

Innovation Management

Maintain Technology Leadership

Continuous investment in advanced technology development to maintain TSMC's technology leadership in the semiconductor industry



Protect Intellectual Property

Patent protection: Strengthen quality and quantity driven patent management, apply early for patents on next-generation process technologies, and expand the patent protection network to maintain TSMC's technology leadership

Trade secret protection: Strengthen business operations and intellectual property innovation by recording, consolidating, and utilizing trade secrets with competitive corporate advantages through trade secret registration and management



Enhance Industry-academia Collaboration

Link academic institutions in Taiwan and overseas by investing resources in university programs based on a long-term mechanism for interaction to cultivate the next-generation semiconductor talent



2030 Goals	2024 Targets	2023 Achievements
<ul style="list-style-type: none"> Maintain TSMC's technology leadership and invest 8.5% of revenue into R&D expenses annually 	<ul style="list-style-type: none"> 2nm process technology (N2) enters risk production 	<ul style="list-style-type: none"> Enhanced 3nm process (N3E) entered volume production Target: 3nm process technology in volume production Maintained TSMC's technology leadership and invested 8.5% of revenue into R&D expenses annually^{Note 1} Target: 8.5%
<ul style="list-style-type: none"> Over 80,000 global patent applications Over 200,000 trade secret registrations 	<ul style="list-style-type: none"> Exceeds 8,500 global patent applications Exceeds 60,000 trade secret registrations Shares TSMC's trade secret registration mechanism with eight companies Assists six companies to successfully build a trade secret registration and management system Exceeds 500 green trade secret registrations 	<ul style="list-style-type: none"> Submitted over 8,700 global patent applications Target: >7,500 Registered over 40,000 trade secrets Target: >40,000 Shared TSMC's trade secret registration mechanism with 23 companies Target: 8 Assisted seven companies to successfully build a trade secret registration and management system Target: 6 Registered over 500 green trade secret registrations Target: >500
<ul style="list-style-type: none"> Cultivate more than 35,000 undergraduate and graduate students globally through university programs that deepen industry-academia collaboration^{Note 2} Introduce STEM workshop for female high school students with over 3,000 participated NEW 	<ul style="list-style-type: none"> Cultivates more than 17,000 undergraduate and graduate students globally through university programs that deepen industry-academia collaboration between 2021 and 2024 Introduces STEM workshop for female high school students with over 2,500 participated NEW 	<ul style="list-style-type: none"> Cultivated up to 12,677^{Note 3} undergraduate and graduate students globally through university programs that deepen industry-academia collaboration between 2021 and 2023 Target: 10,000 people Cultivated up to 11,670 undergraduate and graduate students globally through university programs to enhance industry-academia collaboration Target: 8,000 people

Applicable to all TSMC fabs around the world
 Applicable to TSMC fabs in Taiwan and other specific fabs
 Only applicable to TSMC fabs in Taiwan
 Exceeded
 Achieved
 Missed target

Note 1: Since 2014, TSMC has consistently set new revenue and R&D expense records every year. In 2023, R&D expenses amounted to US\$5,846 million, 3.1 times more than 2014, 8.5% of total revenue in 2023. For historical data on revenue and R&D expenses, please see [Continuous Investment in R&D](#)

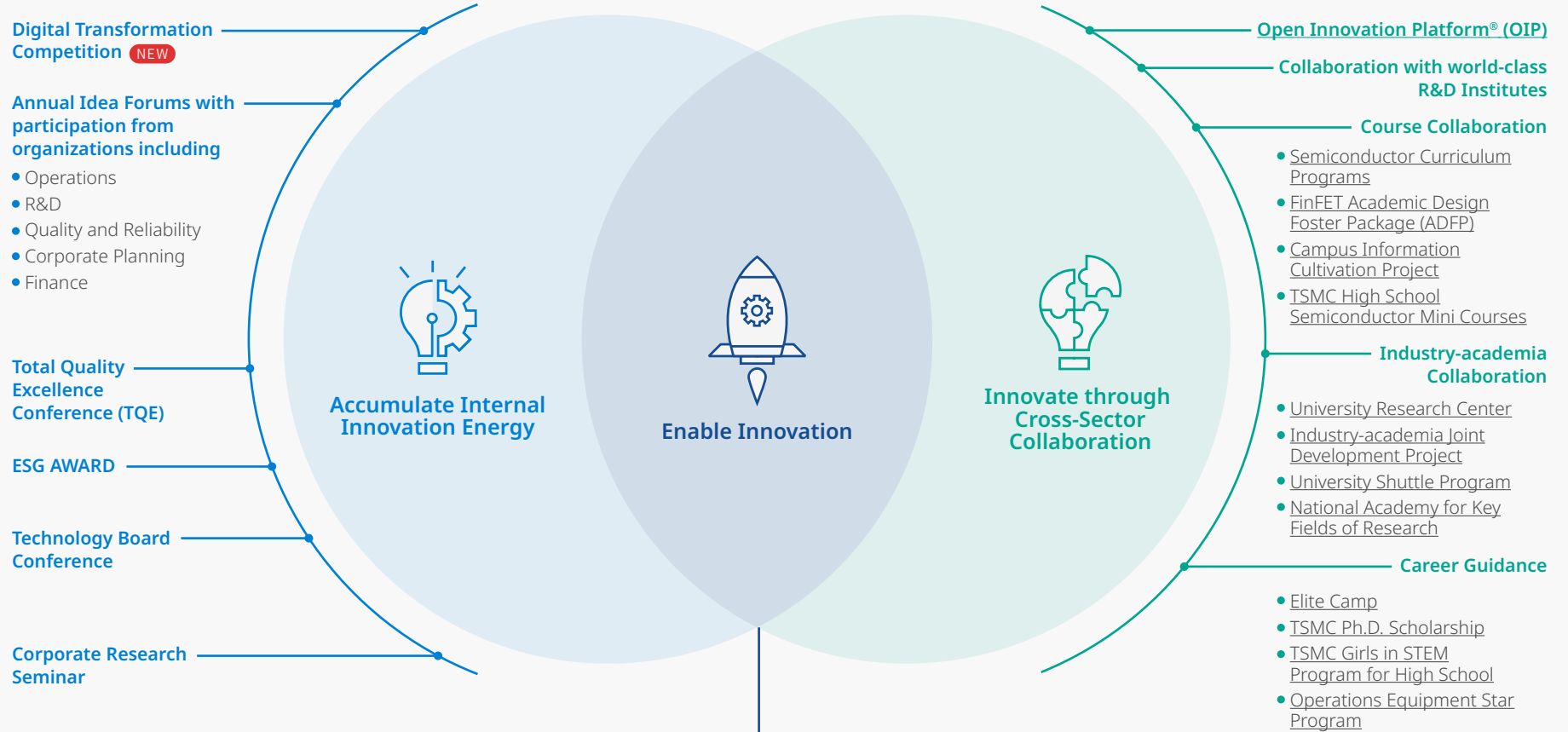
Note 2: Industry-academia collaboration projects include various academic programs, internships, and cooperative education programs

Note 3: As the cumulation of the number of participants can better exhibit the resources invested by TSMC in talent cultivation and benefits, the target for the number of participants in the current year was canceled in 2024

Starting from the innovative business model of being everyone's foundry, Dr. Morris Chang founded the global-first dedicated IC foundry, which has significantly reduced the entry barrier for the semiconductor industry and given rise to a thriving fabless IC design industry. Since its establishment in 1987, innovation has always been the basis of growth. From business models to technical breakthroughs, TSMC continues to seek outstanding performances in all aspects. Meanwhile, it actively cultivates the innovation culture through Technology Symposium, proposal competitions, Total Quality Excellence Conference (TQE), and other internal sharing and exchange systems to establish a work environment that encourages innovative thinking and provides incentives to employees for implementing innovative proposals. In 2023, TSMC organized the first digital transformation competition and encouraged employees to utilize digital transformation technologies to enhance the Company's competitive strength and inspire digitized, automated, and intelligent innovations to continue maintaining its leading position in the everchanging era.

In response to the emerging AI technologies, TSMC accelerated its science exploration and technology innovation and constantly improved its overall operating capacity and efficiency. In 2023, its N3E technologies successfully entered the volume production and the Company created the N2 technical development baseline, with the risk production scheduled for 2024. In addition, TSMC formed cross-industry collaboration with customers, suppliers, industry, and academia, including products, technical talent, and green innovation, in response to the rapid changes in the semiconductor industry to remain consistently devoted to innovation.

Innovation Management Framework



<p>Intelligent Precision Manufacturing</p>	<p>Technology Leadership</p>	<p>Intellectual Property Protection</p> <ul style="list-style-type: none"> • Comprehensive Patent Management Mechanism • Trade Secret 	<p>Innovation Cases</p> <ul style="list-style-type: none"> • Development of High Transmittance EUV Pellicle Wins Three Patents • Introduce New Generation Low-temperature Polyimide to Upgrade Environment-friendly Materials • HPC Technology Platform That Saves 6.8 kWh for every kWh of Power Consumption • Optimized the High-gravity Rotating Packed Bed to Improve the IPA Reduction Rate by 70% • Innovative Real-time Air Pollution Monitoring Technology Acquires Gas Concentration Data in One Minute
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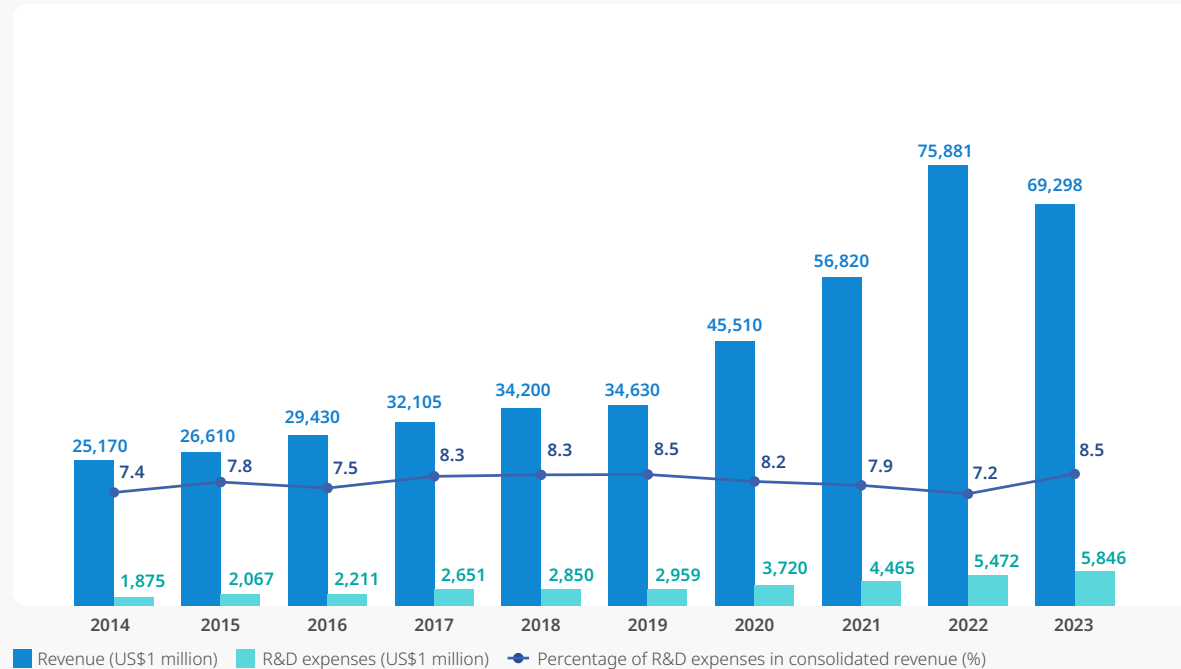
Maintain Technology Leadership

In 2023, TSMC continued to increase R&D investments, with annual R&D expenses accounting for 8.5% of total revenue; its investment scale is equivalent to the world-class technology enterprises. Facing the challenge to significantly improve semiconductors' computing capacity every two years under Moore's Law, TSMC's R&D organization provides customers with advanced technologies and design solutions to contribute to their products' success. In 2023, TSMC completed the N2 development baseline and continued to improve its yield; meanwhile, it also developed the A16 process; as compared with the N2 process, the A16 process will further provide speed and density advantages.

In the future, TSMC will continue to conduct exploratory research into advanced technology innovation. In addition to CMOS logic technology, TSMC is also developing a wide range of semiconductor technologies to meet customer demands on SoCs for mobile and other applications. The existing scope of application includes integrated interconnect and packaging solutions, microcontrollers, AI edge computing, etc.

In 2023, TSMC continued to work closely with world-class research institutes such as the Semiconductor Research Corporation (U.S.), Interuniversity Microelectronics Centre (Belgium), and expanded its research collaboration with world-leading universities to achieve advances in semiconductor technologies and talent cultivation for the next generation.

Continuous Investment in R&D



TSMC's global Research Development Center

Technology Leadership and Innovation

Technology Category	2021	2022	2023
<p>CMOS Logic Technologies</p>	<ul style="list-style-type: none"> Pioneered the industry's first 3nm technology in risk production 	<ul style="list-style-type: none"> Pioneered the industry's first 3nm process technology in high volume production N3E, the enhanced 3nm technology, successfully entered risk production 	<ul style="list-style-type: none"> Pioneered the industry's first enhanced 3nm process technology, N3E, in volume production
	<p>Specialty Technologies/ Interconnect and Packaging Technologies</p>	<ul style="list-style-type: none"> Qualified the fifth-generation chip on wafer on substrate (CoWoS®) with record-breaking Si interposer area up to 2,500 mm², which can accommodate at least two SoC logic and eight high bandwidth memory (HBM) chiplet stacks Successfully qualified InFO-PoP Gen-7 for mobile applications with enhanced thermal performance Initiated high-volume manufacturing of InFO-oS Gen-3, which provides more chip partition integration with larger package size and higher bandwidth Expanded the 12-inch Bipolar-CMOS-DMOS (BCD) technology portfolio on 90nm, 55nm, 40nm, and 22nm processes, targeting diverse mobile power management applications with different integration levels Achieved 13% pixel size scaling down on Quad Phase Detection (QPD) CMOS image sensors structure for the mobile imaging market 28nm and 40nm RRAM entered volume production as a low-cost solution for the price-sensitive IoT market Maintained stable high yield and achieved technical qualification of 28nm eFlash for consumer electronics grade and automobile electronics grade-1 applications 	<ul style="list-style-type: none"> Received CoWoS®-S certification for Gen-3 HBM, silicon interposer now contains sub-micron routing layers and integrated capacitors (iCap) so that various chiplets such as SoC, HBM can be placed on it Successfully qualified InFO-PoP Gen-8 for mobile applications with enhanced thermal performance; launched R&D for next generation InFO PoP, which will introduce backside redistribution layer Successfully qualified InFO-oS Gen-4, which provides more chip partition integration with larger package size and higher bandwidth Optimized quality factors of 5V components on 55nm BCD targeting power switches for portable devices; continued to expand 40nm, 22nm, and 0.13 micron BCD technologies to meet automotive market demands Successfully risk-produced the world's smallest voltage domain global shutter CMOS image sensor chip with 3-wafer stack technology for near infrared and security cameras market Prepared 22nm RRAM for volume production as a low-cost embedded non-volatile memories solution for price-sensitive IoT markets 28nm eFlash entered volume production, which can support mobile HPC and high-performance low-leakage platforms



Technology Leadership and Innovation in 2023

Semiconductor technology innovation profoundly impacts various aspects of human life. Applications like 5G mobile communication and HPC enhance convenience and quality of life. The sustainable application of semiconductor technology also contributes to energy efficiency in end products, leading technology and civilization toward a low-carbon sustainable future.

Process Technology	Product Application	Innovation/Breakthrough	Customer Success
3nm Fin Field-Effect Transistor (FinFET) (N3) technology	5G 𠄎	Entered its second year of volume production	Led the industry to deliver most advanced products
3nm FinFET Enhanced (N3E) technology	5G 𠄎	Started volume production	Led the industry to deliver the most advanced products
3nm FinFET Plus (N3P) technology	5G 𠄎	Industry's most advanced and mature FinFET transistor technology	Led the industry to deliver the most advanced products
4nm FinFET Plus (N4P) technology	5G 𠄎	Started volume production	Introduced products with industry-leading performance and energy efficiency
12nm FinFET Compact Plus (12FFC+) N12e™	𠄎	Compared to its previous generation of N22 technology, the innovative N12e™ technology can achieve >50% power saving	Led the industry to deliver the most advanced products
5nm FinFET Automotive (N5A) technology	𠄎	Led the industry with 5nm logic technology, offering Automotive Grade Reliability and an Automotive Design Enablement Platform	Enabled customers to develop the industry's most advanced ADAS SoC (System-on-Chip)
N6 radio frequency (N6 RF) technology	5G 𠄎 𠄎 𠄎	Received multiple customer product tape-outs	Introduced products with industry-leading RF performance and cost-effectiveness
16nm FinFET Compact (N16FFC) MRAM (Magnetoresistive Random-access Memory) Technology	𠄎 𠄎	Passed <u>AEC-Q100</u> Grade-1 reliability qualification	Introduced industry-leading high-performance microcontroller unit (MCU) for automotive and industrial applications
CMOS Image Sensor (CIS) technology	𠄎	Continued to help customers gain market leadership by introducing the world's smallest pixel size products	Led the industry to deliver advanced products with the world's highest dynamic range in performance
TSMC-SoIC® (System on Integrated Chip) Chip-on-Wafer (CoW) technology and CoWoS®-S integration	𠄎	Led the industry to integrate 3D Si stacking (SoIC) and CoWoS®-S into a single, compact new system chip with improved performance significantly	Led the industry in product performance and energy efficiency
Chip on Wafer on Substrate with Redistribution Layer Interposer, CoWoS®-R technology	𠄎	Led the industry to start volume production of HPC products with better signal integrity	Led the industry to deliver advanced products

- 5G 5G mobile communications
- 𠄎 HPC
- 𠄎 Ultra-low power Internet of Things (IoT)
- 𠄎 Automotive
- 𠄎 True wireless stereo (TWS)
- 𠄎 Wearable devices
- 𠄎 Wi-Fi 7 connectivity/Digital TV/Set-Top Box (STB)
- 𠄎 New automotive zonal control of electrical/electronic architecture (EEA) for software-defined vehicles
- 𠄎 [High-end industrial controllers](#)

Advance Technology to Unleash Customer Innovation

Innovation is the foundation for TSMC's growth. The power brought by innovation not only drives the Company to maintain its leading position in technology, but also innovative breakthroughs in various industries, thereby solving the challenges of human society and technological and societal advancements. As the trusted semiconductor foundry service provider, TSMC is committed to technology leadership by continuously introducing new generation process technologies with higher chip density and lower power consumption, and providing diverse and comprehensive specialty technologies, as well as 3D chip stacking and packaging services to realize a wide spectrum of chip innovations. In 2023, TSMC deployed 288 distinct process technologies and manufactured over 11,890 products for 528 customers, creating more advanced, powerful,

energy-efficient, and affordable electronic products that drive modern society's progress. In 2023, TSMC invited 48 emerging customers to participate in the Innovation Zone at its Technology Symposium, showcasing their innovative technologies and products that will help improve future human life, including power-efficient AI chipsets, automotive controllers, gallium nitride (GaN) power modules, energy-harvesting controllers, and medical sensors. The attendee-voted Demo of the Year Award expanded from North America to Europe for the first time, fueling the world with endless innovation momentum.

Leading RFID Tag Chips to Advance a Smarter, More Sustainable World

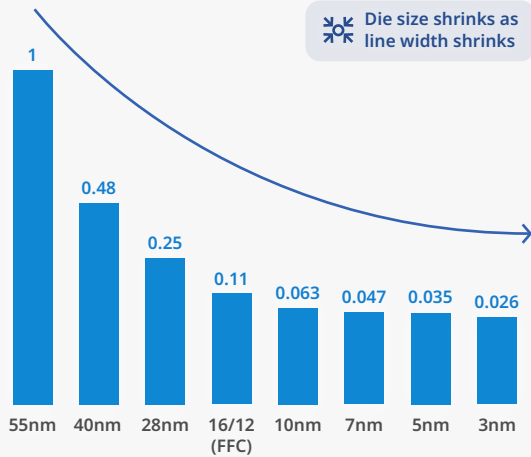
In 2023, TSMC continued to empower its customers with innovation. Partnering with Impinj, TSMC utilized its leading 65-nanometer process technology to assist

in delivering the next-generation Impinj M800 series RAIN RFID tag chips, which successfully entered the global IoT market. The new Impinj M800 series tag chips have excellent features such as high readability and low power consumption, which help to reduce the size and environmental impact of RAIN RFID tags attached to everyday items. Compared to the previous generation Impinj M700 series, the M800 series increases the number of dice per wafer by 25%, while reducing energy consumption by 30%, thereby reducing the carbon footprint of Impinj products and creating a smarter and more sustainable world through everyday items such as food packaging, car parts, and parcels and postal items that use RAIN RFID technology.

Impinj's innovative tag chips can be used to track medical supplies and equipment, ensuring that critical healthcare assets are in the right place at the right time and their priority delivery; for example, during the

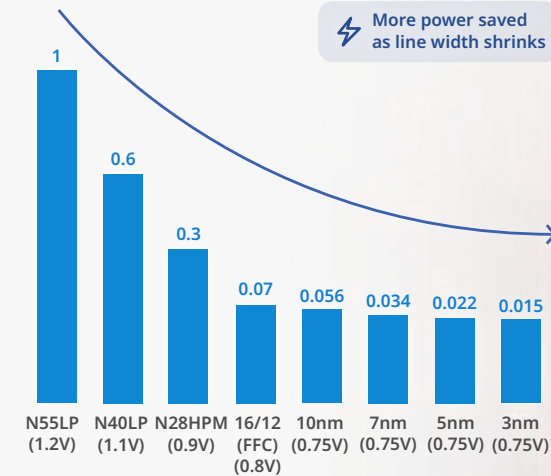
COVID-19 pandemic, Impinj tag chips helped hospitals accurately track and trace medical devices and pharmaceuticals such as vaccines, pills, vials, and syringes, and provide information on dosage, expiration date, and recall, which highlights the value that technology can bring to society. In addition, Impinj tag chips also create a positive impact on environmental sustainability. Taking applications in the food industry as an example, the use of Impinj M800 series tag chips can help improve inventory accuracy and avoid the overproduction or overstocking of perishable goods such as food. For the apparel industry, Impinj tag chips attached to products can help track and trace each stage of the product life cycle, reducing carbon emissions and facilitating circular economy. With the launch of the new-generation RAIN RFID technology, it will further improve supply chain logistics efficiency, help save transportation costs and cut carbon emissions, and drive supply chain upgrades and sustainable development.

Comparison of Chip Die Size on Different Technologies



Note: The logic chip/SRAM/IO (input/output) ratio, which affect die size and power consumption, was re-aligned

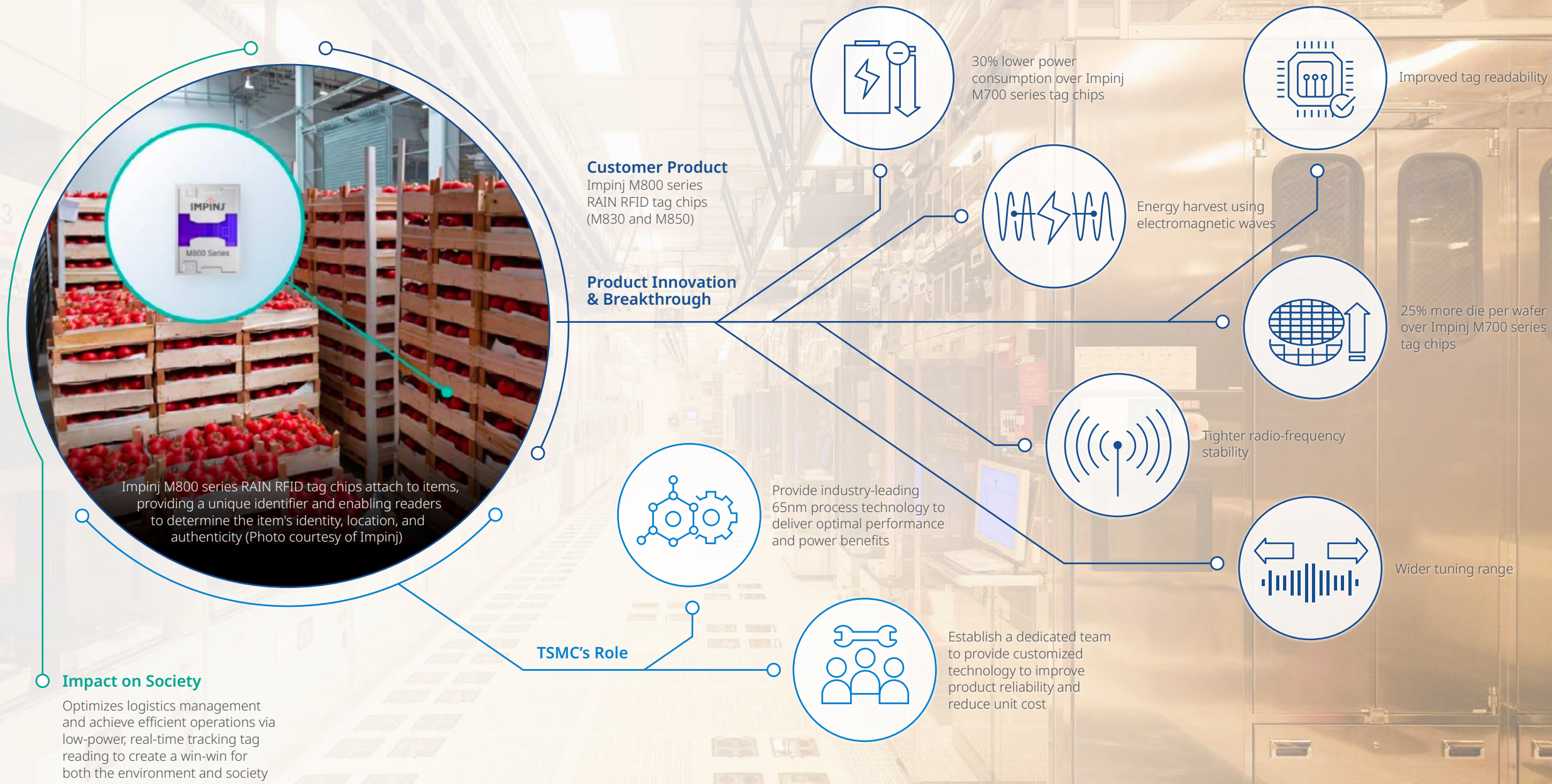
Comparison of Chip Total Power Consumption on Different Technologies



Note: The logic chip/SRAM/IO (input/output) ratio, which affect die size and power consumption, was re-aligned



TSMC Works with Customers to Unleash Innovation



Protect Intellectual Property

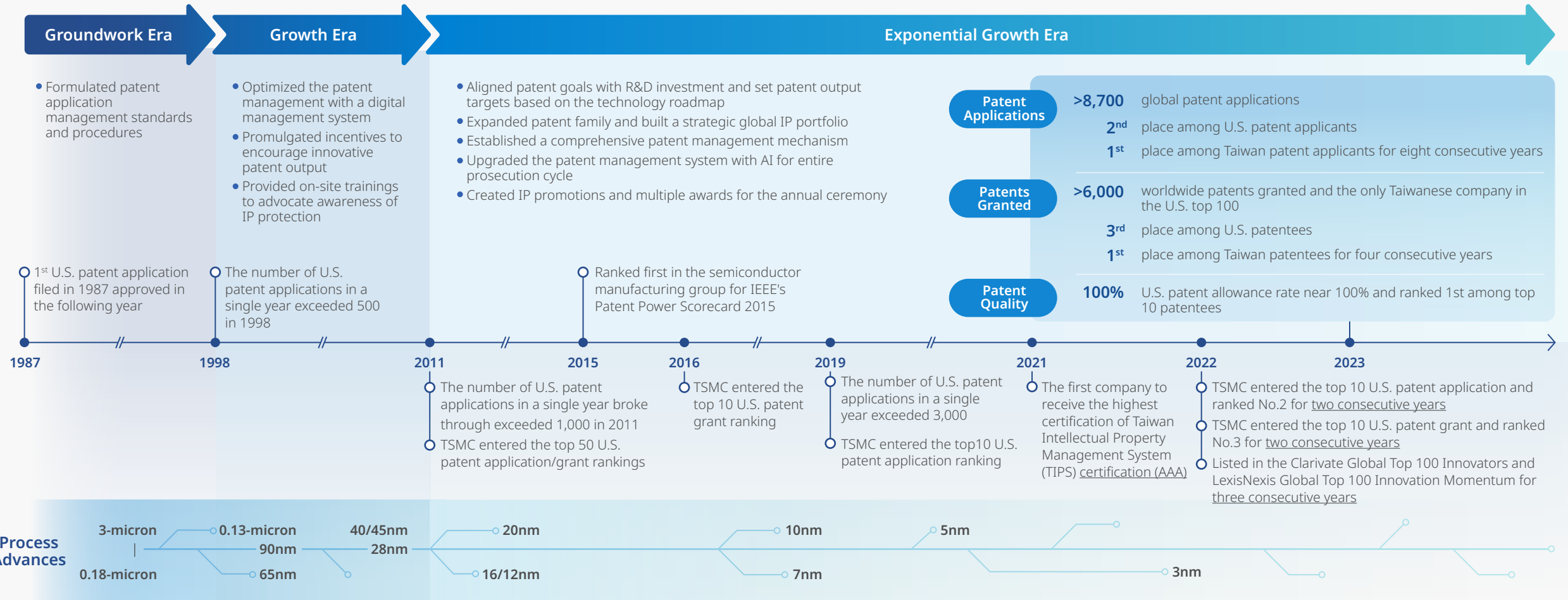
In response to the global development strategy, to fulfill TSMC's vision of sustainable operations, the Company seeks to strengthen its three competitive advantages—Technology Leadership, Manufacturing Excellence, and Customer Trust - by protecting technological

innovations and proprietary information through two approaches: patents and trade secrets. TSMC's IP and R&D teams enable TSMC to build an IP portfolio for each generation's critical innovation ahead of schedule, including the latest 3nm and 2nm process technologies, to ensure the Company's technology leadership in the semiconductor industry using intellectual property

assets. In manufacturing excellence, TSMC applies measures to secure critical information such as capacity planning, manufacturing process management, and information related to intelligent operations in the form of trade secrets while also actively applying for patents for manufacturing technology with strategic value to enhance the Company's competitive edge. In

maintaining customer trust, TSMC maintains strategic leadership in the global patent ranking while protecting confidential information concerning the Company and its customers. These efforts translate into business success, ensuring the freedom of operations around the world and strengthening partnerships with customers.

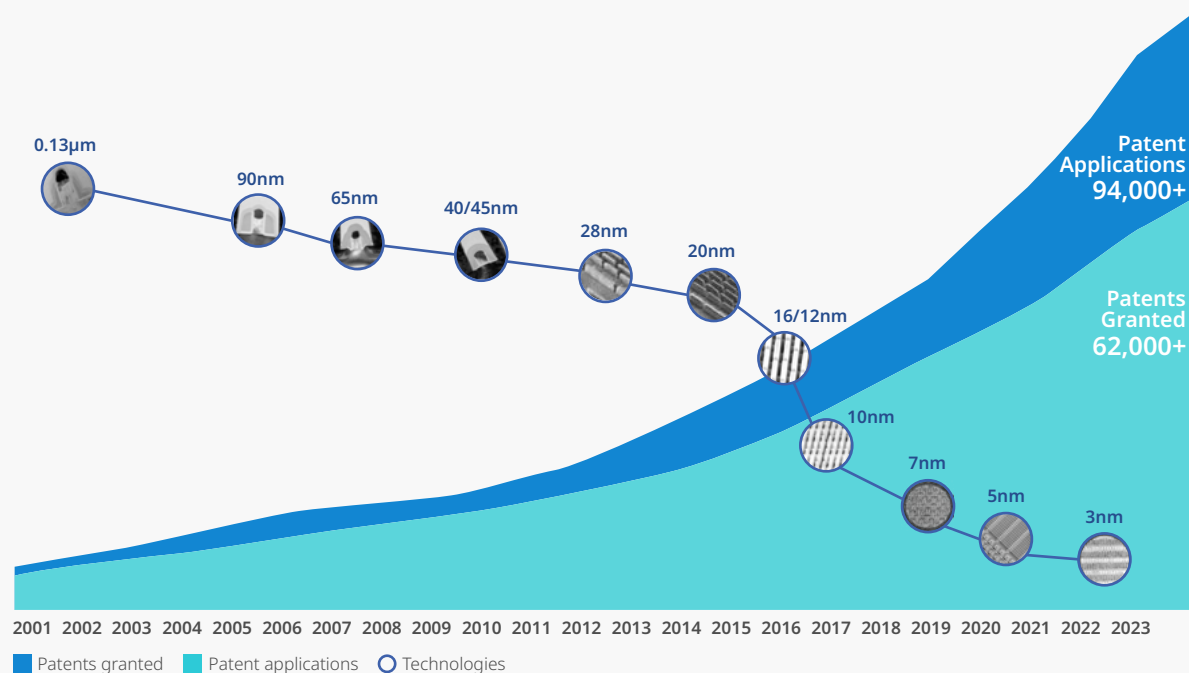
TSMC Patent History



Comprehensive Patent Management Mechanism

TSMC achieved the IP management goals by adopting four major IP management policies to implement its patent strategy and protection through the comprehensive patent management system, including the full patent strategy and patent management systems, and maps out short-, mid-, and long-term patent blueprints using innovative patent strategies and diverse risk control; meanwhile, it monitors and evaluates competitive information by patent map navigation, hosts advanced invention workshops to uncover innovations in core technologies, and makes arrangements for emerging key technology proposals with strategic values in advance. Furthermore, TSMC expands the patent family by targeting key technologies, manages patent prosecutions by invention tiers, and sets patent filing goals based on annual R&D investments. TSMC's average patent/RD spend productivity from 2020 to 2022 was 1; that is, one U.S. patent application was produced by every US\$1 million of R&D investments, with a performance more favorable than the industry. The patent team has also designed a range of incentive systems, including awards for patent invention submission and an annual IP award ceremony. The Prolific Inventor Award recognizes

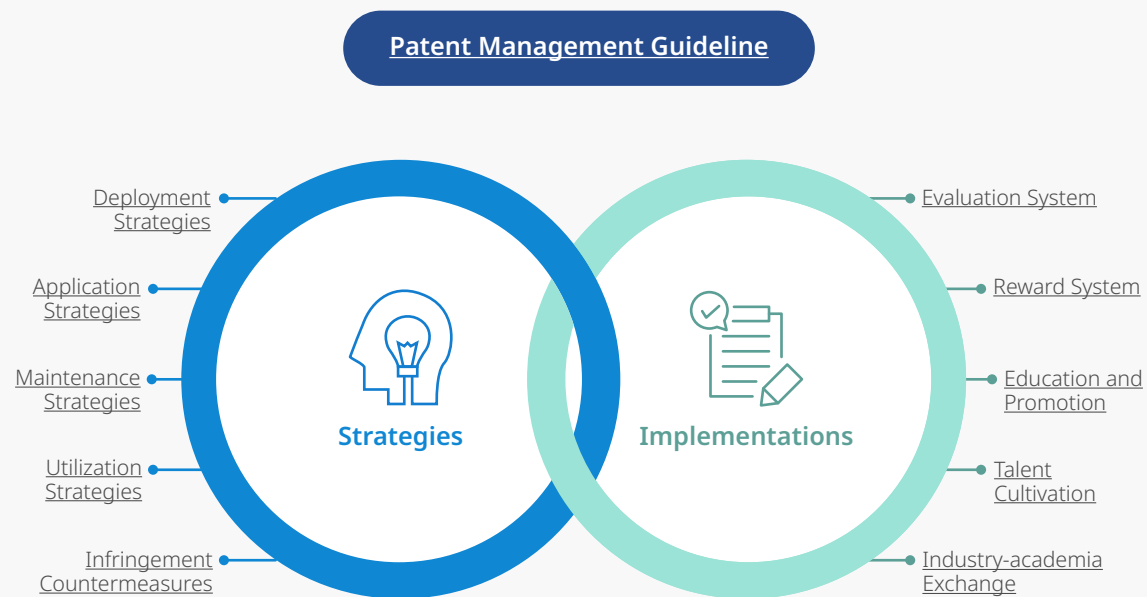
Exploratory R&D Patent Applications



employees who have received over 100 U.S. patents during their employment at TSMC. As of 2023, there have been 160 Prolific Inventor Award recipients, one of whom holds over 1,600 U.S. patents. A total of 594 U.S. patents have been issued from 434 employee inventors who received the New Inventor Award in 2023. In 2023, the patent team also launched a series of patent campaigns, including the Annual Patent Competition, from 1,772 invention submissions; 102 on-site education and training sessions to help employees ideate valuable patents; and the Online Patent Quiz, which saw the participation of around 2,200 employees.

In addition, TSMC continues to promote industry technology and IP upgrades and has been invited to attend the annual technology forum organized by the US Patent Office for ten consecutive years to give speeches on advanced semiconductor technologies and assist patent examiners in grasping patent technologies to strength the review quality and efficiency. Meanwhile, it also directed the IP strategy alliances for the industry's supply chain. TSMC also helps formulate and amend IP laws and provides suggestions on industry policies to help create a robust patent protection landscape.

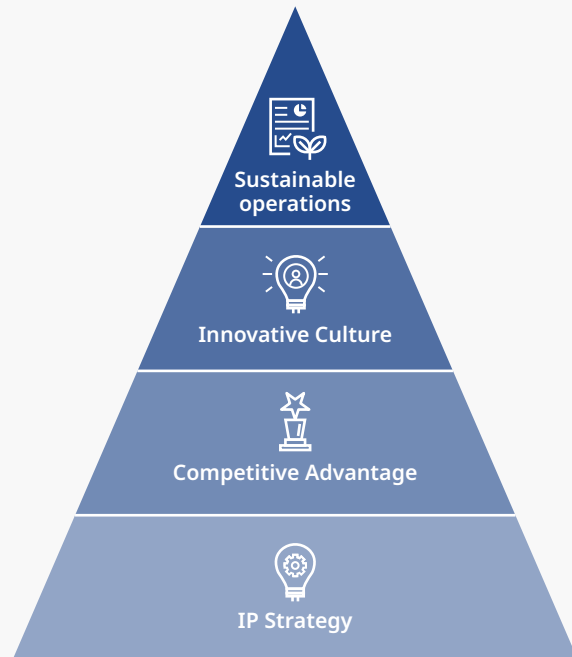
TSMC Patent Management Mechanism



Trade Secret

Trade secrets are technology or business innovations that contribute to the enhancement of corporate competitive strength that should be kept confidential. Driven by its four visions - IP Strategy, Competitive Advantage, Innovative Culture, and Sustainable Operations - TSMC adopts the registration and incentive systems to further improve its corporate operation and IP innovations. TSMC's trade secrets have been evolving with the times, with more than 340,000 trade secrets registered cumulatively as of 2023. TSMC also launched the Trade Secret Intelligent Management Version 2.0 - Innovation Talent Scouting Online Merge Offline Service (ITS OMO) to actively cultivate outstanding talents of trade secrets and inspire technical and sustainable innovations.

TSMC's Vision of Trade Secret Management Innovation



Trade Secret Awards Motivate Employees' Innovations

From 2013 to the end of 2023, 348,503 trade secrets were registered with TSMC cumulatively, and over 38,000 participating employees participated in the registrations. In 2023, the total number of trade secret registrations in a single year exceeded 100,000 cases for the first time, demonstrating incredible innovation capacity and potential. To recognize such fruitful registration achievements, TSMC presented Annual Golden Trade Secret Award to encourage outstanding inventions and innovations. As of 2023, a total of 2,738 Golden Trade Secret Awards were granted to 6,762 employees. In 2023, the "Best Contribution Award for Trade Secret Growth" and "Best Contribution Award for Trade Secret Proliferation" were specially presented to vice presidents to recognize their outstanding performance in their leadership of the R&D and manufacturing teams. Meanwhile, TSMC awarded the "Trade Secret Intelligent Management Version 2.0 Project Best Partner Award" to the IT director and fab director for their contributions in developing innovative

Trade Secret Milestones



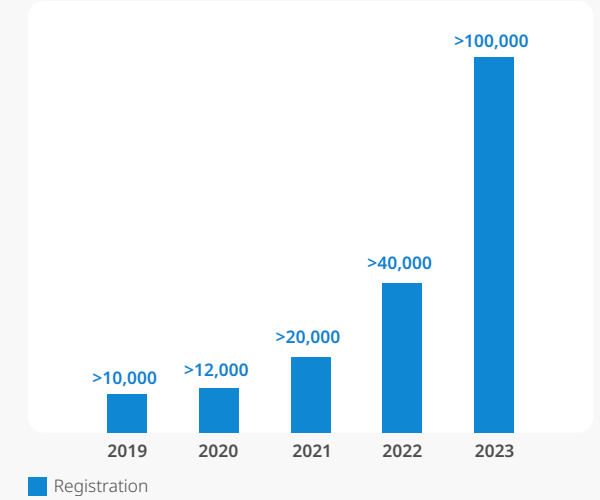
talent and elevating the quality and quantity of trade secret registrations.

Green Intellectual Properties Creates Co-prosperity with the Industry and the Environment

Green manufacturing is a bedrock for TSMC's sustainable operations. Through the promotion of a dedicated "Green Trade Secret Registration Section," TSMC encourages employees to develop more trade secrets that advance environmental protection technologies related to Climate and Energy, Water Stewardship, Circular Resources, and Air Pollution Control. In 2023, there were a total of 633 green trade secret registrations. The registrants were employees from not only facility organizations responsible for energy and water conservation but also from R&D and manufacturing departments, a rich and diverse assortment of green trade secrets. To provide incentives for green innovations, TSMC launched the "Green Trade Secret Award" and awarded 13 awards to a total of 62 employees in 2023; by recognizing employees'

innovation achievements, TSMC hopes that the green innovative culture continues to be deeply rooted in TSMC's daily operations.

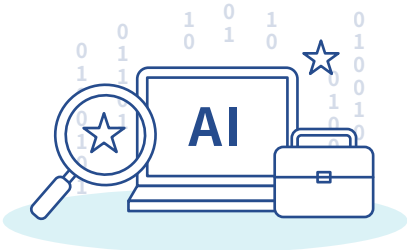
Trade Secret Registrations in Past Years



Case Study

Trade Secret Intelligent Management Version 2.0 Innovation for Talent Development

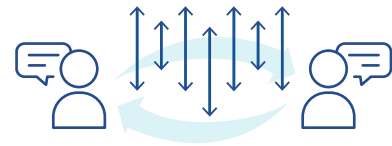
To develop prospective talent and enhance the innovative quality and quantity of our trade secrets, TSMC launched the Trade Secret Intelligent Management Version 2.0: [Innovation Talent Scouting Online Merge Offline Service \(ITS OMO\)](#) in 2023. TSMC successfully piloted the program in Fab 12B, Fab 15A, and Fab 15B. Eighteen inventors with innovative potential, selected by a talent scouting artificial intelligence (A.I.) system, received [one-on-one mentorship](#) from six colleagues with multiple Golden Trade Secret Awards serving as "Golden Coaches." In the future, the service will be implemented in other departments and fabs selected based on the system's analysis, and TSMC expects to develop 100 inventors with innovative potential annually. In addition, TSMC continues to develop its "Trade Secret Intelligent Management Strategy Center" to inspire innovations and implement intelligent management for trade secrets, so the targets of benefit generation and fraud prevention can be achieved.



Online

A.I. Talent scouting system

Analyze and identify departments with innovative potential and prospective inventors who have not received the Golden Trade Secret Award based on the trade secret registration innovation indices and inventor innovative indices



Offline

One-on-one exclusive mentorship

Select colleagues who have received multiple Golden Trade Secret Awards to be Golden Coaches to provide one-on-one mentorship for prospective inventors based on the registrations to improve innovation capacity

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The one-on-one mentorship provided by Coaches to inventors created more diverse innovation thinking, allowed the consideration of solutions from different perspectives, and further increased the scope of contributions, optimizing the content of the registered trade secrets.

Chi-Yang Lin
potential inventor of the pilot project

Intelligent Precision Manufacturing

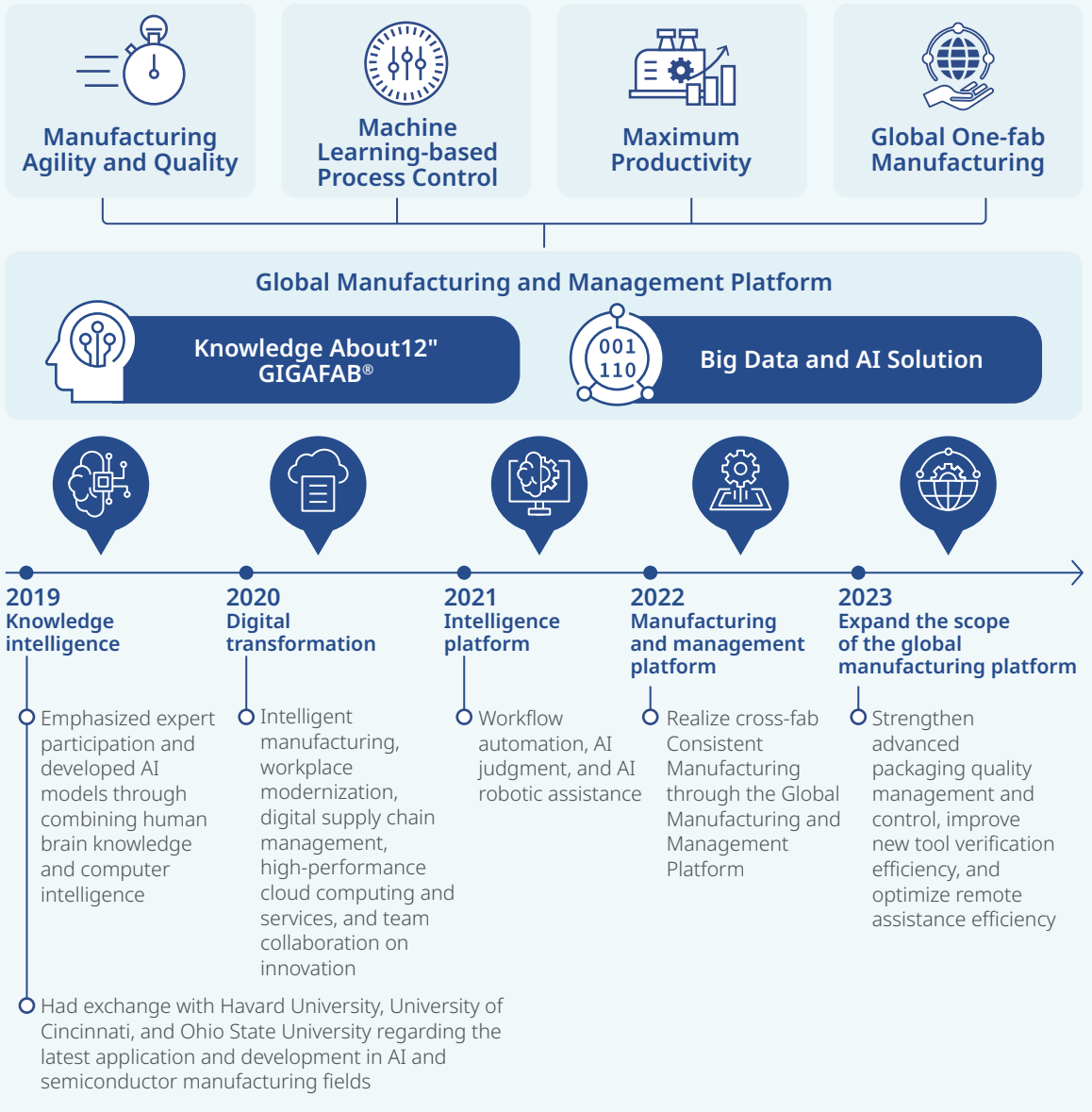
Intelligent precision manufacturing is the core of TSMC to realize manufacturing excellence. TSMC deployed the Global Manufacturing and Management Platform to ensure the implementation of four major strategies: Global One-fab Manufacturing, Machine Learning-based Process Control, Manufacturing Agility and Quality, and Maximum Productivity. By doing so, it ensures consistent operating efficiency and product quality and becomes a reliable technology and production capacity provider in the global semiconductor industry in the mid-to-long-term. In response to the global deployment of TSMC and challenges arising from global climate change and energy consumption, in 2023, TSMC further enhanced the operation of Precise Process Control, Consistent Manufacturing, and Optimize People Efficiency to continue injecting growing momentum for intelligence production.

For Machine Learning-based Process Control, TSMC continued to reinforce the process capacity of its advance packaging fabs. Comprehensive production history is available for inquiries and failure analysis from wafers to dies in the backend packaging process, and intelligence detection, intelligence diagnosis, self-feedback, and other system functions are established to minimize human error to realize precision process control. For Manufacturing Agility and Quality, it introduced a new tool testing platform and improved the testing efficiency of over 2,800 new tools in the 3nm process. Meanwhile, simultaneously comparing over thirty quality defense systems, TSMC set the same tool parameters and quality specifications for control to ensure the consistent setting and tool performance, which enhanced operating efficiency and improved the cycle timetable for new tools to be put into mass production. For Global One-fab Manufacturing, TSMC deployed the cross-sector Global Manufacturing and Management Platform that is beneficial for communication and cooperation to complete the 32 intelligence system development of the [fab process](#), covering fabs in Taiwan and abroad, which effectively increased productivity.



Comprehensive production history of wafer-to-die

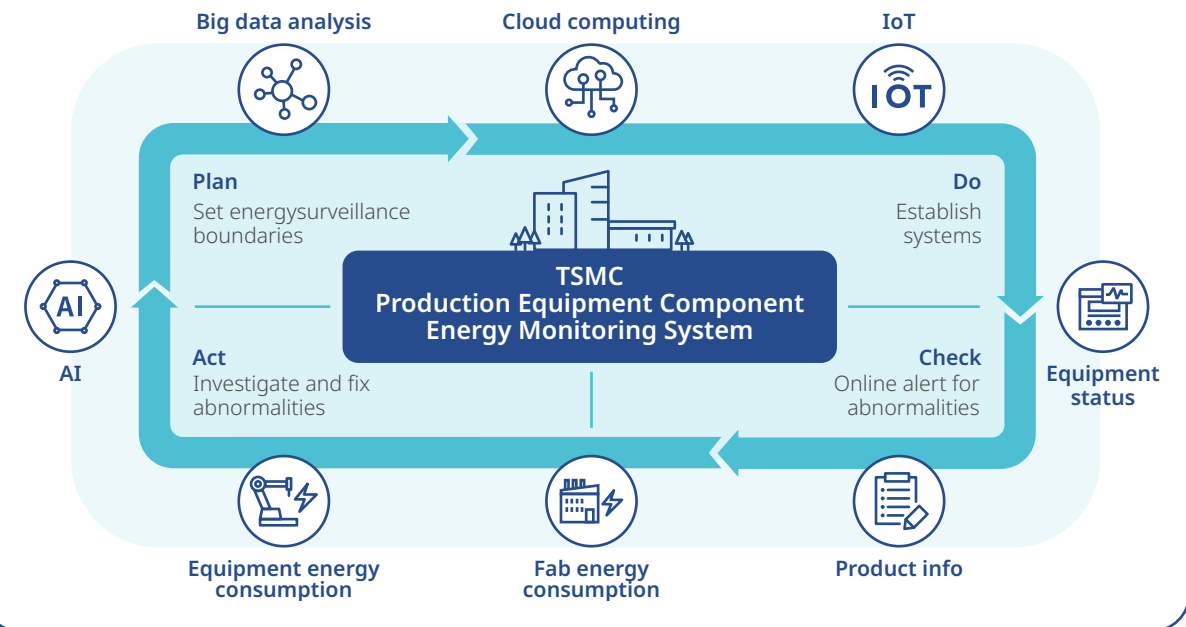
12" GIGAFAB® - Manufacturing Excellence



Case Study

Precision Monitors the Power Consumption of Production Equipment Components to Save 0.94 Million kWh

To improve the energy efficiency of production equipment components, TSMC build its Production Equipment Component Energy Monitoring System in 2023. It utilized IoT technologies to integrate cross-sector information for a platform of transparent information. The system analyzes and calculates the efficiency indicators by adopting Big Data for cross-tool and cross-unit power consumption details to identify whether the tools have circumstances such as an increase in power consumption or poor power conversion rate due to aging, effectively grasping power efficiency and changes in trends. It is also capable of calculating the energy-saving benefits for tool repair and maintenance and component improvements. EUVs, the most advanced semiconductor Lithography (LIT) tool, for example, the equipment department completed the acceptance of four component improvement plans through the Production Equipment Component Energy Monitoring System in 2023, which passed the energy-saving management plan certification under the Total ESH Management of TSMC, saving a total of 0.94 million kWh of power. In the future, the Production Equipment Component Energy Monitoring System will continue to be introduced to global fabs to implement green manufacturing.



Open Innovation Platform

In today's rapidly evolving global technology landscape, Artificial Intelligence (AI), High Performance Computing (HPC), Autonomous Driving, and Mobile Devices are major areas continuously driving the advances of semiconductor industry, influencing people's perception, affecting usage models in computing as well as its potential new applications. TSMC has been enabling innovation through its Open Innovation Platform® (OIP) that encompasses Electronic Design Automation (EDA) alliance, Intellectual Property (IP) alliance, Design Center Alliance (DCA), Cloud Alliance, Value Chain Alliance (VCA) and 3DFabric™ Alliance. The Company collaborates closely with all OIP partners, integrating the cross-industry expertise, accelerating the creation of innovated solutions to meet the customer's technical requirements. As a result, these partnerships have facilitated to realize differentiated new values that are brought by their implementation of products & services.

TSMC hosted the OIP Ecosystem Forum in 2023, celebrating 15 years of collaboration and innovation with OIP partners. As the industry shifts toward embracing 3D IC and system-level innovation, the need for industry-wide collaboration has become even more essential. Since the inception of OIP, TSMC has established an entirely new paradigm of collaboration. Through the development of Design Technology Co-Optimization (DTCO), we jointly deliver solutions with OIP partners, bringing together the creative thinking of customers and alliance partners to lower design challenges and accelerate product design turnaround time to the market in the face of ever-increasing demands and semiconductor design complexity. Along with the advancement of silicon process technology, TSMC has been actively improving power, performance, and area (PPA) in customer chip level products. OIP ecosystem is also expanding its scope to memory, substrate, testing, manufacturing, and packaging integration, enabling a broader range of collaboration model towards System Technology

Co-Optimization (STCO) for elevating customers' products performance and power efficiency.

TSMC's OIP ecosystem has been making continuous improvement over the past 15 years with over 110 partners across six alliances to help customers navigate design challenges in leading-edge logic processes, advanced 3D IC chip stacking solutions, and specialty technologies such as analog, RF (radio frequency), and silicon photonics. As of 2023, TSMC's IP Alliance has grown from 25 partners to 39. Those partners have been working closely together to expand libraries and silicon IP portfolio from 1,500 to more than 73,000 IP titles, supporting a wide range of design applications. The same applies to the EDA alliance with more than 48,000 technology files and over 3,400 process design kits from 0.5 micron to 2 nanometer. Together with certified EDA tools & features, these deliverables help to timely support customer's latest innovation in semiconductor designs.

Furthermore, TSMC hosted three 3DFabric Alliance Workshops in 2023 at domestic and overseas locations to share 3DFabric technology applications and the 3Dblox Standard to enhance design efficiency, discuss 3D IC design challenges and ways alliance partners can collaborate to address them by developing solutions to improve system level design productivity. Through the accomplishments achieved by the OIP partnership, helping TSMC's customers to overcome technological obstacles and create innovative products that have fostered the relentless growth of the global technology trend.

TSMC's Six OIP Alliances

TSMC brings together the creative thinking of customers and partners across the diverse OIP alliances, with the goal of reducing design barriers and improving first-time silicon success, minimizing design cycle time, accelerating time-to-market, and shortening time-to-volume and time-to-revenue.

2023 Major Achievements of TSMC's Six OIP Alliances

IP Alliance

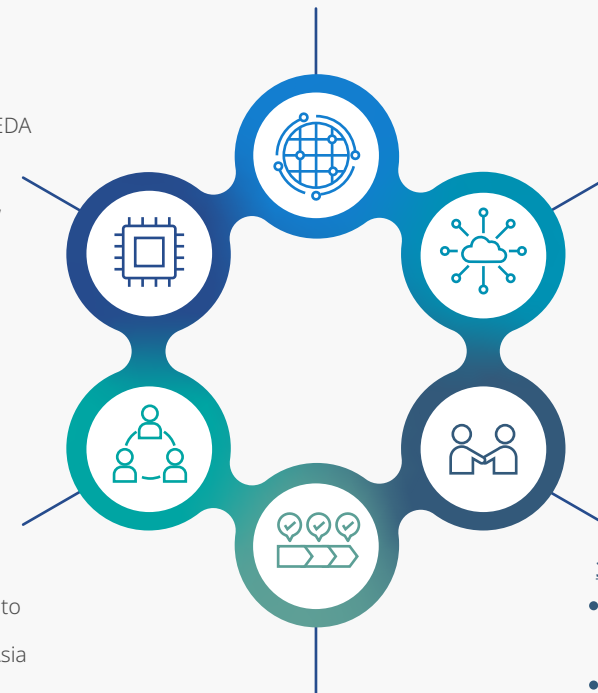
- Enabled IP partners to build up N3E and N3P IP to strengthen TSMC's IP portfolio
- Added additional IP Alliance members in analog IP and foundation IP
- Enabled a 3DFabric test chip process for IP partners to validate their 3D IC IP

EDA Alliance

- Released six Design Reference Flows through collaborations with major EDA Alliance partners
- Certified EDA tools for the following technologies: N2, N3E, N3P and 3DFabric

Cloud Alliance

- The first time to collaborate with two Cloud Alliance members to utilize Cloud's dedicated HPC infrastructure to effectively accelerate the physical analysis of mechanical stress and simulations on multiple chips without sacrificing accuracy, while ensuring high-quality 3D IC designs



Design Center Alliance

- Added three new partners to expand design service support for customers in Asia and European regions

3DFabric™ Alliance

- Added three new partners with expertise in EDA, IP, and substrate for collaboration
- Enhanced 3Dblox features to support system prototyping and design reuse

Value Chain Alliance

- Flexible ASIC (Application Specific Integrated Circuit) Service model from design-in to mass production, enable 900+ fabless customers, system customers and 3D Fabric business
- Enable customer adoption in advanced technology by the first N3 CoWoS test chip

Comprehensive Ecosystem Design Solutions

At the 2023 TSMC Technology Symposium and OIP Ecosystem Forum events, a set of design solutions was unveiled jointly with OIP alliance partners, to address the market demands for mobile, high-performance computing (HPC), automotive and IoT applications. To recognize the outstanding support and collaborative achievements of TSMC's OIP ecosystem partners, the Company granted 15 awards to EDA partners, six awards to IP partners, one award to Cloud partner, and one award to 3DFabric Alliance partner. The respective awards were granted for their contributions to accelerating semiconductor innovation according to specific collaboration areas in 2023.



Advanced Technology

- Comprehensive 3nm family offers N3E, N3P and N3X with improvements in both speed and density
- Major N3E & N3P EDA tools are certified, and IPs are ready for customer's adoption
- N3AE (Auto Early) leverages N5A design rule and learning, with pull-in schedule to enable early automotive design start
- N2 nanosheet technology offers full-node performance and power benefits with major EDA tools and foundation IPs are ready for design start



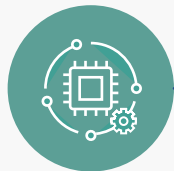
Analog Cell

- Analog cell with structured layout and better yield that boosts analog design productivity
- Parameterized cells are offered with flexible transistors to facilitate migration and improve productivity
- Full analog migration coverage from N40 to N2 will be enabled
- EDA tools are ready to support analog migration



3DFabric™ Alliance

- Collaborates with new partners to lower 3DIC design barrier and accelerate adoption of ecosystem solutions
- Facilitates multi-way collaboration among partners in design enablement and productivity improvement



3Dblox Standard

- New EDA 3D IC integration hubs comprehend 3DFabric™ and 3Dblox Standard design language to execute die and package implementation and multi-physics analysis
- EDA tools are ready to support 3Dblox Standard
- TSMC 3DFabric™ Kit includes design flows, technology files and documentation that supports designs for 3DFabric™ technologies of CoWoS®, InFO, and TSMC-SoIC®



2023 TSMC OIP Ecosystem Forum

Enhance Industry-academia Collaboration

The semiconductor industry in Taiwan represents a crucial position in the global semiconductor supply chain, leveraging its comprehensive industry value chain and leading wafer manufacturing technologies. Facing international competition and increasingly complicated process development, the industry has increased the demand and expectations for finding the right talents. Talent development is a part of the [five TSMC ESG directions](#), and TSMC has been diligently working on long-term campus collaboration programs based on three areas - Course Collaboration, Industry-academia Collaboration, and Career Guidance - to develop semiconductor talent.

Course Collaboration refers to the collaboration between TSMC and multiple universities and high schools for semiconductor-related courses, including Semiconductor Curriculum Programs, the Academic Design Foster Package (ADFP) for FinFET, Campus Information Cultivation Project, and TSMC High School Semiconductor Mini Courses to provide students with semiconductor knowledge close to the industry and implement the connection between learning and applying.

Industry-academia Collaboration includes the University Research Center, Industry-academia Joint Development Project, TSMC University Shuttle Program, National Academy for Key Fields of Research, and multiple projects to work with the industry and academic sectors in jointly developing future talent.

TSMC's Career Guidance covers the Elite Camp, TSMC Ph.D. Scholarship, TSMC Girls in STEM Program for High School, and Operations Equipment Star Program. The Company hopes to give students further insight into the future trends and development of the semiconductor industry through a wide range of events to broaden their horizons and improve their interest in investing in the semiconductor field and, in turn, improve the key talent traits and R&D capacity of the semiconductor industry in Taiwan.

TSMC University Collaboration Programs



Course Collaboration

Semiconductor Curriculum Programs

In 2019, TSMC worked with domestic universities to launch Semiconductor Curriculum Programs. Six majors are offered, including components/integration, processes/modules, equipment engineering, advanced packaging, intelligent manufacturing, and advanced circuit design, which define professional knowledge and capacity for semiconductor talents and the blueprint of programs

FinFET Academic Design Foster Package (ADFP)

In 2022, TSMC launched the ADFP for the N16 process to assist universities in upgrading their advanced circuit design education and bridge the gap between job skills and education

Campus Information Cultivation Project

In 2020, TSMC promoted comprehensive digital transformation. The Company worked with schools to develop information education and attract excellent students to join the digital transformation of semiconductor manufacturing, creating its talent ecology system

TSMC High School Semiconductor Mini Courses

Starting out from the perspective of popular science education, TSMC launched the [Semiconductor in Our Life](#) in 2022 by adopting a blended learning model to help students better understand the importance of semiconductors in daily life and in technological development



Industry-academia Collaboration

University Research Center

In 2013, TSMC collaborated with [four](#) Taiwan national universities in establishing the University Research Center to encourage university professors and students to come up with innovative semiconductor research projects and commit to developing advanced technologies, actively cultivating semiconductor research talent

Industry-academia Joint Development Project

In 2005, TSMC launched the Industry-academia Joint Development Project to encourage professors to conduct research on advanced semiconductor technologies and provide opportunities for students to participate and learn from practical experiences and, in turn, join the semiconductor industry

University Shuttle Program

Provide a physical chip validation platform to assist university faculties and students worldwide in transforming IC designs into physical chips free of charge and validate designs, applications, and terminal performances

National Academy for Key Fields of Research

In 2022, TSMC took on a greater role in supporting [six](#) universities in Taiwan to establish their own National Academy for Key Fields of Research and continued to provide funding to support cutting-edge research and talent cultivation for the semiconductor industry



Career Guidance

Elite Camp

In 2011, TSMC started to organize the Elite Camp to improve students' understanding of the importance of the semiconductor industry, create an open platform to facilitate the interaction between the academic sector and the industry sector and encourage student participants to work in the doctoral-degree research in the semiconductor field

TSMC Ph.D. Scholarship

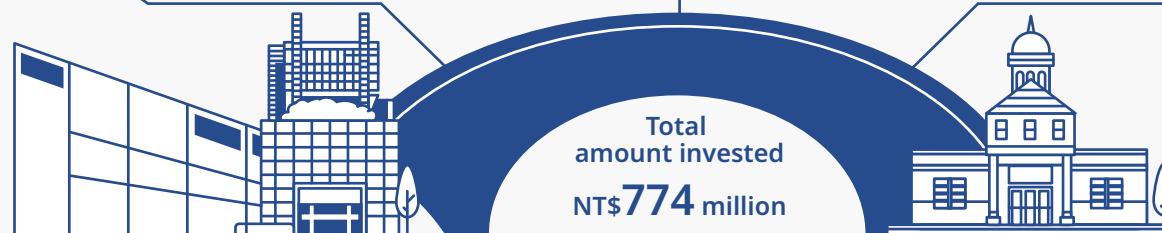
TSMC launched a Ph.D. Scholarship in 2020 as an incentive for elite students to pursue doctoral degrees in scientific specialties related to the field of semiconductors to continue promoting the development of advanced technology and manufacturing excellence

TSMC Girls in STEM Program for High School

In 2020, TSMC hosted the TSMC Journeys of Female Scientist Lectures and held career lectures titled Lean in and Achieve a Better Version of Yourself to allow female students to learn the challenges and fun in the science field to serve as the backup forces of the semiconductor industry

Operations Equipment Star Program

Operations Equipment Star Program launched by the Facility and Human Resources Organizations won the recognition of AMAZING IDEAS under the TSMC ESG AWARD in 2022, and the project was initiated in 2023 to help students in vocational high schools understand the practical knowledge and skills for semiconductor equipment field



Course Collaboration

Semiconductor Curriculum Programs

TSMC worked with Taiwan domestic universities to launch Semiconductor Curriculum Programs to build a solid foundation of scientific principles. In 2023, National Chung Cheng University, Fengchia University, Yuan Ze University, and Chung Yuan Christian University were added as TSMC's partners. There was a total of 13 schools that work with the Company for up to 44 cooperating programs, and over 6,300 students have enrolled in those programs. TSMC also worked with eight universities and assigned the Company executives to teach two courses at those schools, Semiconductor Technology - Process & Equipment and Semiconductor Intelligent Manufacturing Systems, providing students insight into the latest knowledge and practice. There were over 950 students enrolled in 2023. TSMC has made internal training resources available to students enrolled in TSMC Semiconductor Curriculum Programs at various universities and students can visit the TSMC Newcomer Training Center to study. In 2023, the Company also expanded its collaboration to non-partner schools to foster future talent.

FinFET Academic Design Foster Package (ADFP)

To foster alignment between educational design environment and cutting-edge semiconductor technologies, TSMC has launched the Academic Design Foster Package (ADFP) based on its 16nm FinFET technology. This initiative aims to assist universities in enhancing their Very-Large-Scale IC (VLSI) design education, facilitating transition from conventional planar processes to FinFET technology in collaboration with its OIP ecosystem Partners. As of 2023, ADFP has been successfully granted to 105 universities worldwide, with over 186 professors authorized to integrate it into their courses, benefiting students of more than 2,000 attendance. In conjunction with the TSMC University Shuttle Program for N16 and N7 processes, the Company aims to evolve it into a global talent incubation platform for FinFET design, dedicated

to both education and research.

Campus Information Cultivation Project

TSMC realized smart fabs and modernized workflow through AI, Cloud Native, and other technologies, driving the comprehensive digital transformation. To pioneer in information education, TSMC cooperated with the Department of Computer Science of National Yang Ming Chiao Tung University to launch the three-credit Cloud Native Software Development and Best Practices post-graduate program. As of 2023, two sessions were conducted through the efforts of 62 executives of IT organizations and employees, and 257 students participated in the programs. The Cloud Native program was introduced to the National Taiwan University in September 2023 for the fall semester.

TSMC High School Semiconductor Mini Courses

To inspire high school students' interest in science and semiconductors, TSMC collaborates with university professors and high school teachers in developing the semiconductor mini course Semiconductor in Our Life to enrich students' basic semiconductor knowledge by adopting a blended teaching model. As of 2023, the mini courses were introduced to ten high schools, and there were 512 participants in total. In 2023, TSMC organized the first high school summer camp and invited the Semiconductor Mini Courses students to the camp. The camp offered lectures on industry advanced processes and prospects, and group workshops were also performed to nurture teamwork capacity and improve students' learning will and self-efficacy. TSMC also launched the Trainer Program, which offers two sessions of in-person training workshops each year to improve the teaching quality of high school teachers.

Industry-academia Collaboration

University Research Center

To encourage the academic sector to invest in advanced semiconductor research, TSMC worked with National Taiwan University, National Cheng Kung University, and

National Tsing Hua University to establish graduate institutes that are committed to developing cutting-edge technologies in semiconductor materials, components, materials, processes, and chip design, and foster semiconductor researchers. As of 2023, a total of 295 professors and over 3,871 top students have joined the research centers to continue promoting the progress of semiconductor technologies and innovations. TSMC collaborated with eight world-leading universities abroad, launching international research projects to provide drivers for the development of semiconductor technologies.

Industry-academia Joint Development Project

TSMC worked closely with multiple renowned universities in Taiwan for various industry-academia projects to encourage university professors to participate in emerging semiconductor components, processes, materials, equipment, packaging technologies, IC designs, and other semiconductor research fields. In 2023, the Company added two new topics, Green Manufacturing and Circular Economy, and Special Process Technology to work on, and launched 296 industry-academia joint development projects, with 245 professors from ten Taiwan universities and 19 overseas universities participated. Since 2013, these industry-academia joint development projects have resulted in 286 patent applications in the U.S.

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Through the effective teaching of the TSMC instructors, we were able to observe the machine structure and operate it in practice, which has been very helpful for us to apply what we have learned in the future.

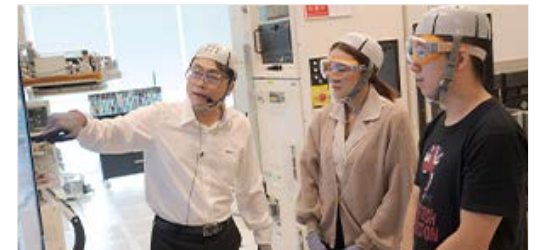
Shu-Wen Yang

A Graduate Student in the Department of Mechanical Engineering at Taiwan National Central University

Case Study

Release the Resources of Newcomer Training Center to Accelerate Industry-Academy Connection

To encourage students to join the semiconductor industry after graduation, corporate trainers at TSMC's Newcomer Training Center designed two courses, Semiconductor Technology - Process and Equipment and Semiconductor Intelligent Manufacturing Systems. They were made available for students in the Semiconductor Curriculum Programs to study for free in 2022. In 2023, the scope was further expanded to science and engineering-related departments at four non-partner schools. Professional insights from corporate trainers at the Newcomer Training Center and the opportunity for hands-on practice with real tools enable students to integrate theory into practice and learn about the latest semiconductor processes and tools. At the end of 2023, a cumulative 42 sessions were offered at the Newcomer Training Center, assigning 1,398 executives to teach those courses and helping 3,011 students pass academic and skill certification, contributing to the talent cultivation of the industry.



TSMC's "Newcomer Training Center" additionally offers courses to university students, strengthening the competitiveness of semiconductor talent

University Shuttle Program

In 2023, TSMC worked with professors and students from 18 of the world's top universities through the University Shuttle Program to realize IC circuit designs and validate the performances. Universities in Japan joined the program for the first time, expanding TSMC's scope of global talent cultivation. In 2023, 57 papers were published on 5G and wireless communication, high-speed wireline communication, electron components, electrical engineering, AI, safety applications, radar applications, and IoT, with 16 of those papers being published in esteemed journals or at renowned conferences such as the IEEE Journal of Solid-State Circuits and the International Solid-State Circuits Conference (ISSCC), often touted as the IC Design Olympics.

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On the path to the shrine of wisdom, I extend my deepest appreciation to the companionship of TSMC's University Shuttle Program, and I hope to provide mutual support in the fields of talent cultivation and electron component innovations to jointly contribute to the semiconductor industry in the future.

Ya-Chin King

professor of the Department of Electrical Engineering and Institute of Electronic Engineering, College of Electrical Engineering and Computer Science, National Tsing Hua University

I appreciate TSMC's University Shuttle Program that provides abundant chip manufacturing resources and allows me to learn comprehensive knowledge of chip design and offline procedures, so I can quickly get up to speed after joining the company.

Yun-Han Lee

master's student at the National Taiwan University, currently a Design and Technical Platform engineer

National Academy for Key Fields of Research

To support the Ministry of Education's National Key Fields Industry-University Cooperation and Skilled

Personnel Training, since 2022, TSMC has been supporting National Taiwan University, National Cheng Kung University, National Tsing Hua University, National Yang Ming Chiao Tung University, National Sun Yat-sen University, and National Chung Hsing University to establish semiconductor or key technology graduate institutes. In 2023, TSMC continued to invest at least NT\$200 million in funding to support cutting-edge semiconductor research, and it also plans to launch a scholarship to encourage students who wish to join the research in the semiconductor field and cultivate top R&D talent.

Key Academic Collaborators and Research Topics in 2023

National Taiwan University	University of California, Los Angeles
National Tsing Hua University	University College Dublin
National University of Singapore	University of Texas at Austin

Note: Universities are listed in alphabetical order

Career Guidance

TSMC Ph.D. Scholarship and Elite Camp

To continue improving the overall semiconductor industry technologies, science researchers with doctoral degrees are necessary and important assets. TSMC launched a Ph.D. Scholarship as an incentive for elite students to pursue doctoral degrees in scientific specialties related to the field of semiconductors and nurture science researchers with doctoral degrees. In 2023, 32 additional students received the scholarship. As of 2023, 107 Ph.D. students have benefited from the scholarship, and two of them have already obtained a Ph.D. degree. Also, the Elite Camp encouraged students to pursue Ph.D., with 84 students participated in 2023 and the overall program satisfaction rate had reached to 90% or above.

TSMC Girls in STEM Program for High School

TSMC actively cultivates female semiconductor talent and inspires female students' interest in the science field for them to pursue tech careers through the promotion of the TSMC Girls in STEM Program for High School, with 3,627 female students participated in 2023. The TSMC Education and Culture Foundation also launched the 7th Female Scientist Journey, attracting 1,387 female students to participated in 19

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During the career lecture, I remembered that I was always curious and enthusiastic about science experiments in high school. Through sharing experiences and encouraging students to pursue their dreams and deem STEM as their career goal, I hope to jointly facilitate technology development with TSMC in the future.

Li-jin, Hong

alumna of Sheng Kung Girls' High School and currently the executive of the 3D IC Integration Division

semiconductor education-related activities. TSMC also continued to hold career lectures titled Lean in and Achieve a Better Version of Yourself. Apart from introducing the trends in the semiconductor industry, the lectures also invited female employees and alumni to share information on their workplace and work content in the tech field, encouraging female students to dare to challenge themselves. In 2023, lectures for ten schools were completed, with a total of 2,240 female students participated, fostering more female talent in the technology sectors.

Operations Equipment Star Program

To cultivate semiconductor equipment and tool upgrade, and facility expertise talent, TSMC launched the "Operations Equipment Star Program" in 2023 and collaborated with three technical and vocational high schools to help students understand work related semiconductor equipment and facilities during the studying stage and cultivate their practical skills required to become equipment and facility engineers through scholarship/fellowship, corporate visits, and seminars, expanding the talent pool of the industry and hoping that they will join the semiconductor field to drive the technology development together. 111 students received the scholarships in 2023.



TSMC organizes the seminar for the Equipment Starlight Program at Hualien Industrial Vocational Senior High School