LISBON INVESTMENT SOCIETY | EQUITY RESEARCH

Semiconductor Industry

Sustainability Report

November 2025

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Executive Summary

This report provides an in-depth assessment of the semiconductor industry through an Environmental, Social, and Governance (ESG) lens. The semiconductor sector sits at the heart of the modern global economy, underpinning innovation across industries from automotive and renewable energy to telecommunications and artificial intelligence. Yet, it also operates within one of the most complex and geographically dispersed global value chains, As sustainability becomes a defining principle of economic competitiveness, ESG considerations are now inseparable from semiconductor strategy.

Governments, investors, and consumers are exerting growing pressure on companies to adopt responsible practices, demanding greater transparency and alignment with international sustainability frameworks such as the EU Taxonomy, the Science Based Targets initiative (SBTi), and the Paris Agreement's 1.5°C pathway. In this context, ESG performance is no longer a matter of compliance alone but a key determinant of access to capital, market share, and long-term resilience.

This report examines the current ESG posture of the semiconductor industry and identifies key sustainability challenges, including emissions reduction, supply chain ethics, resource efficiency, and circular economy integration. It also explores how the industry's future trajectory is shaped by environmental, political, legal, and economic forces, ranging from green policy incentives and carbon regulations to stakeholder expectations and investor scrutiny.

Finally, the report outlines strategic pathways for advancing sustainability in the semiconductor sector. These include reducing Scope 1, 2, and 3 emissions, embedding sustainability into business models, and leveraging ESG leadership as a driver of innovation and competitiveness. By evaluating where the semiconductor industry stands today and the direction it must take, this analysis aims to provide a comprehensive roadmap for aligning technological progress with the global sustainability agenda.

What ESG stands for?

ESG stands for Environmental, Social, and Governance. It represents the core pillars used to assess a company's sustainability practices and ethical impact on its employees, society, and the environment. ESG provides a set of criteria that investors, customers, and other stakeholders use to evaluate a company's performance beyond traditional financial metrics, focusing on its long-term viability, risk management, and overall responsibility. Each component of ESG addresses different dimensions of corporate impact:

- **Environmental**: Evaluates how a company affects and manages its interaction with the natural environment. Examples: Carbon emissions, energy efficiency, waste management, pollution control, and responsible use of natural resources
- **Social**: Focuses on how a company manages relationships with employees, suppliers, customers, and the communities in which it operates. Examples: Labor practices, human rights, diversity and inclusion, community engagement, and customer satisfaction.
- **Governance**: Examines the company's leadership, internal controls, and accountability structures. Examples: Board composition and diversity, executive compensation, shareholder rights, and corporate transparency. By integrating these three pillars, organizations can develop tailored strategies and measurable actions that strengthen sustainability performance and align with stakeholder expectations. (Byrne, 2023)

Why is ESG important?

ESG has become increasingly **attractive** in recent years because it promotes **transparency** for shareholders and contributes to more fulfilling work environments where employees can thrive and businesses can grow. Companies that integrate ESG principles **tend to perform better** in the long term by balancing profitability with **ethical responsibility** and **sustainability.** It matters because:

1. **Risk Management:**
   ESG transparency helps companies identify and manage potential risks that could affect performance and reputation. For example, a company operating in certain regions of Brazil may face higher exposure to floods, potentially leading to supply chain disruptions or regulatory fines. By assessing such risks early, businesses can take preventive measures and enhance resilience.
2. **Competitive Advantage:**
   Companies that adopt strong ESG practices can distinguish themselves from competitors. As global attention to sustainability and social responsibility grows, these organizations become more attractive to investors, customers, and partners seeking long-term, responsible value creation.
3. **Reputation and Trust:**
   ESG performance directly influences a company's reputation. A firm with a record of environmental violations or poor labour practices risks public backlash and brand damage, while one with a strong ESG track record earns greater trust, credibility, and customer loyalty.
4. **Innovation and Efficiency:**
   Integrating ESG principles often drives innovation. Companies committed to reducing their environmental footprint and improving social outcomes are motivated to develop cost-efficient, sustainable technologies and business models. This fosters creativity, strategic capital allocation, and long-term growth.

Beyond these business benefits, ESG engagement also enhances **employee satisfaction and retention**. Workers who believe their company aligns with their values are more engaged, motivated, and loyal. Moreover, ESG-focused companies typically cultivate ethical, inclusive, and value-driven cultures, creating safer, healthier, and more inspiring workplaces that attract top talent. (Byrne, 2023)

Legal Framework

Global ESG reporting

SASB

Sustainability Accounting Standards Board standards: have become a resource of the IFRS Foundation since August 2022. Focus on sustainability issues that significantly affect a company's cash flow, access to finance and cost of capital, mainly for investors and financial providers

TCFD

Task Force on Climate-related Financial Disclosures) recommendations: Formed in 2015 by the Financial Stability Board (FSB) and dissolved in 2023. But provided recommendations for companies to disclose climate-related information, to help assess climate risks in a company. Focused on 4 areas: governance, strategy, risk management, and metrics and targets.

GRI

Global Reporting Initiative standards: launched in 2000, to ensure that companies followed responsible environmental practices. Offering universal standards, sector-specific standards and topic standards. Not only for companies but also are relevant to investors, policymakers, capital markets and civil society. Taking in consideration both the financial materiality and impact.

ISSB

International Sustainability Standards Board standards: Effective from January 2024 it aims to create high-quality global sustainability disclosure standards, primarily for investors and financial markets. It released two standards: IFRS S1, and IFRS S2 where they both align with governance, strategy, risk management, and metrics and targets, consistent with the framework of TCFD recommendations. Building upon ideas of both SASB and TCFD recommendations, while also enhancing the international applicability of those standards

IR

Integrated Reporting Framework: aims to establish guiding principles and content elements, providing a structured approach to communicate how an organization's strategy, governance, performance and prospects lead to value creation, preservation or erosion over various time horizons—short, medium and long term. Being an integrated report, as defined by the framework, a concise document that illustrates how an organization strategy

CSRD

Corporate Sustainability Reporting Directive: aims to align with other EU sustainable finance initiatives and the Taxonomy regulation. Companies subject to it are required to report according to European Sustainability Reporting Standards (ESRS) developed by the European Financial Reporting Advisory Group (EFRAG). CSRD emphasizes the assessment of both the financial and impact dimensions of companies, requiring assurance on disclosures. (KPMG, 2024)

EU taxonomy

The EU Taxonomy is a cornerstone of the European Union's sustainable finance framework and a key element in advancing the goals of the Paris Agreement and the European Green Deal. It serves as a market transparency tool that guides both public and private investment toward activities that support the transition to a climate-neutral economy by 2050.Essentially, the EU Taxonomy is a classification system that establishes clear criteria for determining whether an economic activity can be considered environmentally sustainable. By defining which investments align with a net-zero trajectory and broader environmental objectives, it provides a common language for investors, companies, and policymakers to drive capital flows toward sustainable projects.

The regulation identifies six environmental objectives, which together support the EU's commitment under the Paris Agreement to limit global temperature rise to well below 2°C, and ideally to 1.5°C above pre-industrial levels:

- Climate change mitigation
- Climate change adaptation
- Sustainable use and protection of water and marine resources
- Transition to a circular economy
- Pollution prevention and control
- Protection and restoration of biodiversity and ecosystems

This taxonomy allows for financial and non-financial companies to share a common definition of economic activities that can be considered environmentally sustainable. Aligning each investment towards sustainability, by creating security for investors, protecting private investors from greenwashing, helping companies become more climate-friendly and mitigating market fragmentation.

The EU Taxonomy Regulation officially entered into force on 12 July 2020. It continues to evolve, with the European Commission periodically expanding the list of activities and refining technical criteria to reflect emerging technologies and scientific progress. (European Commission, 2025)

Industry overview

The semiconductor industry stands as a cornerstone of the modern global economy, enabling technological progress across virtually every sector, from telecommunications and automotive to healthcare, energy, and consumer electronics.

Semiconductors are materials whose electrical conductivity lies between that of conductors and insulators, typically silicon, though alternatives such as gallium nitride and silicon carbide are increasingly used. They form the foundation of integrated circuits (ICs) found in computers, smartphones, and vehicles, as well as discrete components such as power transistors, diodes, and sensors (McKinsey & Company, 2025). In essence, semiconductors underpin nearly every modern technology that shapes daily life.

Fabrication is one of the most complex and precise manufacturing processes in existence, requiring atomic-level accuracy, nanometer-scale design, and exceptionally high chemical purity. Many fabrication plants produce thousands of wafers and chips each day, highlighting the sector's scale and technical sophistication.

This is a high-barrier, capital-intensive industry that depends heavily on sustained R&D investment to maintain innovation and competitiveness. While historically characterized by cyclical "boom-and-bust" patterns linked to electronics demand, structural growth drivers — including artificial intelligence (AI), electric vehicles (EVs), and the Internet of Things (IoT) — are stabilizing long-term expansion.

Now exceeding $500 billion in annual revenue, the semiconductor industry remains one of the world's most strategic and innovation-driven sectors. In today's digital age, virtually nothing functions without chips — the tiny devices that encode the 0s and 1s at the heart of AI, autonomous systems, robotics, cloud computing, and countless other technologies (Deloitte Insights, 2025).

Geographic production

The semiconductor industry is one of the most globalized sectors in the world, characterized by vast and intricate Global Value Chains (GVCs). However, these networks are increasingly strained by geopolitical tensions, trade restrictions, and ongoing supply chain disruptions. Despite this complexity, production remains highly concentrated in a few regions.

Asian countries continue to lead global semiconductor manufacturing (Visual Capitalist, 2024). The United States dominates in high-end chip design and intellectual property (IP), while East Asia — particularly Taiwan, South Korea, and China — leads in fabrication. The Netherlands, the U.S., and Japan are global leaders in advanced lithography and deposition equipment, whereas assembly, testing, and packaging are primarily concentrated in Southeast Asia (Malaysia, Vietnam, and the Philippines) and China (Semiconductor Industry Association & Boston Consulting Group, 2024).Although Japan's manufacturing share is projected to continue declining beyond 2030 despite recent government initiatives, production capacity is expected to expand in both Europe and the United States as large-scale investment and reshoring policies take effect (Statista, 2024).

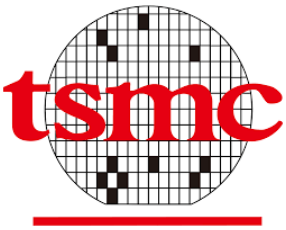
Year	U.S.	Europe	Japan	South Korea	Taiwan	China	Others
1990	37%	44%	19%	0%	0%	0%	0%
2000	19%	24%	17%	13%	22%	2%	3%
2010	13%	13%	18%	15%	22%	11%	8%
2020	12%	9%	15%	21%	22%	15%	6%
2025F	11%	8%	15%	18%	18%	24%	6%
2030F	13%	8%	15%	19%	17%	22%	6%
2032F	14%	9%	15%	19%	17%	21%	5%

Table 1. Source: Visual Capitalist, 2024

The 12 major semiconductor companies include:



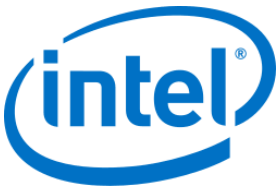
NVIDIA Corporation



Taiwan Semiconductors Manufacturing Company



Samsung Eletronics



Intel Corporation



SK Hynix



Broadcom Inc.



Advanced Micro Services



Qualcomm





Micron Technology Inc.



Global Foundries Inc.



ASML

For comparison terms, we will only consider 5 out this 12 major players, in our analysis.

Demand drivers

- **Memory growth:** Memory ICs (especially DRAM & HBM) have been the fastest-growing segment. (PWC, 2024)
- **Artificial Intelligence:** Explosive demand for GPUs, NPUs. Growth in AI accelerators, high-performance memory, and custom ICs (for/data centres) is a major driver. (Bloomberg Intelligence, 2025)
- **Automotive Electrification**: Growth in SiC/GaN power devices and sensors. The move to electric vehicles and software-defined vehicles (SDVs). (PWC, 2024)
- **Edge & IoT**: Need for low-power, high-efficiency chips.
- **Advanced Packaging**: 2.5D/3D integration and chiplets are redefining scaling beyond Moore's Law.
- **Government incentives**: CHIPS Act like in happen under the Biden administration, also with tariffs, can increase the foster of some countries in this sector, like in the US. And like in 2024, South Korea and Taiwan governments providing large tax incentives programs for R&D support. (Taiwan Chip Innovation program and South Korea's K-CHIPS Act). (Semiconductor Industry Association & Boston Consulting Group, 2024)

ESG and semiconductor sector

The semiconductor industry shows no signs of slowing down, and as production expands, it is becoming increasingly carbon intensive. The manufacturing of advanced semiconductors requires ever more complex processes that consume large amounts of electricity and process gases. This growing demand for computational power and technological sophistication is therefore accompanied by rising environmental pressures.

Both internal dynamics and external forces are driving the industry toward stronger environmental, social, and governance (ESG) alignment. Externally, regulatory frameworks are becoming more stringent, with new policies linking sustainability performance and transparency to market access and competitiveness. Stakeholder expectations are also rising customers increasingly require suppliers to comply with sustainability goals, while investors, shareholders, and employees are integrating environmental and social considerations into their decision-making processes.

Semiconductor production is inherently associated reliance on energy, water, and rare materials, coupled with the significant environmental footprint of wafer fabrication and chip manufacturing, characterized by high-temperature furnaces, ultra-clean manufacturing environments, and complex supply chains, all of which exert considerable pressure on the environment. As the industry's global significance continues to grow, it becomes ever more important to assess its operations through an ESG lens. The industry's heavy positions it as both a critical enabler of the digital transition and a major contributor to global emissions.

ESG principles play a particularly significant role in this sector because of its high resource and energy intensity, including substantial water consumption and greenhouse gas emissions. Semiconductor manufacturing, encompassing electronic design automation (EDA), intellectual property (IP), wafer fabrication, chip design, packaging, assembly, and testing, is directly responsible for approximately 0.3% of global carbon emissions and indirectly contributes another 1% through its upstream and downstream activities.

In this context, ESG reporting has become a cornerstone of responsible business practice. It enables companies to disclose data on their environmental impact, social responsibility, and corporate governance, thereby enhancing transparency and accountability. Through robust ESG reporting, semiconductor companies can communicate their commitment to sustainable and ethical practices to investors, customers, employees, and regulators, ultimately reinforcing trust and long-term resilience.

Outlook

It is expected a significant increase in long-term investment in the semiconductor industry. Despite short-term uncertainty, Bloomberg Intelligence projects global semiconductor capital expenditures (capex) to reach $332 billion by 2033, growing at an annual rate of 7.8% between 2024 and 2033. A fast-growth scenario driven by advancements in AI, 6G, electric vehicles (EVs), and robotics, as mentioned, while persistent trade tensions may result in a slow-growth scenario (Bloomberg Intelligence, 2025).

The industry's capital intensity and supply chain complexity contribute to a rising environmental footprint. Nevertheless, the sector is expected to achieve $1 trillion in annual chip sales by 2030, requiring a compound annual growth rate (CAGR) of 7.5% between 2025 and 2030. If this growth continues, revenues could reach $2 trillion by 2040 (Deloitte Insights, 2025).

New entrants such as India and the United States are expanding local manufacturing capacity, though they remain years behind Asia's leading-edge fabs. The industry is moving toward greater efficiency, with sustainability and transparency evolving from compliance requirements into competitive differentiators.

Demand for chips continues to accelerate as virtually all modern industrial and consumer devices such that Bloomberg Intelligence forecasts that, under its core scenario, global semiconductor capex will grow steadily, but scenarios vary:

- Fast-growth scenario: +10.5% CAGR, driven by AI, 6G, EVs, and robotics.
- Slow-growth scenario: +4.8% CAGR if trade tensions persist (Bloomberg Intelligence, 2025).

Risks remain significant. New U.S. reciprocal tariffs pose a downside risk for 2025–2026, potentially triggering a demand correction similar to 2019, when global semiconductor revenue fell 12% to $419 billion. Bloomberg notes that recent sales strength may reflect "pull-in demand" as OEMs pre-ordered chips ahead of tariffs. Once tariffs fully apply, deferred consumption and inventory drawdowns could pressure global sales.

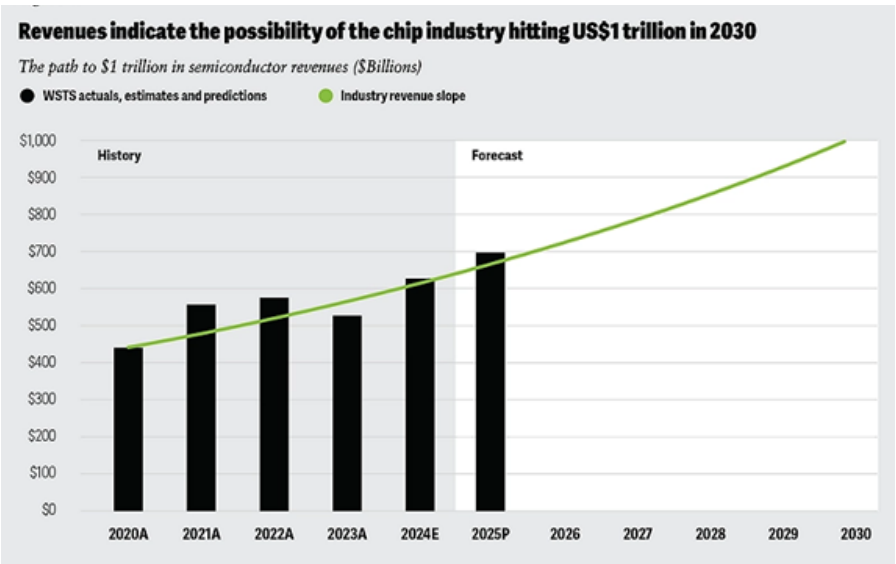


Figure 1; Source: Deloitte 2025 global semiconductor industry outlook report

Furthermore, it is expected that a significant geographic diversification will happen. Not only because of the effect of Trump tariffs but also because of the concentration of each expertise in production throughout the world. We could observe this phenomenon mainly in two areas to start with:

1. Wafer fabrication, particularly in advanced logic.
2. Assembly, Testing & Packaging (ATP) with a diversification of activities outside Mainland China and Taiwan to include substantial gains for new markets.

To a lesser extent, we also expect greater diversification in design, as market leaders source talent globally, and materials, as vendors follow new fab capacity to different regions . In equipment as well as EDA and core IP, meaningful diversification will prove challenging given the high degree of specialization and vendor concentration today, as well as the lesser necessity of co-locating with fab sites. (Semiconductor Industry Association & Boston Consulting Group, 2024)

SCC – Semiconductor climate consortium

This is global industry-consortium launched under the umbrella of SEMI (the global electronics manufacturing and design supply-chain association). Formally launched around late 2022. It is described as the first global, ecosystem-wide effort within the semiconductor value chain to accelerate climate action (i.e., decarbonization, transparency, collaboration).

Although, many individual firms have their own sustainability strategies, the consortium exists because many relevant issues require a joint action, shared standards, common data and economies of scale. The SCC is structured to enable this collective approach, helping the sector speak with a more unified voice and standardized data

With three key objectives: **Collaboration, Transparency** & **Ambition.**

Members commit to transparently report Scope 1, 2 and 3 emissions, collaborate on sector-specific abatement technologies (especially high-GWP process gases), align renewable-energy procurement strategies, and standardize data and methodology. The SCC thus provides a structural platform for tackling decarbonization challenges that are unique and systemic in semiconductor manufacturing. By including companies across the full semiconductor ecosystem; chip makers (IDMs, foundries), equipment & materials suppliers, assembly & test, design automation, etc.



As of 2024, membership was at more than **90 companies**.(SEMI, 2025)

Legal drivers shaping the industry by region

United States

Climate Disclosure: The SEC finalized climate-related disclosure rules in 2024, and state actions (e.g., California's corporate climate disclosure law) are raising expectations. These measures drive investor and lender reporting and may expand mandatory emissions and risk disclosures for U.S.-listed semiconductor firms (Deloitte, 2024).

Forced Labour Ban: The Uyghur Forced Labor Prevention Act (UFLPA) creates a rebuttable presumption that goods mined, produced, or manufactured wholly or partly in Xinjiang—or by entities on the Entity List—are made with forced labour and are prohibited from U.S. import unless proven otherwise.

East Asia

China: Increasing mandatory environmental enforcement, extended producer responsibility, and carbon-neutrality pledges. Emerging corporate disclosure guidelines at central and local levels. Export control and supply-security measures intersect with ESG.

Japan & South Korea: Strong stewardship codes, sustainability reporting expectations, and industry decarbonization guidance. Japan's METI and FSA push for enhanced disclosures and governance reforms. Unlike the U.S. and EU, there is no ban on imports made with forced labour; however, South Korea reintroduced in June 2025 a draft Act on the Protection of Human Rights and the Environment for Sustainable Business Management, which would require large companies to conduct human rights and environmental due diligence across supply chains (Walk Free, 2025).

India: SEBI's BRSR (Business Responsibility & Sustainability Reporting) is mandatory for the top 1,000 listed companies by market cap, impacting semiconductor firms with operations or suppliers in India. Despite this, the market remains relatively deregulated in many areas.

Europe

Overall, there is an overall increase in regulation in the European market. Those include:

Chemical and Product Rules: RoHS and REACH restrict hazardous substances in electrical and electronic equipment, limiting materials and process chemicals that fabs and equipment makers can use in the EU.

European Chips Act: Provides grants and loans via IPCEI, plus national tax incentives and R&D funding to boost semiconductor capacity.

National & Member-State Rules: Additional requirements include strict water and air quality standards, permitting processes, and community consultation for large projects.

EU Forced Labour Regulation (FLR): From 14 December 2027, products made using forced labour at any stage of the supply chain cannot be placed, made available, or exported in the EU market (European Commission, 2024).

Concentration of market

The semiconductor industry faces significant structural constraints due to its high concentration and the necessity of extensive know-how and technical experience, combined with exceptionally high entry costs. Taiwan, and particularly the Taiwan Semiconductor Manufacturing Company (TSMC), represents the central hub of global advanced logic and foundry capacity. The company is frequently described as a "choke point" or strategic vulnerability within the global semiconductor supply chain.
TSMC maintains extremely high utilization rates of its advanced manufacturing nodes (5 nm and 3 nm) and serves as the primary foundry for major clients in high-performance computing (HPC) and artificial intelligence (AI). Its specialization, scale, and technological leadership in advanced packaging make it a critical node to produce cutting-edge logic chips (Techovedas, 2025).

TSMC is not merely a semiconductor manufacturer; it is the industrial foundation of the modern technology ecosystem. (3D InCites, 2024)The company produces chips that power many of the world's most influential products and platforms, including:

Apple: A-series and M-series processors used in iPhones and Mac computers.
NVIDIA: AI GPUs such as the Hopper and Blackwell architectures.
Amazon: Custom chips used in cloud computing infrastructure.

By 2025, capacity constraints at TSMC—particularly in advanced packaging technologies such as Chip-on-Wafer-on-Substrate (CoWoS)—may limit the growth of companies like NVIDIA and the broader AI hardware ecosystem. Although the potential magnitude of disruption remains speculative, any geopolitical event affecting Taiwan represents one of the most significant systemic risks to the global economy.
The production of leading-edge semiconductors depends on Extreme Ultraviolet (EUV) lithography systems, which are exclusively produced by ASML Holding in the Netherlands. ASML is the sole supplier of these tools, essential for fabricating chips at 3 nm and below. This creates a structural interdependence within the industry: TSMC relies on ASML's equipment for advanced manufacturing, while global technology firms rely on TSMC's foundry capacity.

Governments and private firms in the United States, Japan, and South Korea are investing heavily to reduce dependency on Taiwan's semiconductor production. Initiatives such as TSMC's Arizona plant, Samsung's U.S. expansion, and Intel's foundry initiatives aim to localize advanced manufacturing and packaging capabilities. However, replicating TSMC's production ecosystem abroad remains costly, complex, and time-intensive. The expansion of TSMC's foundry operations is key to the industry's geopolitical resilience. Current R&D investments indicate that while core research and process development will remain in Taiwan, U.S. expansion could eventually represent up to 30% of TSMC's 2 nm and beyond capacity (Counterpoint Research, 2025).

Rising tensions between China and Taiwan further amplify the risks associated with this dependency. In a May 2025 speech at the Shangri-La Dialogue in Singapore, U.S. Defense Secretary Pete Hegseth stated that Chinese President Xi Jinping had ordered the People's Liberation Army to be capable of invading Taiwan by 2027, echoing a timeline first suggested by Admiral Philip Davidson, former head of the U.S. Indo-Pacific Command. Hegseth further warned that such an assault "could be imminent" (Time, 2025).

If China were to invade Taiwan, TSMC's production would almost certainly cease, either through direct conflict damage or international sanctions. Taiwan has not aggressively globalized its fabrication network, partly because replicating its manufacturing ecosystem abroad would be prohibitively expensive and risk the loss of critical process know-how. Maintaining its most advanced fabrication plants within Taiwan also functions as a strategic deterrent: the potential destruction of TSMC's facilities in a conflict scenario would have catastrophic effects on the global economy. This reality strengthens U.S. commitment to Taiwan's defense and serves as a geopolitical counterbalance to Chinese aggression.

Analysis

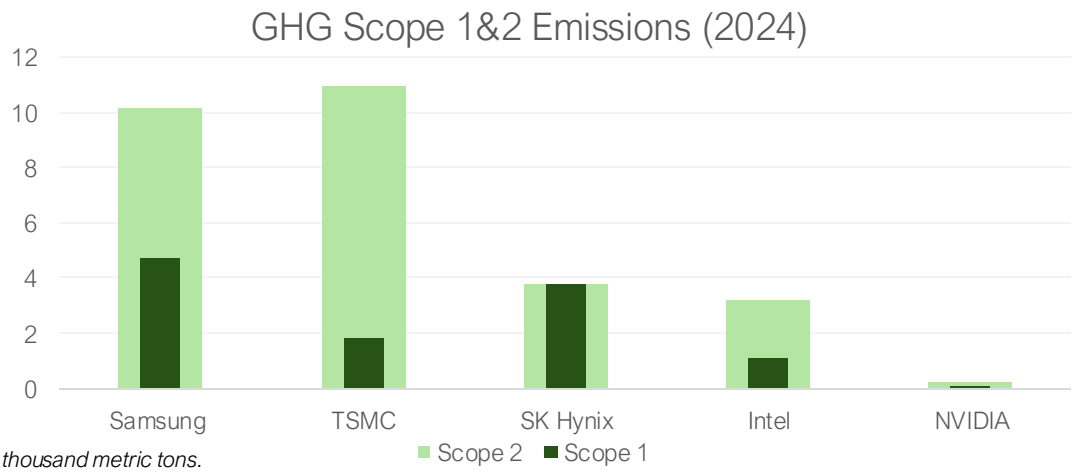
Environmental

Greenhouse gases emissions

Semiconductor production contributes crucially to carbon emissions as mentioned before because its energy-intensive processes, like those involved in electronics manufacturing, transportation of materials, and communication, require substantial power. These emissions are categorized into three scopes:

- **Scope 1 emissions**: Direct emissions from sources owned or controlled by the company, including on-site fuel combustion, and the use of high-GWP gases such as PFCs, NF_3, and SF_6.
- **Scope 2 emissions**: Refers to indirect emissions from the generation of purchased electricity, or heating and cooling consumed by the company.
- **Scope 3 emissions**: All other indirect emissions that occur along the value chain, including those from the production and transportation of raw materials, waste disposal, employee travel, and the downstream use of semiconductor-enabled products

An analysis of the GHG emissions of five big players in the industry reveals that **Scope 2 emissions** are considerably higher than Scope 1 emissions, as **83% of total semiconductor device emissions are linked to the generation of electricity consumed throughout the production lifecycle**, according to BCG.



Values in thousand metric tons.
Source: Own analysis and Bloomberg.

Scope 1 emissions, though smaller in volume, cause a high global warming potential (GWP) of the gases used. These direct emissions from on-site manufacturing are dominated by perfluorinated compounds (PFCs) and other process gases, whose GWP can be 100 to 20,000 times greater than CO_2 due to their unique properties. On the other hand, emissions are also associated with upstream activities, such as the extraction, refining, and transportation of raw materials, which account for **roughly 16% of total emissions.**

The GHG (Scopes 1 and 2) emissions in the semiconductor industry **vary according on each company's subsector and business model**. There is a clear emission gap between firms in the Foundry or IDM sectors (TSMC, Samsung, SK Hynix) and NVIDIA, which operates in the fabless sector. This difference is largely explained by **Foundry and IDM companies owning and operating large and high-consumption fabrication facilities (fabs).** This manufacturing activity requires complex equipment and controlled environments, generating most of Scope 1 and Scope 2 emissions. In contrast, **fabless companies focus essentially on design and R&D** which demand relatively less energy and therefore report significantly lower emissions.

Energy Consumption

The semiconductor industry is one of the most energy-consuming sectors globally, with its total power usage expected to increase as chip designs advance to 3nm and 2nm nodes to meet the rising demand from applications like **AI and 5G**.

The high energy demand is driven by two main aspects of the manufacturing process:

1. *Wafer production in foundries and IDMs*: The process of transforming highly purified silicon into polished wafers that serve as the foundation for all semiconductor chips.
2. *Cleanroom Infrastructure and Climate Control (HVAC):* Ongoing climate control and cleanroom operations to maintain ultra-precise temperature and air purity inside fabs.

Industry's main energy sources

Fossil fuels

Mainly coal and natural gas; Dominant source in Asia (Taiwan, S. Korea, China), driving **high Scope 2 Emissions.**

On-site gas combustion

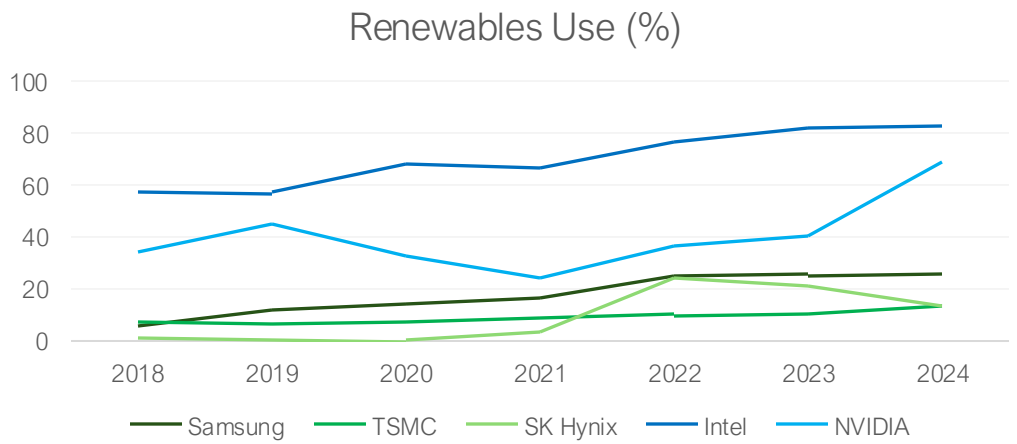
Fuel burned on-site for heat/steam, or by backup generators, resulting in **Scope 1 Emissions.**

Renewables

Purchased via Power Purchase Agreements (PPAs) and Renewable Energy Certificates (RECs) as part of goals like RE100.

Transition to Renewables

To address the high levels of energy consumed, companies in the sector have been engaging in short- and long-term goals such as 100% renewable energy use and net-zero GHG emissions by 2040 or 2050. Moreover, initiatives such as the *GENESIS* program in Europe develop more energy-efficient semiconductor manufacturing processes and accelerate the industry's transition toward greener production.



Source: Own analysis and Bloomberg

The calculated renewable energy share of these five players demonstrated an overall increase and a clear upward trend in renewable adoption for most of the evaluated firms from 2018 to 2024, indicating progress toward climate goals.

Water consumption

Beyond demanding significant energy and chemical inputs, semiconductor manufacturing faces a sustainability challenge due to its requirement for high volumes of water. In fact, a single advanced fab can consume up to 10 million gallons of water per day, comparable to the daily usage of a small city (SEMI, 2023).This demand rises from the necessity of **Ultra-Pure Water (UPW),** which is water that has gone through purification to eliminate minerals, particles, microorganisms, and dissolved gases to be constantly used to clean wafers throughout the fabrication process.

This dependence on UPW is intensified by the **ongoing global capital expenditure (CapEx) rise**, as the expansion of fabrication capacity directly amplifies overall water consumption. Consequently, ensuring a reliable and sustainable water supply has become a strategic priority for the industry. Leading manufacturers are increasingly investing in advanced wastewater treatment and reclamation systems to reduce freshwater dependence and mitigate environmental impact. This shift is particularly vital in regions facing severe water stress, such as Taiwan, South Korea, and parts of the United States (Semiconductor Digest, 2022).

The semiconductor water cycle is defined by the extreme purity required for manufacturing and the subsequent necessity for aggressive recycling. It follows these three primary stages:

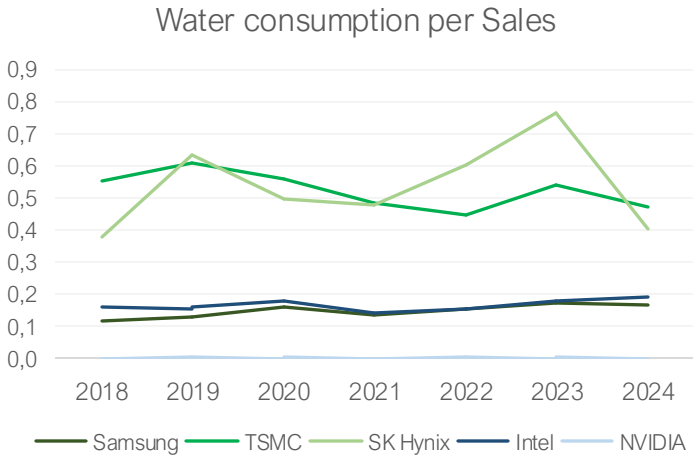
1. UPW Production (Input): Raw water (from municipal or ground sources) is processed through intensive multi-stage purification. This includes chemical conditioning, fine filtration, reverse osmosis (RO), and deionization.

2. Process Consumption (Use): UPW is used heavily for rinsing wafers between chemical baths and maintaining facility environmental controls. During rinsing, the UPW collects various contaminants, acids, and solvents, creating complex wastewater streams.

3. Wastewater Treatment & Recycling (Output/Reuse): This is the core sustainability effort.

1. Segregation: Effluent streams are rigorously segregated (often into dozens of distinct categories, as can be seen at TSMC) based on their contaminant profile.
2. Targeted Treatment: Each segregated stream receives a specific treatment (e.g., pH neutralization, chemical precipitation, biological treatment).
3. Reclamation: The treated water is then recycled back for non-critical plant uses (like cooling towers) or routed back through the intensive UPW purification train to be reused in the fabrication process, significantly reducing the demand for fresh input water.

Semiconductor firms are working to reduce water intensity through ambitious. Leading firms implement closed-loop systems that recycle Ultra-Pure Water (UPW) used in wafer cleaning, while advanced wastewater treatment and zero-liquid-discharge (ZLD) technologies minimize freshwater withdrawal (TSMC, 2024). Intel employs ZLD systems to limit freshwater use (Ultra Facility Portal, 2025), and Samsung and SK Hynix have adopted UPW optimization and closed-loop programs, collectively mitigating water risks in regions with high water stress (Semiconductor Digest, 2022).



Thousand cubic meters / Millions of USD

Source: Own analysis of Bloomberg data.

Waste Management

The fabrication of semiconductor chips, while defined by its precision, generates significant quantities of both hazardous chemical waste and non-hazardous solid waste. The materials used, such as highly toxic solvents, acids, and process gases (often required for etching and cleaning), result in waste streams that necessitate complex, strictly regulated management and disposal protocols (Ruberti, 2024). A crucial, emerging challenge in hazardous waste management involves Per- and Polyfluoroalkyl Substances (PFAS), which are essential in several manufacturing steps but are highly persistent in the environment. Regulatory and public pressure is now driving significant research into either their safe abatement or the substitution of these "forever chemicals." The environmental risk associated with these chemicals, persistent toxic substances, drives the need for robust governance frameworks across the sector (Ruberti, 2024).

One major non-hazardous waste stream is the material remaining after wafer slicing and polishing, known as **slurry or silicon kerf loss**. During manufacturing, up to half of the original silicon material can be lost in this way (MDPI, 2023). Leading manufacturers are responding by adopting circular-economy strategies:

1. Waste Segregation and Treatment: Deploying advanced treatment systems, similar to those used for wastewater, that neutralize or separate hazardous components right at the point of origin.

2. Resource Recovery: Investing in processes to reclaim high-value by-products, like metals from etching waste, and to recover and reuse kerf loss from silicon slicing.

3. Reducing Material Input: Enhancing process controls to reduce virgin chemical and silicon usage per finished wafer, thereby lowering overall waste volumes.

4. Achieving 'Zero Waste' Goals: Leading companies are adopting ambitious targets for Zero Waste to Landfill (ZWTL) certification, which requires diverting nearly 100% of all non-hazardous waste streams through comprehensive recycling, upcycling, or conversion processes.

5. Product Circularity and E-Waste: Beyond factory operational waste, manufacturers are beginning to design chips and devices for durability and recyclability to minimize the volume of electronic waste generated globally and close the loop on critical materials.

Social

The social dimension of sustainability within the semiconductor industry is highly complex, especially due to the sector's operational characteristics. The analysis of this social footprint focuses on critical areas across the entire value chain, including Diversity and Inclusion (D&I), the protection of Human Rights, adherence to stringent Labor Standards, and the overall Community Impact of large-scale operations.

This complexity is amplified by the industry's structural nature: its **reliance on highly globalized supply chains** complicates efforts to ensure ethical sourcing and transparent labor conditions across multiple international borders. Furthermore, the **dependence on a high-skill labor pool** generates competitive pressures around talent development and equity. Finally, the sector's prominence exposes it to **considerable geopolitical tensions and persistent ethical sourcing challenges** (such as conflict minerals), demanding robust due diligence and risk mitigation strategies.

Workforce demographics and Diversity Trends

According to the U.S. Census Bureau (2022), the semiconductor industry is experiencing a notable **demographic shift** characterized by an aging workforce and a growing talent shortage. As a significant share of professionals near retirement, the sector is struggling to attract and retain sufficient new STEM graduates to sustain its highly specialized labor force. At the same time, evolving technological demands (the rise of AI, machine learning, and advanced materials like silicon carbide and gallium nitride) are changing the skill profiles required by semiconductor companies (McKinsey, 2024).

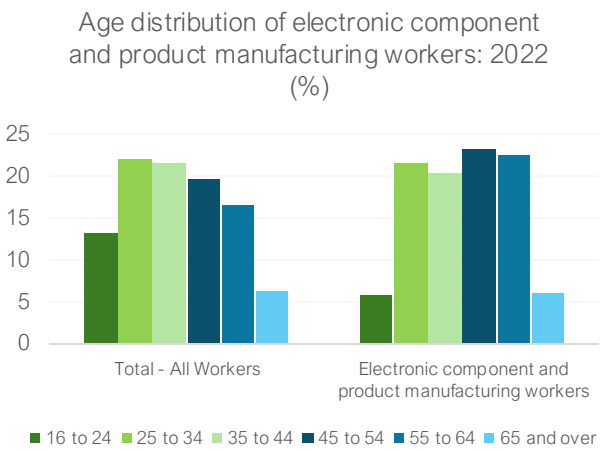


Figure 3; Source: U.S. Census Bureau, 2022 American Community Survey, 1-year estimates.

Another significant workforce challenge in the industry is the underrepresentation of women, as they account only **about 20–25% of the total workforce**, with even lower participation in technical and leadership roles (Accenture/GSA, 2022). To address these challenges, companies and industry groups have implemented programs to attract talent. For instance, Intel offers *Women in Technology Scholarships* to encourage female STEM students, while TSMC runs *Journeys of Female Scientists Lectures* to highlight role models and career pathways. In addition, broader workforce programs aim to address the demographic and skill gaps, including internship and apprenticeship schemes, reskilling initiatives for mid-career engineers, and STEM outreach campaigns targeting younger generations to expand the source of qualified talent. These efforts collectively seek to mitigate the talent shortage and promote a more diverse semiconductor workforce.

Health and Safety Performance

The high-tech environment of semiconductor fabrication plants (fabs) necessitates strict health and safety protocols, as employees are continuously exposed to risks associated with the manufacturing process. Health and safety performance is critical for maintaining regulatory compliance across major manufacturing regions, including the U.S., EU, South Korea, and Taiwan. In this context, the main risks include:

- Exposure to chemicals and gases used in etching and deposition.
- Physical hazards from high-voltage equipment and cleanroom environments.
- Repetitive strain injuries due to high-precision assembly or testing work.

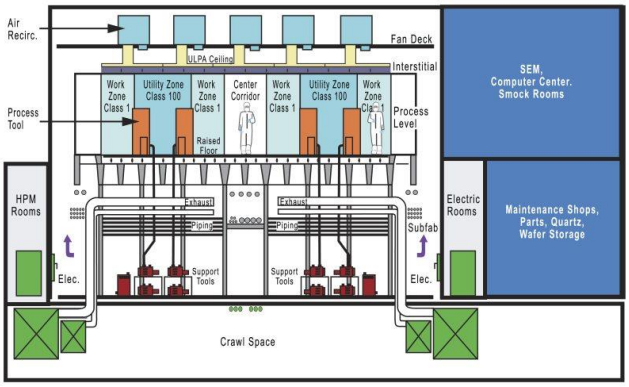


Figure 4: Semiconductor Fab Utilities Overview.
Source: https://www.mks.com/n/semiconductor-utilities-overview (Accessed: 31 Oct. 2025).

Figure 3 illustrates the complexity of a fab, where workers operate within highly controlled cleanroom environments filled with advanced machinery, high-voltage systems, and chemical processing tools. These facilities require constant monitoring of air purity, temperature, and humidity, creating operational challenges that elevate occupational health and safety risks. The handling of hazardous chemicals such as PFCs, silane gases, and photoresists necessitates strict procedural discipline, supported by automated delivery systems and containment technologies.

To address these risks, semiconductor companies have been investing in Environmental, Health, and Safety (EHS) programs that go beyond compliance. Players such as Samsung, NVIDIA, and SK Hynix publicly disclose safety performance indicators, including **Lost-Time Injury Rate (LTIR),** to measure and improve workplace safety. Others, such as Intel and TSMC, report alternative metrics like **recordable injury frequency and disabling injury rates**. Industry trends show **growing adoption of digital safety systems**, and robotics to minimize human exposure to hazards. By embedding safety into every stage of design, production, and maintenance, semiconductor manufacturers aim not only to protect their workforce but also to ensure operational resilience and regulatory trust across global markets.

Human rights in supply chains

The complex and globalized supply chain of the semiconductor sector consists of spanning from the extraction of raw materials through component fabrication, testing, and final assembly. This geographically dispersed approach, with suppliers often located in regions that possess varied labor and environmental regulations, increases the risk of human rights violations. Consequently, multinational enterprises in the industry face constant challenges in maintaining oversight and ensuring ethical conduct throughout their entire value chain.

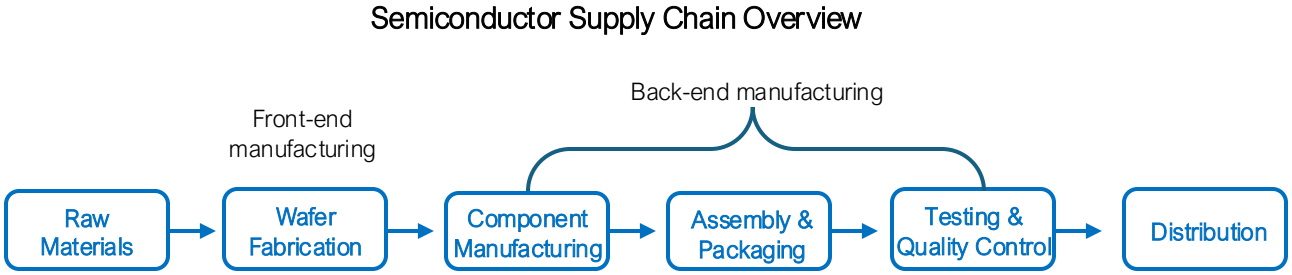
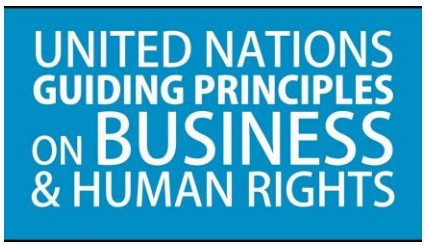


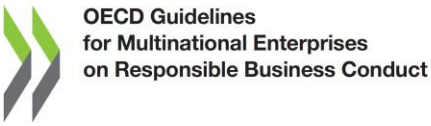
Figure 4; Source: Own analysis.

1. The first critical area of concern involves **raw material sourcing**. Important minerals, specifically tantalum, tin, tungsten, and gold (known as the "3TG"), are frequently sourced from conflict-affected or high-risk areas. This necessitates rigorous due diligence to ensure that sourcing operations are not linked to the use of forced labor, child labor, or the financing of armed groups. Regulatory pressure, driven by frameworks like the U.S. Dodd-Frank Act (Section 1502 on conflict minerals) and the EU Conflict Minerals Regulation, obligates companies to track and disclose their sourcing to mitigate these risks.

2. Further down the supply chain, the **back-end manufacturing sites**, which handle the labour-intensive work, present distinct risks related to working conditions, including potential exposure of employees to various hazardous materials. Beyond specific dangers, the core human rights standards of ensuring safe working conditions, providing fair wages, and upholding the fundamental right to freedom of association remain essential benchmarks that companies must meet globally.

To manage these systemic risks, major semiconductor companies, including Intel, TSMC, Samsung, NVIDIA, and SK Hynix, have implemented sourcing programs. These programs are anchored by **published supplier codes of conduct** and are informed by international standards like the OECD *Guidelines for Multinational Enterprises* and the UN *Guiding Principles on Business and Human Rights*. The practical implementation often involves the use of third-party audits and adherence to industry certification schemes, such as the Responsible Business Alliance (RBA), resulting in continuous improvement and accountability across the extended supply network.





Community Engagement

The semiconductor industry ensures long-term sustainability and social responsibility through active engagement with the community. Given their significant influence in local economies, firms engage in strategic investments toward the development of STEM education, environmental stewardship, and community welfare, reflecting their commitment to motivating future generations and strengthening the social footprint in of their operating regions. Examples include the following community programs:

Companies	Main Community Programs
Samsung	**Samsung Solve For Tomorrow**: global education initiative that encourages students to apply STEM skills to develop solutions for real-world community challenges.
TSCM	**TSMC Education and Culture Foundation**: organization that oversees TSMC's community engagement and initiatives in education, culture, and arts, aimingto minimize the educational gaps between urban and rural areas.
Intel	**Intel Involved**: global employee volunteer program supporting coomunity development through education and sustainability. **Intel Foundation**: A non-profit organization that funds STEM education and community impact initiatives.
SK Hynix	**Heinstein Program**: offers coding and AI education to children and adolescents from underserved communities in South Korea, helping them explore careers in educational technology and develop future-ready scientific skills.
NVIDIA	**NVIDIA Foundation**: focus areas include expanding K–12 STEM education, supporting medical research and healthcare accessibility, and delivering disaster and crisis relief through donations and volunteering.

Table 2 – Big Players' community Programs.

Governance

Typical governance structures in the industry

The governance structure of major semiconductor firms is influenced by factors such as the industry's complexity and high capital demands. While the models vary, for instance, some European companies operate under a two-tier system with a separate Supervisory Boardand a Board of Management (e.g. ASML), the standard is a commitment to board independence.

Table X depicts the independence and average age of the Boards of Directors for each analysed company. Nasdaq-listed firms, especially in the high-growth tech sector, tend to have a higher proportion of independent directors due to listing requirements (Nasdaq Listing Rule 5605(b)(1)) and governance expectations from institutional investors. Barrett (2017) also notes that the median age of directors in the S&P 500 IT sector are slightly lower than in other industries.

Companies	% independence	Avg. Age
Samsung	55.6%	60.4
TSCM	70%	70.8
Intel	91%	61.5
SK Hynix	55.6%	62
NVIDIA	92%	65.8

Table 3 - BoD overview.

To manage risks and responsibilities, the Boards of Directors of major semiconductor companies usually delegate the following committees:

1. Audit and Risk Committee: Supervise financial reporting integrity, internal controls, external auditors, and increasingly, enterprise risk management (ERM), which includes analyzing long-term operational and strategic threats related to the highly concentrated supply chain.

2. Compensation and People Development Committee: Determines executive and director remuneration, and often reviews critical succession planning for the CEO and other senior leaders.

3. Nominating, Corporate Governance, and Sustainability Committee: Responsible for the identification and recommendation of new board members, while ensuring compliance with corporate governance guidelines, and monitoring the company's ESG strategies, which are particularly significant in the semiconductor industry due to its high energy and water use.

ESG disclosure practices and regulatory compliance

Regulatory compliance in the technology sector is rapidly expanding beyond traditional financial reporting to encompass complete ESG disclosures. This shift is driven by investor demand and evolving mandates, such as the SEC's climate-related disclosure rules (SEC, 2024) and the EU's Corporate Sustainability Reporting Directive (CSRD) (European Parliament and Council of the European Union, 2022). Companies, especially those listed on exchanges with high governance expectations like Nasdaq, are moving from voluntary sustainability reports to mandatory reporting.

The board of directors' independent oversight is important for ESG compliance. Independent directors are tasked with verifying that the disclosed data (covering areas such as environmental metrics and human capital metrics) is integrated into the firm's risk profile. Given the complex nature of the semiconductor value chain, regulatory compliance often focuses on the Social pillar, particularly in supply chain in order to ensure ethical sourcing of minerals and adherence to global labor standards. Additionally, the board must assess climate transition risks and technological ethics to maintain long-term compliance and stakeholder trust.

ESG-related compensation

The integration of Environmental, Social, and Governance (ESG) performance targets into executive compensation schemes has become a cornerstone of modern corporate governance in the semiconductor industry, directly linking management's financial incentives to long-term sustainability strategy. This practice is widespread, with a majority of major global firms adopting ESG metrics into either **Short-Term Incentives (STI) or Long-Term Incentives (LTI)** to mitigate managerial short-termism (WTW, 2024). For semiconductor manufacturers, the main metrics focus on the **Environmental and Social pillars.**

- Environmental metrics often tie LTI to reductions in the immense energy and water consumption of fabs and Scope 3 supply chain decarbonization.
- Social metrics emphasize talent development and workforce diversity, focusing on achieving Diversity, Equity, and Inclusion (DEI) goals and improving retention rates among high-skilled employees (Cohen et al., 2022).

While linking pay to these material targets has been empirically shown to drive positive changes, the effectiveness hinges on the Compensation Committee's diligence.

Examples of STIs and LTIs of the analysed players:

1. STIs: **Intel** links its annual bonuses to revenue and profitability targets, **TSMC** ties STI to manufacturing efficiency and on-time delivery for advanced nodes like 3nm and 5nm, and **Samsung** rewards performance based on production output and financial goals.

2. LTIs: **NVIDIA**, for instance, ties its LTI to TSR relative to peers and achievement of innovation goals, **Intel** links PSUs (performance stock units) to long-term financial performance and R&D execution, and **TSMC** incorporates operational KPIs alongside sustainability objectives, including energy and water reduction targets, and **SK Hynix** emphasizes long-term financial results and employee retention in its LTI programs.

Players Comparison

ESG Scores

	Range	Samsung	TSMC	SK Hynix	Intel	NVIDIA
Morningstar	0-100 (lower = lower risk)	15.74	14.59	18.87	18.9	13.43
MSCI ESG Ratings	AAA (leader) → CCC (laggard)	AA	AAA	A	AA	AAA
S&P Global CSA	0-100	43	-	53	58	61
LSEG (Refinitiv)	0-100	77	-	72	88	77

Table 4: ESG Ratings x industry comparison.

Morningstar: Provides ESG risk ratings that measure a company's exposure to industry-specific ESG risks and how well they are managed.

MSCI ESG Ratings: Evaluates companies' ESG performance relative to its peers.

S&P Global CSA (Corporate Sustainability Assessment): Assesses companies' ESG practices through detailed questionnaires, used to determine inclusion in the Dow Jones Sustainability Index.

LSEG (Refinitiv ESG): Offers ESG scores based on publicly disclosed data, covering environmental, social, and governance factors to benchmark companies' sustainability performance.

ESG KPIs

ESG Pillar	Key Performance Indicator	Unit / Year	Samsung	TSMC	Intel	SK Hynix	NVIDIA
Environmental (E)	Absolute Scope 1 & 2 GHG Emissions	Mt CO2e / 2024	14889	12783,3	4284	7574,7	241,4
	Renewable Electricity Use	% of Energy consumption / 2024	26%	30,50%	83%	13%	95%
	Water Recycling Rate	% / 2023	>78% (Target: Maximize water reuse)	89.9% (Taiwan Fabs)	Net Positive Water Goal (Returns more water than consumed)	9.4% (Total Water Recycled Ratio) / 2023	N/A (Focus on Partner/Supply Chain)
	Waste Recycling Rate	% / 2023	≈ 97%	97.6%	95% (Total non-hazardous waste)	98.2%	N/A (Focus on Partner/Supply Chain)
Social (S)	Total Workforce (Approx.)	Headcount / 2024	129480	83825	108900	46863	29600
	Women in Leadership / Management	% / 2023	16% (Samsung Electronics)	N/A (Focus on Gender Pay Ratio)	31.3% (Senior Leadership)	N/A (Focus on HR investment)	26.1% (Leadership roles: Director+) / FY2024
	Lost-Time Injury Rate (LTIR)	Cases per 200,000 hrs / 2023-2024	0.022 / 2024	N/A	0.16 / 2023	0 / 2023	0.01 / 2024
Governance (G)	Board Independence	% Independent Directors / 2025	56%	70%	91%	56%	92%
	ESG-Related Executive Compensation	Status / 2025	Yes (Evaluates ESG performance for exec pay)	Yes (Linked to environmental targets)	Yes (Incentives linked to RISE strategy goals)	Yes (Includes ESG targets for evaluation)	Yes (ESG factors in annual incentive plan)
	Responsible Sourcing Audit Coverage	Scope / 2024	100% (Conflict Minerals)	100% (Conflict Minerals & key suppliers)	100% (Conflict Minerals)	100% (Conflict Minerals & Supply Chain)	100% (Conflict Minerals)

Table 5: ESG Key Performance x industry comparison.

Outlook

For sectors such as semiconductors, aligning with the EU Taxonomy is becoming increasingly critical. Companies in this field must evaluate how their operations and supply chains contribute to achieving climate and environmental objectives.

Efforts should include improving energy efficiency in manufacturing processes, sourcing renewable energy for production, and implementing circular economy principles through recycling rare materials and minimizing electronic waste. Additionally, strengthening environmental risk management and enhancing ESG reporting practices are key to demonstrating compliance and accountability. By integrating these actions, semiconductor companies can strengthen their ESG reputation, attract sustainable investment, and contribute meaningfully to the global effort to limit temperature rise to 1.5°C, as outlined in the Paris Agreement.

Market Trends

Sustainability has become a defining theme in the semiconductor industry, has mentioned before, with leading manufacturers such as Samsung demonstrating strong commitments to sustainable development. These initiatives underscore how environmental responsibility can coexist with technological advancement, often leading to performance breakthroughs. Achieving meaningful progress, however, requires coordinated global efforts and collaboration between the public and private sectors. Jointly allocating resources and taking decisive climate actions can fundamentally change the trajectory of global emissions and enable the realization of ambitious net-zero targets.

International research institutions are increasingly partnering with semiconductor companies to address emissions across the value chain and help firms exceed their reduction targets. Yet, a key challenge remains which is managing value chain emissions amid rising semiconductor demand. As global consumption of chips accelerates, companies must take more deliberate steps in selecting and engaging suppliers. The industry's continued expansion and technological advancement depend on a robust global economy, but growth must be balanced with minimizing climate impact. This creates a nuanced challenge—expanding production capacity while limiting the number of suppliers that align with strict environmental standards.

Addressing these interconnected pressures will require sustained innovation, cross-sector collaboration, and policy alignment to ensure that semiconductor growth supports both technological advancement and climate objectives and can be done through some strategies developed in the following section.

Roadmap & Recommendations

According to Deloitte, the semiconductor sector can pursue six strategic pathways to accelerate sustainability:

1. Reduce direct manufacturing emissions (Scope 1 & 2) and other environmental impacts.
2. Address supply chain and business ecosystem emissions (Scope 3).
3. Optimize manufacturing processes and product design to reduce energy consumption and emissions across the full product lifecycle.
4. Reengineer products, logistics, and business models for circularity.
5. Leverage sustainability as a business value driver, generating new brand value, products, and revenue streams.
6. Integrate and continuously revise sustainability strategies into core business operations.

Roadmap & Recommendations

In terms of reducing the gas emissions (strategy 1 and 2) during the production line. Specific strategies for Scope 1, Scope 2, and Scope 3 are recommended.

1. Scope 1

For Scope 1, semiconductor companies should take aggressive steps to lower direct manufacturing emissions, recognizing that emissions will fluctuate with economic cycles and production utilization rates. Companies can invest in research and development to identify alternatives to high-global warming potential (GWP) process gases and develop innovative manufacturing methods. Abatement technologies should be implemented to capture or neutralize harmful gases before they are released into the atmosphere. Collaboration with research institutions can accelerate breakthroughs in gas reduction and electrification, while electrification of thermal processes where feasible can further reduce fossil fuel dependence. (Boston Consulting Group & SEMI Semiconductor Climate Consortium, 2023).

2. Scope 2

Firms can transition to low-carbon energy sources through Power Purchase Agreements and on-site renewable generation such as solar and wind for fabs and offices. Energy efficiency should be enhanced through advanced facility and equipment design, automation, and process optimization. Additionally, companies should advocate for grid decarbonization in key semiconductor regions, including China, Taiwan, South Korea, and Japan.(Boston Consulting Group & SEMI Semiconductor Climate Consortium, 2023).

3. Scope 3

Addressing Scope 3 emissions requires engaging suppliers to develop low-carbon materials and energy-efficient equipment. Transparency and standardized methodologies for Scope 3 reporting should be promoted across the supplier network. Circular economy initiatives, including the reuse and recycling of wafers, chemicals, and packaging, should be prioritized. Chip and device design should focus on energy efficiency to reduce emissions during end-use, while collaboration with hyperscalers and OEMs can accelerate renewable energy adoption in data centers and downstream environments. Improving the design of manufacturing facilities and offices to consume less electricity, alongside working with suppliers and device users to enhance energy efficiency, can further reduce value chain emissions. According to Boston Consulting Group, SEMI, and the Semiconductor Climate Consortium (2023), these three categories of action can address over 80% of total value chain emissions.

4. Cross-scope actions

Cross-scope actions are also critical. Semiconductor firms should set science-based targets aligned with a 1.5°C pathway and publish clear decarbonization roadmaps. Participation in industry consortia, such as the Semiconductor Climate Consortium, can facilitate the sharing of best practices and drive collective action. Sustainability should be embedded into procurement policies and supplier contracts, and investments should be made in innovation and partnerships to advance process gas alternatives, energy efficiency, and electrification solutions.

However, the industry faces challenges, including the energy rebound effect, in which greater energy efficiency leads to increased consumer demand that may partially offset emission reductions. Variability in grid decarbonization poses another challenge, as access to low-carbon energy differs significantly across regions, particularly in major manufacturing hubs such as China, Taiwan, South Korea, and Japan. Companies, suppliers, and customers must invest in on-site renewable energy, purchase available low-carbon energy, and advocate for faster grid transitions to overcome this barrier. Emissions associated with the extraction and refinement of raw materials are also difficult to eliminate, particularly in lower-margin activities or processes requiring high heat or specialized chemicals. Collaborating with suppliers to develop lower-carbon materials and continuing R&D on alternative processes and abatement technologies is therefore essential.

To ensure credibility, semiconductor firms should align emission reduction targets with the Science Based Targets initiative (SBTi). Which is a global, voluntary initiative that helps companies and financial institutions set greenhouse-gas (GHG) emissions reduction targets in line with climate science, particularly to meet the goals of the Paris Agreement. (Science Based Targets Initiative, 2025)

Furthermore, they should provide Corporate Net-Zero guidance, disclose interim 2030 targets, clarify assumptions regarding residual emissions, and define the role of carbon removals. The methodology for estimating Scope 3 emissions and progress toward reductions should also be disclosed. Alignment with SBTi enhances comparability, transparency, and investor confidence, ensuring that sustainability actions are both meaningful and measurable.

Conclusion

In conclusion, the semiconductor industry faces unique environmental, social, and governance challenges due to its capital-intensive, high-tech, and highly globalized nature. Environmentally, fabs demand enormous amounts of energy, ultra-pure water, and chemicals, creating significant greenhouse gas emissions and hazardous and non-hazardous waste streams, which companies are increasingly managing through circular economy strategies, emissions reduction targets, and water reuse programs. Socially, the sector is navigating a complex workforce landscape characterized by an aging population, a shortage of skilled STEM talent, and the underrepresentation of women, prompting initiatives in reskilling, diversity, and educational outreach. Governance practices are crucial to ensuring ethical supply chain management, board independence, and executive accountability, with ESG-linked compensation programs further aligning management incentives with long-term sustainability goals. These efforts are increasingly shaped by stringent regulatory frameworks, including conflict minerals legislation, governance requirements, and environmental disclosure rules, while the industry's exponential growth, driven by the global surge in semiconductor demand, intensifies pressures on resources, talent, and operational resilience. Furthermore, as global chip consumption accelerates, companies face the added challenge of managing value chain emissions while aligning the expansion of production capacity with strict environmental standards.

Strong ESG performance reduces several risks and brings several corporate benefits, ultimately contributing to resilient and sustainable business growth. Moreover, achieving meaningful progress requires sustained innovation and alignment with policy and research initiatives to ensure that semiconductor growth supports both technological advancement and climate objectives.

Webgraphy

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This report was prepared by the Equity Research team at the Lisbon Investment Society. Our analysts combine rigorous financial modeling, critical thinking, and collaborative research to deliver high-quality, student-led investment analysis.
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