



Focus 4

Green Manufacturing

A Practitioner of Green Power

Green management is deeply ingrained in the daily operations of TSMC, and the Company continues to push forward with green fabs and green manufacturing. TSMC strengthens its green process capability through the four dimensions of energy management, water management, waste management, and air pollution control. The Company also selflessly shares its experience in sustainability, broadening its impact on society and realizing the goal of an environment in harmony with technology.

- Climate Change and Energy Management
- Water Management
- Waste Management
- Air Pollution Control

524 measures

Number of conservation measures which effectively reduced energy consumption by 300 GWh

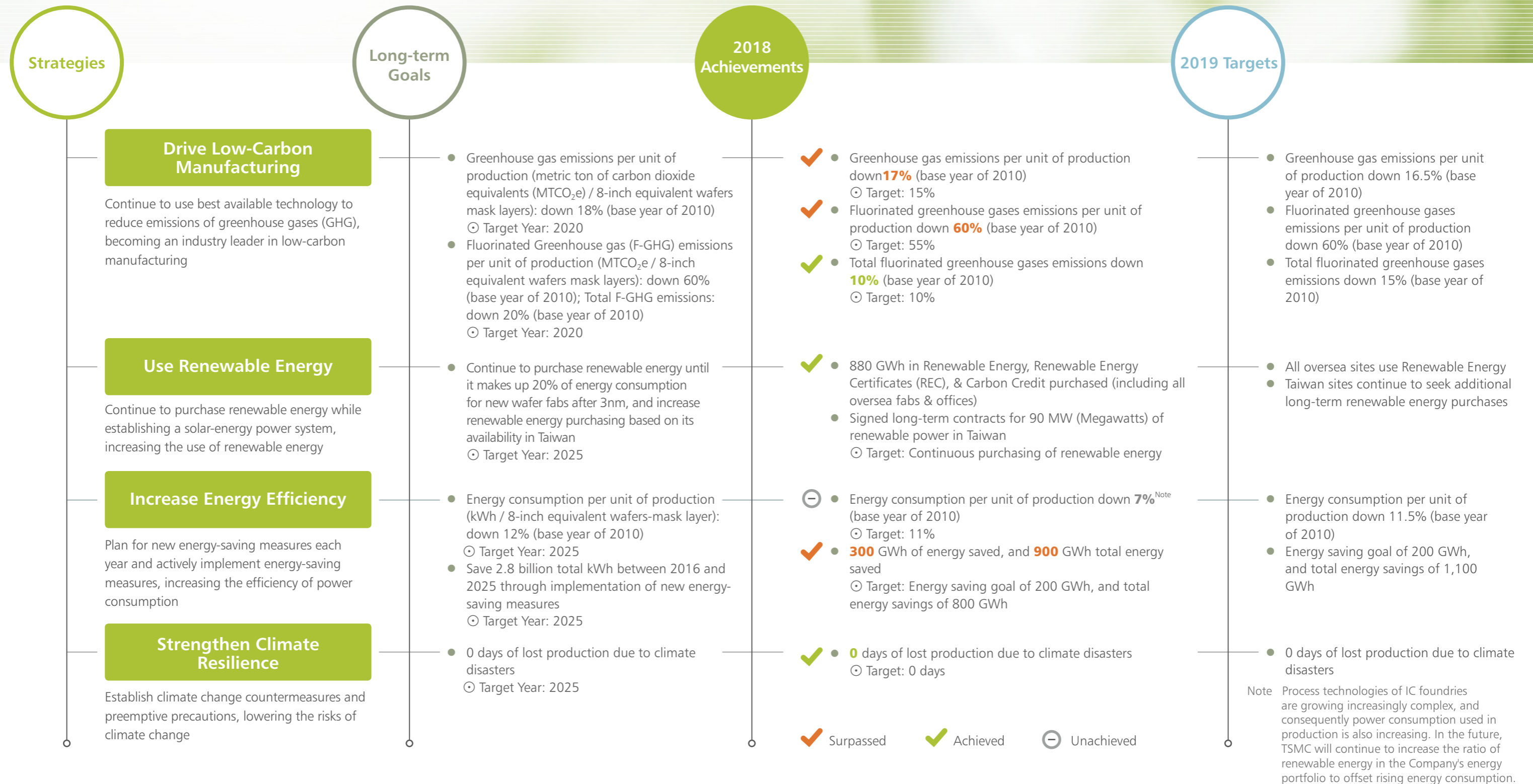
129 million metric tons

129 million metric tons of water recycled, equivalent to 4.1 times the volume of Baoshan Reservoir II

96.9%

Annual volatile organic gas emissions reduced by 96.9%

Climate Change and Energy Management



Note Process technologies of IC foundries are growing increasingly complex, and consequently power consumption used in production is also increasing. In the future, TSMC will continue to increase the ratio of renewable energy in the Company's energy portfolio to offset rising energy consumption.



Responding to Climate Change is the Responsibility of a Sustainable Business

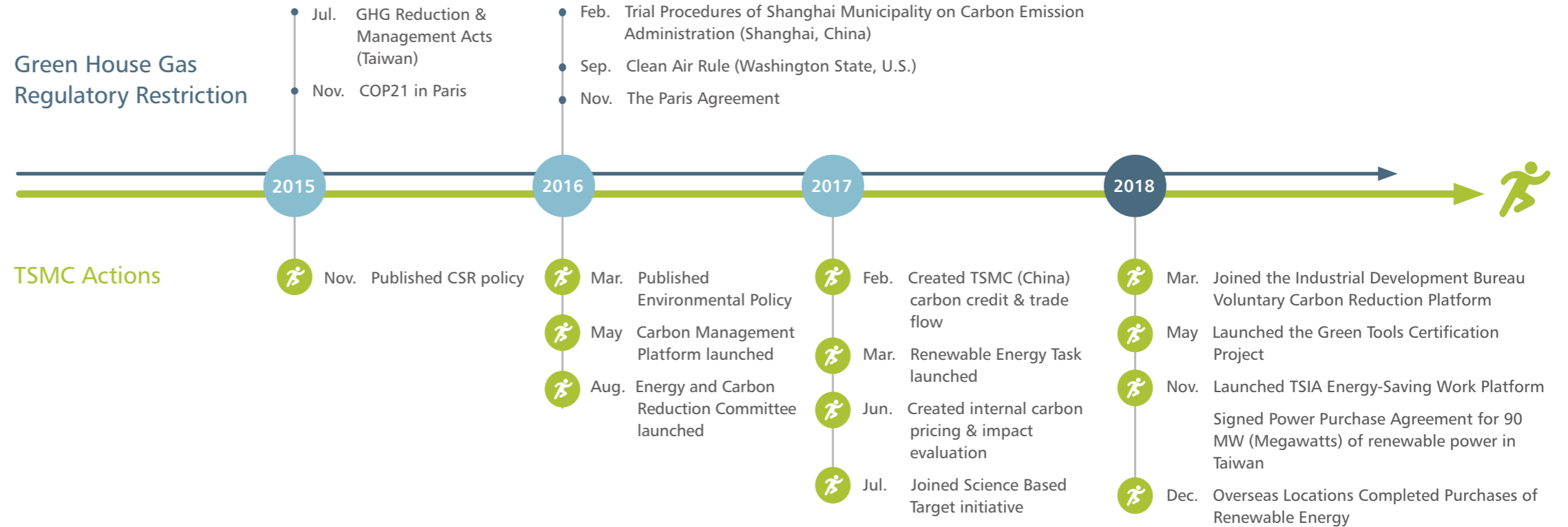
In the face of a changing global climate, TSMC has not only strengthened its resilience to climate change, but also made preparations to lessen the possible impact disasters could have on operations and made efforts to reduce greenhouse gas emissions. As declared in the Corporate Social Responsibility Policy and Environmental Protection Policy, responding to climate

change is the responsibility of a sustainable business. TSMC faces the harsh challenges of climate change in collaboration with business partners, academia, government, and all of society by continuing to use energy more efficiently and by using renewable energy. TSMC strives to become a world leader in green production.

Looking back to 2018, energy management was one of TSMC's most urgent issues. With the continuous advancement of process technology, integrated circuits

are growing increasingly complex and the power required to manufacture them continues to grow. Even though TSMC invested significant resources into 524 energy-saving measures and saved 300 GWh in electricity, energy consumption per unit of production still exceeded set goals. As a result, the Company actively responded by buying renewable energy and built a renewable energy power station. The percentage of renewable energy in the energy structure of TSMC increased and effectively reduced greenhouse gas emissions.

A History of Responses to Climate Change



Note Science Based Targets Initiative, SBTi is an initiative jointly established by the Carbon Disclosure Project (CDP), the "We Mean Business" Coalition, the UN Global Compact, and the World Wide Fund for Nature (WWF). It aims for companies to set reductions in line with the Paris Agreement.

TSMC established a comprehensive Carbon Management Platform, with three main goals of complying with regulations, reducing energy consumptions and carbon emissions, and the management of carbon assets. Under the guidance of the Corporate Social Responsibility Committee, the platform has continuously tracked climate change trends and changes in local and global government regulation. The platform supports regular reports to the Board of Directors on the status of the Company's operations in response to climate change. In addition, an Energy and Carbon Reduction Committee led by two senior vice presidents responsible for fab operations and materials management and risk management regularly follows up and checks on energy-related carbon emission performances, setting goals for continuous improvement. Given that climate change could potentially affect operations and pose financial risk, in 2018 TSMC began using the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) released by the Financial Stability Board (FSB) to determine risk and opportunities, and based metrics and target management on the results.



60%

Fluorinated greenhouse gases emissions per unit of production decreased 60%, meeting 2020 long-term goals ahead of schedule.

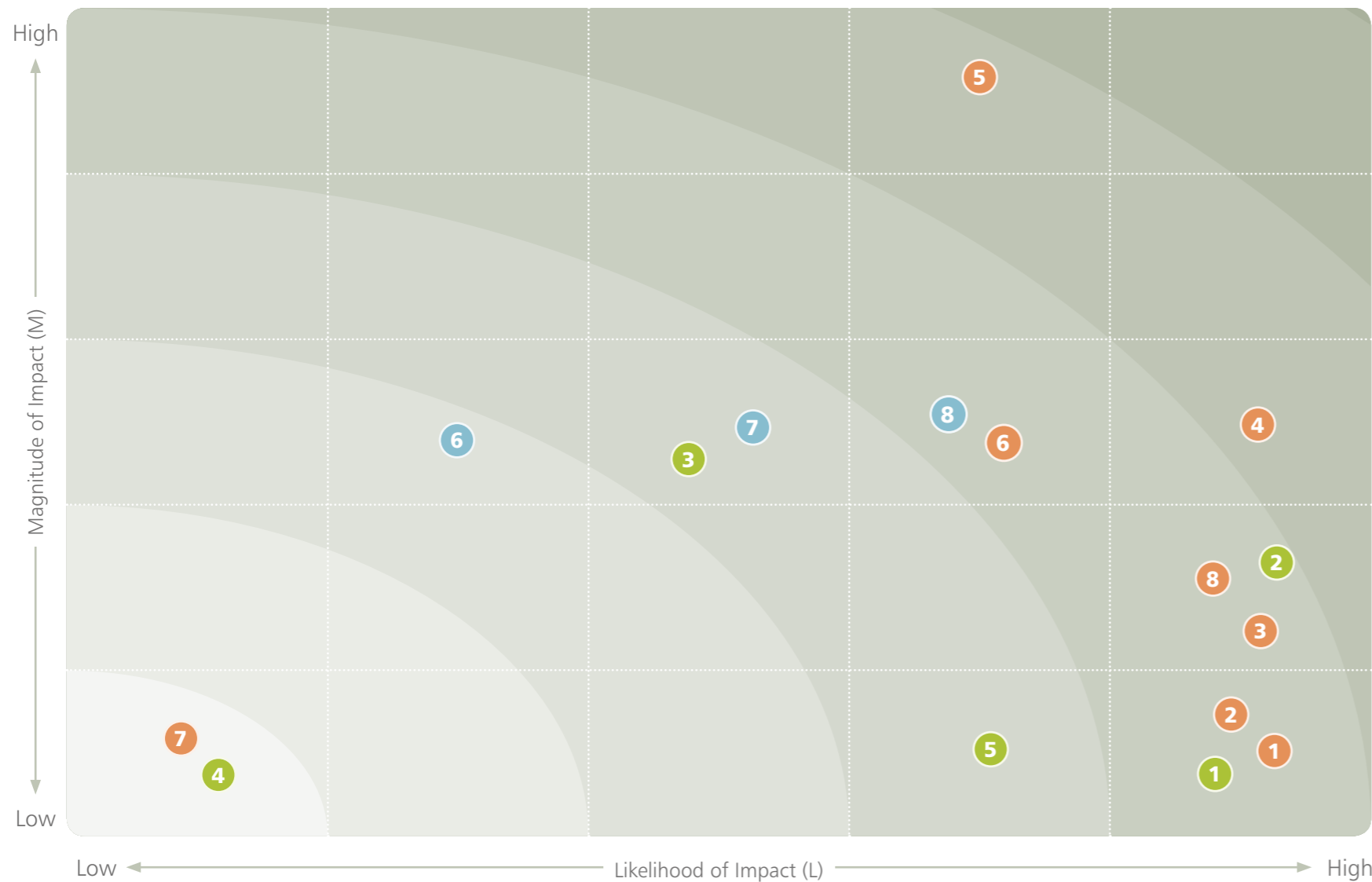
TSMC TCFD Framework

Category	Management Actions	
 Governance	Board of Directors	The risks to water and energy resources by climate change are integrated in corporate risk management, and the Senior Vice President of Materials Management and Risk Management makes annual reports to the Board of Directors on corporate risk and measures taken
	Corporate Social Responsibility Committee	The Company's top organization in dealing with and managing climate change. The CFO serves as chairperson and oversees quarterly reviews of climate change-related issues and progress, and annual reports are made directly by the chairperson to the Board of Directors on results of climate change-rated measures
	Energy and Carbon Reduction Committee	The Company's top management organization in taking action on climate change risk and opportunity. It is led by the senior vice presidents of Operations and of Materials Management and Risk Management, who serve as Co-Chairmen. This committee holds quarterly reviews on execution of management plans, holds in-depth discussions and makes decisions on these plans
 Strategy	Determining risk and opportunity	Climate risk and opportunity is divided into short (less than 3 years), medium (3 to 5 years), and long (greater than 5 years) term based on internal target management periods
	Evaluating potential economic impact	Major risks and opportunities are evaluated by the possibility of affecting Company operations and economic impact
	Setting Climate Strategy	Four major strategies have been set based on the Company's long-term climate change goals: low-carbon manufacturing, using renewable resources, improving resource usage efficiency, and strengthening climate resilience
	Climate Scenario Analysis	In response to global carbon reduction goals, scenario analyses are carried out with science based targets (SBT) and preemptive measures are carried out in response to possible impact on the Company
 Risk Management	Using TCFD	Using the TCFD framework to recognize climate change risk and opportunities and hosting workshops to reach a consensus approved by senior management
	Climate Risk Management	Using Enterprise Relationship Management (ERM) process to manage climate change risks and integrate climate risk factors within operational risk management to create an action plan
 Index and Goals	6 Main Indexes of Climate Strategy	Decrease total greenhouse gas emissions per unit of production, decrease fluorinated greenhouse gases emissions per unit of production, increase the use of renewable energy as the market matures, decrease energy consumption per unit of production, increase total energy saved, minimize potential for disruption of production due to climate disaster
	Climate Strategy Action Policies	Best available technology is fully implemented in new fabs, and abatement equipment is upgraded in existing fabs, build a renewable energy power system, purchase renewable energy, comply with US LEED green architecture guidelines, expand power-saving measures, set long-term goals in preparation for climate risk. Set long term goals for 2020 to 2025 based on the six indexes above and manage climate risk and opportunities
	GHG Emissions Disclosure	Examine emission data annually according to ISO 14064-1 and accept external verification

Determining Climate Risk and Opportunities

In response to the potential dangers of climate change and energy supply, TSMC has set policies and solutions that encompass economical development, environmental protection, and sustainable development. The Company actively implements energy saving, carbon reduction, and water-saving plans; mitigates climate change risk, establishes CO₂ assets, develops energy-saving products and services, strengthens climate resilience, and develops a culture of environmental sustainability.

Climate Risk and Opportunity Matrix



Transformation Risks

- 1 GHG Restrictions and Carbon Trading System
- 2 Voluntary GHG Reduction Commitment
- 3 Unstable Utilities (Water, Electricity)
- 4 Cost of Development for Low Carbon Energy Saving Products
- 5 Impact on the Company's Image

Tangible Risks

- 6 Typhoon, flooding
- 7 Drought
- 8 Rise in Temperature

Opportunities

- 1 Participate in Carbon Trading / Renewable Energy Market
- 2 Cooperation with Public Sector Reward Programs
- 3 Construct Green Buildings
- 4 Increase Water Resource Usage Efficiency and Use Recycled Water Sources
- 5 Develop Low-Carbon Products and Serve the Market
- 6 Increase Willingness for Long-term Investments
- 7 Strengthen Resilience to Natural Disasters
- 8 Promote Energy-Saving Low-Carbon Production

Financial Impact Analysis of Climate Risks and Opportunities

Climate Risks		Climate Opportunities		2018 Actions
	Potential Financial Impact		Potential Financial Impact	
GHG emissions cap and carbon trading system	Restriction on capacity expansion, increase in operation costs	Participation in carbon trading and renewable energy plans	Early purchases of renewable energy, successfully increasing capacity	<ul style="list-style-type: none"> Signed a long-term contract for 90 MW (Megawatts) of renewable energy in Taiwan 880 GWh in Renewable Energy, Renewable Energy Certificates (REC), and Carbon Credit purchased
GHG Voluntary Reduction Commitments	Increased cost of installation for carbon reduction facilities and operating costs	Win public recognition / cooperation	Accumulate carbon rights in preparation for future expansion	<ul style="list-style-type: none"> Application to exchange increased compressor system efficiency for project rewards was approved
Unstable Utility Supply	Impact on production, increase in operating costs	Construct green buildings	Lower utility costs	<ul style="list-style-type: none"> Built two additional green fabs and six LEED-certified buildings
		Increase efficiency of water consumption and water recycling	Strengthened climate resilience, lower the impact of disasters on production	<ul style="list-style-type: none"> Built new fabs (Fab 15, Fab 16, and Fab 18) while maintaining a water recycling rate greater than 85%
Cost of developing low-carbon energy saving products	Increased cost of developing low-carbon energy saving products	Develop or increase energy-saving products or services	Satisfy customer demands for energy-saving products, increase in revenue	<ul style="list-style-type: none"> Investing in the development of energy-saving products
Impact on the Company's Image	Unable to satisfy the expectations of stakeholders, impacting the Company's reputation or image	Increase investors' willingness for long-term investment	Stabilize stakeholder structure, lessen the risk of large stock fluctuations	<ul style="list-style-type: none"> Boost green production
Typhoon, Flooding	Production is affected, causing financial losses and a decrease in revenue	Increase resilience against natural disasters	Strengthened climate resilience, lowering risk of operations being disrupted and potential losses	<ul style="list-style-type: none"> Installed flood doors in Fab 18 Raised the building base of Fab 18 two meters higher
Drought				<ul style="list-style-type: none"> Fab 18 is committed to using and developing renewable water Established a comprehensive water monitoring system
Rising Temperatures	Increase in energy demand, cost, and carbon emissions	Driving low-carbon green manufacturing	Save energy and cut cost	<ul style="list-style-type: none"> Conserved 300 GWh of electricity through energy-saving projects

Drive Low-Carbon Manufacturing

Greenhouse Gases (GHG) Inventory

TSMC is committed to being a world leader in low-carbon manufacturing. Through annual analysis and examination of GHG inventories and tracking overall carbon reduction, TSMC has found that fluorinated greenhouse gas emissions and the indirect emission of GHGs due to power consumption are the two main sources of emissions. As a result, TSMC comprehensively adopted the industrial best practice measures of reducing both exhaust and gases used in production.

Coupled with the continuous implementation of energy saving projects, along with increasing usage of renewable energy, TSMC has lowered the amount of GHG emissions per unit of production. The most important aspect of reducing GHGs is following Science-Based Targets (SBT) in accordance with the Paris Agreement of restricting global warming to within 2°C. The Company diligently searches for any opportunity to achieve this goal, and hopes to lead its supply chain to save energy and reduce carbon emissions together, stimulating the development of regional renewable energy and the sustainability of the environment.

Fluorinated GHGs and nitrous oxide were found to be the main sources of GHG emission from the semiconductor manufacturing process. As a result, TSMC optimizes the amount of gases used in the

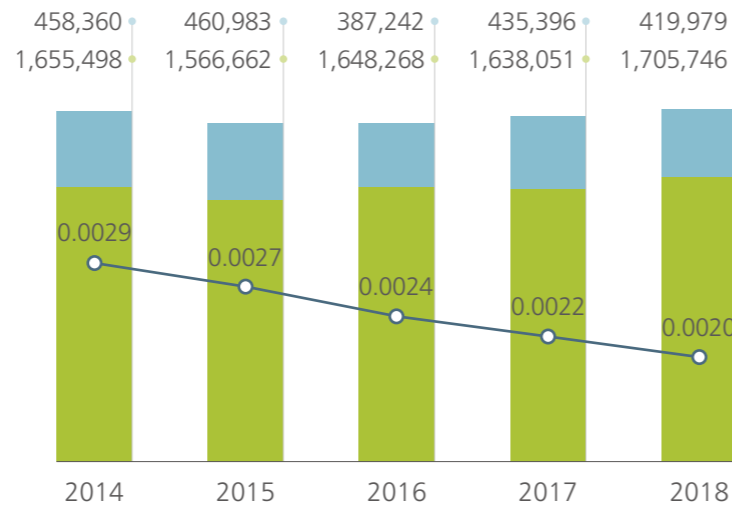
manufacturing process, adopts gases with low Global Warming Potential (GWP), and installed exhaust-removal apparatus in order to reduce direct emissions. In 2018, emissions were cut by 2.6 million tons of CO₂

equivalent, a major decrease from the previous year. GHG emission per unit of production was down 60% compared to the base year of 2010, and successfully achieved the Company's annual goal, far surpassing

the 2020 voluntary PFC agreement target set by the World Semiconductor Council (WSC). TSMC is number one in the industry for reduction of emissions in the manufacturing process.

Scope 1 – GHG Emissions

Unit: metric ton CO₂e



■ GHG Emission of Taiwan Facilities
■ GHG Emission of Subsidiaries
—○— GHG Emission Intensity (tCO₂e / wfr-layer)

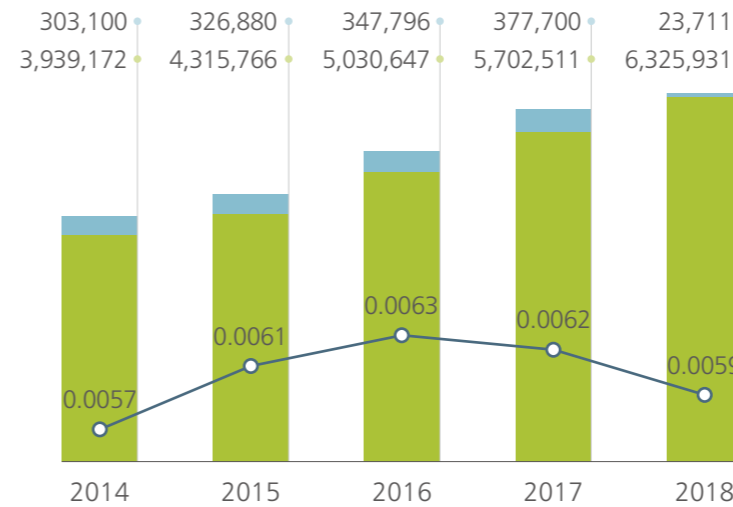
Note 1 The GHG Emission data of scope 1 and scope 2 included TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing), and VisEra.

Note 2 The GHG Emission Intensity data of scope 1 and scope 2 included TSMC's wafer fabs in Taiwan, WaferTech, TSMC (China), TSMC (Nanjing), and VisEra.

Note 3 Emission factor is based on data released in 2018 by the Bureau of Energy stating that 0.554 kg of CO₂ equivalent / kWh, where 1 kg of CO₂ equivalent equals 6,805 kilojoules.

Scope 2 – GHG Emissions

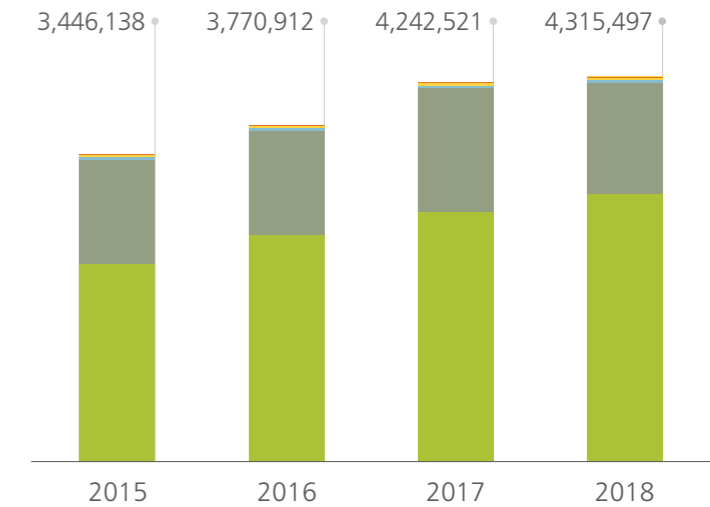
Unit: metric ton CO₂e



■ GHG Emission of Taiwan Facilities
■ GHG Emission of Subsidiaries
—○— GHG Emission Intensity (tCO₂e / wfr-layer)

Scope 3 – GHG Emissions

Unit: metric ton CO₂e



■ Purchased Services and Products (SimaPro model)
■ Fuel and Energy Related Activities (EPA CFP Database)
■ Operational Waste Management (EPA CFP Database)
■ Upstream Logistics (EPA CFP Database)
■ Downstream Logistics (EPA CFP Database)
■ Employee Commute (EPA CFP Database)
■ Business Travel Abroad (Boustead model)

Note 1 Data of scope 3 included TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants).

Note 2 Emission factor is based on data released in 2018 by the Bureau of Energy stating that 0.554 kg of CO₂ equivalent / kWh, where 1 kg of CO₂ equivalent equals 6,805 kilojoules.

GHG Reduction Standard Practices

	TSMC Standard Practices	2018 Implementation Status
Scope 1 Direct Emissions of GHG	ISO 14064-1 inventory and third party verification	100% All fabs and subsidiaries underwent inventory and third party verification
	Optimization of gas quantity used in fabrication	Optimization process parameters Fab 15B introduced GHG optimization process parameters in accordance with the manufacturing specifications of the Technical Committee
	Substitute high-GWP fabrication gases	100% All 12-inch fabs are now using optimized carbon reduction technology - enthalpy of dissociation of nitrogen trifluoride, while 6-inch and 8-inch fabs are using nitrogen trifluoride / octafluorobutane
	Install Point-Of-Use abatement equipment for fluorinated GHGs	100% 100% installed POU abatement equipment on new process tools using F-GHG in new and existing fabs (including subsidiaries) 87% Continued to replace and upgrade 127 POU abatement equipment in 2018, install rate increased to 87%
	Continue to develop on-site nitrous oxide removal technology	1 → 3 Continued to develop removal technology, and certified equipment increased to 3 from 1 Added to the standard equipment of new fabs
Scope 2 Indirect Emissions of GHG	ISO 50001 energy management and third party verification	ISO 50001 The Company underwent ISO 50001 inspection and third party verification
	New-generation fab tools use energy-saving, carbon-reducing designs	Only semiconductor foundry in the world Launched an energy conservation project for next-generation fab tools, and in 2018, implemented 42 energy saving projects to 30 process tools
	Introduce renewable energy	880 GWh Leading semiconductor manufacturer in Taiwan, with 880 GWh in Renewable Energy, Renewable Energy Certificates (REC), & Carbon Credit purchased
	Energy efficiency standards	524 Energy efficiency of advanced-technology fab tools leads industry peers, with 524 energy saving measures implemented and 300 GWh saved

Note Data comparison with industry peers is taken from the World Semiconductor Association Report

Use Renewable Energy

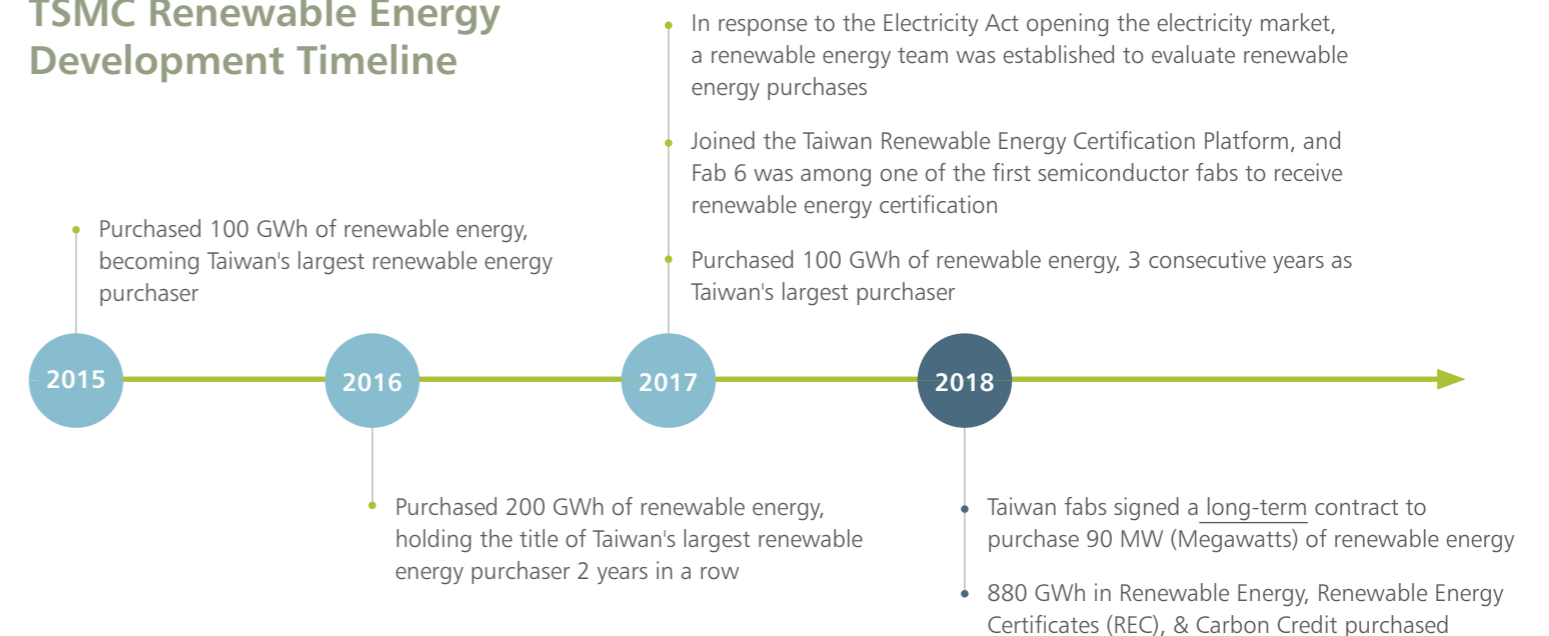
TSMC practices environmental sustainability by continuing to invest in its own renewable energy facilities, and collaborates with energy suppliers and other companies to widen adoption of renewable energy.

Purchasing Renewable Energy

TSMC is committed to directly buying renewable energy or renewable energy certificates (REC) under mature regulatory and market conditions, supports the UN sustainability goals of affordable and clean energy and climate action, and works to reduce the impact climate change will bring to the environment. TSMC

operates around the world, and different countries operate under different legislation on renewable energy and different market conditions. Beginning in 2018, TSMC started to purchase renewable energy, RECs, and carbon rights in countries with comprehensive regulations and ample supply. About 600 thousand tons of carbon dioxide equivalent was offset from the 880 GWh of power used in locations around the world such as the United States, Canada, Europe, China, and Japan. At the same time, TSMC is also actively seeking a source of renewable energy in Taiwan. Despite a low supply of renewable energy, TSMC signed a long-term contract in 2018 for 90 MW (Megawatts) of renewable power, and has committed to powering 20% of 3nm production with renewable energy. TSMC supports the development of renewable energy through concrete actions with the goal of effectively curbing GHG emissions.

TSMC Renewable Energy Development Timeline

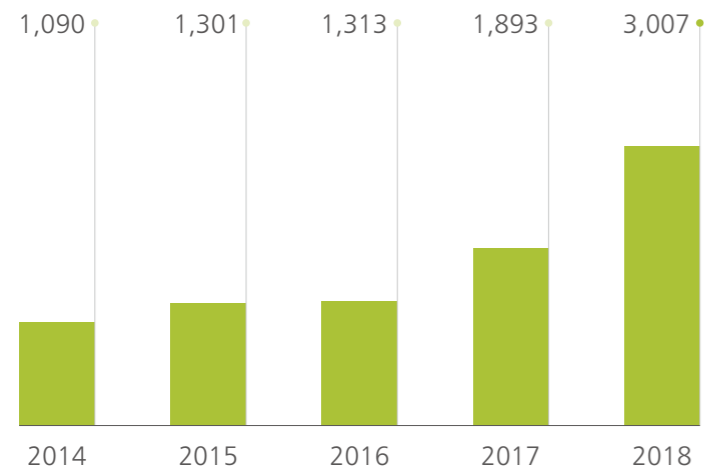


Installing a Renewable Energy Power System

Apart from purchasing renewable energy, TSMC has also installed solar panels at its sites, providing zero-carbon emission renewable energy for fabs. In 2018, 1,114 kW of solar panel capacity was installed, and has already provided 3 GWh, decreasing carbon emissions by 1.67 million kilograms, or the annual carbon absorbed by 167,000 trees. In 2019, an additional 2,000 kW in capacity of solar panels will be added.

Total Capacity of Renewable Energy Facilities (kW)

Unit: kW



Note Data included TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing), and VisEra.

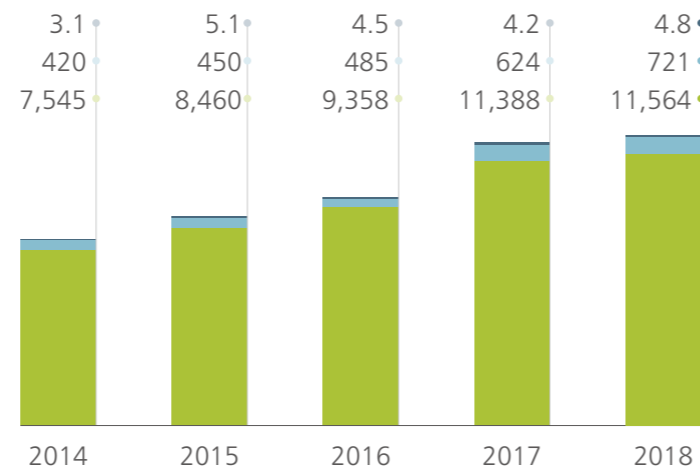
Increase Energy Efficiency

Comprehensive Energy Examination and Efficiency Boost

In 2018, TSMC consumed a total of 12,290 GWh in non-renewable energy; with electricity making up 94.2%, natural gases coming second at 5.9%, and diesel with less than 0.1%. Electricity is the main energy used to power TSMC's manufacturing

TSMC Total Energy Consumption

Unit: GWh



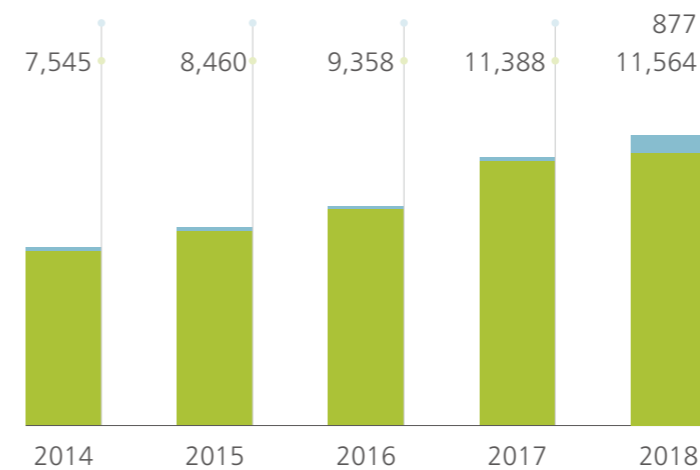
Note 1 cubic meter of natural gas=10.5kWh of electricity
1 kWh=3,600 kilojoules

equipment and fab systems. Natural gas is used in exhaust processing facilities to decrease the direct emission of fluoride gases. Diesel is not used directly in production, but to run power generators and fire pumps during emergencies, power outages, or during annual maintenance.

TSMC proposed a plan spanning from 2016 to 2025 to enhance energy efficiency, with projected annual energy saving rates greater than 1%. In 2018, the energy savings rate was 2.4%, while between 2016

TSMC Total Power Consumption

Unit: GWh

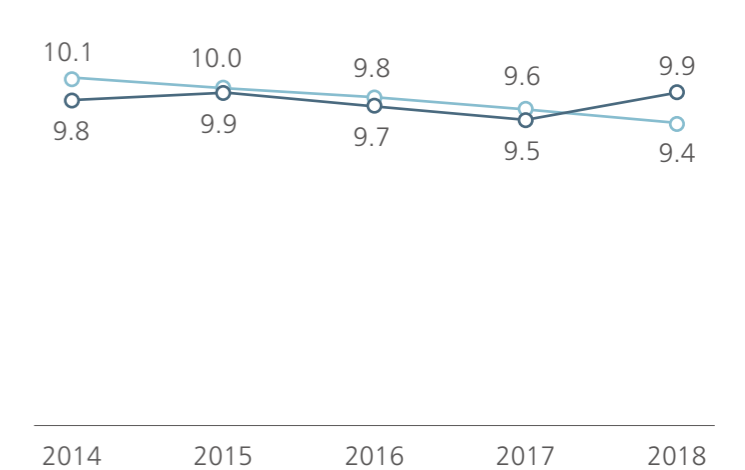


Note Data included TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing), and VisEra.

and 2018, the average energy savings rate was 2.6%, higher than the average energy savings rate of 2.4% of the Taiwan Semiconductor Industry Association and reaching TSMC's target. However, due to test production in new fabs and transition to advanced process technology production lines, total energy expenditure was 9% greater than 2017, missing the previously set target of 11%, while 7% lower than the base year of 2010. Going forward, the Company will

Unit Power Consumption and Goal Completion

Unit: kWh / 8-inch e wafer-layer



Note 1 Data included TSMC's wafer fabs in Taiwan, WaferTech, TSMC (China), TSMC (Nanjing), and VisEra.
Note 2 Diesel and natural gas are excluded from calculations as they are not used for production.

adopt more energy-saving measures, follow national energy conservation targets, further develop an energy conservation management platform, and undergo comprehensive energy inspections ensuring that each unit of power is optimized to its fullest. In 2019, all TSMC fabs will be ISO-50001:2018 certified and reach international standards, seeking more opportunities for better energy management.

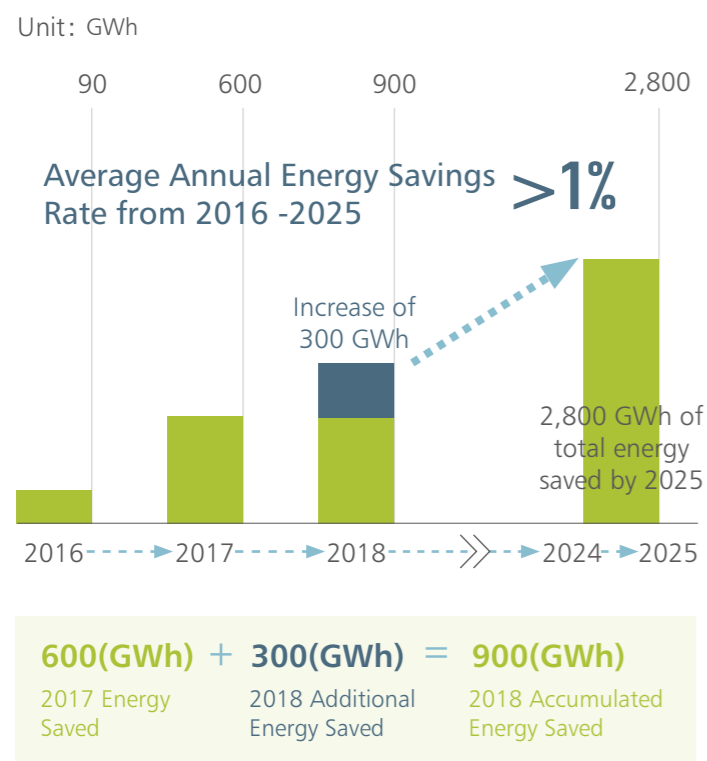
Expanding Energy Saving Measures

TSMC's primary consumers of energy are production tools and fab facility systems. At the same time, the Company's Operations and Facilities organizations are the main advocates of energy conservation. In 2018, the Facilities department completed the innovation of an energy-saving autonomous intelligent chilled water system, and plans on replacing large air

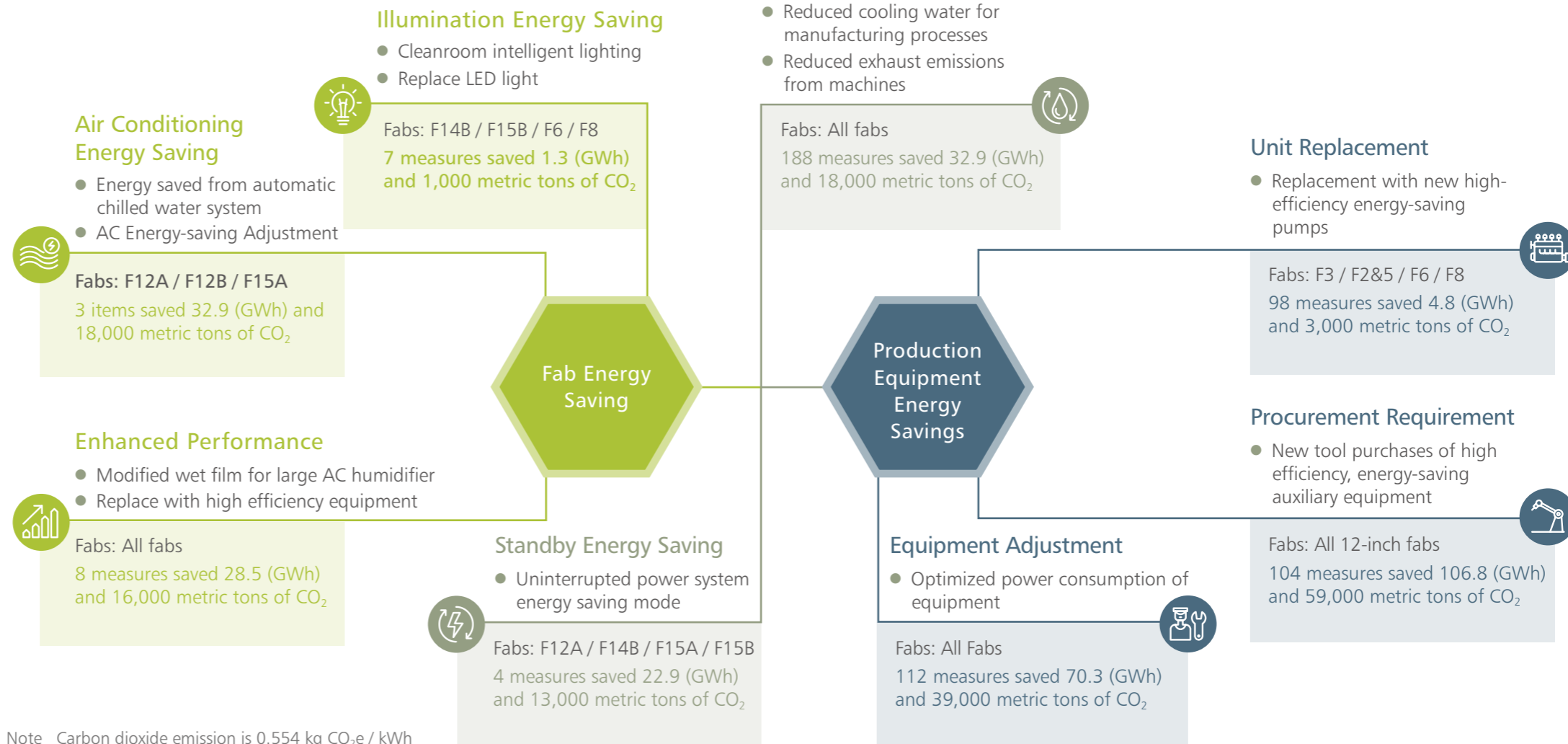
conditioning units with open circuit cooling towers over the next few years. In addition, the Operations department implemented a plan to replace low energy efficiency components and optimize energy usage of its equipment, carrying out a total of 524 energy-saving measures spanning 8 different categories. These measures saved 300 GWh, which is equal to eliminating 166 thousand metric tons of carbon dioxide emissions, and saved NT\$750 million in utility fees. By

cutting down on carbon dioxide emissions, NT\$250 million was saved in potential external carbon costs. To further promote green innovation in the supply chain, TSMC has continuously worked with equipment suppliers to develop next-generation energy saving equipment. In 2018, 42 energy-saving projects were introduced to 30 equipment models, with 24 models reaching average energy savings of 10%, surpassing annual energy targets.

TSMC 10-year Energy-Saving Targets



2018 New Energy Saving Performances



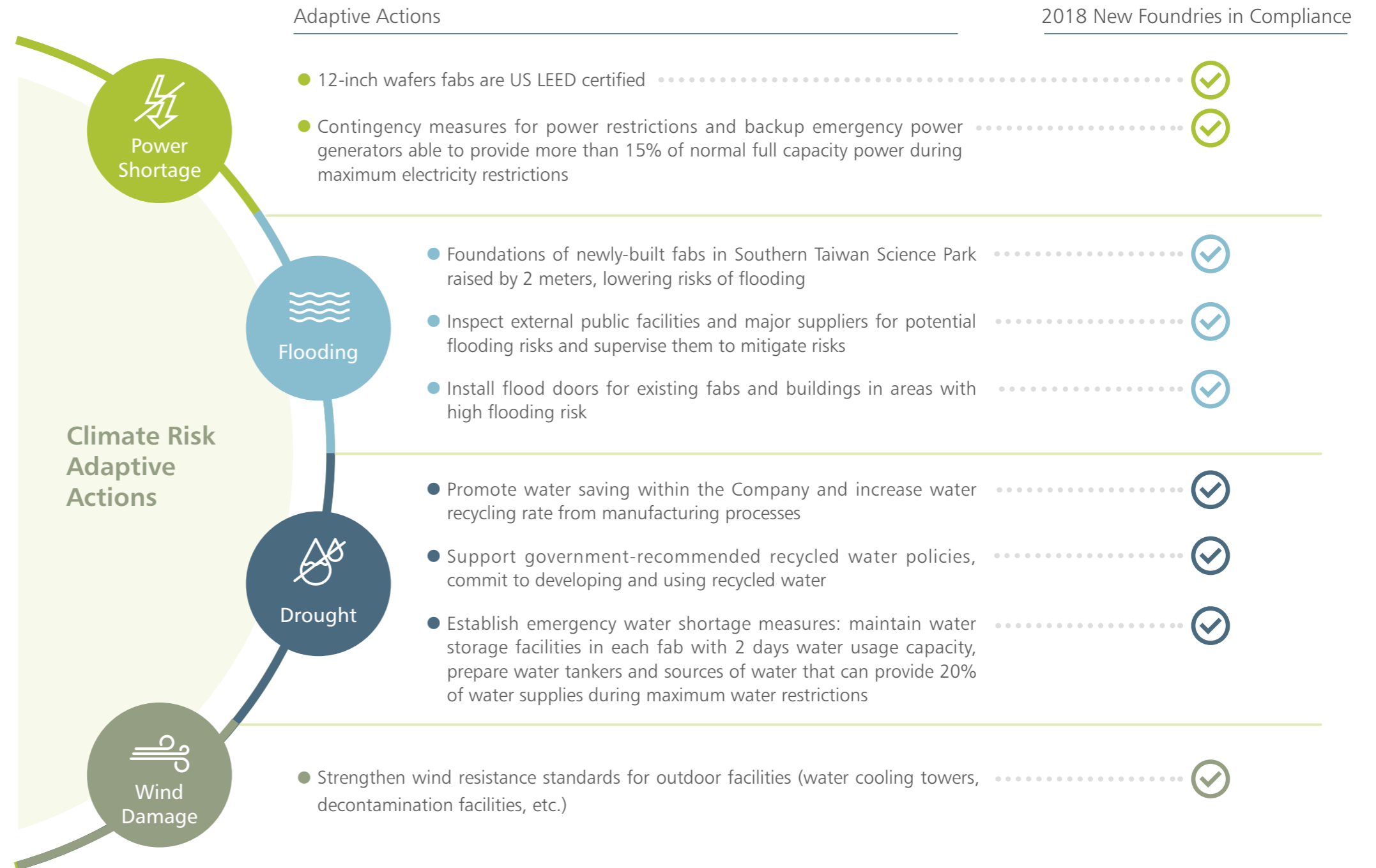
Note Carbon dioxide emission is 0.554 kg CO₂e / kWh

Strengthen Climate Resilience

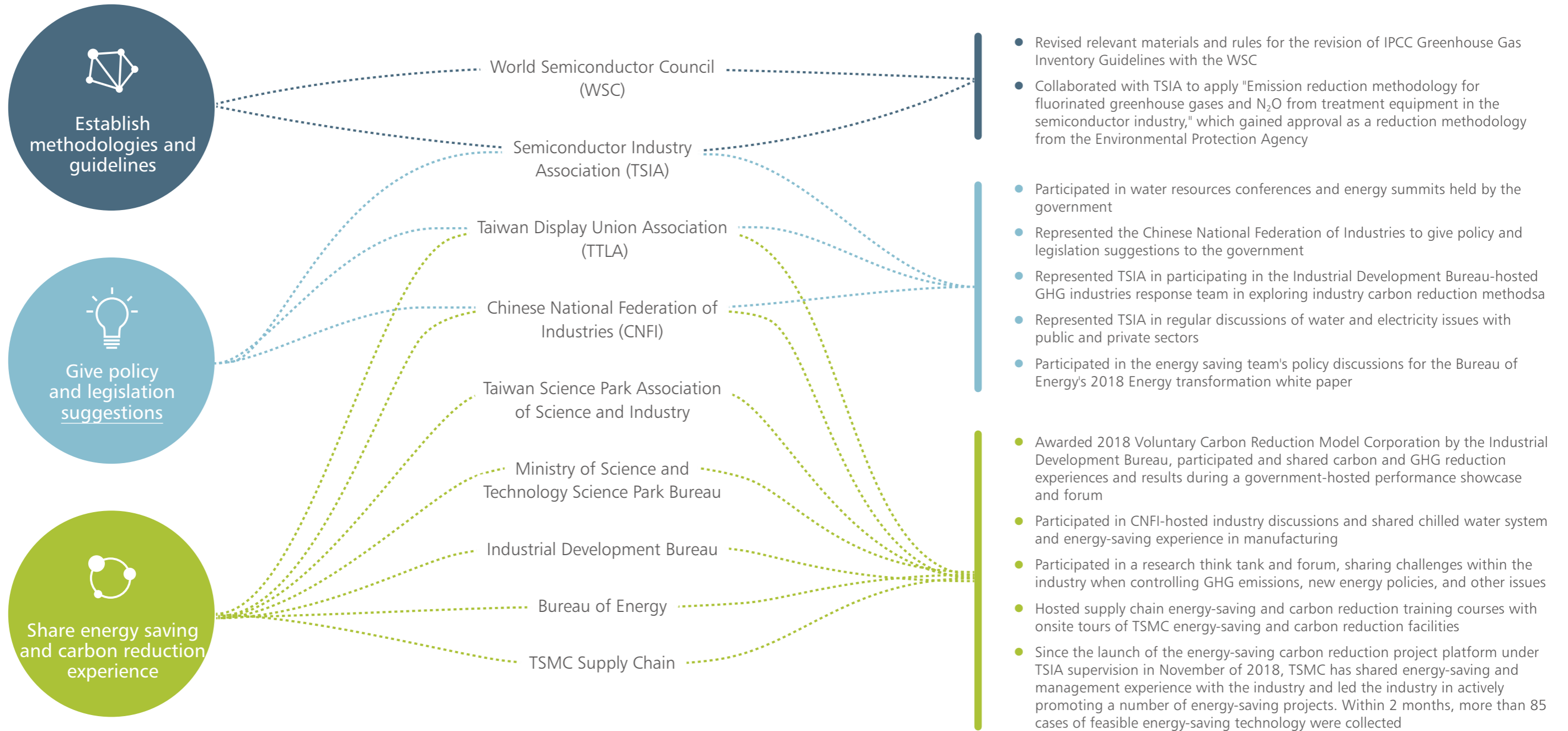
TSMC identifies key factors from climate change and extreme weather each year that could affect operations such as drought, high temperatures, power shortages, flooding, and wind damage, and establishes standard guidelines for all fabs to strengthen operational resilience. The Company successfully achieved its target of uninterrupted production in 2018, and successfully protected against possible natural disasters brought on by climate change.

Leading the Industry in Facing Climate Change

No business is excluded from the impact of global climate change. TSMC has been proactively adjusting its operations to mitigate the impacts of climate change and is more than happy to share environmental knowledge, experience, and optimized measures through public associations so that industry standards can be improved. The Company has received the support of the Allied Association for Science Park Industries, Science Park Administrations, the Ministry of Science and Technology, the Water Resources Agency, Taiwan Power Company, and Taiwan Water Corporation. TSMC firmly believes that only industry-government-academia collaboration and the participation of leading companies in various industries can deal with the severe challenges brought by climate change.



Collaborating with Government, Industry and Academia to Build Sustainability for the Next Generation



Case
Study

Most LEED Certified Semiconductor Industry Architecture Area in the World

As the trusted long-term technology and capacity provider to the global logic IC industry, TSMC not only leads the way in terms of technological advancement, but also continues to build fabs to expand production capacity. In order to be an environmentally friendly, energy- and water-efficient "green foundry", TSMC has diligently developed world-class environmental capabilities, ensuring that the environment is not left behind in the pursuit of technological advancement. From 2006, all newly-built TSMC fabs and office buildings must be in compliance with LEED and EEWB green architecture standards and certifications. Existing fabs and office buildings also have started strengthening environmental protection measures to lessen their impact on the environment.

Currently, all TSMC 12-inch fabs are LEED certified. In 2018, a total of 30 TSMC fabs and office buildings received LEED certifications, 21 received EEWB green architecture certifications, and 12 received green factory certifications, making TSMC the leading Taiwan corporation in number of green buildings. TSMC is also the leading semiconductor company worldwide for the largest LEED-certified architectural area, and number one in Taiwan for largest green building-certified areas and certified green fabs. As of end-2018, TSMC was number one worldwide for the semiconductor industry in terms of LEED certified architecture area, and number one in Taiwan for certified green architecture area and green factory certifications.

In addition to these green certifications, TSMC's Fab 14 introduced a smart control system with features including automatic curtains that open and close to control lighting, and automatic carbon dioxide detectors that draw fresh air from outside. Room temperature and air quality can be adjusted according to the season and temperature, maintaining a comfortable, low-energy consumption, and smart work environment. Fab 14 received the first exceptional smart building award from the Ministry of the Interior, and became the largest building in Taiwan to receive the award.



TSMC Four Top Green Achievements

	U.S. LEED Green Architecture	1 Number 1 semiconductor industry in the world with the largest LEED-certified building area, number 1 most LEED-certified company in Taiwan	30 green buildings All 12-inch fabs are LEED certified
	Taiwan Green Architecture EEWB	1 Largest EEWB-certified building area in Taiwan	21 green buildings All 12-inch fabs are EEWB certified
	Green Factory	1 Most green factory certifications in Taiwan	12 green fabs
	Exceptional Smart Building	1 Most exceptional smart building-certified building area in Taiwan	



Case
Study

Green Innovation—Intelligent Chilled Water System

TSMC fulfills its promise of green manufacturing and protecting the environment through innovation and development. In 2017, TSMC developed an industry first "optimal energy-saving control program" for its chilled water system. Furthermore, in 2018, an energy-saving measure incorporating artificial intelligence (AI) and machine learning (ML) was introduced as an upgrade for chilled water systems, building a low energy consumption model that further increased energy savings rates by 2%.

Precise Control, Optimal Control Point

TSMC fosters the spirit of innovation through "Energy-Saving Competitions" that encourages employees to come up with ground-breaking ideas to discover more energy-saving actions in our daily lives. In 2018, the facilities and operations organizations collaborated to participate in the "Energy Saving Competition" using analyses of AI algorithms to precisely predict the correlation between the chiller, cooling tower, and cooling water pumps of the chilled water system. Optimal efficiency was

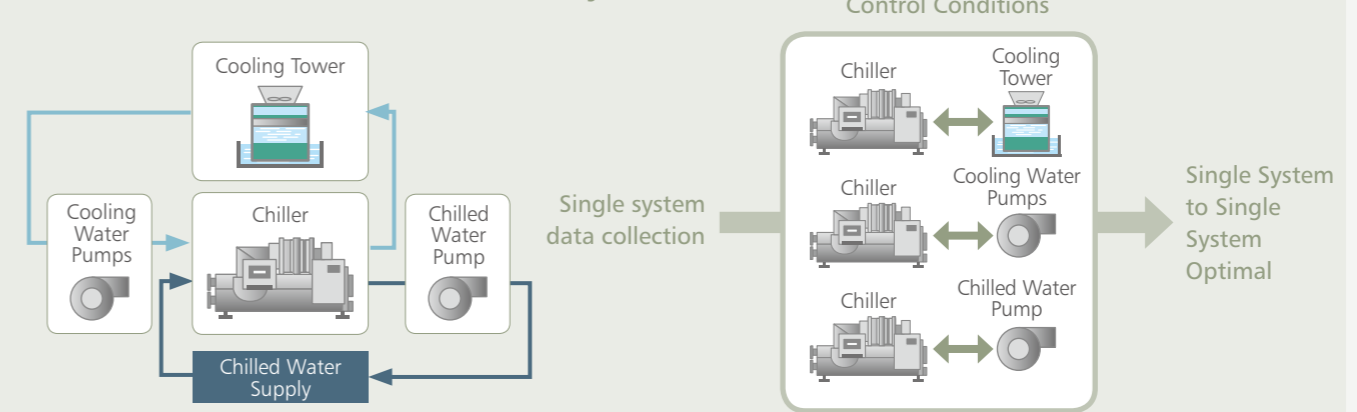
reached for the control system by taking into account the ageing of equipment, difference in plumbing, and other factors.

Successful Integration Maximizing Promotional Benefits Within the Industry

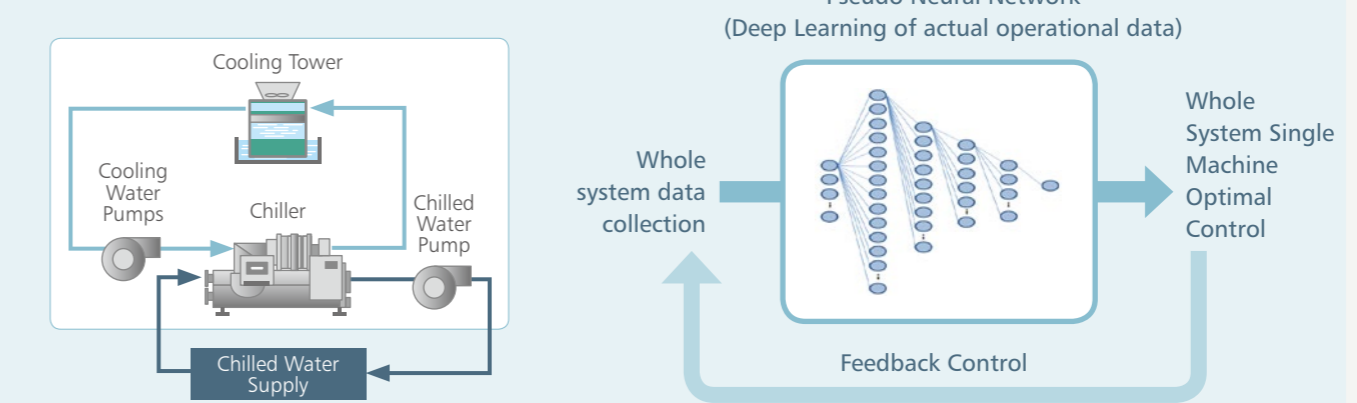
In order to find the optimal energy efficiency of the chilled water system, TSMC uses the massive amounts of data produced by the optimal energy-saving control program and a pseudo neural network to create a model. By taking 90 key parameters from amongst thousands of related variables, and after 4.15 million numerical models lasting 15 months exploring the relationship and weighting between variables, the real-time prediction function of the chilled water system was finally completed. Energy efficiency increased by 2% and TSMC estimates that 30GWh can be conserved each year. TSMC has selflessly shared this technology with the Taiwan Semiconductor Industry Association in hopes of raising the standards of environmental protection and continue the promotion of green innovation.

AI-ML Intelligent Energy-Saving Chilled Water System

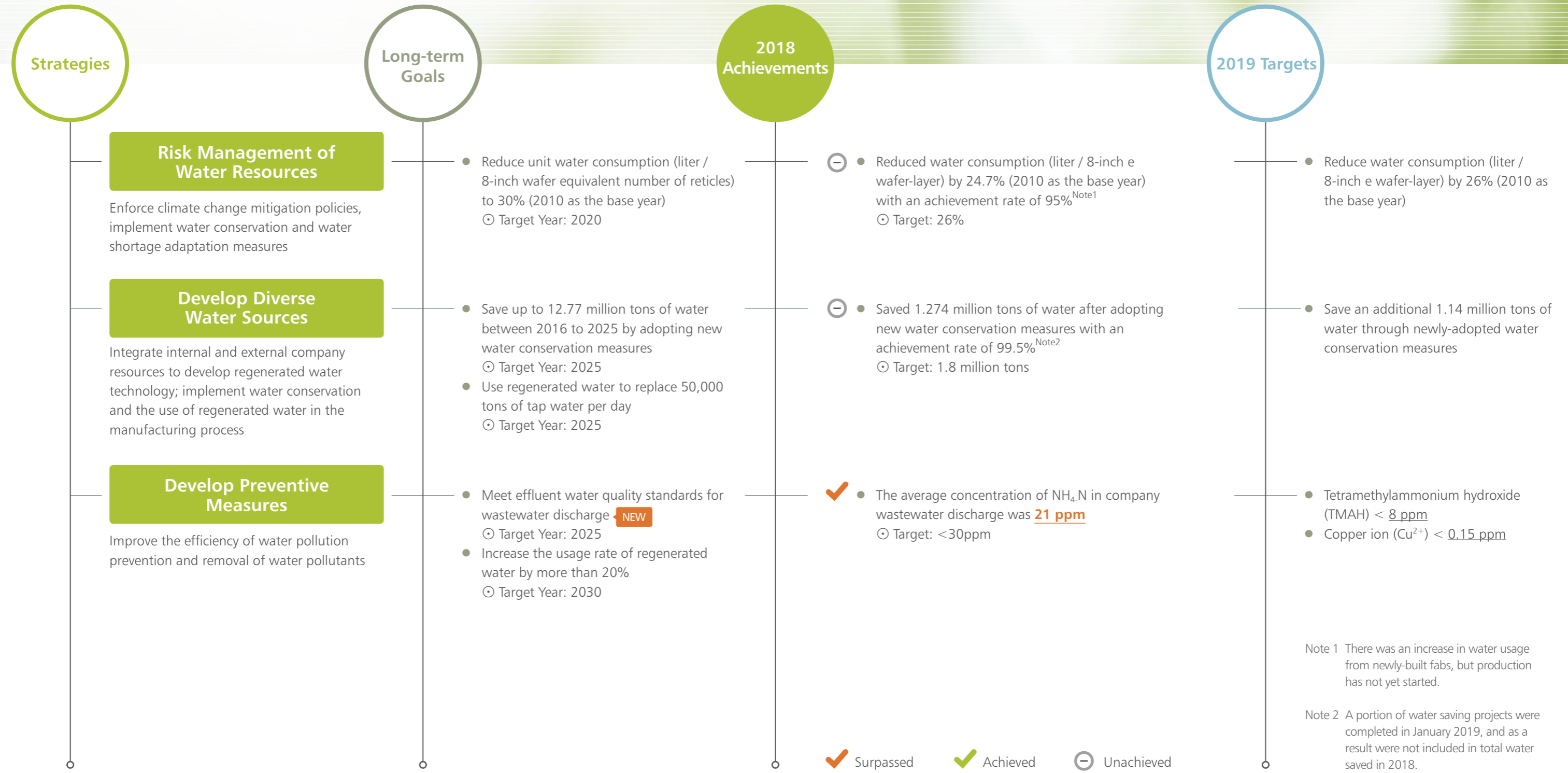
Traditional Control Point Manual Adjustment



Optimal Control Point Automatic Control



Water Management



Surpassed
 Achieved
 Unachieved

Note 1 There was an increase in water usage from newly-built fabs, but production has not yet started.

Note 2 A portion of water saving projects were completed in January 2019, and as a result were not included in total water saved in 2018.



Expand Sources and Reduce Consumption to Ensure Sustainable Production

Water is a precious life-giving resource for our planet. In recent years, the impact of global climate change is tipping the balance between water supply and demand. As a global citizen, TSMC is taking concrete action to expand new resources and cut down on consumption by actively integrating internal and external resources. It has invested great effort in water resource risk management, expansion of diverse water sources, and the development of pollution prevention techniques while cooperating with external partners to ensure sustainable production.

Risk Management of Water Resources

Establishing an Effective Index for Monitoring Water Use

With a comprehensive water reporting system, TSMC monitors the volume of each reservoir and the water usage rate at every plant, thereby establishing an effective water resource management index. During a water shortage in Tainan County from January to May 2018, TSMC took action prior to the government's announcement of Stage One water restrictions, such as reducing landscaping irrigation by 50% and decreasing pressure in its water supply. It also saved up to 3% of water, lowering demand from reservoirs and mitigating the impact of the water shortage on the environment.

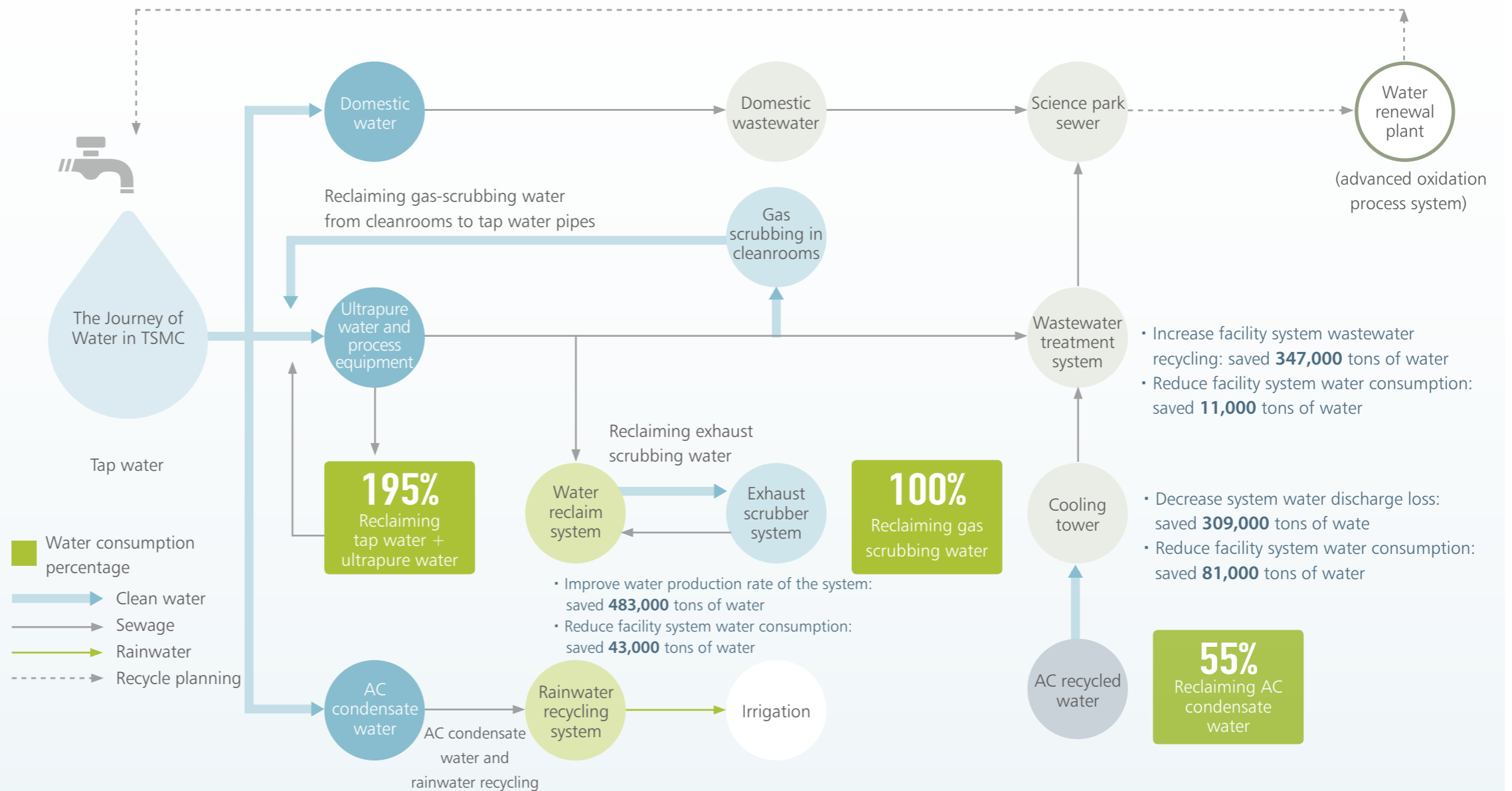
Pre-emptive Water Management Measures

TSMC Water Resource Management Benchmarks	Government Water Status Indicator	Government Water Restriction Measures	Situation in 2018
Establish a comprehensive water use monitoring system → Early warning of long-term water use trends → Assess water installations for any improvements	 Blue Normal	Stabilize supply and demand	<ul style="list-style-type: none"> Constantly monitored the water supply of every reservoir as reported by the Water Resources Agency, and held periodic drills
Create a contingency group → Assess the demand for water tankers / reserve water sources → Formulate and negotiate water conservation guidelines between fabs	 Green Slight Water Shortage	Encourage farmers to leave lands fallow	<ul style="list-style-type: none"> Created a contingency group to take inventory of water sources and water tanker capacity Lowered water supply pressure by voluntarily reducing water use by 3%
Voluntarily reduce water consumption by 3% → Formulate a systematic water conservation mode → Practice drills in using water tankers to transport water	 Yellow Stage One	Decrease water supply pressure during specific time intervals	<ul style="list-style-type: none"> Did not occur
Implement water restrictions at all levels and enforce necessary water conservation measures → Cross-organizational drought emergency response team → Systematic water conservation and water transportation via water tankers	 Orange Stage Two	Industrial Consumers 5-20% cut in water supply	<ul style="list-style-type: none"> Did not occur
	 Red Stage Three	Rotating Water Outages	<ul style="list-style-type: none"> Did not occur

Actively Promote Water Recycling

In order to use water more efficiently, TSMC categorizes wastewater from purification and processing equipment according to purity. The cleanest water is given priority to be purified and recycled for use in the manufacturing process; the next grade goes through water recycling system treatment to serve as water for non-manufacturing processes; unrecyclable wastewater is discharged to an on-site wastewater treatment plant for terminal wastewater management. TSMC has invested considerable effort into building various wastewater recycling systems to enable water purification and reuse. Through layers of recycling, all tap water is completely reclaimed every day. Each drop of water can be used an average of 3.5 times. In 2018, the total amount of water recycled by TSMC reached a record high of 129 million tons, equal to 4.1 times the volume of the Second Baoshan Reservoir.

Main Water Cell and On-site Recycling System



How one drop of water can be used 3.5 times?

$$\frac{\text{Tap water} + \text{Recycled water}}{\text{Tap water}} = \text{Water usage times}$$

Note Water consumption percentage is the ratio of recycled water to tap water, or in other words, the proportion of water recycling volume to water consumption volume in treatment. Proportions of these water treatment equipment may vary depending on allocation by the science parks

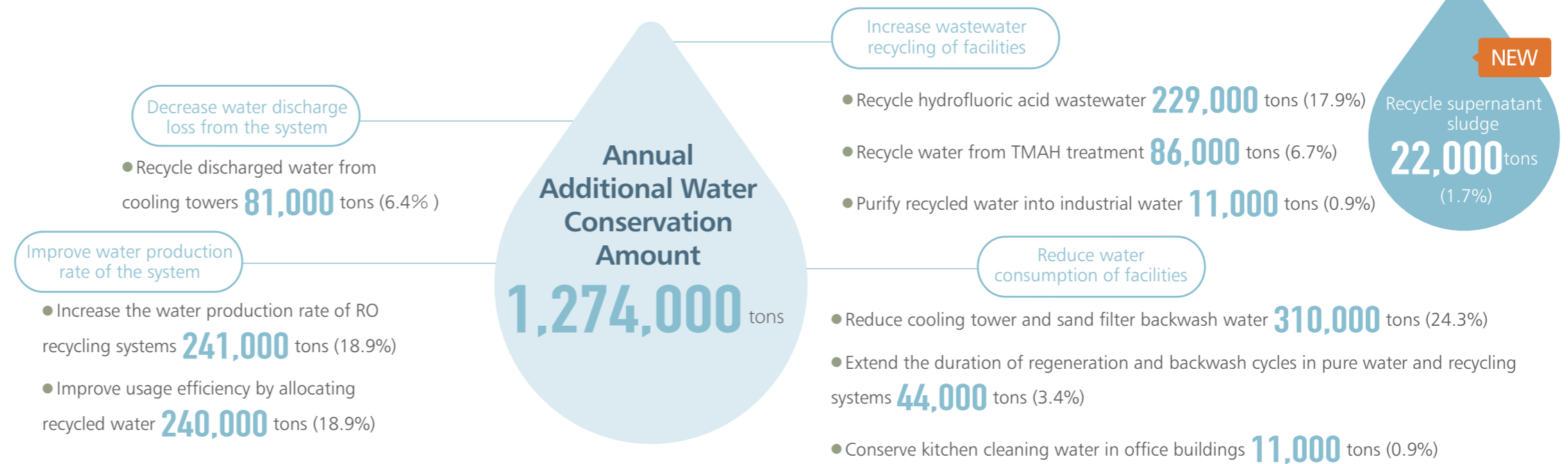
New Water Conservation Measures in 2018

Water recycling has become a more urgent issue than ever as advanced process technologies take a larger proportion of the Company's production, IC line widths continue to shrink, requirements for product purity continue to rise, and water needed per unit wafer of production continues to increase. In an effort to develop more water-saving methods, TSMC's water conservation guidelines focus on four aspects: reduce water consumption by facility systems, increase wastewater recycling in facility systems, improve system water production rates, and decrease water discharge loss from the system.

In 2018, the Company enhanced the effectiveness and expanded the scale of the ten existing water-saving measures. It also took a further step by putting sludge supernatant into coagulation-precipitation treatment through strict separation for water reuse. This method not only puts water conservation into practice, but it reduces wastewater and sludge. In 2018, an additional 1.27 million tons of water was conserved.

Many newly-built TSMC fabs (Fab 15B) began operating in 2018. To deal with the increasing consumption of tap water, TSMC has continued to propose many innovative water conservation measures to improve the water use efficiency, water recycling rate, and recycling volume of advanced manufacturing processes. In total, water use intensity (Water Consumption Per Wafer-layer) in 2018 decreased 24.7% from 62.6 (liter / 8-inch e wafer-layer) in 2010 to 47.1 (liter / 8-inch e wafer-layer). The rate of reduction was down from 2017 due to water consumption by newly-built facilities.

Water Conservation Measures and Results in 2018



Water Conservation Effectiveness

	2014	2015	2016	2017	2018
Average recycling rate of water for manufacturing processes (%) ^{Note1}	87.6	87.3	87.4	87.5	87.5
Ultrapure water consumption (Million metric tons) ^{Note2}	56.6	61.0	68.8	79.7	85.1
Tap water consumption (Million metric tons) ^{Note2}	38.2	37.5	42.0	49.0	56.8
Total amount of water recycling (Million metric tons) ^{Note3}	81.0	85.6	94.3	103.4	129.0
Equivalent volume of the Second Baochan Reservoir (number) ^{Note4}	2.57	2.72	3.00	3.29	4.10
Equivalent volume of a standard swimming pool (number) ^{Note5}	32,396	34,252	37,732	41,360	51,612
Number of times each drop of water is used	3.3	3.5	3.5	3.5	3.5

Note 1 Statistics are calculated by a standard formula assigned by the Science Park Administration

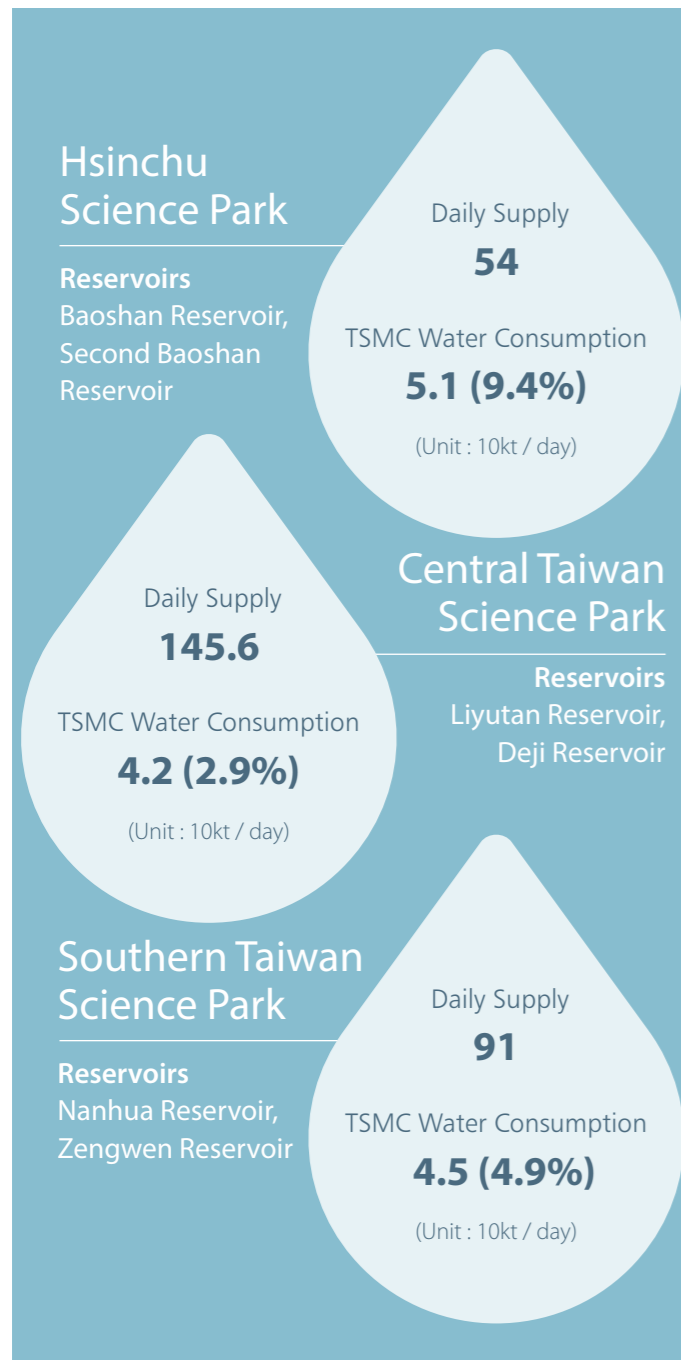
Note 2 Ultrapure water and tap water consumption includes numbers from Taiwan sites (all wafer fabs and back-end assembly facilities), WaferTech, TSMC (China), TSMC (Nanjing) and VisEra

Note 3 Total amount of water recycling includes all data from Taiwan sites (all wafer fabs and back-end assembly facilities in Taiwan)

Note 4 The water in Hsinchu Science Park is mainly supplied by the Second Baoshan Reservoir, whose full capacity amounts to 31.49 million tons

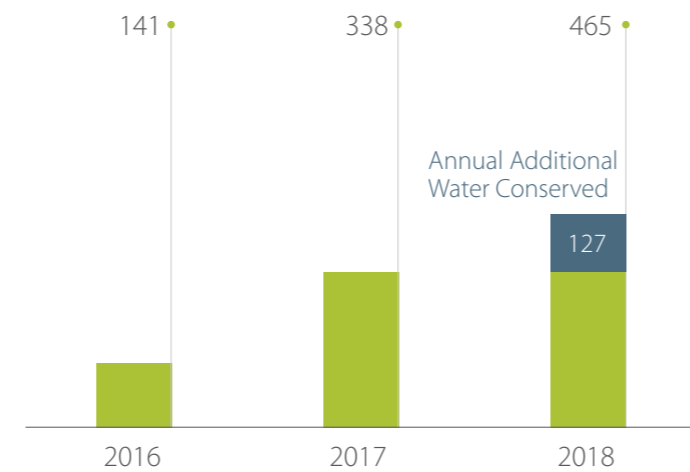
Note 5 A standard swimming pool is 50x25x2 meters in size, or 2,500 tons in volume

TSMC Water Consumption Rate at Three Science Parks

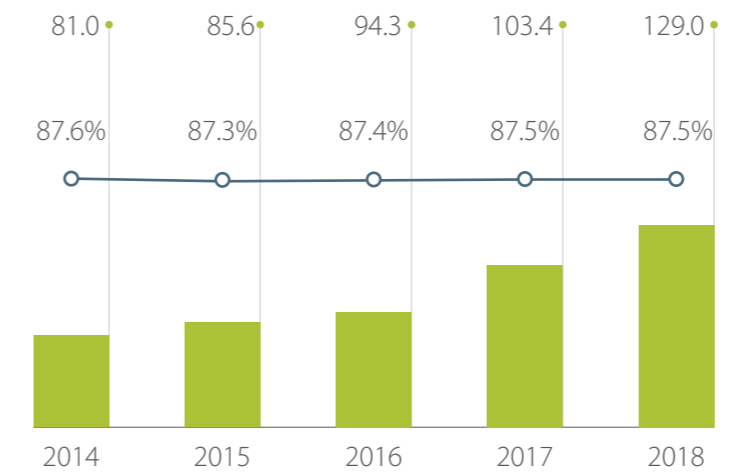


Annual Water Conserved

Unit: Ten thousand tons



Water Recycling and Usage Efficiency

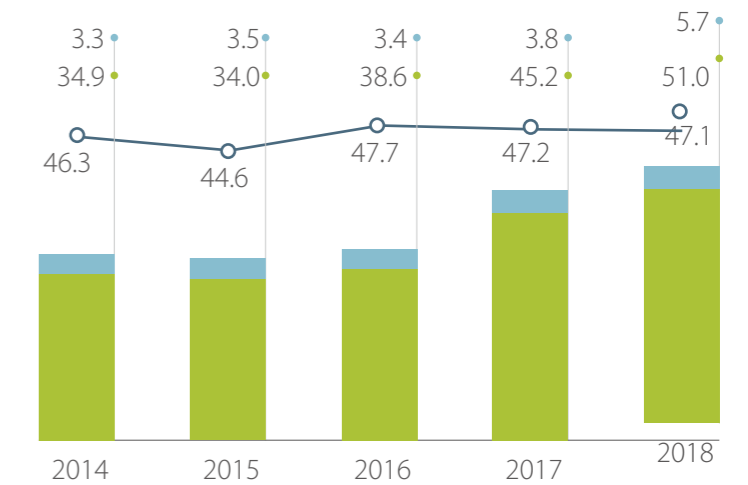


■ Total amount of water recycled (Million metric tons)
○ Average Process Water Recycling Rate (%)

Note 1 Total amount of water recycled includes numbers from manufacturing process water treatment and recycling as well as manufacturing process water recycling in scrubber towers

Note 2 The total amount of water recycled is 2.5 times the volume of tap water consumption

City Water Consumption and Water Consumption per Wafer-Layer



■ Total tap water consumption of subsidiaries (Million metric tons)
■ Total tap water consumption in Taiwan facilities (Million metric tons)
○ Water Consumption Per Wafer-layer (liter / 8-inch e wafer-layer)

Note 1 Tap water consumption includes numbers from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing), and VisEra

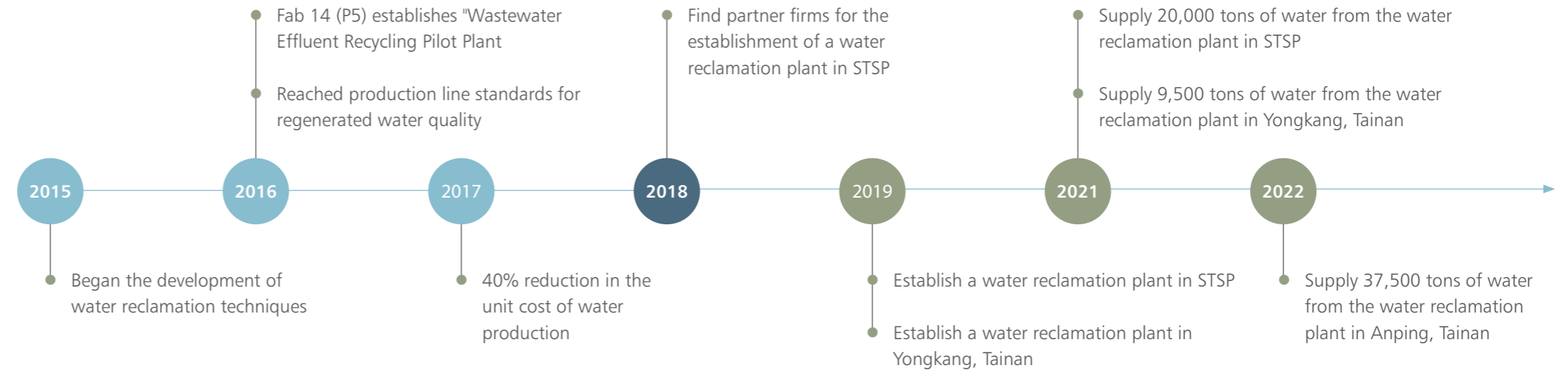
Note 2 The indicator for water usage per wafer-layer represents data from all wafer fabs of TSMC and subsidiaries

Note Reservoir capacity is according to the water supply information of all regions published on the Water Resources Agency website. The capacity of reservoirs supplying Central Taiwan Science Park includes numbers from Taichung and Miaoli

Develop Diverse Water Sources

TSMC's water sources include tap water, air conditioning (AC) condensate water, and rainwater. Tap water is used for manufacturing processes and domestic purposes; AC condensate, for manufacturing processes and irrigation; and rainwater, for irrigation systems. In order to cope with water shortages and comply with water supply diversity policies, TSMC has been developing water reclamation technologies since 2015. Currently, the Company has successfully decreased the number of water quality factors, such as total organic carbon (TOC), carbamide, and electric conductivity in wastewater, and it now meets water management standards for manufacturing processes in wafer fabs. The quality of its wastewater has also reached effluent discharge standards. TSMC's achievements all mark a significant development milestone in water reclamation. In addition, the Company succeeded in reducing the unit cost of water production by 40% and made regenerated water more economical in 2017. TSMC also began to find partner firms for the establishment of a water reclamation plant for its Southern Taiwan Science Park (STSP) site, and the plant is expected to be approved and constructed in 2019, providing 20,000 tons of industrial regenerated water per day. In the future, TSMC will continue to promote the development of water reclamation and support it with tangible actions to expand the supply and recycling of sustainable fresh water.

Timeline of Highlights for Regenerated Water



Note The actual schedule of introducing regenerated water may be adjusted according to the water supply timetable in water reclamation plants

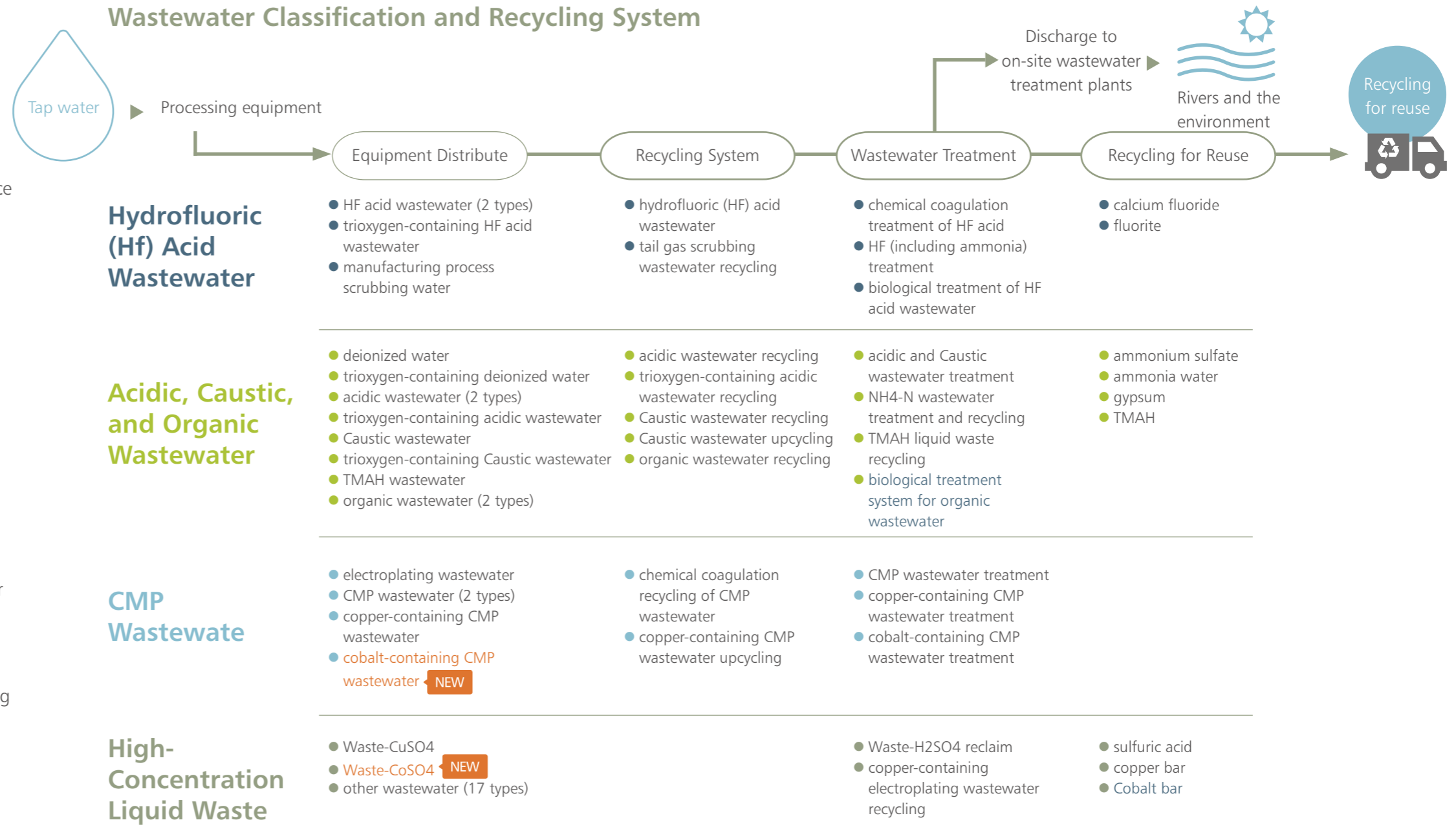


Develop Preventive Measures

More Effective Distribution Methods in Source Management

To maximize the performance of pollution prevention, source classification and management must be comprehensive. TSMC has put many resources into upgrading existing treatment equipment and constructing treatment facilities to direct to wastewater towards appropriate treatment systems and preliminarily degrade all pollutants. Following this, wastewater is condensed and reclaimed through the recycling system to further reduce the concentration of pollutants in line with the Company goals. Wastewater from manufacturing processes are distributed into several categories: hydrofluoric acid wastewater, acidic and caustic wastewater, chemical mechanical polishing (CMP) wastewater, and high-concentration liquid waste. All wastewater is stringently classified immediately at the tool. At total of 38 distribution systems have been established based on the composition and concentration of wastewater from manufacturing processes. In 2018, following changes to manufacturing processes, TSMC began to use cobalt as the material of choice for interconnect and installed a new distribution and treatment system for wastewater containing high concentrations of cobalt and cobalt-containing CMP wastewater. Manufacturing process wastewater can flow through distribution pipelines to be collected by different wastewater treatment facilities. TSMC has built a comprehensive wastewater classification and resourcing system and made much progress in acid-base neutralization systems and coagulation-precipitation systems. Since the beginning of development, each plant now has 9 recycling systems and 12 wastewater treatment systems. With robust classification and treatment techniques, all components in wastewater can be transformed into reusable resources.

Wastewater Classification and Recycling System



Note 1 TMAH stands for tetramethylammonium hydroxide

Note 2 Among all recycled products, sulfuric acid and electronic grade coating copper are reused in TSMC sites, while the rest are reused externally by other industries

Note 3 Categories of cobalt-containing wastewater and cobalt-containing liquid waste were added in 2018

Wastewater Discharge Monitoring

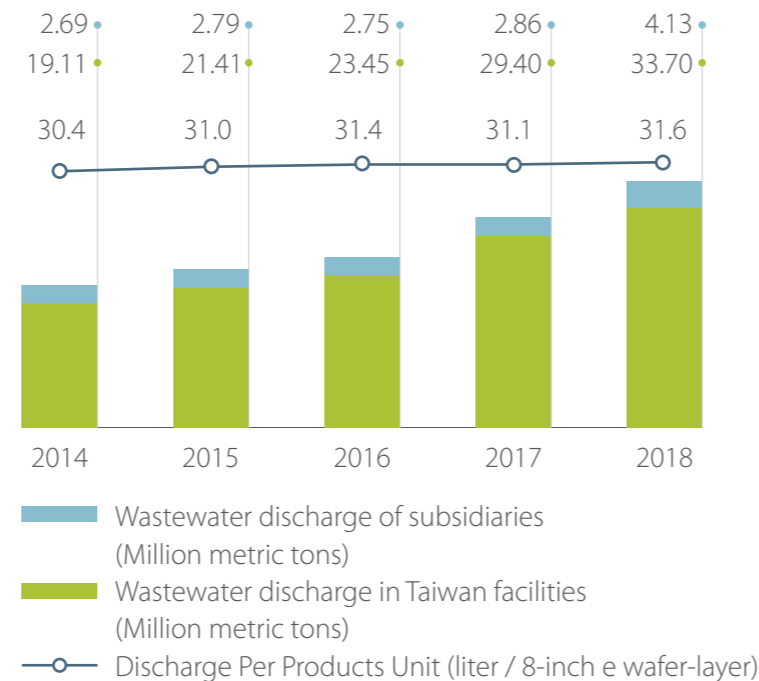
The amount of wastewater discharge is closely related to the volume of tap water consumption and water recycling. As TSMC's advanced process technology production continues to rise, unit water consumption, along with unit wastewater discharge, are increasing. TSMC has intensified its water recycling to reduce wastewater discharge. The discharge volume per product unit decreased by 2.4% from 2017 to 28.2 (liter / 8-inch e wafer-layer).

Wastewater Quality Improvement

All TSMC fabs have installed equipment to continuously monitor water quantity and quality at effluent spouts of wastewater treatment facilities. By closely monitoring and recording changes in water quality and quantity, TSMC can respond appropriately when abnormalities occur. TSMC not only follows statutory effluent water quality standards but also participates in eco-friendly activities. After assessing manufacturing raw materials by referencing domestic and international studies on biological toxicity, TSMC has focused on pollutants in the semiconductor industry, such as TMAH (strong base), copper ions (heavy metal) and ammonia, as well as suspended solids and chemical oxygen demands that directly impact marine life, setting these as key targets to be improved. The Company has carried out various improvement measures and reduced the impact of wastewater discharge on the environment.



Wastewater Discharge Per Product Unit



Note 1 Total wastewater volume included numbers from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing), and VisEra

Note 2 Unit wastewater discharge intensity index is calculated with statistics from all TSMC wafer fabs and its subsidiaries

Preventive Techniques on Key Pollutants of Wastewater Quality and Improvement Achievements

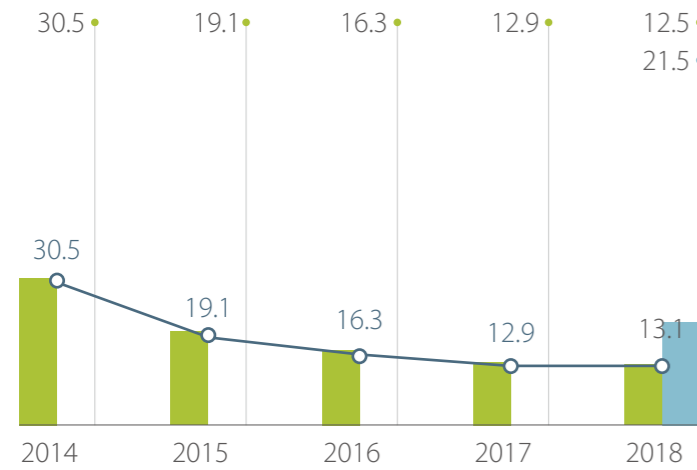
Item	Standards set by Science Park Administration	TSMC Long-term Goals (2025)	Status in 2018	Improvement Achievements in 2018	Preventive Techniques
TMAH	HSP : 30 CTSP: 20 STSP: 60	1.0	13.1	Reduced by 57% from the previous year	<ul style="list-style-type: none"> Recycle low-concentration liquid waste Establish anion exchange resin towers
copper ion	HSP : 1 CTSP: 0.8 STSP: 3	0.1	0.18	Reduced by 53% from the previous year	<ul style="list-style-type: none"> Distribute copper-containing liquid waste Concentrate and recycle in resin towers (under planning)
NH4-N	HSP : 30 CTSP: 20 STSP: 60	20	21.0	Reduced by 87% from the previous year	<ul style="list-style-type: none"> Expand ammonia treatment systems
chemical oxygen demand	HSP : 500 CTSP: 500 STSP: 450	100	177.5	Raised by 47% from the previous year	<ul style="list-style-type: none"> Implement combustion treatment in strippers (under planning) Establish biological treatment systems (Bioprocess) (under planning)
suspended solids	HSP : 300 CTSP: 300 STSP: 250	30	29.4	Achieved long-term goals ahead of schedule	<ul style="list-style-type: none"> Recycle backwash wastewater after coagulation and precipitation

Unit: ppm

Note Hsinchu Science Park (HSP), Central Taiwan Science Park (CTSP), Southern Taiwan Science Park (STSP)

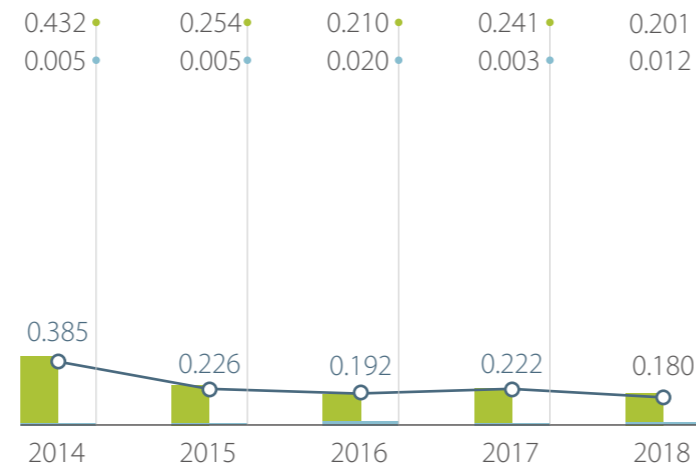
Pollutant Discharge Trends

TMAH Unit: ppm



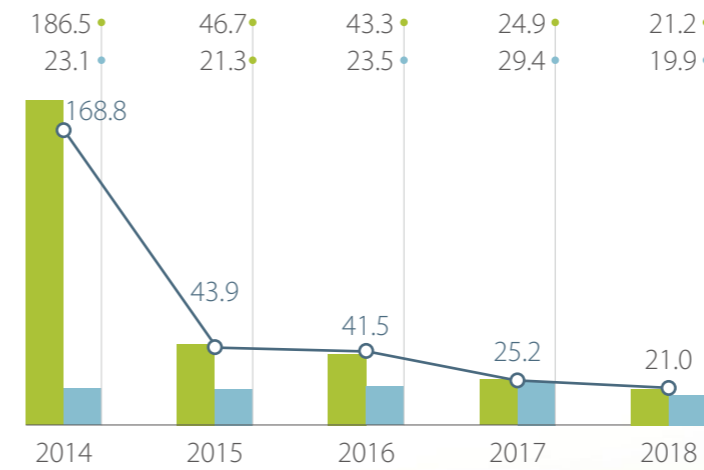
■ TMAH (Taiwan facilities)
■ TMAH (Subsidiaries)
○ TMAH (TSMC)

Cu²⁺ Unit: ppm



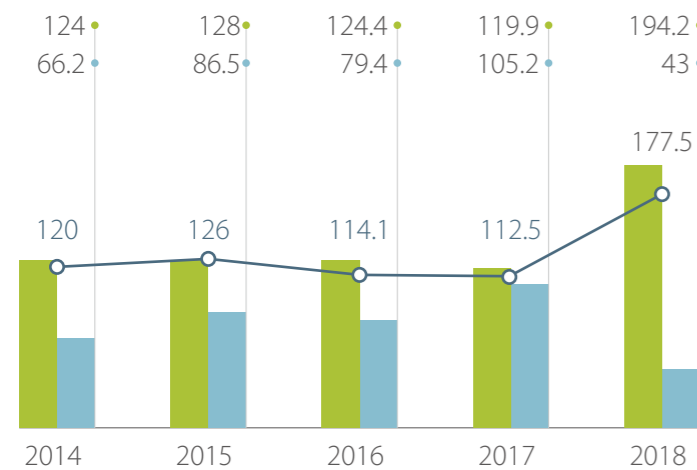
■ copper ion (Taiwan facilities)
■ copper ion (Subsidiaries)
○ copper ion (TSMC)

NH₄-N Unit: ppm



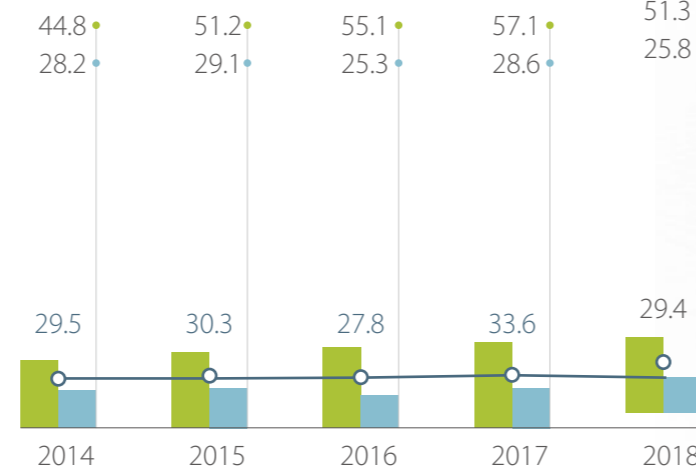
■ NH₄-N (Taiwan facilities)
■ NH₄-N (Subsidiaries)
○ NH₄-N (TSMC)

Statistics on the Chemical Oxygen Demand of Wastewater Unit: ppm



■ chemical oxygen demand of wastewater (Taiwan facilities)
■ chemical oxygen demand of wastewater (Subsidiaries)
○ chemical oxygen demand of wastewater (TSMC)

Statistics on Suspended Solids in Wastewater Unit: ppm



■ suspended solids in wastewater (Taiwan facilities)
■ suspended solids in wastewater (Subsidiaries)
○ suspended solids in wastewater (TSMC)

Note 1 Statistics of TMAH include data from TSMC (all wafer fabs and back-end assembly facilities), TSMC (China) and TSMC (Nanjing)

Note 2 Statistics of copper ions, chemical oxygen demand, and suspended solids in wastewater include data from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), TSMC (China), TSMC (Nanjing), and VisEra

Note 3 Statistics of NH₄-N include data from TSMC (all wafer fabs and back-end assembly facilities), TSMC (China), TSMC (Nanjing), VisEra, and WaferTech

Note 4 The 2018 statistics on the chemical oxygen demand of wastewater and suspended solids in wastewater are calculated with the weighted average of water volumes across all campus

Note 5 Data for TSMC (Nanjing) were added in 2018



Case
Study

Distribute Low-Concentration Wastewater and Reduce Chemical Use During Treatment

Appropriate water pollution prevention measures require considerations of treatment procedures and chemical dosage to effectively reduce target pollutants without increasing the discharge of other pollutants. In order to enhance the efficiency of copper capture, TSMC reduced its chemical dosage in treatment procedures and decreased the amount of copper sulfate liquid waste and chemical coagulation byproducts. After evaluating the raw material consumption and wastewater discharge status in 2018, TSMC included lower concentrations of copper-containing liquid waste (< 2 ppm) for treatment. The concentration of wastewater discharge is expected to decrease to 0.1mg / L by 2025 as a result of TSMC's unrivalled strict adherence to industry standards.

Repeated Examinations and Efficiency Enhancement of Mid- and Low-Concentration Wastewater Treatment

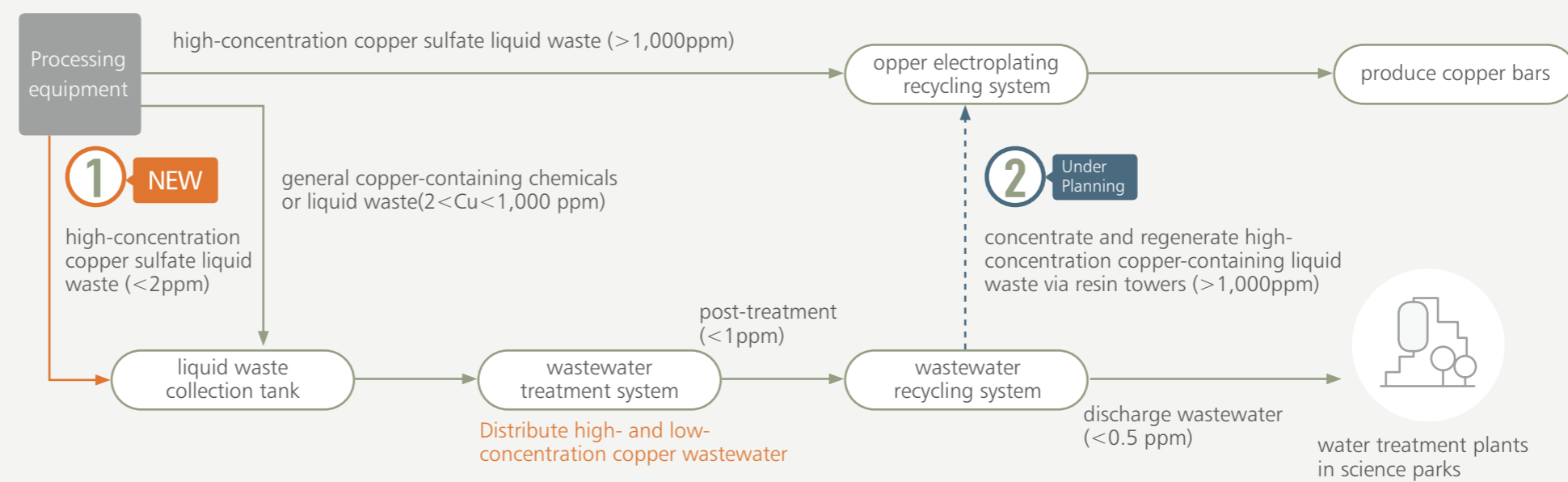
After approximately a thousand rounds of testing, examining, and analysis in 2018, TSMC has determined the optimal amount of chemicals for various concentrations and established two processes: recycling of low-concentration copper-containing chemicals and liquid waste, and the distribution of

wastewater containing high-concentration coordination complex ions. Compared to 2014, these processes maximize the functions of a copper ion capturing agent (Cu chelating agent) while decreasing the concentration of copper from 3-4 ppm to less than 1 ppm, leading to an accumulated reduction of 53%. Additionally, the concentration of effluent water was reduced from 0.38 ppm to 0.18 ppm, much lower than the standards in all science parks and the copper ion standard of 1 ppm for drinking water.

Condensate Wastewater - Concentration, Recycling, and Copper Bar Production in Resin Towers

Based on wastewater treatment results in 2018, TSMC is actively conducting assessments and examinations for the establishment of a wastewater condensation and high-concentration copper regeneration and electroplating system in the hope that through resin and regeneration concentration selection and mixing tests, low concentrations of copper ions absorbed by the cation resin tower following regeneration and concentration by strong acids (hydrochloric acid) can be reclaimed as copper bars via electroplating. Through this measure, the treatment procedures for copper liquid waste can be further refined and become more eco-friendly.

TSMC Treatment Procedures of Copper-Containing Liquid Waste



Case Study

Comprehensive Collection and Double Treatment Reduces TMAH Concentration by 57%

Tetramethylammonium hydroxide (TMAH) is a strong alkali-containing neurotoxin commonly found in the wastewater of semiconductor manufacturing processes. TSMC has taken considerable efforts to capture TMAH through resin towers to mitigate its environmental impact. It has also cooperated with partner firms to reduce 25% concentrated TMAH into recyclable industrial-grade materials. In addition, TSMC has determined the optimal treatment curve for all fabs through long-term operation and continuous testing, thereby considerably reducing the amount of recycling by-products. To further decrease the concentration of TMAH, TSMC has extensively researched and analyzed the status of raw material use and waste discharge from equipment in 2018, following the two main guidelines of comprehensive collection and double treatment. In comparison to 2014, the average concentration of TMAH was reduced by 57% from 30.5 ppm to 13.1 ppm, and is expected to be reduced by 95% in 2025.

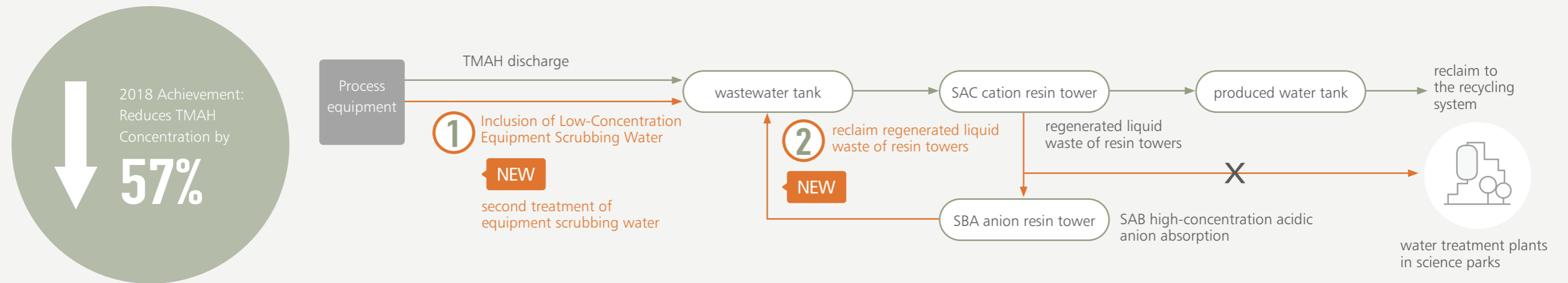
Comprehensive Collection: Inclusion of Low-Concentration Equipment Scrubbing Water

TSMC has established the most robust wastewater classification management system in the industry. It continues to improve the stability and efficiency of the system with thousands of parameter adjustments and resin category testing data every year. In 2018, the Company took a further step to collect and manage low-concentration liquid waste (TMAH < 1,000 ppm). Instead of directly discharging the wastewater as before, pipelines for equipment scrubbing water were designed to recycle and manage the TMAH system in order to reclaim precious water resources.

Double Treatment: Recycle Regenerated Liquid Waste from Resin Towers

Cation resin towers are often used to absorb TMAH in the semiconductor industry. After saturable absorption, TMAH is regenerated during neutralization with strong acids. In the past, low-concentration TMAH acid could not be reabsorbed in the process due to sulfate ions (SO₄²⁻) and would often be discharged into wastewater. To resolve this issue, TSMC repeatedly examined and refined regeneration procedures until it successfully developed an anion resin tower mode, which takes regenerated liquid waste from resin towers and removes sulfate ions before introducing them into cation resin towers for effective absorption to further reduce TMAH concentration.

TSMC's Refined Procedures of TMAH Treatment



Waste Management



Note 1 Vendors who are exempted from on-line listing or public organization are excluded from the aforementioned vendors
Note 2 For more information, please refer to "Circular Economy"

✔ Surpassed ✔ Achieved ⊖ Unachieved



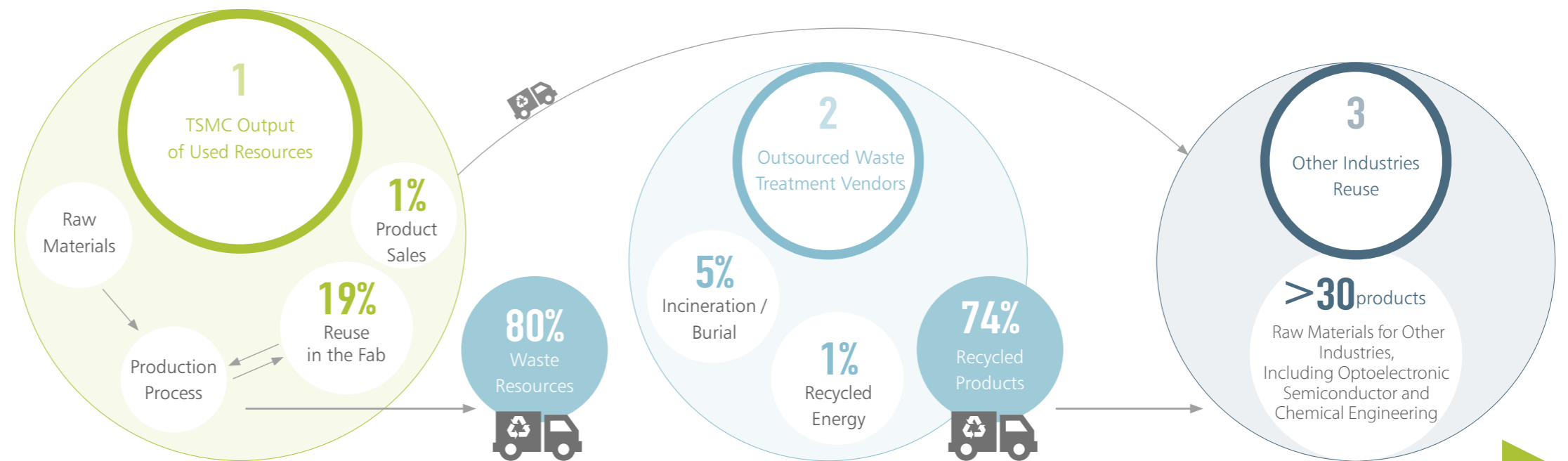
Minimizing Waste Production and Maximizing Reuse of Resources

TSMC's principle in waste management is to continuously reuse resources. As the Company's production and R&D continues to increase in scale, TSMC prevents corresponding increases in waste production and the potential impact on the environment by following the guidelines of "Minimal waste production, maximum continuous reuse of resources." To reduce waste production, TSMC requires production sources to adjust process technology and parameters for raw material use. With the assistance

of its supply chain, TSMC optimizes material usage and minimizes material consumption. With regard to maximizing the reuse of resources, TSMC constantly seeks out for new reusable materials; the Company's manufacturing fabs have been reducing material consumption and environmental impact by maximizing the reused resources. As for waste disposal, TSMC renews waste through resource renewal technology and converts waste into reusable resources that can be reused interanlly or sold to other industries. For non-reusable resources that cannot be converted through resource renewal technology or reused, TSMC prioritizes recycling and recovery by sending them to

certified waste disposal vendors in accordance to the principles of circular economy. When all options have been exhausted, TSMC's final option is to resort to waste incineration and landfill. In 2018, the recycling rate was 95%, and has been over 90% ten years in a row. TSMC has been actively implementing circular economy and has also established a "waste disposal vendor management procedure" with periodic onsite audits to ensure that all waste management and waste reuse is compliant with the law. TSMC also shares relevant environmental and sanitary management experience with waste treatment and recycling vendors, and requires them to be ISO certified to further improve the quality of waste management.

Life Cycle and Management of Sustainable Resources in TSMC



Source Management

- Categorize and collect from the source
- Tracking of output and fab waste reduction projects
- Wastes preprocessed in-house as reused resources

Waste Resource Management

- TSMC Satellite Management Tracking System
- Tracking of GPS Anomalies

On-site Audits

- Safety management and facility availability
- Inspection on input and output

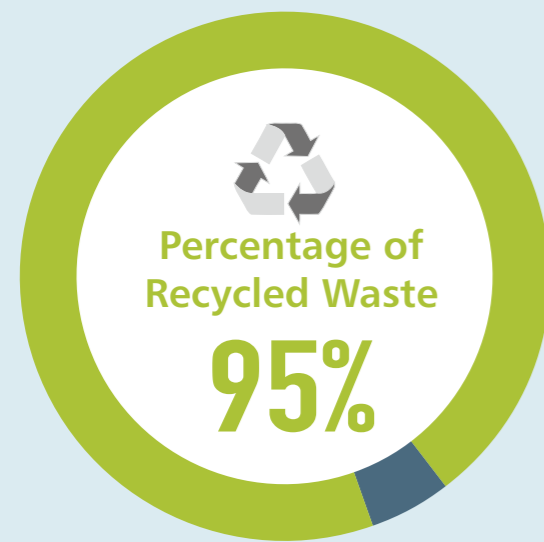
Follow-up on reused products

- Monthly sales of reused products
- Evaluation of the industry, clients, and usage
- Inspection of invoices and shipping records

2018

Recycled Waste **447,940** tons

Total Waste Production **473,756** tons



95%

Recycled Waste (447,940 tons)

- 74% Recycled Materials
- 19% Reused in Fabs
- 1% Converted to Products and Sold
- 1% Recycled Energy (Auxiliary Fuel)

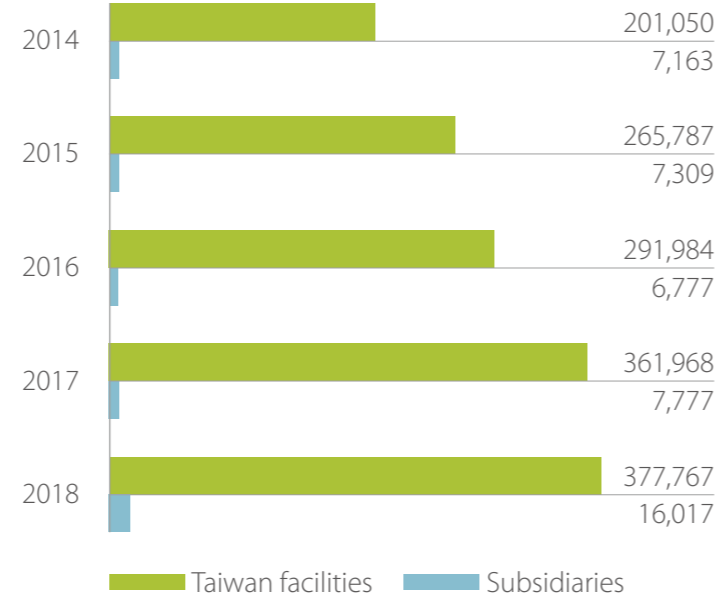
5%

Non-recyclable Waste (25,816 tons)

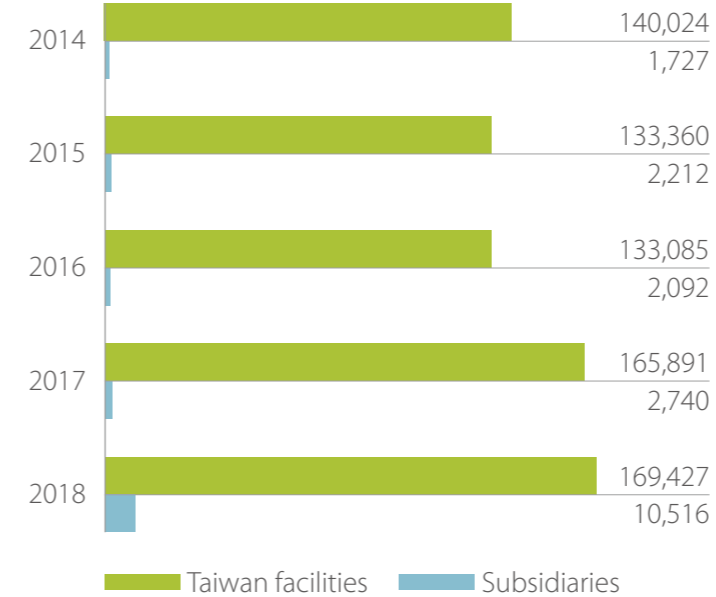
- 5% Incineration / Burial

Waste Quantity and Treatment Status Statistics

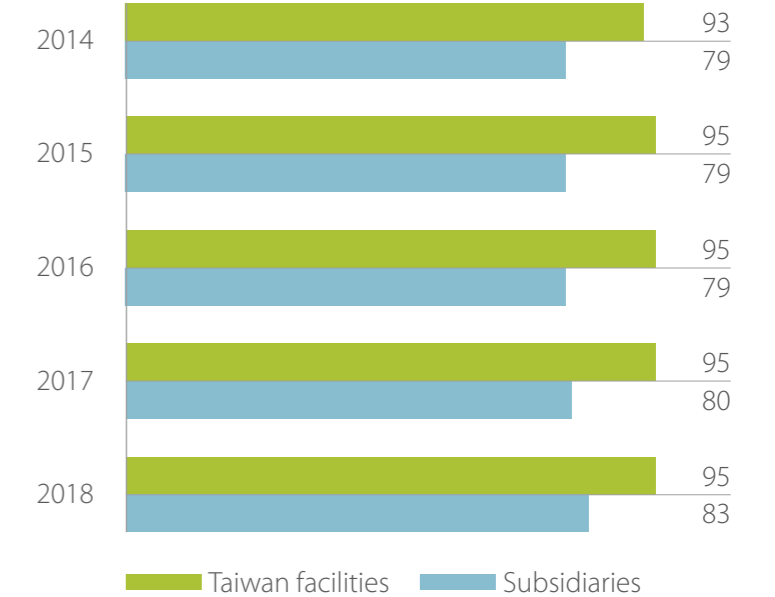
Waste from Outsourced Businesses Unit : tons / year



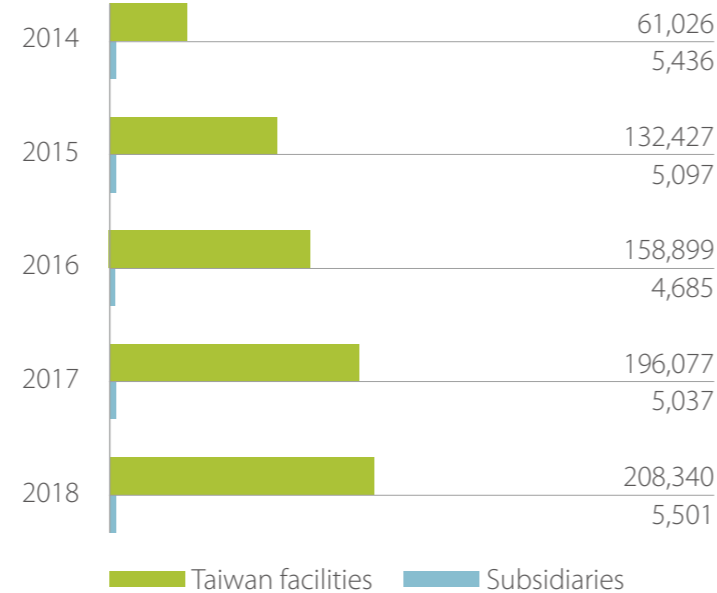
Hazardous Business Waste Unit : tons / year



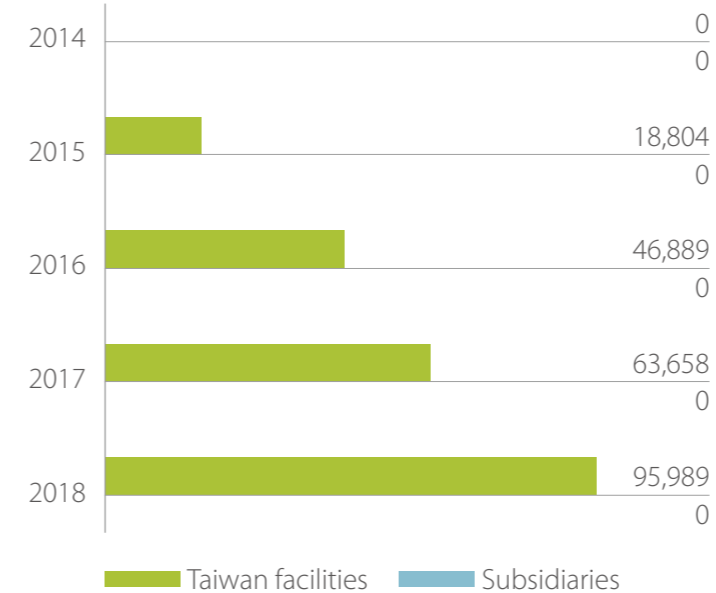
Percentage of Recycled Waste Unit : %



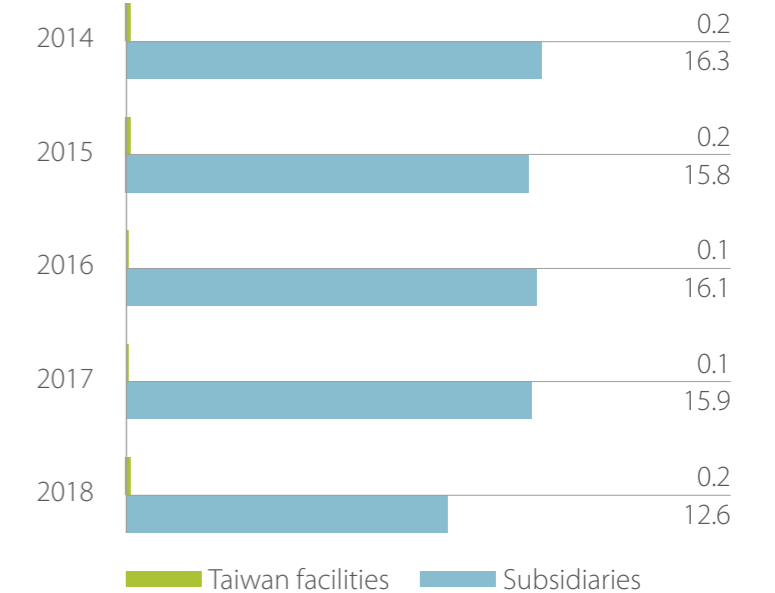
General Business Waste Unit : tons / year



Reused Resources Unit : tons / year



Rate of Buried Waste Unit : %



Note 1 Data included TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), and subsidiaries (WaferTech, TSMC (China), TSMC (Nanjing), and VisEra).

Note 2 The amount of waste from outsourced businesses is determined by the sum of both general and hazardous business waste

Note 3 The definition of waste from hazardous businesses is determined by local regulations

Note 4 Data for hazardous business waste in 2015 and 2016 has been corrected and recalculated

Source Reduction

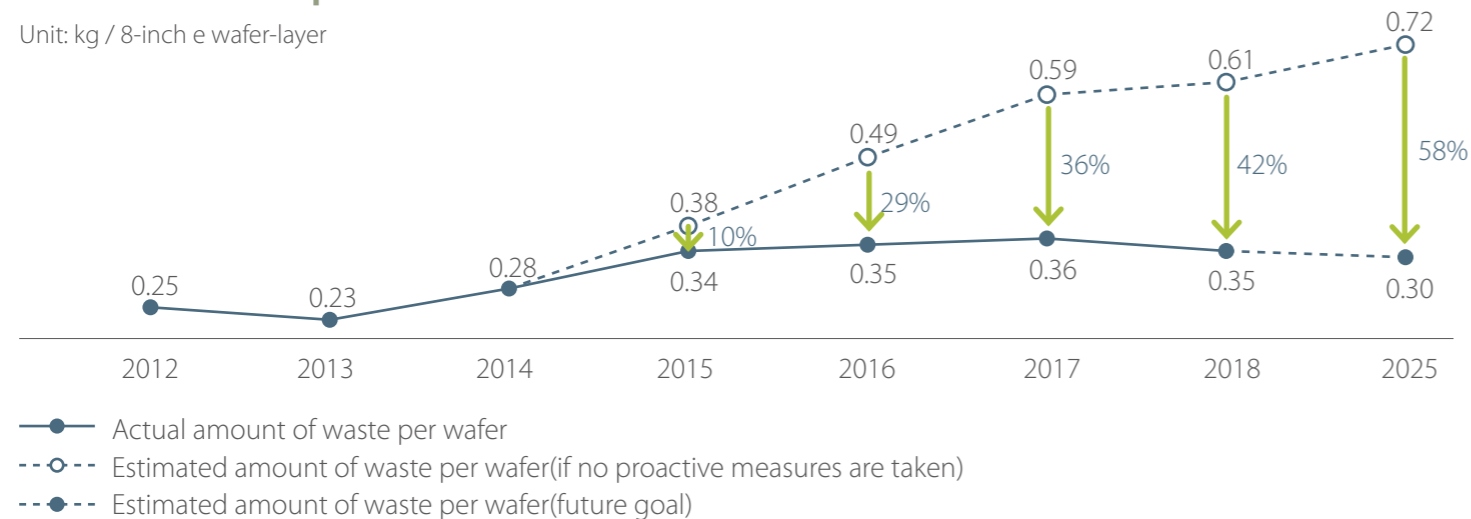
TSMC continuously develops advanced process technologies and expands its capacity, with rising demand for raw materials and standard of environmental regulations, TSMC estimates that by 2025, the weight of the Company's outsourced waste disposal per wafer will be at 0.72 kilograms.

TSMC established a "Waste Management Task Force", and within the committee, the Vice President of Operations designates inter-fab coordinators to come up with waste reduction plans with fab managers at the beginning of each year and to hold monthly progress checks. If it becomes apparent that a

reduction objective cannot be met, better solutions and measures will be implemented. In addition, TSMC has built a real time management system to track the amount of waste produced in the production process per unit. By doing so, fab managers can monitor the output of waste in real time and compare outputs with other fabs. When an effective solution to waste reduction is successfully verified, the method will be adopted by the other fabs in order to maximize waste reduction. In 2018, TSMC implemented 217 waste reduction proposals and reduced the amount of outsourced waste disposal for diluents. The weight of outsourced waste disposal per wafer was reduced to 0.35 kilograms from the projected 0.61 kilograms. TSMC will continue to seek opportunities to reduce chemical waste used in fabrication from the source, and increase the scope of waste renewal facilities and projects to meet the 2025 goal of reducing the amount of outsourced waste disposal to 0.3 kilograms.

Unit Waste Output Trendchart

Unit: kg / 8-inch e wafer-layer



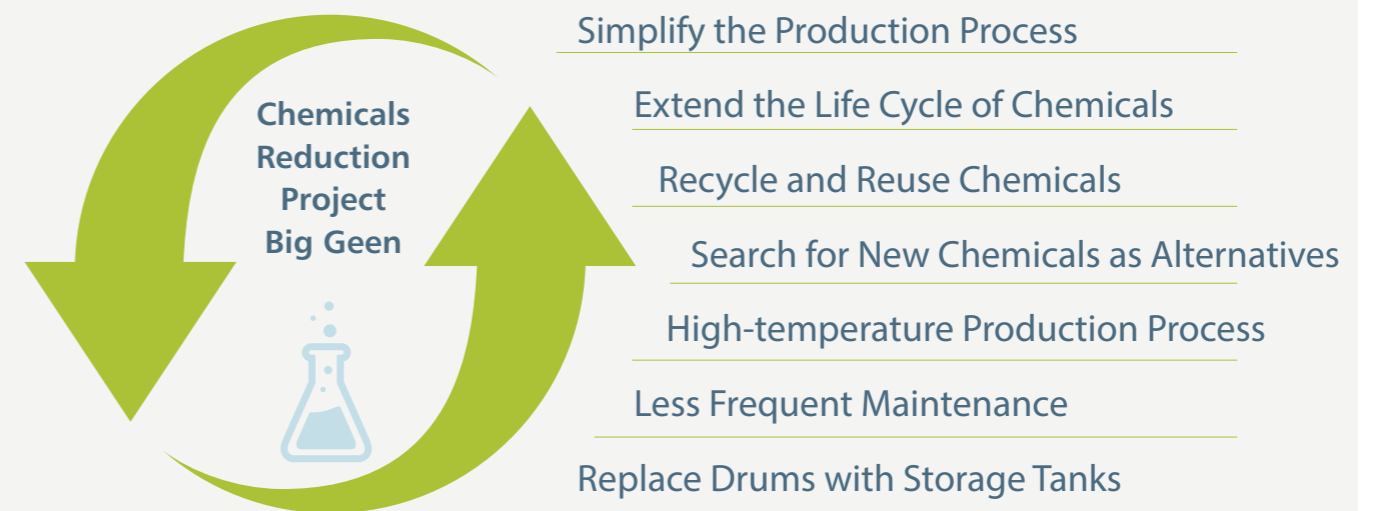
Note 1 Outsourced waste per wafer increased because of
(1) Increased wafer production
(2) TSMC lists its ammonia nitrogen in wastewater as waste in order to comply with new wastewater regulation beginning in 2015

Note 2 Since 2015, TSMC has been promoting waste reduction and waste reuse. Projected amounts are based on 2014 as the base year before waste reductions

Case Study

"Project Big Green" —A Full-Scale Chemical Reduction Plan

TSMC's environmental vision is to become an environmentally sustainable and world-class business in environmental protection. To live up to this aspiration, TSMC is actively making efforts to reduce waste production from the source, and has shown improvement each year by implementing the "Project Big Green" plan to reduce consumption of heavily used chemicals. Goals for 2018 include simplifying the manufacturing process, extending the life cycle of chemicals, and recycling and reusing resources. At the same time, TSMC has been exploring alternative chemical replacements, introduced high-temperature production processes to reduce the use of chemicals, and is seeking to extend the frequency of regular maintenance. Furthermore, the feeding system was replaced from storage drums to storage tanks to reduce residue materials. Once an effective solution for waste reduction is verified, the process is adopted by all fabs, ensuring product quality and at the same time cutting down on chemical use. In 2018, through a variety of source reduction plans, TSMC reduced the amount of waste per wafer by 28,907 tons per year, and decreased waste disposal expenses by NT\$220 million per year.



Circular Economy

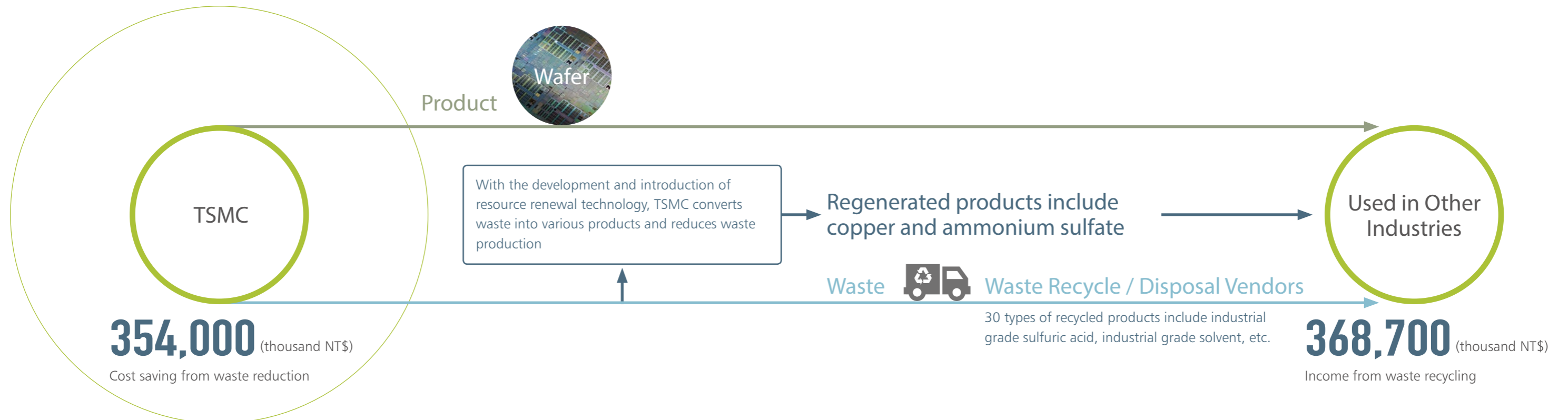
TSMC fulfills circular economy through the Company's actions, hoping that while people enjoy the convenience of technology, TSMC can at the same time lessen environmental impact by reusing materials. TSMC not only introduced resource renewal facilities, but also added chemical materials and 3 other categories of business items to the Company's Articles of Incorporation. By successfully converting waste material into valuable resources, TSMC began to sell

self-produced recycled products to other businesses in 2018, and expects to gradually expand its "High Added-Value Resource Plan" over the next five years. Through the development and introduction of resource renewal technology, the waste produced in the manufacturing process will be converted to products and directly reused in TSMC fabs or sold to other businesses. TSMC is transforming from a waste producer to becoming an advocate for circular economy, and actively shares the Company's experiences and management techniques in resource renewal with other businesses in the industry, hoping to improve the recycling capability of Taiwan's manufacturing industry and reach the goal of sustainable development in its supply chains.

In 2018, TSMC introduced new technology that converts wastewater containing ammonia nitrogen to ammonium sulfate crystals and successfully produced small amounts of ammonium sulfate. TSMC's first-ever drying system for ammonium sulfate was set to begin full operation in 2018 with a target of achieving over 30% resource renewal rate. However, due to the adjustments made to operating parameters during the production process, the ammonium sulfate drying system was only able to produce 40% of expected amounts. TSMC has made more adjustments to facilities and operating parameters and is now projecting to reach the target of 30% resource renewal rate in 2019.

In 2018, TSMC improved the existing electronic-grade copper material extraction from its copper sulfate recycling process, and copper can now be extracted from low concentrations of copper sulfate. TSMC has also been adding preprocessing facilities to extract low concentration copper sulfate wastewater which is to be used in the recycling process. The Company estimates that copper-contaminated wastewater will no longer have to be outsourced in 2019. In 2018, TSMC recycled a total of 95,989 tons of waste and reclaimed 90 tons of products for sale, bringing in an economic value of NT\$8 million in recycled resources.

TSMC Aspires to be a Practitioner of Circular Economy

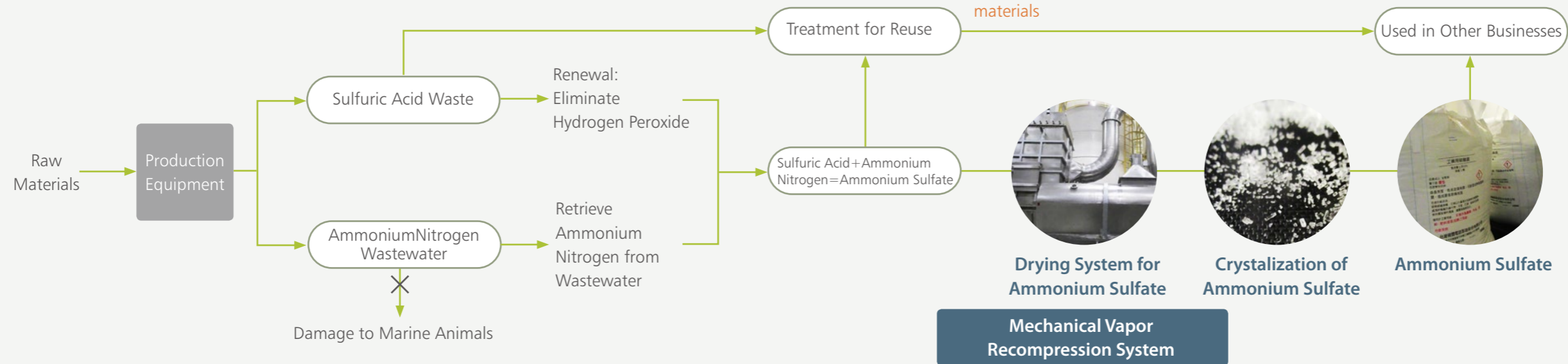


Case Study

First in the Industry— Converting Ammonia Nitrogen Wastewater into Valuable Industrial-Grade Materials

Adhering to the principle of "Minimizing Waste and Maximizing Resources," TSMC developed a pre-processing system for sulfuric acid and ammonia nitrogen wastewater in 2015, and in 2017 it was adopted by all TSMC fabs. Recycled sulfuric acid waste in fabs was used as adsorbents and combined with ammonia nitrogen wastewater, creating ammonium sulfate wastewater, which was then outsourced and used for other purposes. In 2018, TSMC further improved the ammonium sulfate crystallization system by introducing Mechanical Vapor Recompression (MVR) to create a more energy-efficient and effective way to convert ammonium sulfate wastewater into valuable industrial-grade ammonium sulfate products for resale. This is a successful case of combining used sulfuric acid waste with ammonia nitrogen wastewater into a valuable resource that can be reused. The outsourced disposal of sulfuric acid waste and ammonium sulfate wastewater decreased by 90,409 tons (eliminating the expense of purchasing the same amount of industrial-grade sulfuric acid) and 1,956 tons respectively, creating an economic value of NT\$180 million per year, reducing outsourced disposal fees and sales fees for recycled resources.

Combining Used Sulfuric Acid Waste with Ammonia Nitrogen Wastewater into a Valuable Resource that Can Be Reused



Remanufacture ammonium sulfate from ammonium nitrogen wastewater, which can be used to produce leather products and dyeing materials

The first business in Taiwan



Sulfuric Acid Waste Recycling System

Case Study

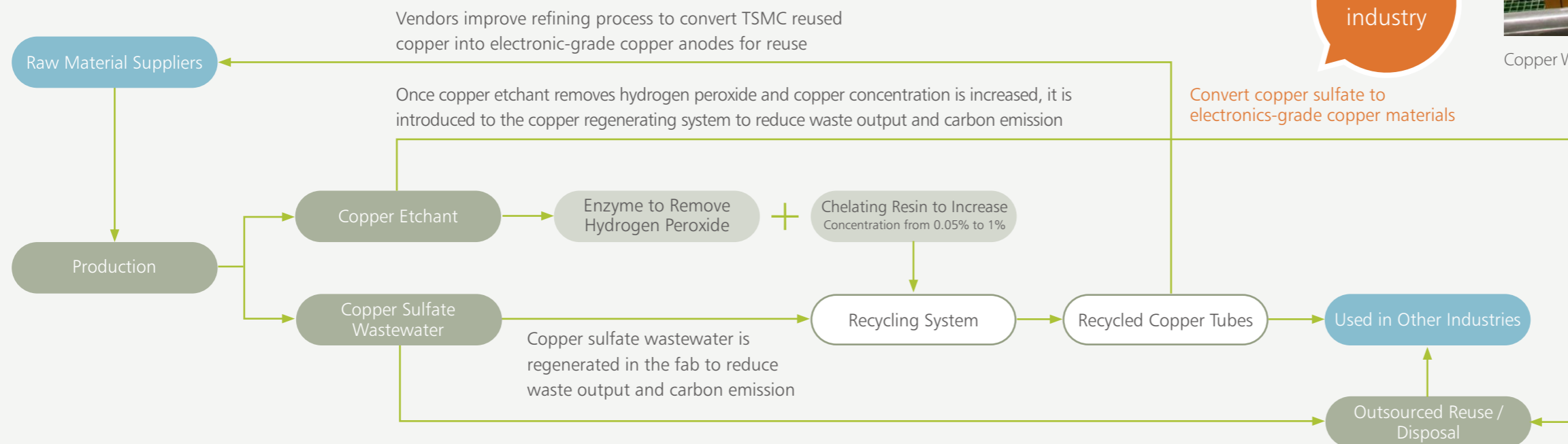
Copper Wastewater Fully Utilized as a Resource

TSMC has assessed and understands the valuable nature of copper wastewater as a resource. In addition to reusing previously outsourced copper sulfate wastewater (concentration of 1-3%) and remaking it into valuable copper tubes and electronic-grade copper anodes, in 2018 TSMC successfully recycled copper wastewater that previously could not be reclaimed. This copper wastewater containing hydrogen peroxide from the etching process of the packaging phase could not be treated with electroplating due to the low concentrations of copper (400-500 ppm). It was instead treated with enzymes to eliminate hydrogen peroxide and chelating resin to increase the copper concentration in the pre-processing stage.

A total of 3,624 tons of copper wastewater was processed and 50 tons of copper tubes were produced. In 2019, the Company's goal is to extend this recycling process to additional manufacturing processes and achieve zero outsourced copper wastewater. TSMC works with suppliers to develop production processes in the fab for the reclaimed copper tubes, where they are remade into electronic-grade copper anodes and reused in TSMC, taking a big stride towards a circular economy.



Copper Wastewater Recycling System



First in the industry

Convert copper sulfate to electronics-grade copper materials

Audit and Guidance

When it comes to waste management and reusing waste, TSMC has a thorough procedure for choosing business partners. A documentary review that includes business scale, reputation, and related certifications of its business partners is first conducted. Next, TSMC conducts an onsite audit and carefully chooses outstanding vendors to work with. Qualified vendors must go through inter-departmental annual evaluation by TSMC's Material Supply Chain Management Division, Corporate ESH Division, and Legal function and follow the "Waste Disposal and Waste Recycling Vendors Audit Plan" for an onsite audit. The provisions of the audit plan include 165 items that cover eight areas, including operating management, waste management, wastewater management, air pollution prevention, maintenance records, safety / health management, fire safety management, and emergency response. Vendors are also required to make a self-evaluation beforehand. This aids vendors in implementing these provisions in their daily management.

In 2018, TSMC conducted its annual audits and provided guidance for improvements in the eight areas in environment, safety, and health as follow-up management. The percentage of business partners evaluated as "excellent" and "good" increased from 36% in 2015 to 66% in 2018. In addition, since 2016, TSMC has been pushing for vendors to gain ISO certifications from third-party organizations recognized by TSMC. In 2018, the number of ISO-certified vendors increased

from 23 to 36, accounting for 68% of all vendors. In 2019, TSMC plans to increase the scale of the plan and work towards guiding all vendors towards certification. When selecting new vendors, certification will be a strong point for consideration in order to increase the quality of sustainable development management of vendors to reach the goal of 100% vendor certification by 2025.

To take responsibility for outsourcing the cleaning and management of its waste, TSMC requires all waste recycling vendors producing the recycled or regenerated products are to report their production and sales records on a monthly basis. TSMC also periodically conduct onsite inspection to cross-reference the actual disposals and recycling of the processing waste and compares that with the product sales records to ensure that recycled products are compliant with the law. TSMC ensures that all waste produced by the Company is properly tracked and well executed. To further increase management effectiveness, TSMC joined the Taiwan Semiconductor Industry Association and collaborated with Taiwan's Environmental Protection Agency to push for an "Electronics Manufacturers' Waste Resources Renewal Platform" in hopes that through the efforts of the government and business, a more efficient and effective management system for the flow of recycled resources can be established.



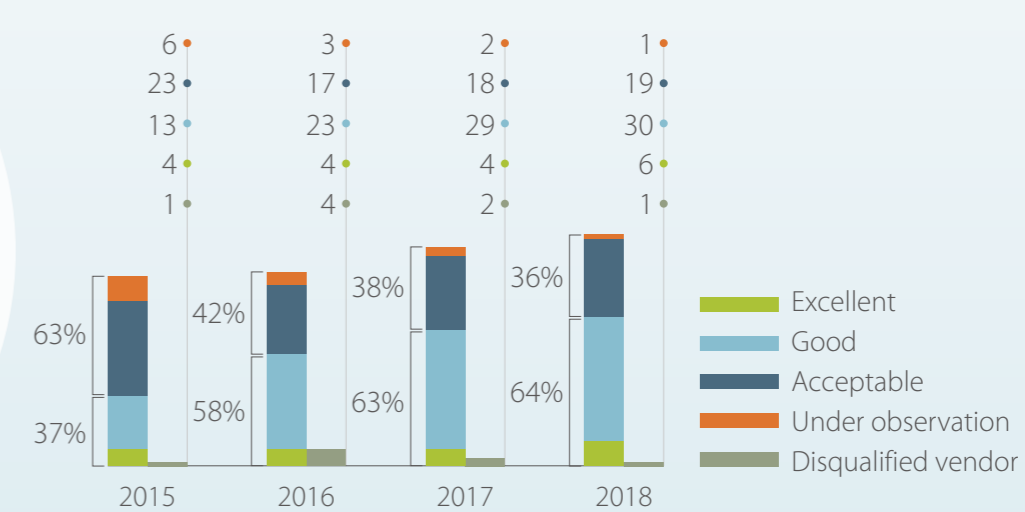
100%

Increase the number of ISO-certified vendors to reach the goal of 100% by 2025

Waste Cleanup and Disposal Vendor Management Process



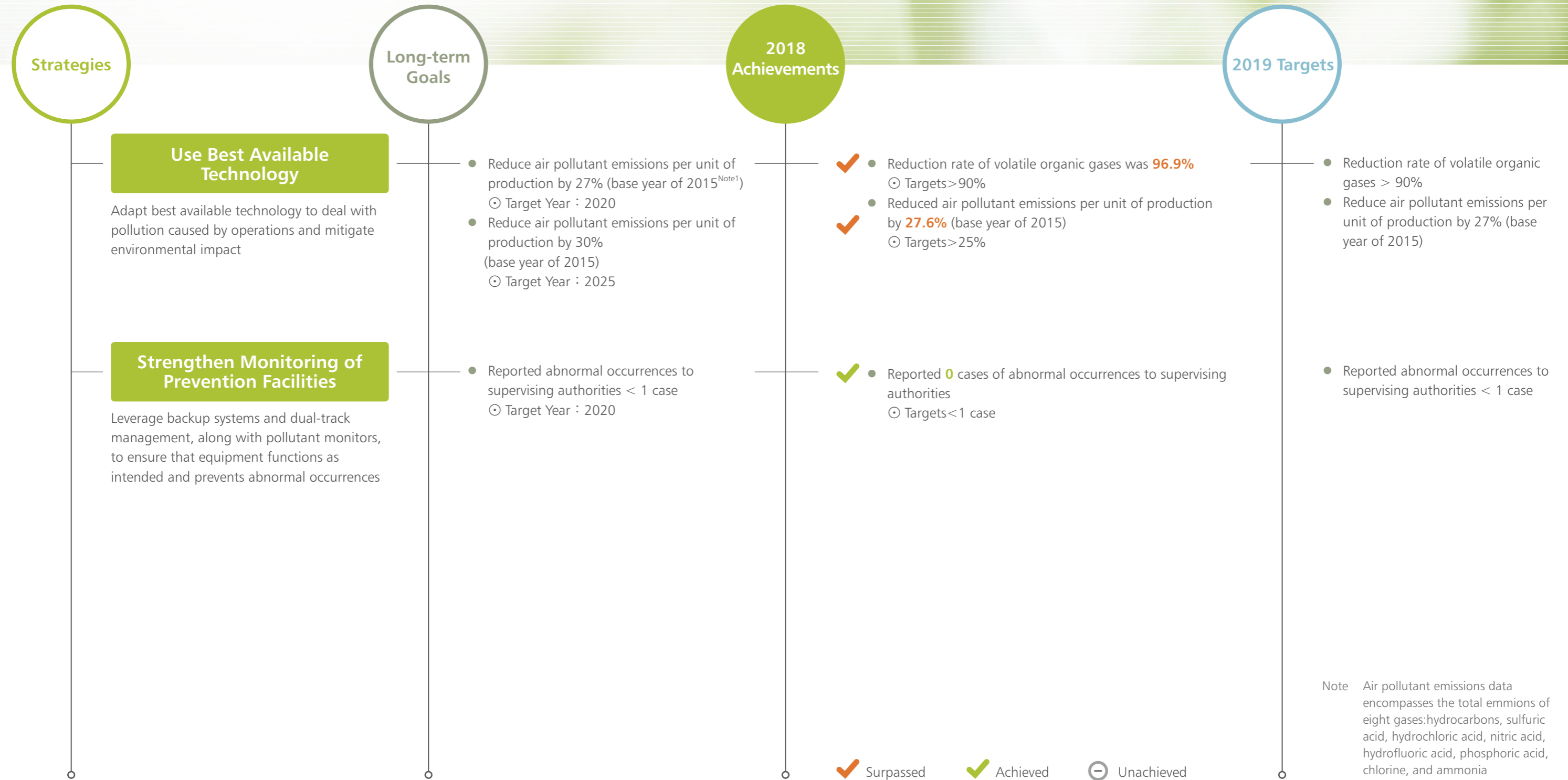
Evaluation Result



Cease transactions with vendors scored as "under observation" and showing no improvement



Air Pollution Control



Surpassed
 Achieved
 Unachieved

Note Air pollutant emissions data encompasses the total emissions of eight gases: hydrocarbons, sulfuric acid, hydrochloric acid, nitric acid, hydrofluoric acid, phosphoric acid, chlorine, and ammonia



Effectively Reducing All Types of Air Pollutant Emissions

TSMC strives to reduce air pollution with the best technology available such as source categorization and multi-station treatment so that various air pollutants can be treated effectively and concentrations of pollutants emitted to the atmosphere can meet or surpass governmental standards. In addition, to guarantee optimal operating conditions and to ensure that all colleagues are aware of the reduction rate and pollutant emission situations, all prevention facilities are equipped with N+1 backup systems and real-time monitoring systems. Related monitoring results are transmitted to the facility monitor control center and the industrial safety emergency response center to ensure that prevention facilities can immediately switch to backup systems if any abnormalities occur, and all air pollutants can still be properly treated.

Use Best Available Technology

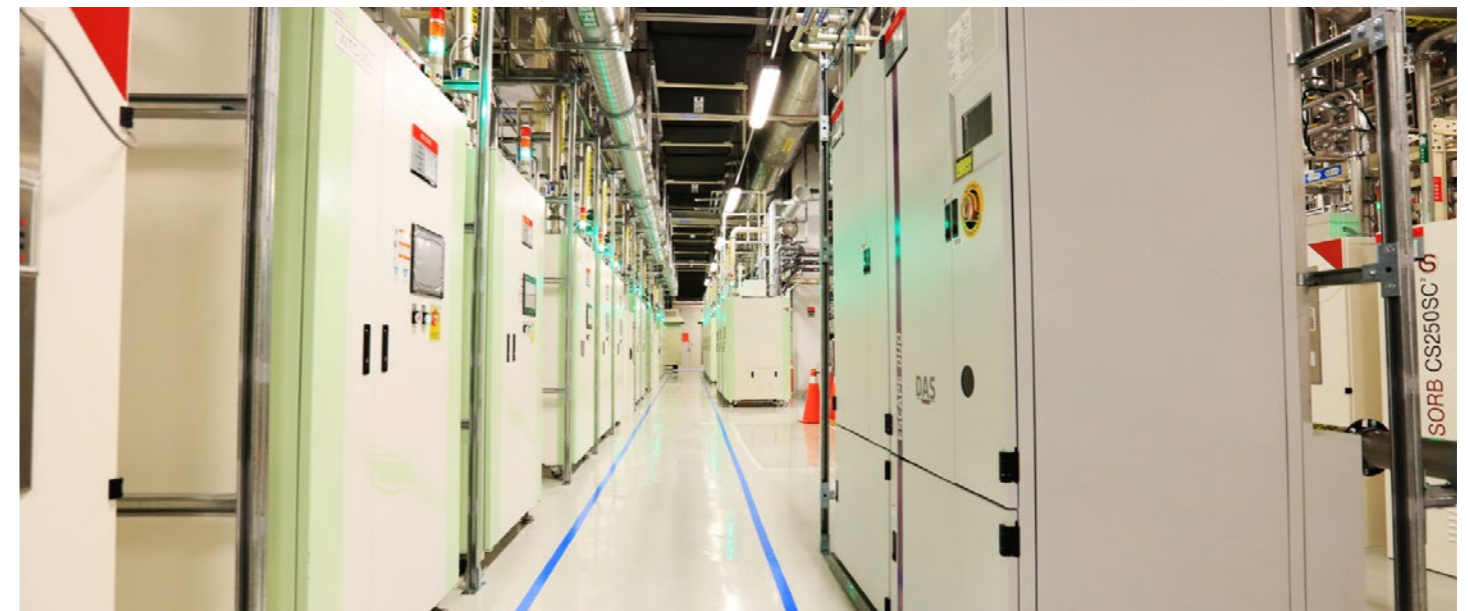
According to the "Air Pollution Control and Emissions Standards for the Semiconductor Industry" and "Stationary Pollution Source Air Pollutant Emissions Standards" in Taiwan, air pollution caused by the semiconductor manufacturing industry is mainly composed of volatile organic compounds (VOCs), acid gases, and alkali gases. In order to reduce the probability and volume of pollutant emissions to the atmosphere, TSMC divides the prevention strategy into two phases: "effective reduction of emission from sources" and "strengthened management of terminal prevention facilities". In the first phase of source classification, manufacturing process air pollutants are classified according to their properties, and newly-installed high-efficiency local scrubbers will treat

toxic gases, corrosive gases, flammable gases, and perfluorocarbons, while the rest of manufacturing process waste gases will also be treated effectively through special facilities such as thermal-wet scrubbers, combustion-wet scrubbers, and plasma-wet scrubbers. Then in the second phase, waste gases containing low-concentration of inorganic acids or bases will be sent to the central scrubber for second-stage water rinsing and neutralization treatment. With effective classification and a two-phase treatment process, the treatment efficiency of air pollution emissions has increased significantly.

Effective Reduction of Emission from Sources - Local Scrubbers

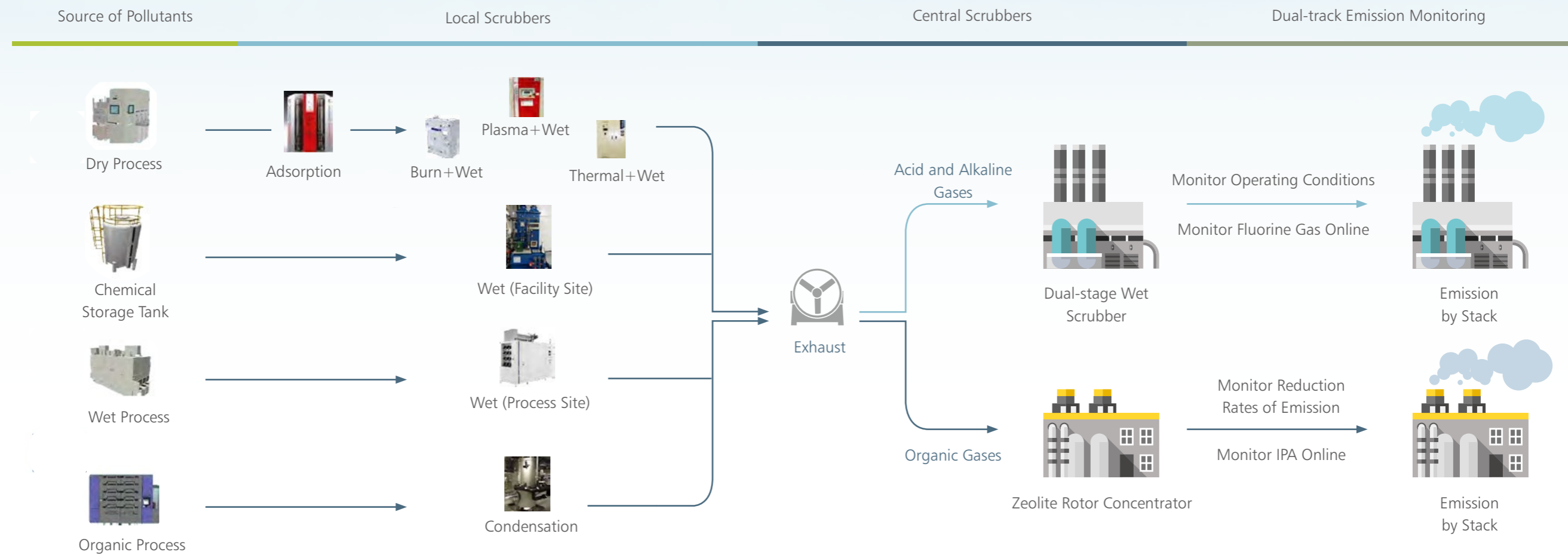
According to different properties of pollutants in high-concentration waste gases, TSMC performs preliminary treatments through seven types of local scrubbers: thermal, combustion, plasma, wet type

in facility site, wet type in process site, absorption, and condensation. The efficiency of each special gas treatment is certified by third-party institutions, and the reduction rate of the target pollutant can even surpass 95%. Due to the increasing proportion of lead-edge process technology products, TSMC continuously collaborates with suppliers to introduce new treatment facilities. The Company added a dosing system into the thermal-wet scrubbers in 2018, which can handle chlorine through scrubbing neutralization and reach a reduction rate above 99%. Moreover, in regards to chlorine-using dry process equipment, TSMC has demanded that dosing systems should be batch installed on all the equipment to improve the results of chlorine reduction and further decrease air pollutant emissions of the central scrubber.



High-Efficiency Air Treatment Equipment (Local Scrubber)

Air Pollution Prevention Treatment Procedures



Local Scrubbers Categories

Process Type	Semiconductor Manufacturing Process	Target Pollutants	Technology	Equipment Pictures	Reduction Rates	Real-time Monitoring Parameters
Dry Process	Epitaxial Dry Etching	Corrosive Gases	Burn-Wet		>99%	<ul style="list-style-type: none"> Natural Gas Flow Oxygen Flow Circulating Water Inlet Pressure
		PFCs				
	Dry Etching	Corrosive Gases	Plasma-Wet		>95%	<ul style="list-style-type: none"> Current Amperage Circulating Water Inlet Pressure
		PFCs				
		Combustible Gases				
Thin film	Corrosive Gases	Thermal-Wet		>95%	<ul style="list-style-type: none"> Reactor Temperature Circulating Water PH Value Inlet Pressure 	
Diffusion	PFCs					
Sputtering	Combustible Gases					
Wet Process	Wet Etching	Corrosive Gases	Wet (Process Site)		>95%	<ul style="list-style-type: none"> Pressure Difference In Scrubber Circulating Water Inlet Pressure PH Value
		Organic Gases				
Organic Process	PR Stripping	High Boiling Point Organics	Condensation		Specific High Boiling Point Organics >95%	<ul style="list-style-type: none"> Pressure Difference In Scrubber Condensation Temperature
Storage Tank	Chemical Storage	Corrosive Gases	Wet (Facility Site)		>95%	<ul style="list-style-type: none"> Pressure Difference In Scrubber PH Value Circulating Water Inlet Pressure



Strengthened Management of Terminal Prevention Facilities — High-Efficiency Central Scrubbers

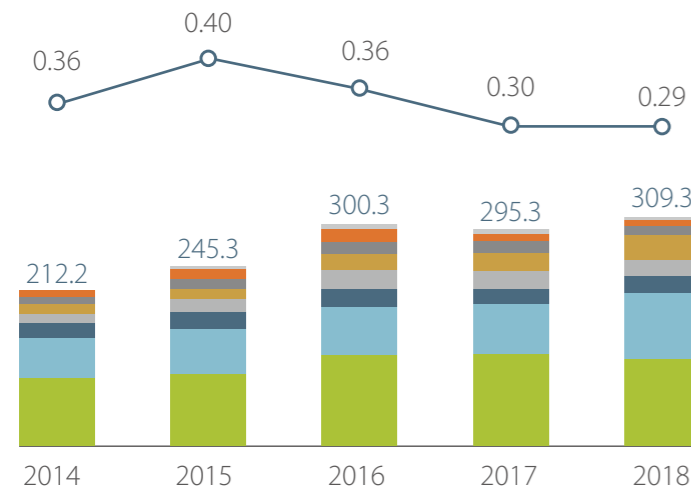
After first phase treatment, the processed waste gases containing low-concentration inorganic acids or bases are delivered to high-efficiency central scrubber for acid-base neutralization, while waste gases containing volatile organic components are delivered to zeolite rotor concentrators in terminal prevention facilities and exhaust to the atmosphere after condensation and combustion. TSMC not only adopted the most cutting-edge and suitable pollution reduction technology but also continuously improved the treatment results of existing prevention facilities. Air pollution emission per unit of production in 2018 has decreased by 27.6% from 0.40 (grams / 8-inch wafer equivalent mask layers) in 2015 to 0.29 (grams / 8-inch wafer equivalent mask layers), achieving the 27% reduction goal for 2020 ahead of time. According to TSMC's past sampling results, the concentration of air pollutant emissions has always been below the emission standards set by the Science Park Administration and

the domestic Environmental Protection Bureau.

In terms of volatile organic gas prevention results, TSMC's average reduction rate of organic waste gas emissions are above 95% and surpassed the 90% reduction rate of regulations for four consecutive years since 2015. In 2018, new "clean-gas-desorbing zeolite rotor concentrators" technology was introduced to Fab 12, Fab 14, and Fab 15, increasing the Company's average reduction rate of organic waste gas emissions to 96.9%. Due to the ever growing prevention efficiency, the total emission of VOCs did not increase with new fabs being constructed. Instead, total emission in 2018 decreased by 1.4% from 2017 to 168.4 tons. The unit emission of VOCs also decreased by 28% to 0.140 (grams / 8-inch wafer equivalent mask layers), compared to 0.195 (grams / 8-inch wafer equivalent mask layers) in 2015.

Total Emission and Air Pollutants Emissions Per Unit of Production

Unit : metric ton

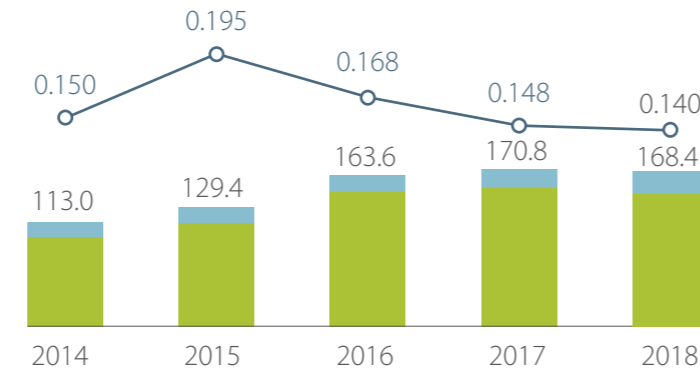


- Total Hydrocarbon
- Ammonia
- Chlorine Gas
- Hydrofluoric Acid
- Phosphoric Acid
- Nitric Acid
- Hydrochloric Acid
- Sulfuric Acid
- Emission of Air Pollutants Per Unit of Production (g / 8-inch equivalent mask layer)

Note 1 Total emission of air pollutants included the emission reported by TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants). Data excluded WaferTech, TSMC (China), TSMC (Nanjing), and VisEra due to different categories to report.
 Note 2 Air pollutants emission per unit of production included TSMC's wafer fabs in Taiwan, but excluded testing and assembly plants as there is no wafer production to be calculated.
 Note 3 Total emission of air pollutants include the emission of hydrocarbon, sulfuric acid, hydrochloric acid, nitric acid, hydrofluoric acid, phosphoric acid, chlorine, and ammonia

Total Emission and Emission of Volatile Organic Gases Per Unit of Production

Unit : metric ton

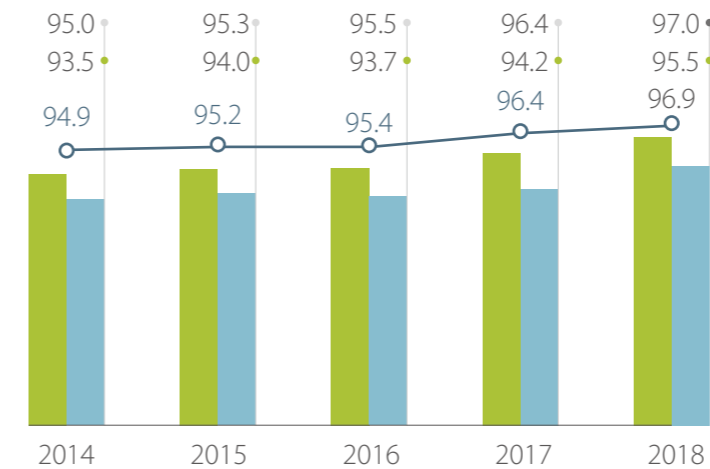


- Total Emission of Volatile Organic Gases (Taiwan facilities)
- Total Emission of Volatile Organic Gases (Subsidiaries)
- Emission of Volatile Organic Gases Per Unit of Production (g / 8-inch equivalent mask layer)

Note 1 TSMC volatile organic gas emissions included data collected from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing) and VisEra.
 Note 2 Emissions per unit of production included data collected from all TSMC's wafer fabs in Taiwan, WaferTech, TSMC (China), TSMC (Nanjing), and VisEra. Data excluded testing and assembly plants as there is no wafer production to be calculated.

Reduction Rates of Volatile Organic Gases

Unit : %



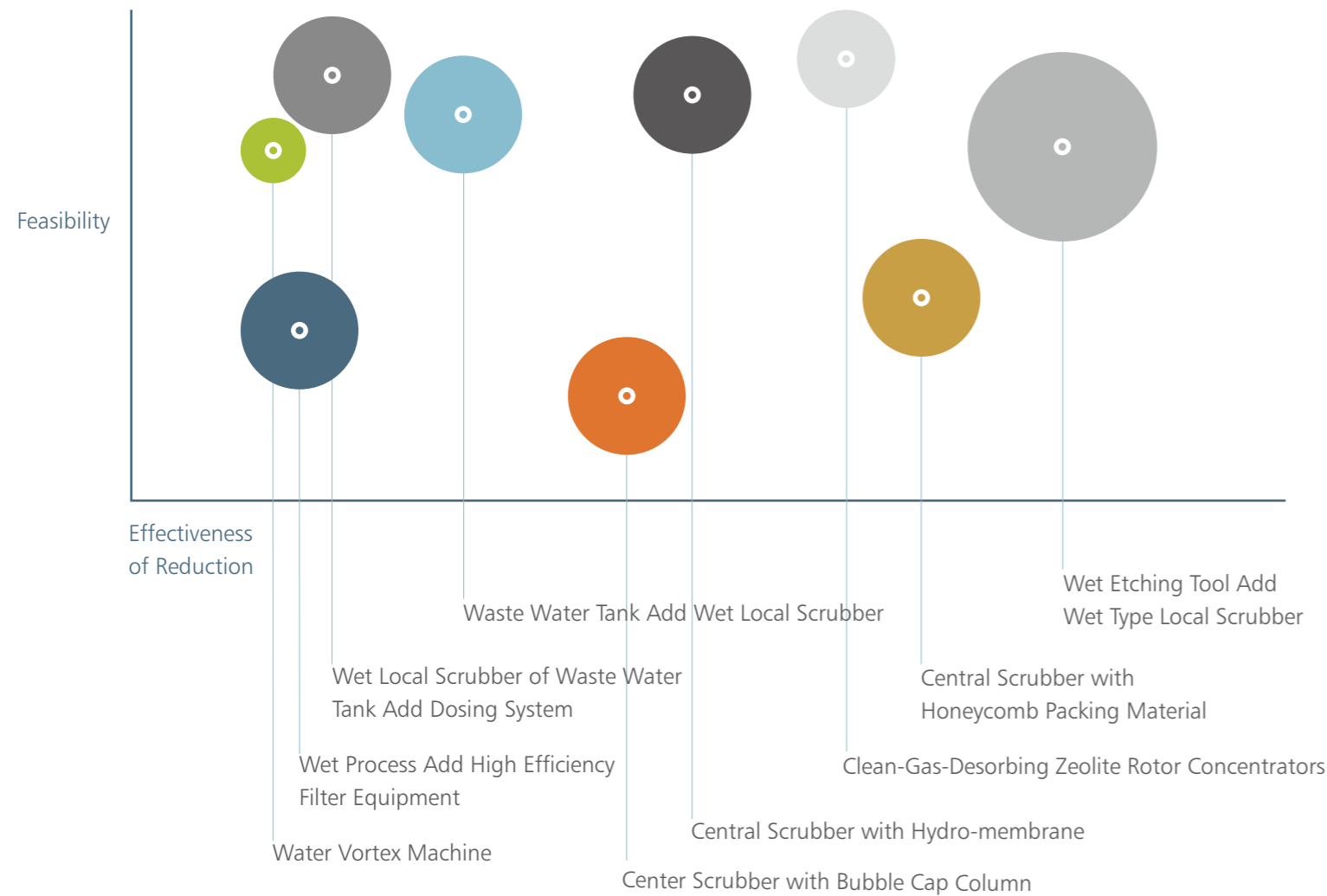
- Reduction Rates (Taiwan facilities)
- Reduction Rates (Subsidiaries)
- Reduction Rates

Note 1 Historical emission reduction rates of volatile organic gases included data collected from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), TSMC (China), TSMC (Nanjing), and VisEra. Data excluded WaferTech as there is no total hydrocarbon monitor to provide any record of reduction rates.



TSMC Assessment of Best Available Technology

In order to improve the capabilities of air pollution prevention facilities, TSMC continuously strives to develop reduction technology, evaluates feasibility from factors such as fab space, technical safety, and economic interests, and considers the reduction effectiveness of prevention technology to make multi-faceted, comprehensive assessments of whether to introduce such prevention technology.



Note The size of circles represents the importance of the prevention technology. Higher proportion target pollutants require greater emphasis on reduction

Strengthen Monitoring of Prevention Facilities

TSMC's air pollution prevention facilities comply with Taiwan regulations in both treatment capacity and monitoring equipment, and the treatment capacity of relevant prevention facilities in overseas fab sites also meets local regulations. In order to guarantee a 24-hour and 365-day stable operation of pollution prevention facilities, all facilities should be equipped with at least one backup system (N+1 design) and protected by an uninterrupted power supply system to reach the management goal of zero failure and ensure the stable, continuous monitoring of pollution. In addition to the monitoring equipment required by regulations, TSMC has also established an automatic pollutant monitoring system. In 2018, Fab 12, Fab 14, and Fab 15 introduced an "Online IPA Monitor" and "Online Fluorine Gas Monitor," which prevent abnormal odors and reduce the impact of air quality in cleanroom. These online monitors, along with existing hydrocarbon monitors, make waste gas treatment results of all air pollution prevention systems always accessible and allow relevant information to be reported to the facility monitor control center and the industrial safety emergency response center. The dual-track independent monitoring system has been adopted to make sure that the gas emitted from stacks are in compliance with regulations. With the protection of an early warning system and real-time responses, no abnormal occurrence was reported to the supervising authorities in 2018



Facility Monitor Control Center



Industrial Safety Emergency Response Center

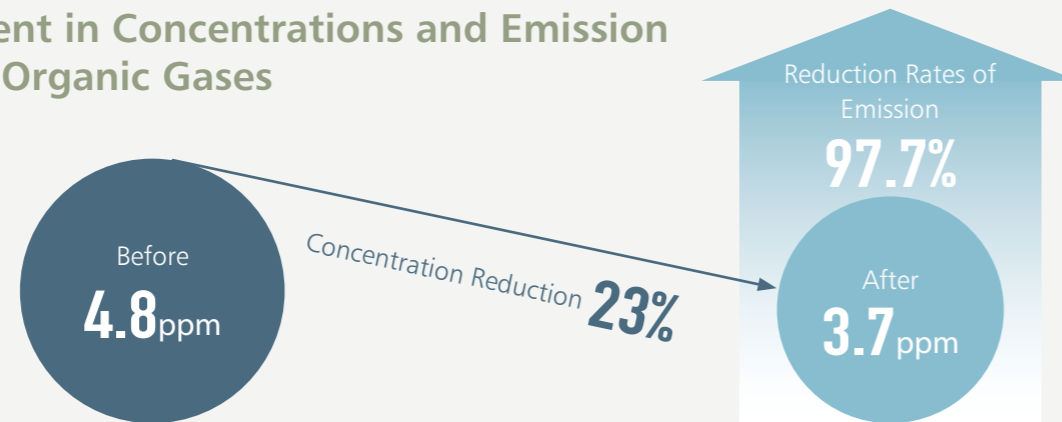
Case Study

Utilize Zeolite Rotor Concentrators to Introduce Clean Air for Desorption and Reduce the Concentration of Volatile Organic Waste Gas Emission by 23%

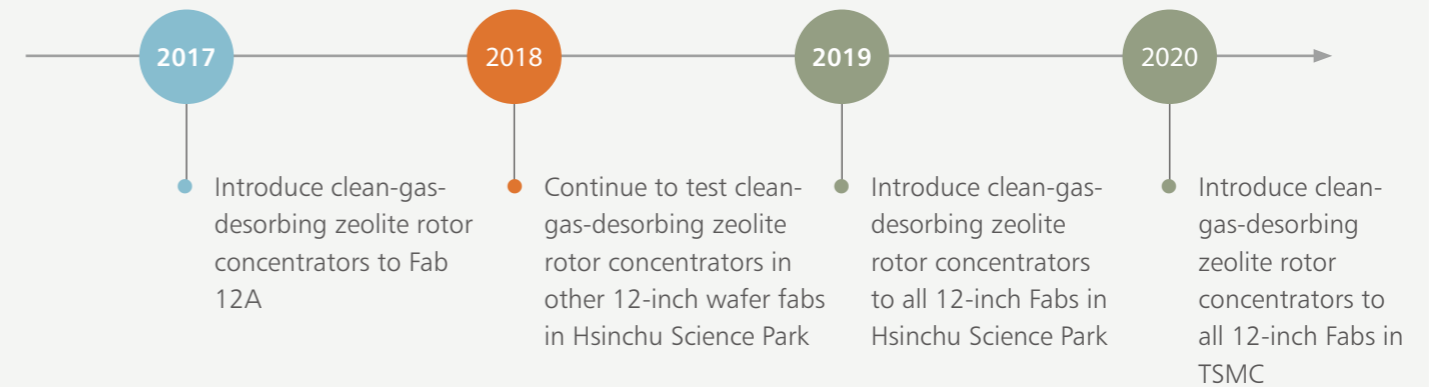
TSMC utilizes zeolite rotor concentrators and combustion furnaces to deal with the emission of VOCs, and the removal rate can reach 95~97%, which exceeds than the 90% required by the "Air Pollution Control and Emissions Standards for the Semiconductor Industry." In order to promote environmental sustainability and become the world-class benchmark enterprise in environmental protection, TSMC continuously develops new technology to improve prevention results.

TSMC Fab 12A in Hsinchu adopted the technology of "clean-gas-desorbing zeolite rotor concentrators" to refine the existing VOC emission prevention facilities, and the Company's concentration of volatile organic gas emissions decreased considerably by 23% and increased reduction rates by 0.7%. The technology effectively reduced volatile organic gas emission and lowered total emissions of VOCs to below that of 2017, instead of increasing with the growth of production capacity in new fabs. The technology comes from the first air pollution treatment project of Fab 12A in Hsinchu Science Park in 2017. It replaces processed waste gas (concentration of volatile organic gases > 100 ppm) with clean air treated in the absorption zone as the air source that supplies the cooling zone, increasing the efficiency of desorption and effectively decreasing the concentration of VOC emission. All facilities in TSMC Fab 12, Fab 14, and Fab 15 are expected to be refitted by 2020.

Improvement in Concentrations and Emission of Volatile Organic Gases



Rollout Schedule of Zeolite Rotor Concentrators



Improvement of Zeolite Rotor Concentrator

