Air Pollution Control

V Achieved ↑ Exceeded — Missed Target

Strategies	2030 Goals	2021 Targets	2020 Achievements	
Best Available Technology Adopt Best Available Technology to control pollutants emitted through operations and lower impact on the environment	▪ Reduce unit air pollutant emissions by **50%** (Base year: 2015)[Note1 & Note2]	▪ Reduce unit air pollutant emissions by **45%**	▪ Reduced unit air pollutant emissions by **46%** (Base year: 2015) **Target:** 32%	↑
	▪ Reduction rate of volatile organic gases **> 98%**	▪ Reduction rate of volatile organic gases **> 96%**	▪ Reduction rate of volatile organic gases **> 98.3%** **Target:** > 95%	↑
Strengthen Monitoring of Air Pollution Prevention Equipment Leverage backup systems and dual-track management, along with pollutant monitors, to ensure that equipment functions as intended and to prevent abnormal occurrences	▪ Report **< 1** case of abnormal occurrences to supervising authorities[Note3]	▪ Report **< 1** case of abnormal occurrences to supervising authorities[Note3]	▪ Reported **0** cases of abnormal occurrences to supervising authorities **Target:** < 1	V

Note 1: As of 2020, the unit for unit air pollutant emissions is changed from 'L/ 8-inch equivalent wafer mask layer' to 'L/12-inch equivalent wafer mask layer'.

Note 2: Increased the 2030 Sustainable Development Goal from 45% to a 50% reduction from the base year.

Note 3: Abnormal occurrences are defined as equipment failure that cannot be repaired within 24 hours or abnormal emissions due to suspended use.

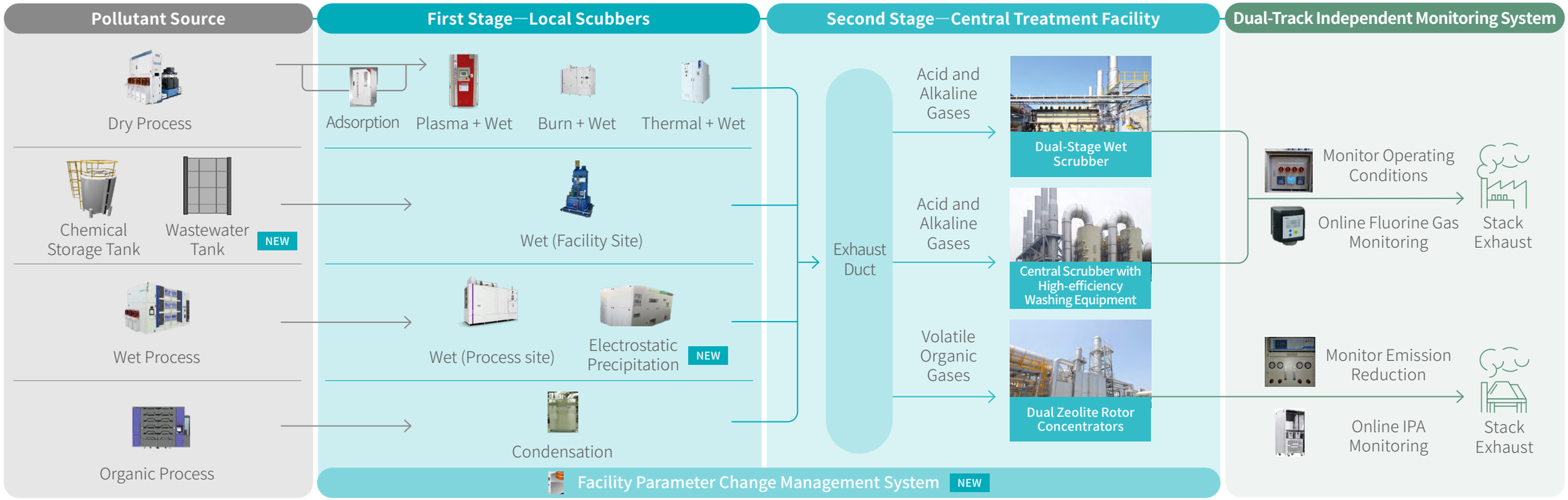
TSMC is committed to air pollution control. In 2020, we were able to enhance volatile organic gases reduction rate to 98.3% and achieve our 2030 Goals ahead of schedule because of the Low-efficiency Single Zeolite Rotor Concentrators Upgrade Initiative and the introduction of dual zeolite rotor concentrators to new facilities. This 98.3% significantly exceeds legal requirements of 90% from the Air Pollution Control and Emissions Standards for the Semiconductor Industry and the suggested reduction rate of 92% from the Environmental Protection Administration (EPA) in the BACT for Volatile Organic Gases. Through effective separation of emissions from sources and highly effective local scrubbers, TSMC is now managing air pollutants through multi-phase BAT to reduce unit air pollutant emission and build a sustainable future.

Best Available Technology

Air pollutant emissions from the semiconductor industry are primarily comprised of acid/alkaline gases and volatile organic gases. TSMC has adopted Separation Emission from Sources and Multi-Phase BAT for pollution prevention. We continue to work with experts in the industry to advance prevention systems by introducing additional local scrubbers and improving terminal prevention facilities to ensure that air pollutant emissions meet or exceed government standards.

In the first phase of source separation, newly-installed high-efficiency local scrubbers will be treating specific toxic gases, corrosive gases, flammable gases, perfluorocarbon greenhouse gases, and other acid/alkaline gases. In the second phase, waste gases containing low concentrations of inorganic acid/alkaline gases will be sent to the central scrubber, which is the terminal prevention facility, for second-phase water rinsing and neutralization treatment. For volatile organic gases, facilities determine whether condensing local treatment facilities are required based on boiling points. The exhaust will then be channeled into zeolite rotor concentrators. By classifying and separating exhaust gases from the source and utilizing second-phase treatment, we can effectively increase air emission treatment efficiency.

Air Pollution Prevention Treatment Procedures



Effective Source Separation-Local Scrubbers

TSMC continues to expand on existing production capacity and accelerate R&D progress. To prevent further air pollution from new processes and chemicals, TSMC established the New Tool and New Chemical Review Committee, comprised of personnel from the Corporate Environment Safety and Health Division, Industrial Safety and Environmental Protection Division, and Facility Division. The committee is responsible for reviewing the safety and environmental impact of new tools and chemicals. New chemicals must go through two stages of review. The first review verifies risks related to the new chemicals and establishes control measures, and determines the environmental impact of the new process or chemical based on its properties. During this stage, the review committee also assesses how to classify exhaust gases and which local treatment facilities to use. The second review is to assess environmental impact from production verification tests and establish the exhaust gas classification to serve as the standard when using the new chemical.

Fabs must apply for a Management of Change before they become eligible for new chemicals that have already passed the second review. The Industrial Safety and Environmental Protection Division and Facility Division must first confirm the effectiveness of air pollution prevention equipment towards the new chemical before its deployment into mass production. In 2020, TSMC remained proactive in air pollution prevention and conducted 422 reviews for 239 new chemicals and 183 new tools. In 2020, TSMC collaborated with suppliers to test new local treatment facilities with different mechanisms such as adsorption, burning, and wet electrostatic precipitation (Wet-EP). Local treatment equipment were evaluated for safety and performance by TSMC and for efficiency by a third-party. Intensive testing was conducted to ensure that local treatment equipment are able to deliver on-target pollutant reduction before they are introduced into pollutant treatment for specific semiconductor process.

Review Process for New Chemicals

First Review	Experimental Test	Second Review	Production Verification Test	Management of Change	Mass Production
Process for Identifying Risks from New Chemicals and Conducting Experiments	Facility Operations & Monitoring Center	Assess human and environmental impact from production verification test and establish effective pollutant classifications/ BAT	Facility Operations & Monitoring Center	Review and confirmation from the Facility Division and Industrial Safety and Environmental Protection Division in all fabs	Facility Operations & Monitoring Center

Local Scrubbers Categories

Process	Semiconductor Fabrication	Target Pollutant	Control Technologies	Equipment	Reduction Rate	Real-time Parameter Monitoring
Dry Process	Epitaxial Dry Etching	Corrosive Gases Perfluorocarbons	Burn + Wet		> 99%	▪ Natural gas flow ▪ Oxygen flow ▪ Circulating water flow ▪ Inlet pressure
	Dry Etching	Corrosive Gases Perfluorocarbons Flammable Gases	Plasma + Wet		> 95%	▪ Current amperage ▪ Circulating water flow ▪ Inlet pressure
	Thin Film Diffusion Sputtering	Corrosive Gases Perfluorocarbons Flammable Gases	Thermal + Wet + Chemical Dosage		> 95%	▪ Reactor temperature ▪ pH value ▪ Circulation water flow ▪ Inlet pressure
	Ion Implantation Sputtering Epitaxy	Toxic Gases	Adsorption		> 95%	▪ Pressure difference of local scrubber ▪ Inlet pressure
	Thin Film	Nitrous Oxide (N_2O)	High-Temperature Thermal+Wet		> 90%	▪ Reactor temperature ▪ Circulating water flow ▪ Inlet pressure
Wet Process	Wet Etching	Corrosive Gases Organic Gases	Wet + Chemical Dosage (Process Site)		> 95%	▪ Pressure difference of local scrubber ▪ pH value ▪ Circulation water flow ▪ Inlet pressure
		Sulfuric Acid (H_2SO_4)	Electrostatic Precipitation NEW		> 95%	▪ Corona voltage ▪ Corona current ▪ Inlet pressure
Organic Process	PR Stripping	High Boiling Point Organics	Condensation		Specific High Boiling Point Organics > 95%	▪ Pressure difference of local scrubber ▪ Condensation temperature
Storage Tanks	Chemical Storage Tank	Corrosive Gases	Wet + Chemical Dosage (Facility Site)		> 95%	▪ Pressure difference of local scrubber ▪ pH value ▪ Circulating water flow ▪ Inlet pressure
	Wastewater Tanks NEW	Acid and Alkaline Gases				

Enhance Local Scrubber Performance

TSMC adopts eight different types of local scrubbers to pre-treat high-concentration exhaust based on pollutant properties. The eight different local scrubbers include thermal-wet, burn-wet, plasma-wet, wet type in facility, wet type in process, adsorption, condensation, and high-temperature thermal scrubber. As TSMC continues to develop its manufacturing, the company also continues to collaborate with suppliers for new local scrubbers. In 2020, TSMC started using Wet-EP local treatment for wet etching. Wet-EP local scrubbers use a corona technology that is highly effective against acid/alkaline gases and can deliver >95% sulfuric acid (H_2SO_4) reduction. In 2020, our 12-inch wafer fab became the first to extend the use of local treatment facilities from chemical storage tanks to wastewater tanks. By installing a highly efficient wet local scrubber with dosing system for acid alkaline gases from high concentrations of wastewater tanks, the reduction rate was able to achieve a 95%, thereby relieving the load from central terminal treatment facilities. By upgrading local treatment facilities and separating emissions from the source, TSMC was able to achieve a 27% reduction in ammonia (NH_3) emissions from 2019 to 2020.

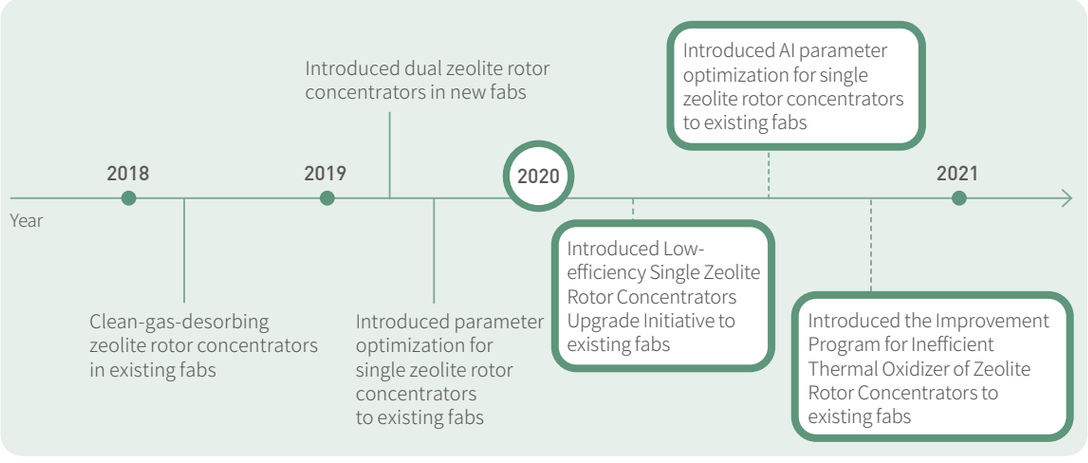
Evolving Terminal Prevention Facilities

As air pollutant emissions evolve and increase with process technology, TSMC has been working to improve the performance of terminal prevention facility. In 2019, volatile organic gases accounted for 34% of TSMC air pollutant emissions, and we consider volatile organic gas reduction to be a top priority. In 2020, TSMC collaborated with prevention equipment suppliers to raise the reduction standard for single zeolite rotor concentrators from 95% to 97%. To further improve adsorption, the concentrators will also adopt a new and highly effective fiberglass substrate. Between 2019 to 2020, a total of eight single zeolite rotor concentrators were replaced as part of the Low-efficiency Single Zeolite Rotor Concentrators Upgrade Initiative. We intend to replace eight more low-efficiency single zeolite rotor concentrators in 2021 to ensure the reduction rate of volatile organic gases can exceed 97% steadily. In 2020, a full roll-out was achieved for the clean-gas-desorbing zeolite rotor concentrators developed in 2017 in all 12-inch wafer fabs before 7nm process. All 12-inch wafer fabs are now equipped with optimized parameters for single zeolite rotor concentrators to ensure the average reduction rate for volatile organic gases in all 12-inch wafer fabs exceeds 98%.

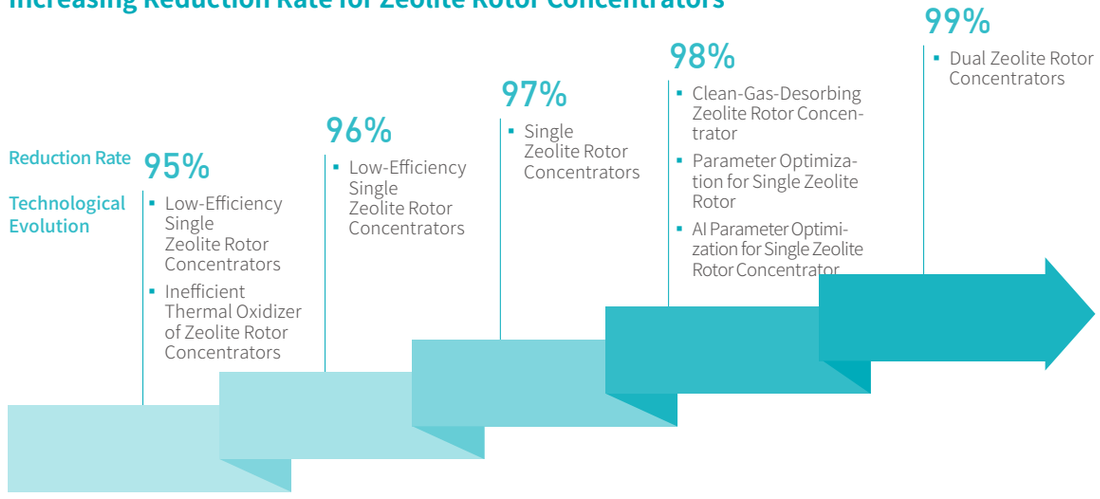
The Facility Division collaborated with prevention equipment suppliers and adopted dual zeolite rotor concentrators, which is an upgraded technology that adds a new rotor concentration process after the exhaust is adsorbed and burned by the first rotor concentrator. After the second rotor concentration process, exhaust will be channeled back into the first rotor concentrator for processing. The repeated process achieves a 99.5% reduction rate. As of 2020, Fab 15B and Fab 18A have adopted dual zeolite rotor concentrators. In 2021, dual zeolite rotor concentrators are expected to roll out to Fab 18B, Fab 12 P8, Advanced Backend Fab 6, and other fabs.

In 2020, the average reduction rate of volatile organic gases in TSMC reached 98.3%, enabling us to meet our 2030 Sustainable Development Goals ahead of schedule. The reduction is a testimony to our commitment to air pollution reduction.

Zeolite Rotor Concentrators Milestones



Increasing Reduction Rate for Zeolite Rotor Concentrators



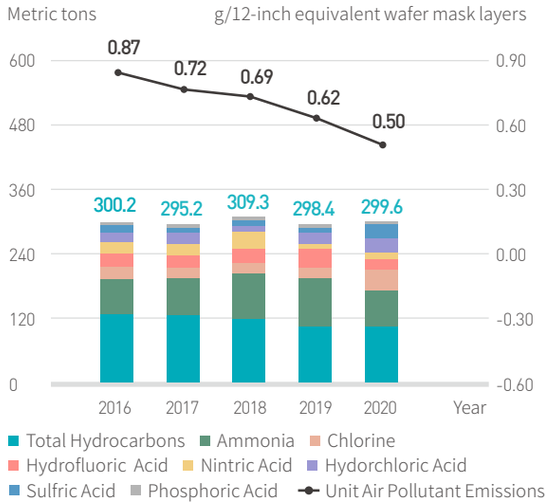
TSMC uses scrubbing towers and regular demister layer treatment approaches against acid/ alkaline gases. To improve the overall efficiency of terminal prevention facilities, in 2020, the Facility Division and the Industrial Technology Research Institute collaborated to design a High-efficiency Acid and Alkaline Scrubber. This new scrubber is equipped with a high-efficiency demister, airflow distributor, and filter. Regulations for packed layers, sprinklers, and Raschig rings were also updated. Fab 18B is set to be the first to acquire the new scrubber in 2021.

In 2020, the Facility Division also collaborated with the Corporate Environment Safety and Health Division to establish a Stack Emission Baseline. TSMC implemented mitigation measures for stack emissions and monitor results regularly. As a result of the aforementioned reduction efforts, unit air pollutant emission (L/12-inch equivalent wafer mask layer) in 2020 was reduced by 46% against the base year of 2015, meaning that we achieved the 2030 Goal of 45% reduction ahead of schedule, and have therefore increased the 2030 Sustainable Development Goals to a 50% reduction from the base year.

Improve Air Pollution Prevention Technologies

TSMC continues to explore ways to achieve air pollution reduction and improve the performance of air pollution prevention equipment. Before introducing new prevention technologies, we assess viability in terms of space, safety, and economics. In 2020, TSMC introduced three new technologies: High-efficiency Acid and Alkaline Scrubber, Improvement Program for Inefficient Thermal Oxidizer of Zeolite Rotor Concentrators, and AI Parameter Optimization for Single Zeolite Rotor Concentrators. To achieve our goal of smart manufacturing, we began applying smart parameter tuning to air pollution prevention facilities for single zeolite rotor concentrators. Concentration level at entry, temperature, air flow, and other external parameters are imported into the tool so that it can automatically set the optimal burning temperature, desorption temperature, rotor revolution, and other operating parameters. By stimulating functions and the artificial neural network, we can enable equipment to recommend optimal settings for maximum reduction of volatile organic gases. TSMC completed preliminary testing and found that optimal desorption flow and rotor revolution will be able to increase the reduction rate of volatile organic gases of single zeolite rotor concentrators to 98% or more.

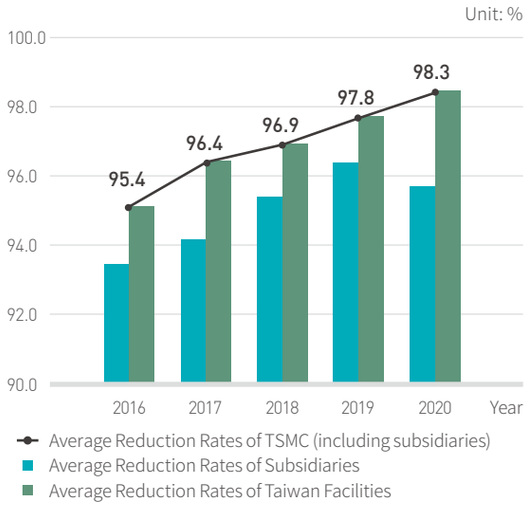
Total Emission and Air Pollutants Emissions per Unit of Production



Note 1: TSMC air pollutant emissions were reported in accordance with local laws and regulations.

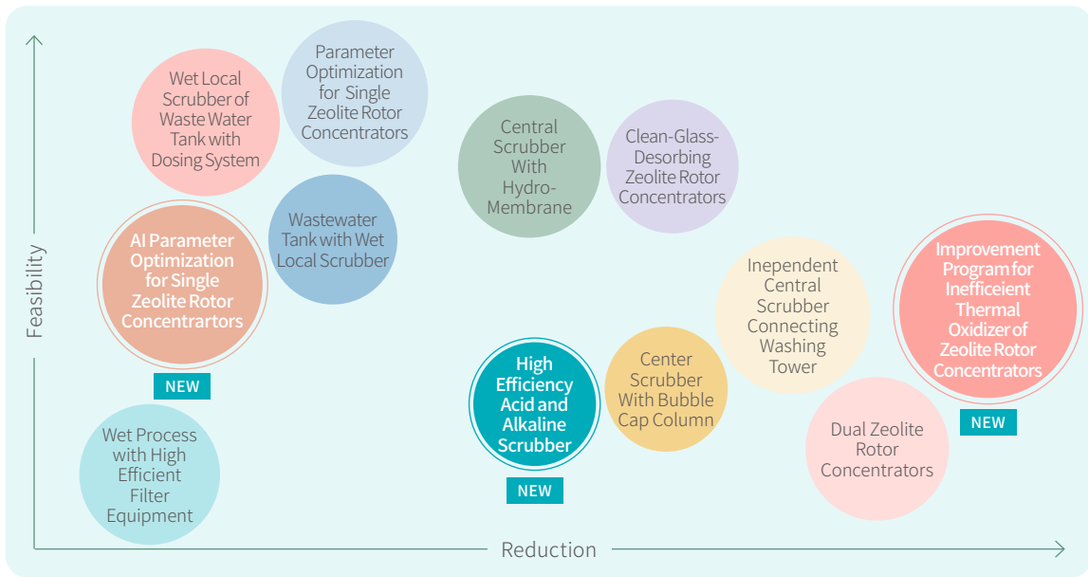
Note 2: Air pollutant emissions include the total emissions of eight gases: hydrocarbons (THC), sulfric acid (H_2SO_4), hydorchloric acid (HCl), nintric acid (HNO_3), hydrofluoric acid (HF), phosphoric acid (H_3PO_4), chlorine (Cl_2), and ammonia (NH_3).

Annual Reduction Rate of Volatile Organic Gases



Note : Figures from TSMC Fabs in Taiwan, TSMC (China), TSMC (Nanjing), and VisEra. Data excludes WaferTech as there is no total hydrocarbon monitor to provide any record of reduction rates.

Prevention Technology Feasibility & Reduction Effectiveness Evaluation



Strengthen Monitoring of Air Pollution Prevention Equipment

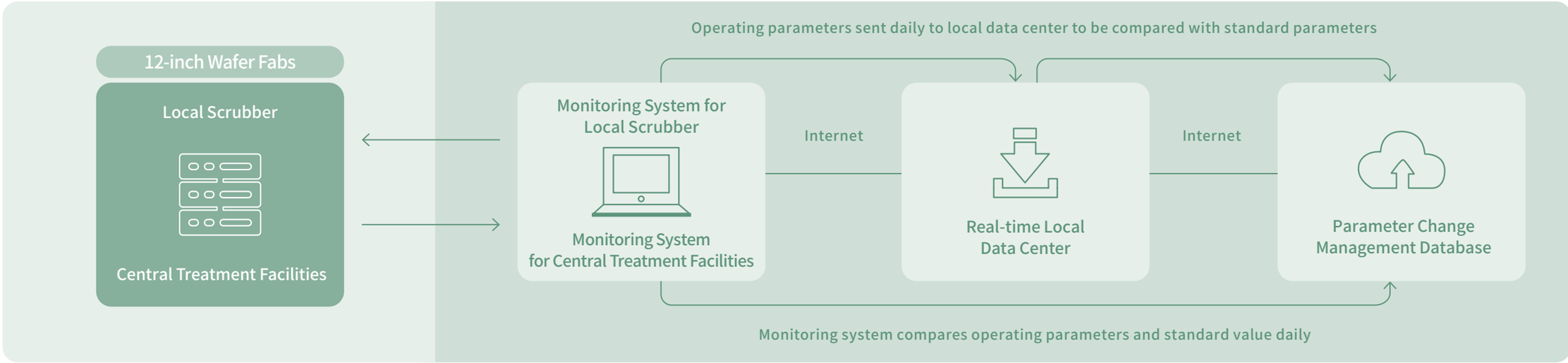
TSMC works to actively improve equipment efficiency, and is strengthening stability and monitoring of air pollution control equipment to ensure compliance with local rules and regulations. All air pollution prevention equipment are equipped with "N+1" (at least one) backup system(s) and an uninterruptable power supply system to guarantee continuous operation. In order to maintain continuous emissions monitoring, prevention equipment is also equipped with comprehensive alert systems, including a dual-track independent monitoring system that is immediately activated upon system failure. The system will alert the Facility Monitoring and Control Center and Industrial Safety Emergency Response Center to repair equipment or switch backup systems.

Due to rapid advances in process technology, 12-inch wafer fabs use different fabrication processes, emit different pollutants, and require different local scrubbers. To ensure effective management over the parameters on local scrubbers, TSMC debuted the Facility Parameter Change Management System in 12-inch wafer fabs in 2020. The system can effectively manage operating parameters on local scrubbers and terminal prevention facility. The parameters will then automatically be compared to standard parameters at a fixed time every day to ensure prevention equipment are operating on optimal parameters. Inconsistent parameters will be automatically reported to the person in charge for system confirmation and to confirm stack emission in normal condition. With the addition of an early warning system, the Air Pollution Prevention Equipment Operation Status Platform, TSMC reported 0 abnormal occurrences in air pollution prevention equipment to supervising authorities in 2020.

Industrial Safety Emergency Response Center.

Facility Monitoring & Control Center.

Facility Parameter Change Management System



Case Study

Achieving 45% Reduction Goal for Unit Air Pollutant Emissions Ahead of Schedule by Introducing a Management Mechanism for Stack Emission Baseline

TSMC believes in "Zero Emissions"and is committed to reducing air pollutant emissions. In order to maintain high efficiency in air pollution prevention equipment, TSMC introduced the Facility Parameter Change Management System to monitor optimal operating parameters and also consistently monitor and control concentration levels at the stack emissions. We are deploying a two-method approach – emissions separation at the source and improving performance of terminal prevention facilities – to reduce concentration levels in our emissions.

In 2020, the Facility Division and Corporate Environment Safety and Health Division collaborated to introduce the Management Mechanism for Stack Emission Baseline. The air pollutant baseline was developed by gathering data on emission concentration levels at stack emissions in TSMC Fabs in Taiwan. We discovered that the concentration level of volatile organic gases exceeded regulatory standards from cross-contamination in exhaust duct. Stacks generally employ a regenerative thermal oxidizer that uses shared exhaust duct, which can result in cross-contamination. As such, we were only able to achieve a 95% reduction in volatile organic gases for regenerative thermal oxidizers, which still has room for improvement when compared to the 98% for direct-fired thermal oxidizers.

In order to target exhaust ducts with high concentration levels, TSMC launched the Improvement Program for Inefficient Thermal Oxidizer of Zeolite Rotor Concentrators in 2020 to replace regenerative thermal oxidizers with direct-fired thermal oxidizers, a single pathway oxidizer. Condensation type scrubbers were also installed at the pollution source to capture organic matter with high boiling points and drastically reduce concentration levels in stack emission from terminal prevention facilities. In 2020, upgraded regenerative thermal oxidizers achieved an average of over 98% reduction in volatile organic gases. In addition to deploying the Renovation Program for Air Pollution Prevention Equipment to replace expired terminal prevention facility for stacks with exceeding acid/ alkaline gases emission baseline, TSMC is also investigating pollutants from the source, implementing the Roll-out Program for High-Efficiency Local Scrubbers, and regularly monitoring progress.

In 2020, TSMC carried out three programs to target 79 stacks that exceeded concentration baselines. A total of 36 exhaust ducts were renovated and inspected. A budget will be allocated to continue renovating the remaining stacks.

By implementing the Management Mechanism for Stack Emission Baseline and renovating stacks that exceed the concentration baseline, TSMC achieved 46% (L/12-inch equivalent wafer mask layer) reduction in unit air pollutant emission from the base year of 2015 and was able to achieve our 2030 Sustainable Development Goals ahead of schedule.

Management Mechanism for Stack Emission Baseline