

P41. Green product development

Rewards for improvement proposals reached 207 cases, showing that employees adapted well to the culture of work improvement.





Strategy and Performance of Material Topics



R&D and Innovation

- Strategy**
- Design new next-generation products
 - Entered the high-density server module market
 - Develop 10nm process technologies
 - Smart factory

2022 Goals	2021 Goals	2021 Performance
Complete the verification of 10nm DRAM technology for product shipment	Complete the verification of 10nm DRAM technology for product shipment	● Complete the verification of 10nm DRAM process and component technology reliability
Cultivate a total of 400 engineers with AI theories and development capabilities	Cultivate a total of 400 engineers with AI theories and development capabilities	● Cultivate a total of 350 engineers with AI theories and development capabilities
Complete 90 items for AI application development	Complete 70 items for AI application development	● Complete 70 items for AI application development



Eco-friendly products

- Strategy**
- Technology improvements: Research and develop advanced and highly efficient products to assist consumers in lowering energy consumption and reducing carbon emissions during the usage of products
 - Consider product life cycle: Improve the environmental friendliness of products on the environment
 - Hazardous substance management: Continue to promote replacement plans for substances in the production process

2022 Goals	2021 Goals	2021 Performance
Ratio of 20nm and other advanced processes accounted for 88% and above	Ratio of 20nm and other advanced processes accounted for 84% and above	● 86.9%
Complete product life cycle inventory on 100 percent of products	Complete product life cycle inventory on 100 percent of products	● 100%
100 percent of products conform to hazardous substance free regulations and customers' specifications	100 percent of products conform to hazardous substance free regulations and customers' specifications	● 100%
100 percent of materials contained zero perfluorooctanoic acid (PFOA) or related substances	100 percent of materials contained zero perfluorooctanoic acid (PFOA) or related substances	● 100%

● Exceeded ● Achieved ● Partially achieved



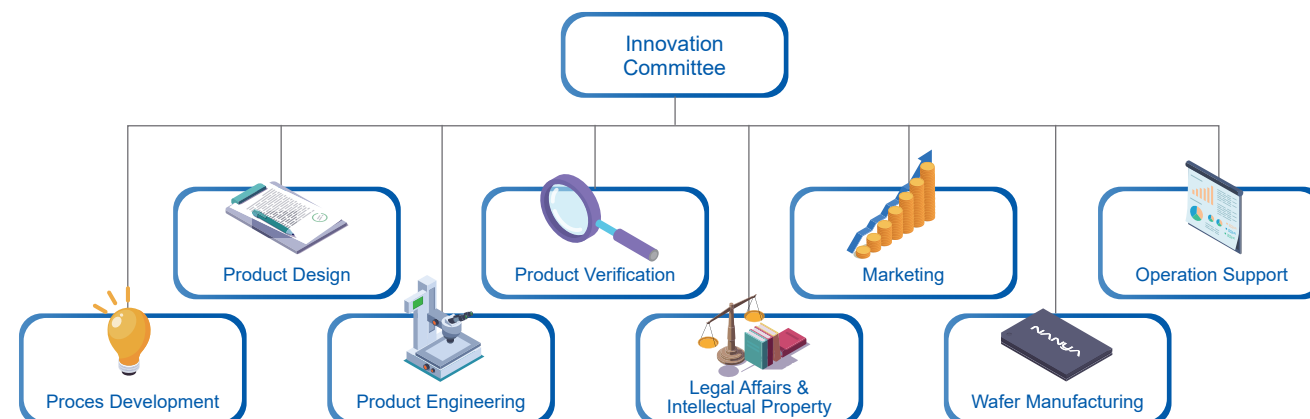
R&D and Innovation

R&D and Innovation

Smart products have been completely improving the quality of life for human beings and helping energy conservation and carbon reduction. Therefore, every year, Nanya invests large amounts of resources in technological development of new types of DRAM products, next generation processes, and advanced 3D stacked packaging. The developments provide customers with value-added services, and reinforces protection for intellectual property and trade secrets, accelerating the move towards product diversification and smart factories. Moreover, we have set a vision for innovative development to introduce the second generation 10nm DRAM process into mass production in 2025, develop the third generation 10nm DRAM process and the next-generation DDR5 and LPDDR5 products, and manufacture 16Gb high density products at large scale so as to enter fast-growing markets (artificial intelligence (AI), data centers, automotive and the Internet of Things), and set up high-efficient production lines with an AI-aided system.

► Innovation Committee

In order to implement innovation management, create a culture of innovation, and enhance the company's innovative energy and value, Nanya especially set up the Innovation Committee, a cross-departmental unit, formed by the senior management and chaired by Executive Vice President (EVP). The Innovation Committee is positioned to coordinate and plan the overall innovation strategy, setting short, medium and long-term goals. The committee holds regular meetings to review the progress of various major projects. In 2021, we completed the reliability verification of 10nm DRAM process and component technology, and also completed the design of two 10nm DRAM products at the same time. As for AI, we cultivated a total of 350 engineers with AI theories and development capabilities, and developed 70 AI applications between 2019 and 2021.



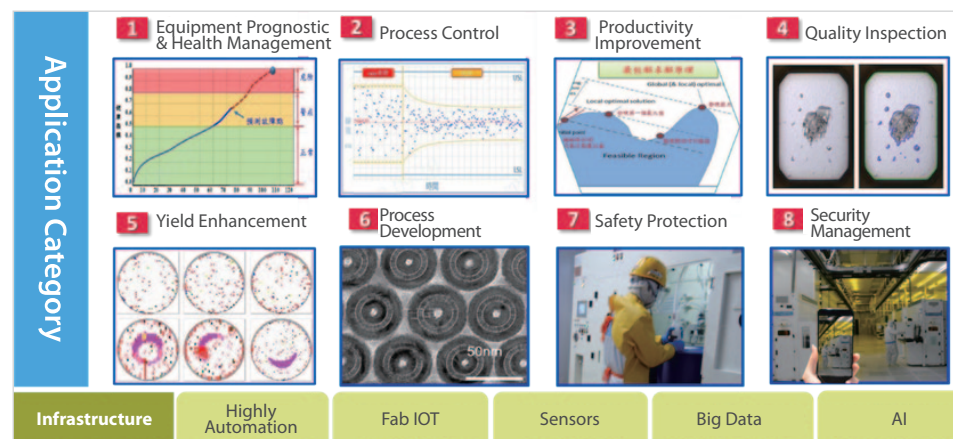
Nanya Smart Factory

Smart Factory Framework and Applications

Nanya's 12-inch fab has all essential infrastructure that a smart factory requires, including highly automated production lines, Fab IoT, large numbers of sensors, and big data integration. The fab utilizes AI technology in eight important categories, including equipment prognostic & health management, process control, productivity improvement, quality inspection, yield enhancement, process development, safety protection, security management.

Currently, Nanya has developed several innovative production line applications, including the machinery diagnosis, advanced process control, optimization of production schedules, wafer quantity prediction, smart handling, wafer probe testing, defect image recognition, and wafer pattern recognition. These applications can effectively enhance overall operation efficiency, and make important contributions for manufacturing key indices - Yield, Quality and Output.

NTC AI Application Category



AI Development Benefits and Promotion

As of the end of 2021, Nanya completed the development of 70 AI applications that can improve product yield and quality, reduce manufacturing abnormality, increase machine utilization, lower equipment maintenance costs and raw material consumption, increase production capacity and flexibility, and more effectively use human resources. Annual benefits reach NT\$330 million. As we continue to develop new AI applications, we expect annual benefits to increase by 10% each year, and the total amount of benefits in the next 5 years to reach NT\$2 billion.

Innovation and promotion are mainly carried out through three major platforms – AI application development, AI technology research, and AI education.

AI application development platform

Integrated 60 engineers, including field experts, IT experts, and statistics experts, to plan the development of highly efficient smart systems.

AI technology research platform

Strengthened the AI team's technical capabilities, and systematically implemented machine learning, deep learning (CNN, RNN, object detection), and edge computing technologies.

AI education platform

AI training courses were conducted by internal and external instructors, and trained a total of 350 engineers with AI theories and practical technical abilities.

CNN : Convolutional Neural Networks
RNN : Recurrent Neural Networks

Investment in Innovative R&D

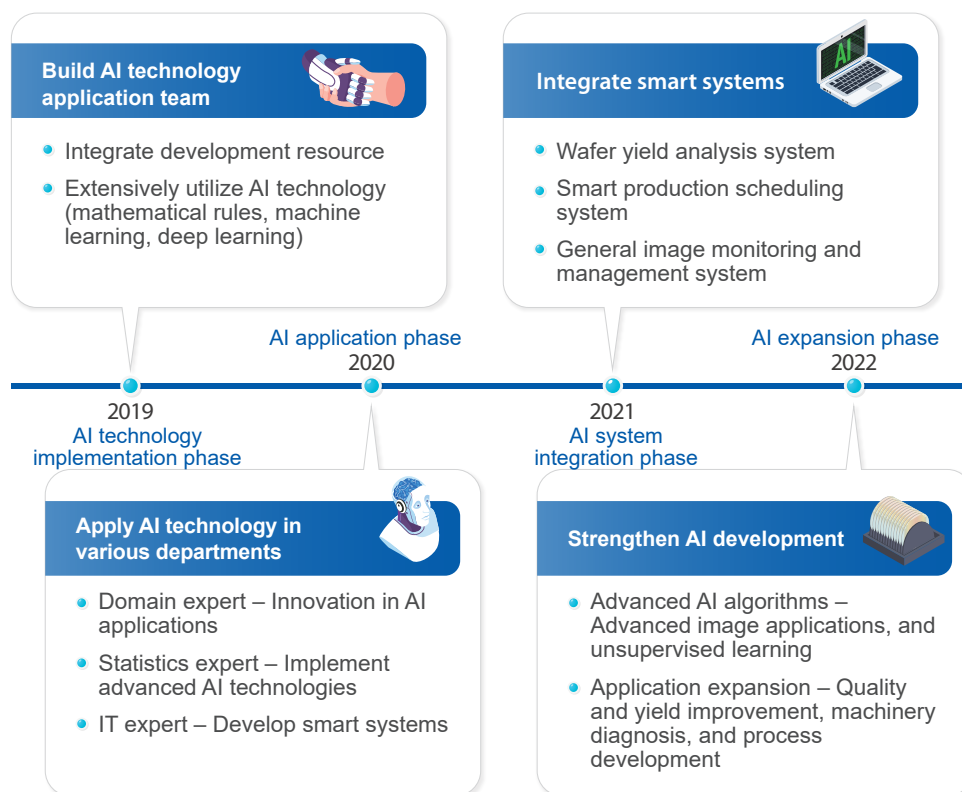
	2021	2020	2019	2018
Operating revenue (A) NT\$100 million	856	610	517	847
R&D and innovation expenses (B) NT\$100 million	74.9	51.4	49.3	48.9
R&D expenses as a percentage of operating revenue (B/A)	8.8%	8.4%	9.5%	5.7%
Total number of employees (C)	3,554	3,542	3,307	3,219
Total number of R&D personnel (D)	953	922	639	501
R&D personnel as a percentage of all employees (D/C)	26.8%	26.0%	19.3%	15.5%

Output of Innovative R&D

	2021	2020	2019	2018
Number of patents awarded	465	438	459	502

► AI Application Development Planning

Nanya's development plan was to build an AI technology application team in 2019, gradually implement AI technologies in the work scenes of different department starting in 2020, and link together smart systems, such as the wafer yield analysis system, smart production scheduling system, and general image monitoring and management system in 2021. In order to create synergies through AI and allow production lines to operate more efficiently, we continue to strengthen AI development in 2022, adopt advanced AI technologies and expand more AI applications to various departments. With that, Nanya can comprehensively improve overall manufacturing performance.



Status and Strategy of Intellectual Property

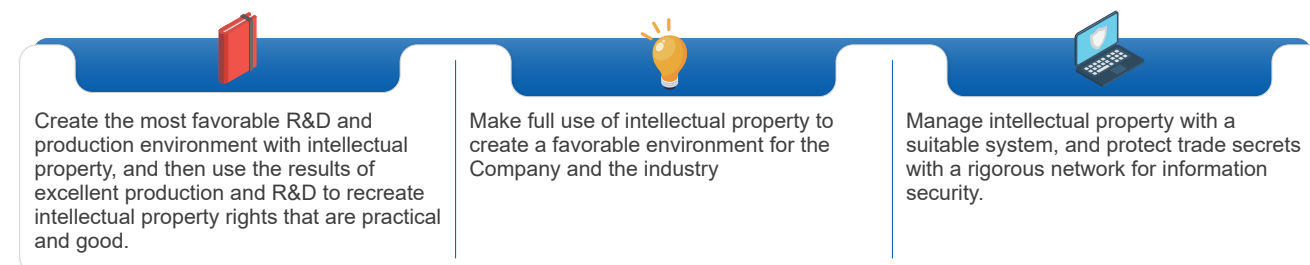
Besides working with world class talent to adopt advanced technologies, Nanya has spared no effort in the development of proprietary technologies, and has accumulated considerable intellectual property over the years. As of the end of 2021, Nanya has accumulated over 5,000 patents, protecting technological development results and securing a competitive advantage, while flexibly utilizing intellectual property rights to effectively defend against frivolous patent lawsuits. This provides a powerful tool for technology and business competition.

Critical legal cases related to intellectual property involving Nanya were as follows:

In October, 2016, Lone Star Silicon Innovations accused Nanya and its subsidiaries (collectively "Nanya") in U.S District Court of East Texas for patent infringement. The plaintiff withdrew the lawsuit in April 2021 and the case was closed.

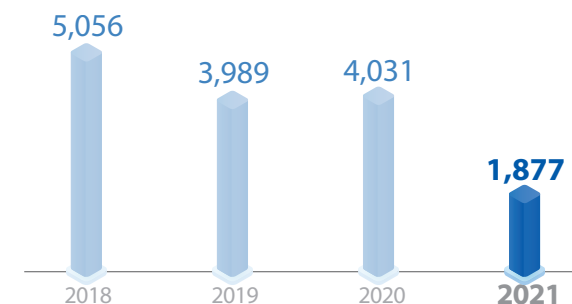
The U.S.-based Monterey Research LLC. accused Nanya and subsidiaries Nanya Technology USA and Nanya Technology Delaware in the U.S. District Court for the District of Delaware for patent infringement in November 2019. We have engaged counsels to properly handle the case to protect our rights and interests.

Nanya intellectual property strategy



In addition to patents, trade secrets are also an extremely important intellectual property in the semiconductor industry. Nanya has been actively implementing advanced process technologies and developing new products and innovative sales models in recent years. Besides applying for patents to protect the intellectual property, any technology, method, process, formula, program, design, or other information that can be used for production, sales, or business are trade secrets of Nanya strictly protected by systems, as long as they are confidential and possess economic value. To minimize the risk of leakage, Nanya implemented ISO 27001 Information Security Management System in 2019, and continued to pass external certification in 2021.

Number of trade secrets



Note: The number declined in 2021 due to the change of archive rules.

Incentives for Innovation

"Innovation" is one of the driving forces behind Nanya's technological growth and competitiveness enhancement and one of our core values. To encourage employees to propose innovative ideas, the Company holds annual innovation competitions, offers patent rewards and rewards for improvement proposals, and organizes essay competitions and the best team competitions. We recognize and reward innovative ideas proposed by each employee, hoping that all employees will internalize the spirit of innovation.



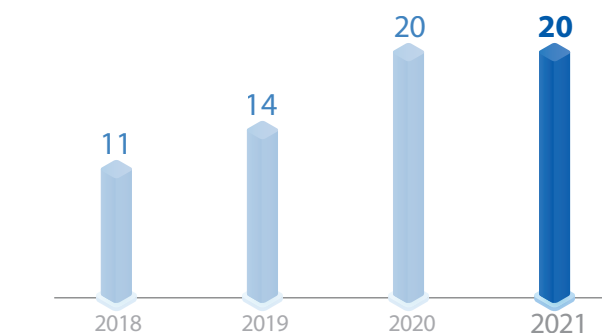
Results of innovative activities

	2021	2020	2019	2018
Patent rewards: Number of patents granted	465	438	459	502
Rewards for improvement proposals: Number of proposals	207	207	225	51
Rewards for improvement proposals: Actual annual benefit(NT\$)	882,517,200	1,583,318,400	368,721,600	311,059,200
Technological essay competitions: Number of entries	93	79	65	58
Best team competitions: Number of entries	13	17	15	15

In addition, we attach great importance to technology R&D. We incorporate external innovation into our R&D in open and innovative ways, and accelerate and expand technology R&D. We have worked on basic research, product design, and product testing for next generation memory with National Taiwan University, National Central University, Chang Gung University, Industrial Technology Research Institute, and testing equipment suppliers. We have also partnered with manufacturers of masks and machinery in joint development of 10 nm process and materials. Through customized Wafer Level Packaging and multiple application products developed rapidly with downstream system developers, Nanya has launched new open innovation programs every year in the past four years in coordination with the Company's short, medium, and long-term R&D plans.

Technology R&D open innovation program

Unit: Number of cases










■ Technology R&D open innovation program



Green Product Development

Nanya and clients both aim to protect a green planet. We implemented the Life Cycle Thinking (LCT) and the Design for Environment. For a long time, we have made an effort to research and develop advanced and highly efficient eco-friendly products. We not only have helped clients develop products with low energy consumption design, but also have engaged in hazardous management and conflict minerals management through our influence on supply chains. In order to continue improving the environmental friendliness level of products, we have formulated environmental health and safety performance indicators, promoting various waste reduction and resource reuse, greenhouse gas reduction and other projects. In coordination with the Green Product Promotion Committee (GPPC) on green product management, right from the start of product development, we consider seven aspects of environmental impacts, including procurement, manufacturing, transportation, product use, disposal, and recycling in order to identify improvement opportunities to increase environmental benefits.

Nanya green design matrix

	Procurement	Manufacturing	Transportation	Product use	Disposal and recycling
Energy efficiency 	●	●	●	●	
Greenhouse Gas Emissions 	●	●	●	●	
Material reduction 	●	●	●		
Conflict minerals 	●				
Hazardous substances 	●	●			●
Waste reduction 		●			●
Water resources reduction 		●			

Life Cycle Assessment

In response to the EU's new wave of requirements for environmental issues, we used the Simapro, a life cycle assessment tool, to conduct life cycle assessment on 100 percent of our products, calculated environmental footprints of products, and identified directions for future improvements. In the meantime, the company would use the product environmental data and coefficients accumulated through analysis processes to build a decision support system for green product development. The company gave multiple considerations on the requirements, and conducted quantitative life cycle assessment on products in each life cycle stage. Pursuant to the contents of quantifying and communicating requirements and guidelines for the Product Environmental Footprint of the life impact assessment under the ISO 14040s series, the company participated in product environmental footprint declarations, and referred to the regulations of ISO 14064-1 Greenhouse Gas Inventory and ISO/TS 14067 Carbon Footprint International Standard to execute the declarations. The analyzed products were various DRAM we manufactured, and boundaries of the life cycle system included raw materials manufacturing, transportation, wafer manufacturing, packet packaging, module packaging, product use, and recycling/disuse. Because the company's main production was memory wafer manufacturing, other system boundaries were outsourced. Therefore, the main system boundary was wafer manufacturing. Among 14 items of environmental footprint sources, greenhouse gas emissions of three main resources listed in the results of the 2020 product life cycle assessment were reduced.

Three main hotspots of greenhouse effect listed in the results of the 2020 product LCA results

Electricity use

▶ Percentage of product carbon footprint
80.18%

▶ Improvement plan
Implement energy conservation improvement plans

▶ 2021 Operation result
Completed 33 energy conservation management plans under ISO 50001, energy conservation benefits: 7585 MWh

▶ Direction for further improvement
Continue to implement the ISO 50001 Energy Conservation Plan

Use 12-inch production wafers

▶ Percentage of product carbon footprint
3.75%

▶ Improvement plan
Require wafer manufactures to implement energy conservation and carbon reduction management

▶ 2021 Operation result
Improvements were not yet completed in 2021 and the energy conservation plans are expected to be completed in 2022 and save 5,355 MWh.

▶ Direction for further improvement
Continue to require wafer manufactures to implement energy conservation and carbon reduction management plans

Steam

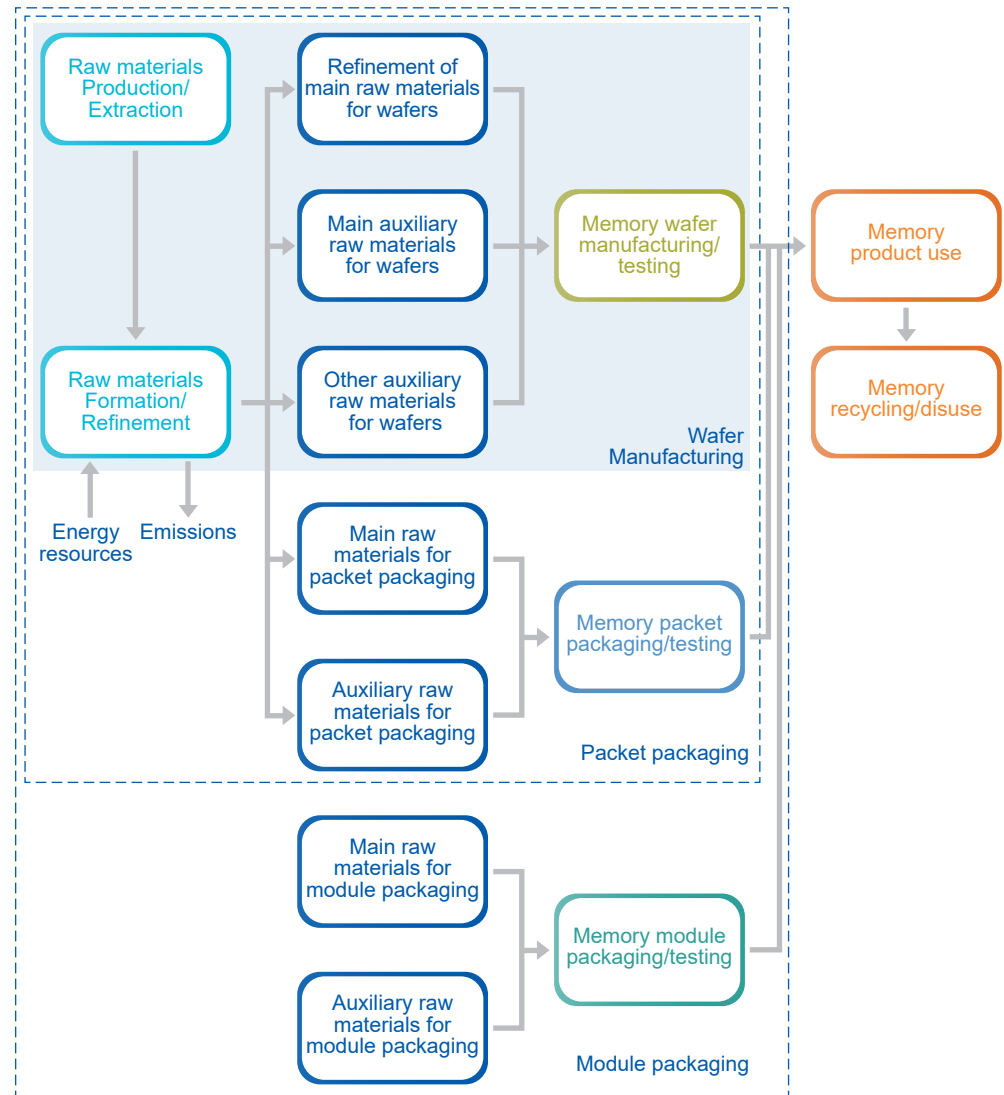
▶ Percentage of product carbon footprint
3.45%

▶ Improvement plan
Replace the heating medium of steam sources

▶ 2021 Operation result
Boilers are the source of steam and the heating medium was changed from coal to natural gas, which reduced GHG emissions by 6,670 metric tons CO₂e compared to 2020

▶ Direction for further improvement
Reduced steam consumption

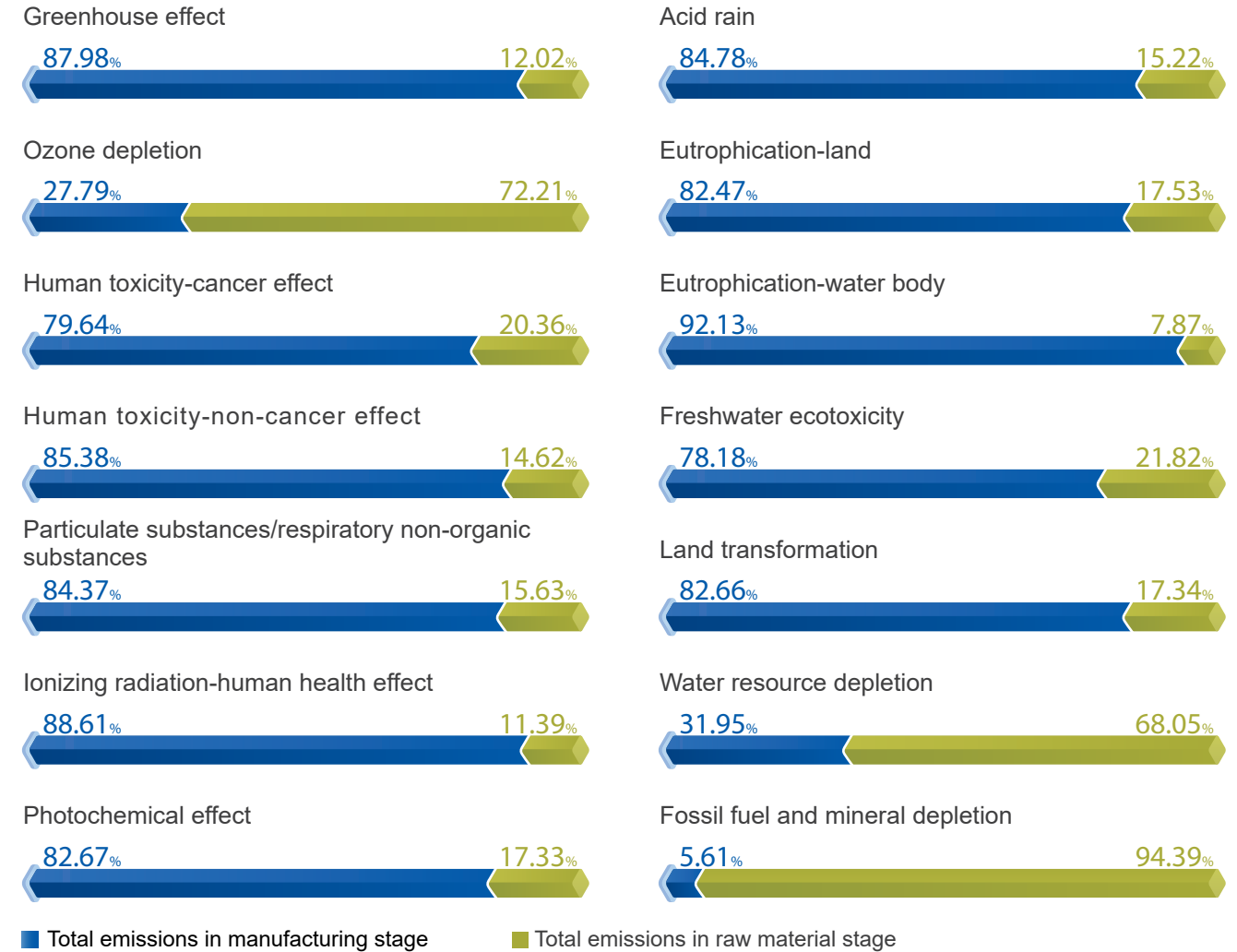
Environmental footprint system boundaries of key products



Raw material manufacturing → Wafer Manufacturing → Packet packaging → Module packaging

■ Mandatory inclusion □ Non-mandatory inclusion

Ratio chart of product's 14 items of environmental footprints in stages of raw materials and manufacturing process



Product life cycle inventory for 2021 was completed. We used staple product SA30 memory to show the ratio of 14 items of environmental footprints in stages of raw materials and manufacturing process. Manufacturing process at factories accounted for about 88% of greenhouse effect, and procurement of raw materials accounted for around 12% of greenhouse effect.

Green Product Design

Nanya has been dedicated to the research, development, manufacturing, and sales of DRAM, becoming the fourth largest DRAM company worldwide. Moving towards the smart era, DRAM is a key component to be used in the applications of smart city, smart home, smart office, unmanned vehicles, Internet of things (IoT), cloud, artificial intelligence (AI). With continuous promotion of independently developing process technology, Nanya started researching and developing new generation process technology of 1Anm-class and 1Bnm-class in 2017, and planned to develop products with high integration, faster speed, and lower energy consumption, such as DDR4/DDR5. Different from the past methods of cooperating with other DRAM companies on technology development or technology licensing, Nanya itself independently developed the process technology of 1Anm-class and 1Bnm-class. Product verification for 1Anm-class process technology is expected to be completed in 2022. This is the first 10nm-class DRAM technology in Taiwan, and proves that Taiwan's DRAM technology development ability is among the top companies across the world. Meanwhile, we have constantly expanded our existing product lines into diverse applications, providing clients with whole product solutions to become the best memory partner in the smart era.

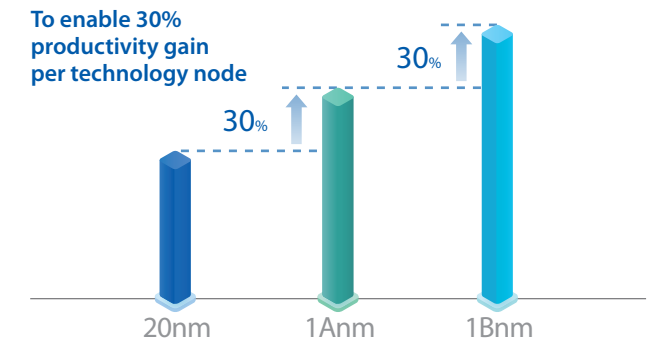
Driven by the demand for 5G communications, cloud, AI, and smartphone memory upgrade, DDR5 and LPDDR5 (low power double data rate memory) became the main supply of new generation memory. Compared with current mainstream memory, new generation memory possesses faster transmission efficiency while saving energy due to lower operating voltages. When comparing DDR4 with DDR5, average power is about 16% lower, but bandwidth is doubled.

DDR5&LPD5 provided specifications that save more electricity with high bandwidth/high speed



Nanya has focused on the development of advanced processes, and began independently developing 1Anm-class process technology in 2017; trial production began in 2020. 1Anm-class process technology will significantly shrink the size of chips and increase the capacity of a single wafer by 30%. Furthermore, we also began developing 1Bnm-class process technology in 2019 and expect to begin trial production in 2022. 1Bnm-class process technology further shrunk chips made using 1Anm-class process technology and increased the capacity of a single wafer by 30%. This will allow factories to further achieve energy conservation and carbon reduction goals while achieving the same production capacity.

NTC DRAM Technology Strategy



Environmental external benefits

When we develop new products, the environmental impact of the entire life cycle is considered. To electronic products, the energy consumption in use is one of the most significant indicators in environmental impacts. Nanya actively researches and develops low energy consumption products, and assist clients lower demand for energy during their usage of electronic products so that greenhouse gas emissions can be reduced.

Over
71,217 million kWh of electricity saved

Product:

low power DRAM and 20nm consumer DRAM

Scope:

Total sales volume in 2021

Calculation:

Based on the quantity of products sold in one year, and compared the energy consumption of the aforementioned DRAM products with that of the previous generation

Benefits:

Saved the annual electricity consumption of 189.710 households^{Note1} and reduced greenhouse gas emissions^{Note2} by 357,509 ton-CO₂e, which is the equivalent of 919 times the carbon absorption of Daan Forest Park in an entire year³.

R&D Policy for Low Energy Consumption Products



NTC cooperates with major chip customers, adopting the method of multi chip package (MCP) to reduce back-end assembly and testing as well as energy consumption.



NTC strengthens the development of low energy consumption product lines and enlarges product portfolios in order to satisfy the need of various mobile devices and electronic products.



NTC continues to develop advanced manufacturing processes, so the energy consumption of new generation products developed with new processes is reduced by 15% compared with the previous generation.

Hazardous Substance Free Product Management

In 2005, Nanya established the Green Product Promotion Committee (GPPC) to promote hazardous substance free (HSF) management. During the product manufacturing process, we continued to prevent pollution, save energy, reduce wastes, and avoid hazardous substances. Through concatenating suppliers of raw materials, process materials, rear-section packaging outsourcing and packaging materials, Nanya built an effectively green product supply chain to managed raw material provider, process material provider, back-end assembly house subcontractor and shipment packing material provider and its materials to meet green product policy and conform to the laws and regulations of current global environmental protection trend.

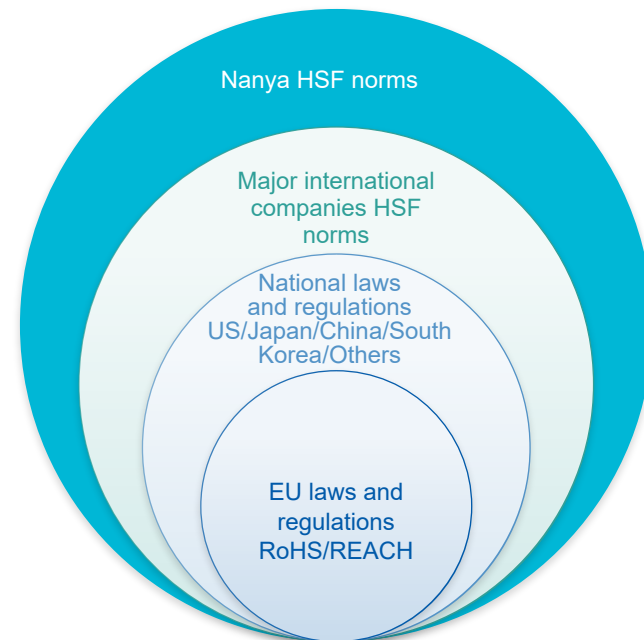
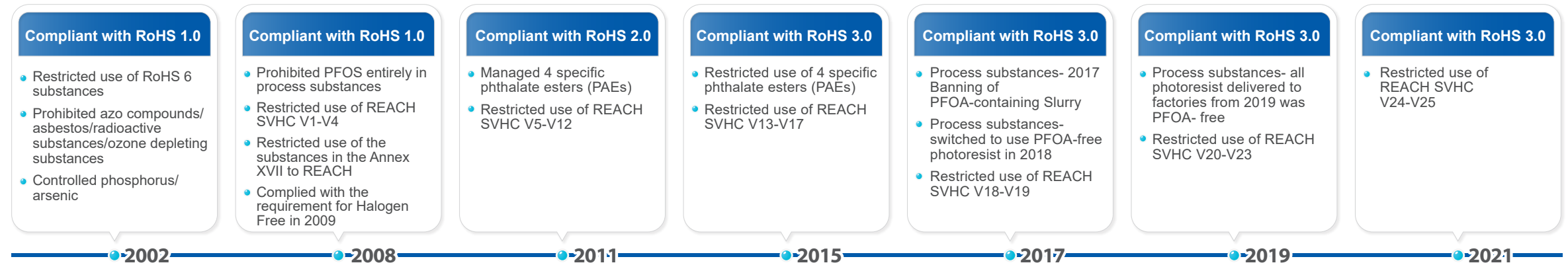
Through the GPPC, we referred to laws and regulations of the EU and countries in other regions and the hazardous substance management specifications of major international customers to stipulate the General Rules of Environmental Management Substances for Components and Materials, continuing to effectively control and manage the sources of raw materials and related materials in order to achieve standards of green products and mitigate impacts on natural environment during manufacturing process of products. Under the instruction of the General Rules of Environmental Management Substances for Components and Materials, all of our products needed to conform to international regulations, WEEE Such as WEEE and RoHS, PPWD and , as well as clients' requirements. Moreover, we do not use chemicals concerned by the IEC 62474 so products non-compliant with the IEC 62474 Material Declaration account for 0% of revenue. In addition, through the establishment of HSF management system of materials, we ensured the finished goods that the product wafers, IC assembly products and DIMM module products are green products. would conform to the international regulations and related specifications of clients towards HSF management.

Note 1: Estimated based on the actual monthly electricity consumption of 3,754 kWh/year of housing units and small stores on the website of Taiwan Power Company (2022/1/19)

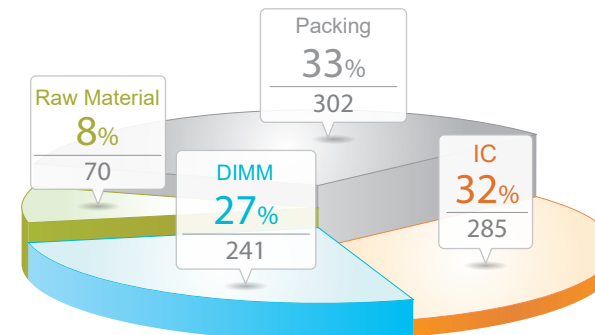
Note 2: The carbon emission factor of electricity is based on the announcement of the Bureau of Energy in 2020: 0.502 kg CO₂e/kWh

Note 3: According to the Bureau of Energy: Calculated using the CO₂ absorption of Daan Forest Park at 389 metric tons per year.

Established HSF management system

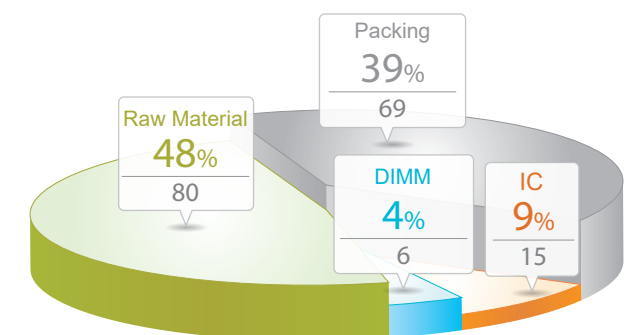


Y2021 Test Reports



RoHS report items of 6 contractors and 47 raw material suppliers were reviewed while 898 RoHS reports were reviewed. The completion rate was: 100%.

Y2021 HS Surveys



Two versions of REACH SVHC item survey (REACH SVHC V.24&V.25) were completed while 158 hazardous substances survey reports were reviewed. The completion rate was: 100%.

Completed 7 copies of one version of HS survey (HS Survey V.41) required by clients, while 165 hazardous substances survey reports were reviewed. The completion rate was 100%.