needs, including advanced packaging technologies, more power-efficient facilities, big data, and new functions to keep pace with design innovation. As automation increases, spending on equipment, in turn, increases relative to labor costs. Because equipment is expensive, the ability to refurbish, ship, and reutilize equipment across global sites helps manage costs, especially for more mature chip technologies. And yet, this introduces other regulatory considerations (discussed further below).

Tax and related compliance costs also weigh heavily in companies' cost assessments. On one hand, the tax burden adds to the net cost of an investment; on the other hand, tax credits can deduct from other costs. Across the world, and particularly in Southeast Asia, governments have made corporate income tax breaks (including exemptions, holidays, and tax rate reductions) a centerpiece of their semiconductor industry strategies.

Going forward, however, implementation of the global minimum tax—underpinned by the Pillar II disciplines in the OECD/G20 *Inclusive Framework*—will oblige companies to pay a minimum rate of 15% across their global businesses. For companies that operate in multiple jurisdictions, the way in which they find value in a corporate tax incentive may shift, raising questions around what alternatives a host government can offer.

Companies are already adapting to this reality. To offset the cost of paying the corporate income tax, for example, they are seeking more generous capital grants for new equipment.



Specific Recommendations for Governments

1. *Design simple and flexible programs.* Incentive programs are most attractive when they are objective and predictable, with limited conditions, and can be integrated seamlessly into a company's investment planning and financial estimates. The semiconductor industry is dynamic, with extended periods of downturn and sudden unexpected upturns. Semiconductor companies therefore cannot commit to building a site and filling it by a certain date or starting operations without securing sufficient demand. Incentives with overly strict conditions are unattractive.

2. *Offset construction and equipment costs.* Governments can make a meaningful difference in offsetting construction and equipment costs for building semiconductor facilities, including by providing large plots of land at or below cost, connecting a facility to utility networks, or offering grants and tax credits that cover a portion of the total construction outlay and equipment costs. Designated zones can serve as a platform for such support. Incentives can also go hand-in-hand with streamlined permitting and compliance review processes that reduce the time for a productive investment by several months or even years **(see Business and Environmental Permitting and Approvals sub-section below)**.

2

Workforce and Talent

Talent is a prime concern for the semiconductor industry. Nearly all semiconductor workers—from design engineers to technicians that operate an assembly, test, or packaging site—require technical specialization across a variety of physical science disciplines, as well as an interdisciplinary STEM education and critical thinking and teaming skills. Semiconductor engineers are needed to research, develop, and improve semiconductor devices and packaging processes, playing a crucial role in innovation in both chip design and manufacturing. Computer scientists are needed to design and develop software and hardware solutions for semiconductor-based systems and technologies.

Textbox 2: Public-Private Partnerships in Education

Semiconductor companies form public-private partnerships with governments and educational institutions to improve local talent pipelines. Such consortia have proven successful in Southeast Asia. In Vietnam, for example, a U.S. university and a U.S. semiconductor company have forged a close relationship to train the local workforce. Their cooperation has evolved into a consortium involving USAID and over 20 other companies that have collectively committed $60 million over the next decade to introduce applied training in hardware and software through teaching labs. That U.S. university is now scaling this approach from Vietnam to other ASEAN countries as well.

Consortia such as these also help to facilitate participating companies' plans to offer internship programs for students and graduates from universities and vocational schools. Companies often use these programs to develop talent. Once on site, interns receive regular on-the-job experience and training to build "industry-ready" skills. One company reported committing to hire a certain number of interns and hires ever year, stating, "We view this as a win-win because it helps us get the trained talent we need, especially in a location where our footprint is expanding (doubling output) and more talent is needed in a short amount of time."

Automation can help address some of the workforce shortage for certain technicians. But as chips become more advanced, skills requirements are evolving. In advanced packaging, the disaggregation of large dies into dozens of smaller dies—or chiplets—dramatically improves yield per wafer, but also heightens the complexity of the supply chain at wafer-level assembly. Managing these intricate processes necessitates new skills. Even at conventional assembly and test sites, technicians on the factory floor today must be able to interpret large amounts of data for product engineers at R&D sites.

As the semiconductor industry expands, workforce needs are coming up against supply constraints for skilled talent. When evaluating new sites, companies consider the number of science and engineering university students and graduates from a technical college or higher degree level. Manufacturers look at the ratio of manufacturing industry headcount requirements to the economically active population. A pervasive challenge globally is that too few students are entering STEM fields, and too few computer science and electrical engineering graduates are entering the semiconductor industry.

In a labor-constrained market, moreover, companies face difficulties attracting and retaining workers, thereby creating costs associated with ongoing recruiting, on-boarding, and re-training of new hires. Visa backlogs and related regulatory burdens can also make it difficult to hire foreign workers. In particular, employers want to ensure that the foreign workers they train and develop will not lose their visas and be forced to leave the country.

Educating workers for the semiconductor industry is challenging, as the body of skills and competencies required is interdisciplinary and there are no industrywide credentials for design or manufacturing. Both chip design and packaging, for example, require a holistic knowledge of materials, chemical, industrial, mechanical, and electrical engineering. Companies have formed public-private partnerships with governments and educational institutions to equip up-and-coming talents with industry-relevant skills—particularly at the university and post-graduate levels—but building these partnerships takes time **(see Textbox 2)**.

Securing talent is only half the battle. Semiconductor companies also contend with how to best deploy their workforce. Semiconductor design and manufacturing operations need to run continuously—24 hours a day, 365 days a year—so that companies can recoup large capital investments, maintain complex equipment and facilities, and fulfill a dynamic pipeline of customer orders. Semiconductor technicians must always be onsite. In many countries, however, strict labor policies make it difficult to staff facilities on a continual basis, even when companies are willing to provide higher pay for longer shifts.

In light of the workforce shortages in the semiconductor industry, companies prefer sites with attractive living and working conditions. Companies value "livability"—in terms of social stability, healthcare, culture and environment, education, and infrastructure.[5] One company noted, for example, that it developed a commuter heatmap for its local staff to ensure that a new facility's location would allow for a comfortable commute. Companies must also consider factors that attract expatriates from headquarters or other regions to a new site. These individuals are often brought over to establish new teams and train local staff, and need work visas, family housing, and schooling for their children.

Specific Recommendations for Governments

1 *Develop a semiconductor skills roadmap, update curricula, and develop certification "micro-steps."* Governments should work proactively with industry to determine what skills companies require and facilitate partnerships with industry, research, and academic institutions to design targeted courses and curricula for both students and mid-career workers. Governments should not only consider how to foster next-generation talent, but also how to provide existing engineers a pathway to upskill in order to keep pace with developments in the industry.

Changing course curricula for standard STEM fields in universities and vocational colleges can meet bureaucratic complications, especially where curricula are defined at the national level. In lieu of changing curricula, educational institutions can partner with semiconductor companies to offer students opportunities to obtain micro-credentials, skills badges, and on-the-job experiences to complement their core degrees. These can amount to a series of "micro-steps" en route to a career in the semiconductor industry.

2 *Upskill faculty.* Investing in further training of STEM faculty, in terms of internationally accredited curricula pertinent to the semiconductor industry, can unlock significant improvements in local STEM education. For example, some U.S. educational institutions offer "train the trainer" programs to faculty from Southeast Asia, to teach STEM courses according to U.S. Accreditation Board for Engineering and Technology (ABET) standards. This strategy is particularly important for technician-level education programs where community college professors often teach across a wider range of content than more specialized PhD faculty.

3 *Incentivize STEM education.* To build an effective talent pipeline, companies recognize the importance of intervening early, at the junior high and senior high school levels, to get students and parents excited about math and science and a future career in semiconductor manufacturing or design. Governments should reinforce these efforts, for example, by instituting K–12 requirements for computer science and electrical engineering classes, giving young students the opportunity to interface with the semiconductor industry, and creating incentives or scholarship opportunities for K–12 graduates to go on to pursue STEM degrees.

4 *Permit flexible work shifts.* Semiconductor manufacturing sites derive significant cost and efficiency benefits from hiring two workers for 12-hour shifts, instead of three workers for 8-hour shifts. This setup is more attuned to the needs of continuous manufacturing operations and, while rewarding the two workers with premium pay, also economizes wage costs (given benefits and employment taxes). Governments should consider labor policies that permit and even incentivize such arrangements.

5 *Increase flexibility to employ foreign workers.* Governments should take a multi pronged approach to attracting and retaining talent from abroad, including by streamlining visa processes, pursuing policies that increase flexibility for companies to retain foreign workers, and examining domestic policies that impact "livability," such as how a temporary visa status may hinder a worker's access to a home mortgage.

3

Infrastructure

When considering an investment, companies place considerable weight on a country's infrastructure—from energy and water to logistics and communications. Their first-order concern is whether the necessary infrastructure is reliable and available at the scale required for their operation. A next-order concern is the cost of using that infrastructure, which may involve upfront investments in upgrades and, on an ongoing basis, operational costs for utilities and other services.

Unreliable infrastructure can make a location a no-go. When it comes to manufacturing, in particular, semiconductor companies have "zero tolerance" for unreliable power.[6] For example, even a "micro-outage" in the power grid, lasting nanoseconds, can interfere with a semiconductor design or manufacturing facility's operations. A true outage is much more damaging—not only resulting in lost production, but also causing contamination of clean rooms or tool failure, which can only be repaired and recertified at considerable time and cost. Given the amount of electricity consumed by a semiconductor manufacturing site, no backup generator exists that would suffice to fully power a facility. Even in semiconductor design activities, power plays a crucial role to allow for computing and data storage for Computer-Aided Design (CAD) and Electronic Design Automation (EDA) tools, prototyping and emulation systems, and a controlled environment in laboratories. Companies across the supply chain investigate the minutiae of the local power grid, down to the capacity and reliability of individual substations.

Water, particularly deionized (DI) water or ultrapure water, is also critical to semiconductor manufacturing. It is used extensively in cooling systems; to clean and rinse semiconductor components; as a solvent for removing flux residues, contaminants, and particles; and as a reliable base for diluting and preparing chemical solutions used in assembly and packaging processes. Companies undertake comprehensive evaluations of water supplies at a given site, including the source of supply (city water, wells, or drilling) and the process and cost to acquire water rights. They even study the details of a city's water treatment system and the availability of discharge waterways, such as creeks or rivers.

Provided that sites can offer a reliable supply of water and power, a more difficult question is how they can do so sustainably. More and more semiconductor companies are making sustainability pledges, including commitments to net-zero greenhouse gas (GHG) emissions, use of 100% renewable energy ("RE100" Initiative), and net positive water use. Notably, such pledges are also being made by semiconductor end customers, who are working to decarbonize their supply chains, and pressing semiconductor suppliers to account for their own carbon usage and provide detailed emissions data for their operations.

To achieve these goals, many semiconductor companies seek to maximize the use of renewable energy in a manner that is verifiable for their customers. At the same time, companies still require power to be reliable and renewable sources to be cost-effective relative to conventional options. As large energy consumers, semiconductor facilities drive significant demand for renewable power in the local grid.[7] Demand for renewable energy, and related strains on power grids, is expected to grow exponentially over the next decade due to artificial intelligence and data centers, heightening the need for government investment in these energy sources.

Transportation, logistics, and communications networks are also an important factor in semiconductor investment decisions. In terms of logistics, air transport is vital to ensuring companies can ship semiconductor equipment and devices to their sites and customers in a timely manner, which entails not only proximity to an airport but also well-paved, uncongested roads to convey sensitive items to and from the airport safely and quickly. In Japan, for example, the local government expanded the number of road lanes to ease transport between a major new fabrication site and the local airport.

Furthermore, the ability to move people should not be overlooked. Whether they are involved in manufacturing or R&D and design, companies frequently fly in experts to troubleshoot a technical problem or participate in an R&D project, and company leaders travel between sites. Efficient travel accommodations, combined with ease of obtaining business visas, benefits both existing and prospective investors.

Communications networks are also critical. A large portion of the semiconductor supply chain operates through data conveyed across borders, such as designs and prototypes and updates to CAD and EDA software. Chip design also routinely utilizes cloud-based EDA software, so unreliable communications networks can cause significant issues in day-to-day operations. In a simpler sense, because most companies operate globally, they rely on video conferencing and other virtual communication across long distances between colleagues and with customers.

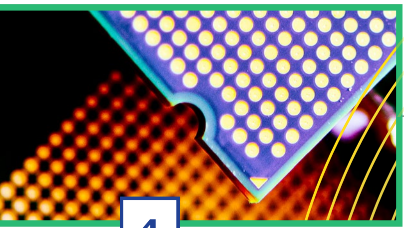
Specific Recommendations for Governments

1. *Support efficient utilities infrastructure.* Governments should consider what types of programs their local governments may have to help semiconductor companies build power- or water-efficient sites, to optimize consumption and minimize the strain on local utilities. They should also explore incentives to help companies reduce utility costs, such as exemptions from electricity bills, power subsidies per unit, and support for project costs when constructing a desalination plant.

2. *Ensure stable power supplies.* Governments should demonstrate that power utilities are able to maintain day-to-day stability in the grid as well as service during disaster risk events (e.g., through redundant systems). Authorities should also have demonstrable plans in place to repair any damage expediently.

3. *Develop green energy.* Companies are willing to pay for green energy sources—such as solar, wind, and hydropower—to meet their global GHG reduction commitments, but many countries have not prioritized investments in renewable power generation. At the same time, renewable energy sources need to be reliable and reasonably cost-competitive. Governments should make a firm commitment to investors to provide a portion of electricity needs from green sources. Even if not all green energy needs are immediately met, companies see the value in a formal agreement to expand future availability and an ambition to phase out traditional energy sources. Additionally, governments could consider offering incentives to companies that improve GHG emissions of equipment through abatement or other means.

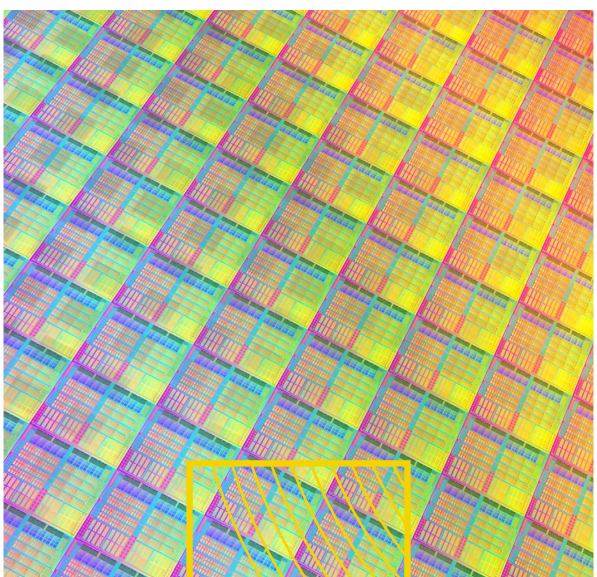
4. *Optimize communications and transportation logistics.* While governments should consider a variety of steps to improve transport and communications infrastructure—such as building faster telecommunications networks, larger ports, and high-speed rail—what the semiconductor industry values above all is an efficient nexus of road and air transportation, which allows companies to convey sensitive products effectively and minimizes travel time for global staff transiting in and out of sites.



4

Regulatory Environment

A country's policy environment has a multifaceted impact on investment decisions. Semiconductor companies with multinational operations face an increasingly complicated global regulatory landscape, resulting in higher compliance costs and lower risk tolerance. Because they often spend billions of dollars to build and operate a site, semiconductor companies also generally avoid investing in countries with weak rule of law and unpredictable regulatory environments, which present elevated corporate, legal, and political risks. To maintain seamless global operations, moreover, companies seek to avoid operating in countries that impose onerous restrictions or costly and burdensome barriers to the flow of goods, data, and people.



i) Trade and Customs

Semiconductor companies value ease of doing business. Few industries have a supply chain and R&D ecosystem as complex, geographically spread, and interdependent as the semiconductor industry. Thus, a country's trade regulations directly impact investment decisions. Companies evaluate how tariffs and taxes, customs fees, administrative paperwork, customs clearance delays, and other policies might raise the cost of importing equipment and materials. They are particularly sensitive to costs incurred for capital-intensive equipment needed to build energy-efficient facilities.

Semiconductor investment, production, and trade corridors are clustered in and around countries that are part of the World Trade Organization's (WTO) 1996 Information Technology Agreement (ITA-1) and its 2015 Expansion Agreement (ITA-2).[8] ITA-1 and ITA-2 have created a most-favored nation (MFN) "zero in/zero out" tariff environment for semiconductors and the technology goods and equipment necessary for semiconductor production. While many governments offer duty drawback regimes or negotiate regional trade agreements that offer tariff preferences for products that meet a specific rule of origin, semiconductor companies prefer MFN duty-free regimes that do not impose conditions for receiving a tariff benefit. Participating in ITA-1 and ITA-2 also signals a country's alignment with the semiconductor industry; indeed, it has become a virtual prerequisite for attracting industry investment.

Companies also value simple, consistent, and streamlined customs procedures, which reduce time to market, lower costs, and lighten the regulatory burden. Under the WTO's 2017 Trade Facilitation Agreement (TFA), governments agreed to undertake customs reforms to expedite the movement, release, and clearance of traded goods (including goods in transit). They also agreed to formalize cooperation between customs and other authorities on trade facilitation and customs compliance issues. When implemented, these measures can lower trade costs by the equivalent of a 134% ad valorem tariff.[9] Semiconductor companies closely monitor a government's TFA commitments and the pace at which reforms are implemented.

As noted above, semiconductor companies often ship used and refurbished equipment between their global sites to support design, R&D, and ATP operations. However, many governments restrict or even prohibit the importation of "secondhand" equipment, requiring companies to go through an onerous process to seek an import authorization, causing shipment delays and potentially supply chain disruptions.

Specific Recommendations for Governments

1. *Liberalize tariffs.* Governments should consider eliminating import tariffs on semiconductor-related products, materials, manufacturing and testing equipment, multi-component ICs (MCOs), and certain machine tools by joining and implementing the commitments under the ITA-1 and ITA-2 agreements at the WTO.

2. *Optimize trade facilitation.* Governments are currently at different stages of maturity in implementing the WTO TFA. Governments that accelerate TFA implementation and also go above and beyond through WTO-plus measures—such as more advanced single-window digital platforms—can improve investment attractiveness. Semiconductor companies seek to operate in locations that minimize "barriers to execution." Governments should work to alleviate pain points specific to semiconductor operations, such as simplifying import authorizations for used or refurbished equipment.

3. *Establish and/or expand Free Trade Zones (FTZs).* Governments should optimize conditions for international trade in specially designated zones in which supplies, equipment, and even building materials enter duty-free, and local authorities are focused on facilitating exports and imports. FTZs are critical for enhancing operational efficiencies due to the tax-exempt and duty-free zone-to-zone transfers they enable within the supply chain. Semiconductor investors have come to expect local governments to have such zones in place.

ii) Intellectual Property

Robust IP protection and enforcement are critical in all locations where a semiconductor company operates. US semiconductor companies devote an estimated 19.5% of sales revenue to R&D[10] to keep pace with innovation in design and manufacturing and related software tools, equipment, and materials. R&D intensity is especially high in design (over 20% of revenue) and EDA and core IP (over 30%).[11] IP takes many forms, including patents, trademarks, trade secrets, industrial designs, trade dress, and copyrights. Due to the pace of technological change, all these forms of IP are gaining in value.

Companies manage a variety of IP challenges in their global business. Weak patent protection or insufficient remedies for patent infringement lead to underinvestment in R&D. On the flip side, for example, abusive patent litigation—often initiated by patent assertion entities and funded by outside investment—is costly, time-consuming, and a distraction from R&D activity. Trade secrets—manufacturing know-how, chemical formulations, chip designs, and other proprietary information—are vulnerable to misappropriation through corporate espionage, cyber intrusions, and other means. Former staff, for example, may share IP with competitors. Abusive litigation can also result in inappropriate disclosure of trade secrets. Once misappropriation occurs, companies face an uphill struggle of assessing the damage and taking steps to recover lost profits and/or mitigate further harm.

While semiconductor companies value strong enforcement measures, they are most comfortable in countries that maintain a "culture" of respect for IP, widely shared among market participants and regulators.

Specific Recommendations for Governments

1. *Safeguard IP.* Governments should take comprehensive steps to promote a "culture" of respect for IP in their country, through a combination of rule of law, anti-corruption measures, public discourse, education, and transparent regulatory practices. Governments should also be encouraged to enhance transparency in litigation and administrative enforcement actions, through disclosure and other forms of accountability, to minimize any negative effects of abusive litigation finance models.

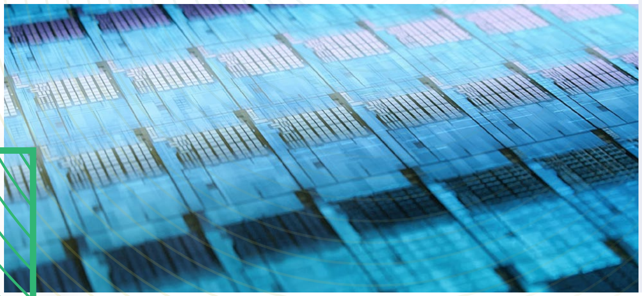
2. *Enforce criminal penalties.* Governments should consider making trade secret infringement a criminal offense, codified in national laws as well as international agreements, to strengthen deterrence and reassure companies that all forms of IP infringement are taken very seriously.

3. *Adopt clear conformity assessments.* Governments should limit regulatory conformity assessments to the minimum necessary for market regulation, as well as take steps to prevent IP leakage during conformity assessment procedures, such as banning forced disclosure of software source code.

iii) Business and Environmental Permitting and Approvals

Once an investment decision is made and capital is allocated, every month of delay puts a semiconductor project's success at risk. When establishing a new site, semiconductor companies often contend with a web of business permitting and environmental, health, and safety regulations at the national and subnational levels that can lead to project delays. Companies therefore seek locations where approvals and permitting processes are streamlined and can be expedited in accordance with project timelines.

Regulatory hurdles are especially burdensome at the construction stage of a manufacturing site. For example, a company needs to acquire water usage rights, conduct environmental impact assessments, and obtain air pollutant and waste treatment infrastructure permits. Semiconductor manufacturing also involves gases and chemicals that are subject to strict, country-specific environmental regulations, including for the construction of chemical storage spaces. To clear these hurdles, companies have to hire local consultants and, in some cases, adapt planned facilities for compliance purposes.



Specific Recommendations for Governments

1. *Establish "single window."* Governments can differentiate their countries as desirable targets for investment by establishing a single platform, or "one-stop shop," where semiconductor companies can identify, track, and obtain permits and approvals required by both national and subnational authorities. Such a platform would help to minimize duplication of information submitted to different authorities and reduce compliance burdens. Likewise, establishing a dedicated development office or investment authority can also help semiconductor companies navigate the regulatory landscape and act as an intermediary when companies deal with other authorities.

2. *Eliminate redundant requirements.* Given that permitting and approvals often occur in parallel at local and national levels, governments should identify areas where national and subnational regulations or procedures are redundant and modify or remove those requirements. Governments should also consider creating additional "fast track" permitting options.

3. *Harmonize environmental standards.* Companies share a country's aspiration to preserve a clean environment, conserve resources, and reduce emissions. At the same time, governments can be more attractive to companies by devising standards—such as for chemical substances and chemicals storage—that are in line with global best practices and do not impose an excessive compliance burden.

iv) Trade Controls Compliance

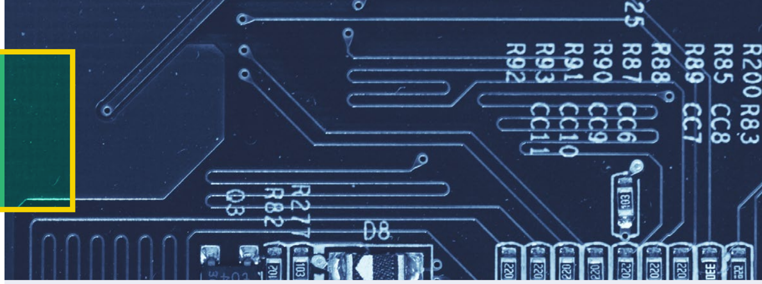
As geopolitical frictions rise, semiconductor companies confront an increasing number of trade controls and other compliance requirements governing their global business activities, including investments, research, supply chains, and transfers of technologies. Export controls, which are extraterritorial in nature, are a particularly complex domain that govern a long list of physical and non-physical products and, in addition to its ability to export, can impact a company's imports, R&D, technology partnerships, data transfers, and local hiring. In addition, companies must comply with supply chain regulations that affect their sourcing decisions. For example, certain governments ban the import of products that include components from certain regions or designated entities on forced labor or other grounds.

In the process of optimizing their global trade compliance capabilities, semiconductor companies value locations that make their work easier, not harder. They prefer countries with established trade-control frameworks and a "culture of compliance," underpinned by competent authorities, rule of law, and transparent regulatory processes. Semiconductor firms expect their local suppliers and customers not only to abide by relevant regulations and understand their own compliance obligations, but also to be partners in implementing best practices, sharing relevant information, and flagging potential compliance risks throughout the supply chain.

Specific Recommendations for Governments

1. *Implement a transparent export control regime.* Governments that establish and implement an export control system in line with international standards provide a predictable set of norms for semiconductor companies and convey the importance placed on protecting sensitive goods, technologies, and IP. Knowing that the government is a partner in preventing illegal technology transfers enhances the attractiveness of a local market.

2. *Educate local companies.* Effective implementation of export controls requires local suppliers and customers of semiconductor companies to be educated about their regulatory obligations. Governments should build mechanisms for regular industry outreach, including general educational programming as well as targeted outreach to firms at a higher risk of trade diversion. Sharing clear, practical guidance on building internal capabilities to comply with regulations can help local firms incorporate meaningful export control measures without significant administrative burdens.



v) Data Regulations

The semiconductor supply chain relies on open and secure data flows across international borders, as virtually every step in the value chain involves the electronic transmission of data. Designing an individual chip typically involves collaboration between engineering teams in multiple countries, such that design data can cross borders hundreds of times in the integrated circuit development phase. Huge amounts of data are also generated and collected at every step in the manufacturing process, with data coming from wafer fab, probe/testing, assembly, and final testing.

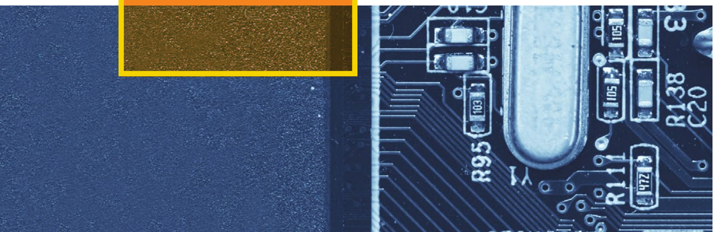
Government requirements to store data in local data centers or receive government authorization to transfer data across borders create serious challenges for individual companies. They also disrupt the global nature of semiconductor production. The current lack of an international agreement governing data flows magnifies uncertainty and raises compliance costs, as companies are forced to navigate a complex web of digital economy agreements between different economies.

Some governments are also exploring how to charge import tariffs and impose customs administration requirements on the movement of data, such as requiring companies to file a customs declaration when semiconductor data or design software is "imported" from another country. Such measures would be extremely costly and disruptive to semiconductor supply chains—countries that impose them will be significantly less attractive for semiconductor investment.

Specific Recommendations for Governments

1. *Ensure free movement of semiconductor data.* Governments can send an important message to semiconductor companies by committing not to impose customs administrative requirements or charge import tariffs on semiconductor data and software. Governments should further commit to a permanent and binding multilateral agreement at the WTO along these lines.

2. *Avoid unnecessary data localization rules.* Governments should carefully weigh the impact on the semiconductor industry and its supply chains when imposing data localization or data transfer requirements. To the extent such regulations and restrictions are imposed, companies should have recourse to clear and practical methods for legal data transfer. Many regulations stem from concerns regarding access to data by government or law enforcement agencies in the importing country. Affording companies the ability, for example, to object to data disclosure orders could help alleviate such concerns.



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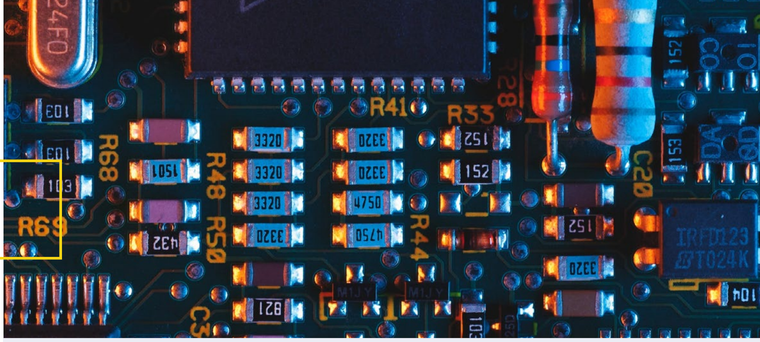

Integrated Ecosystems

Semiconductor companies evaluate a technology and supplier ecosystem holistically. They value locations where suppliers and service providers cluster in immediate proximity, which saves logistics costs and improves operational efficiency. As one company noted, successful clusters also tend to draw in competitors, which further compels suppliers and service providers to co-locate, and adds to the vitality of the local ecosystem.

Semiconductor companies also consider whether downstream industries and chip customers are present in a potential investment location. The emerging chips supply chain can benefit from talent, know-how, and infrastructure developed in those downstream industries, such as electronics manufacturing. As downstream industries achieve sufficient scale, semiconductor companies can also generate a larger share of their final sales from local customers and reduce the need to export to distant markets.

Not all site selection decisions hinge on whether an ecosystem already exists. The commitment of governments to develop an enabling business, regulatory, and technology ecosystem can instill investor confidence, particularly for “first-mover” investors. Companies value countries that take a deliberate approach toward building ecosystem capabilities. For example, semiconductors are typically assembled with other components onto a printed circuit board (PCB), which is a rigid structure that contains electrical circuitry. PCB production or assembly can be a starting point for countries with a limited track record in electronics manufacturing, and a gateway for future assembly, test, or packaging activities. Many countries already have mechanical, electrical, and programming capabilities to support PCB manufacturing. Such an approach signals that a country is investing in building local know-how, developing its workforce, and moving up the value chain.

Specific Recommendations for Governments

1. *Develop clusters.* Governments should develop a detailed understanding of multi-tier supplier networks in different segments of the semiconductor supply chain and create special economic zones or science and technology parks that incentivize local suppliers to concentrate in one location.

2. *Link semiconductors to downstream industries.* Governments should explore synergies between existing downstream industries and the semiconductor industry, including by mapping domestic and regional electronics supply chains, commissioning studies that identify transferrable skillsets, technologies, and infrastructure, and identifying downstream semiconductor-consuming industries. Governments can also organize events and forums that convene representatives from semiconductor companies and other industries, such as medical devices, automotive, and electronics.

3. *Seek deliberate evolution.* Governments should look to move up the value chain by leveraging their strengths and focusing on parts of the electronics supply chain with lower barriers to entry, such as developing PCB manufacturing or PCB assembly capacity.

Summary Lessons

Semiconductor companies evaluate numerous factors in their site selection processes. Countries with a strong value proposition across these factors, where the business and regulatory environments can facilitate a vibrant technology ecosystem, will ultimately be most successful. At a strategic level, policymakers should consider the following three summary lessons:

1. **Long-Term Stability and Support.** Semiconductor companies tend towards large investments that require a meaningful, long-term commitment, and carefully project the return on those investments. Accordingly, they value locations where government policy remains stable, supportive, and predictable over many years. Governments can inspire confidence by devising a long-term strategy and establishing an investment authority with staff dedicated to supporting the semiconductor industry.

2. **Systemic, Not "One Off," Policies and Approaches.** Most semiconductor companies operate globally and are clear-eyed about the challenges of running a site in a foreign country. They gravitate toward locations that have built a reputation for excellence in numerous dimensions—such as STEM talent, reliable infrastructure, trade-enabling legal and regulatory frameworks, IP protection, and a culture of compliance among local companies. Governments that implement systemic approaches and codify incentives and regulatory frameworks enjoy greater credibility and make steadier progress toward higher value-added activities.

3. **A Blend of Resilience and Openness.** Semiconductor companies are exploring new ways to diversify their global footprint and make their supply chains more resilient. But they also continue to value frictionless operations across their global businesses. Even as the world economy trends toward less openness and more regulation, governments are well-advised to keep conditions for companies simple and flexible, and make a steadfast commitment to open, duty-free trade.

The global chip industry is currently undergoing structural shifts, with companies taking concerted actions to increase supply chain resilience and diversify their investments globally.

Governments seeking to present their countries as a destination for semiconductor companies to invest must move quickly and deliberately to take advantage of this window of opportunity, mindful that other governments are likewise competing for such investments. By implementing the policy recommendations set out in this blueprint, which directly respond to the needs and priorities of semiconductor operations, governments can improve their value proposition and help to build local semiconductor ecosystems that benefit their workers and their economies, drive greater resilience in global semiconductor supply chains, and ultimately power the innovations of tomorrow.

1. US Department of State, “The U.S. Department of State International Technology Security and Innovation Fund,” https://www.state.gov/the-u-s-department-of-state-international-technology-security-and-innovation-fund/.

2. The White House, “FACT SHEET: Republic of India Official State Visit to the United States,” https://www.whitehouse.gov/briefing-room/statements-releases/2023/06/22/fact-sheet-republic-of-india-official-state-visit-to-the-united-states/.

3. To date, foreign investment has gravitated toward more labor-intensive activities such as printed circuit board (PCB) and PCB assembly, as well as assembly, test, and packaging (ATP). By comparison, specialized equipment and materials suppliers often prefer to locate production in their HQ region, given the low-volume, specialized nature of their products.

4. Stephen Ezell, “Assessing India’s Readiness to Assume a Greater Role in Global Semiconductor Value Chains,” Information Technology & Innovation Foundation, February 2024, https://www2.itif.org/2024-india-semiconductor-readiness.pdf.

5. The Economist Intelligence Unit compiles an annual “livability index” based on five categories: stability, health care, culture and environment, education and infrastructure. “The world’s most liveable cities in 2023,” *The Economist*, June 21, 2023, https://www.economist.com/graphic-detail/2023/06/21/the-worlds-most-liveable-cities-in-2023.

6. Kara Carlson, “NXP Could Lose $100 Million Due to Weather Shutdown of Austin Plants,” Austin American Statesman, March 12, 2021, https://www.statesman.com/story/business/2021/03/12/nxp-could-lose-100-million-due-weather-shutdown-austin-plants/4664621001/.

7. A potential mitigating factor is the emergence of truly automated “lights-out facilities.” The lights do not need to be on because the facilities are primarily run by automated systems or robots, with highly skilled workers monitoring the systems remotely. Such facilities can help reduce downstream energy costs.

8. “Information Technology Agreement,” WTO, https://www.wto.org/english/tratop_e/inftec_e/inftec_e.htm.

9. “Trade facilitation — Cutting ‘red tape’ at the border,” WTO, https://www.wto.org/english/tratop_e/tradfa_e/tradfa_introduction_e.htm.

10. *See 2024 SIA Factbook.*

11. R&D intensity is still considerable at about 10% for wafer fabrication and equipment production. *See* BCG & SIA, *The Growing Challenge of Semiconductor Design Leadership* (November 2022).

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