# Optimizing Semiconductor Manufacturing Operations from Floor to Cloud™

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*Monitoring and control technologies can help new and established foundries address productivity, sustainability, talent and safety challenges.*

SEMICONDUCTOR MANUFACTURING IS expanding around the world due to the long-term demand for smaller, faster and more energy-efficient chips. It's driving competition in an aggressive market even higher, and governments are offering considerable incentives to bolster semiconductor research, development and production within their borders. In the U.S., the CHIPS and Science Act will provide $52 billion for the semiconductor industry to strengthen U.S. leadership. The act includes $39 billion in manufacturing incentives, which encourage new construction of domestic semiconductor fabrication plants. Significant investment in both greenfield and brownfield expansions by U.S. companies and other companies that serve the U.S. market can give those companies a significant market advantage.

However, due to chip shortages, this capital expenditure (CAPEX) is done under extreme pressure. To catch up, foundries and OEMs may be tempted to simply meet specifications rather than utilize and qualify the latest technology to make more intelligent solutions. Foundries and OEMs have the opportunity — right now — to create a next-generation solution from the ground up rather than retrofitting it later.

Even with incentives, foundries require large capital and operational expenditures. To remain competitive, it's critical that foundries maximize availability, minimize underutilization and optimize utility and resource consumption. The semiconductor manufacturing industry uses some of the most advanced and sophisticated production systems in the world to achieve these outcomes. However, foundries may not be using all the monitoring and control technologies available to them — missing critical opportunities and significant benefits.

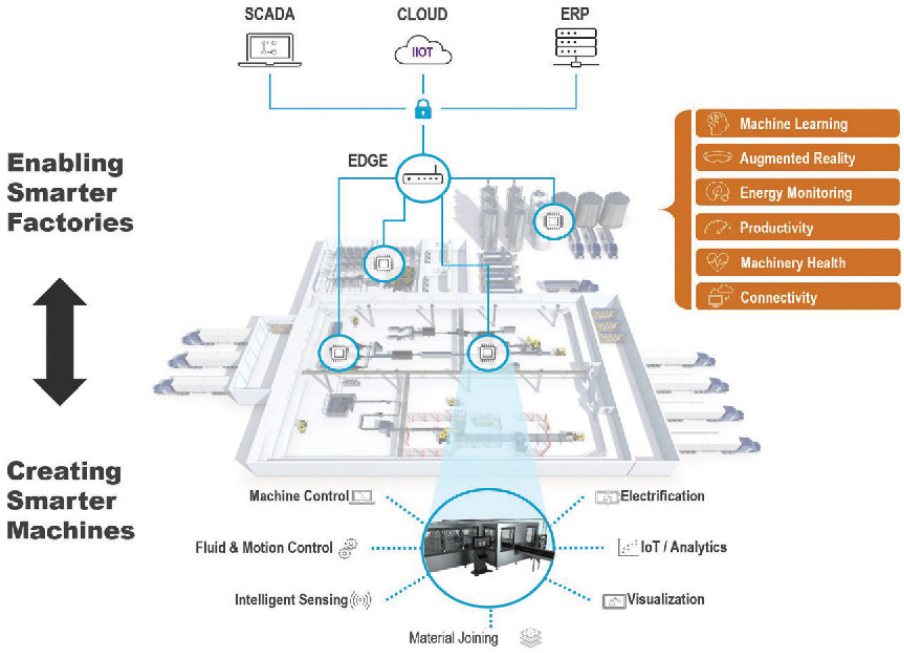


**Figure 1.** A Floor to Cloud approach to semiconductor manufacturing results in smarter foundries and more efficient processes that continuously improve productivity, sustainability and safety. *(Source: Emerson)*

By applying complete solutions and advancing digital maturity, foundries can meet net-zero targets, optimize resource use, address talent shortages, improve overall equipment effectiveness (OEE) and enhance safety, all at the same time.

## Applying a Floor to Cloud™ approach

A comprehensive approach to semiconductor manufacturing provides real-time visibility and control that

optimizes operations and automates key processes. It starts by unlocking data across the foundry floor with next-generation sensors, valves, actuators and regulators. It then moves to the cloud via edge controllers and industrial PCs running control strategies, HMI/SCADA and analytics software platforms that provide centralized monitoring and control (**FIGURE 1**). The result is smarter foundries and more efficient processes that continuously improve productivity, sustainability and safety.

The technologies of a Floor to Cloud approach address different stages of the digital transformation (DX) journey. Smart sensors monitor equipment and processes, then feed data to edge-enabled programmable logic controllers (PLCs). Depending on the scale of the application, the collected data can be stored in a cloud, an enterprise level data management software or a fast-access historian. Industrial software performs machine learning (ML) algorithmic processes on PLCs (edge control) or industrial PCs (edge computing) using historical and real-time data (**FIGURE 2**).

This pre-processed information is then communicated to the cloud for deeper analysis. Software translates data and provides real-time visualization, control interventions, diagnostics and predictions directly at the machine edge so operators can quickly respond to changing conditions.

There is a variety of hardware and software combinations available, and some suppliers have optimized pairings that best suit a foundry's requirements and objectives. Designers can build solutions incrementally, from floor upward, in an integrated way for optimal compatibility, scalability and security. Operators can use visibility and insights these technologies provide to coordinate production and base-of-plant systems and optimize processes and equipment. In this way, new foundries are positioned to increase yield rates and throughput, reduce waste and enhance safety.

## Meet net-zero goals

The precise processes in semiconductor manufacturing use a lot of energy — manufacturing one square inch of microchip (6.5 square centimeters) uses 7.5 kilowatt-hours (kWh) of power. Of the total energy foundries consume, fabrication machines use about 40% and balance of plant (BOP) processes use the rest. As technology for producing smaller, nm-format chips evolves, energy use will significantly increase. To get ahead of this potentiality while addressing current consumption, it's in a manufacturer's best interest to design infrastructure that optimizes energy use across processes.

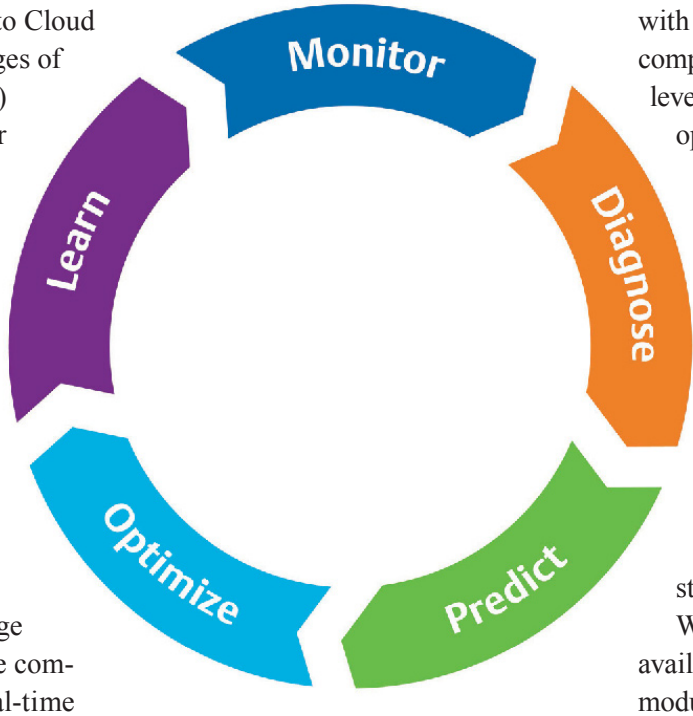


**Figure 2.** Different stages of the DX journey use different technologies. *(Source: Emerson)*

DX has become known for its ability to influence sustainability, and a Floor to Cloud approach allows operators to track a foundry's energy consumption from the machine to enterprise level in real time. Through continuous monitoring, manufacturers can evaluate the energy consumption per unit of output by comparing all machines of a given type, such as lithography, etching and chemical mechanical planarization. Once baseline values are established, engineers can identify deviations across machine makes/models and entire equipment fleets. For manufacturers with multiple locations, systems can run comparative analytics at the enterprise level, then derive insights around operational excellence and replicate across sites. In other words, a foundry running in Texas and another running in Taiwan can "inspire" each other by competing for better performance. Additionally, an ultrapure water OEM managing a global equipment fleet can remotely diagnose and increase output, predict failures or performance degradation and dispatch service staff on a need basis.

While custom solutions are available, some analytics software modules are specifically designed to address energy consumption. These modules can present usage and trends on a dashboard that operators and sustainability teams can access to make decisions and generate reports (**FIGURE 3**). With this real-time information about energy use, foundries can optimize energy use. Companies with more insights about their energy use have a greater understanding and are better positioned to make decisions that help reach net-zero targets.

## Optimize resource use

In addition to power, semiconductor manufacturing uses huge amounts of corrosive gases and water. Manufacturing one square inch (6.5 square

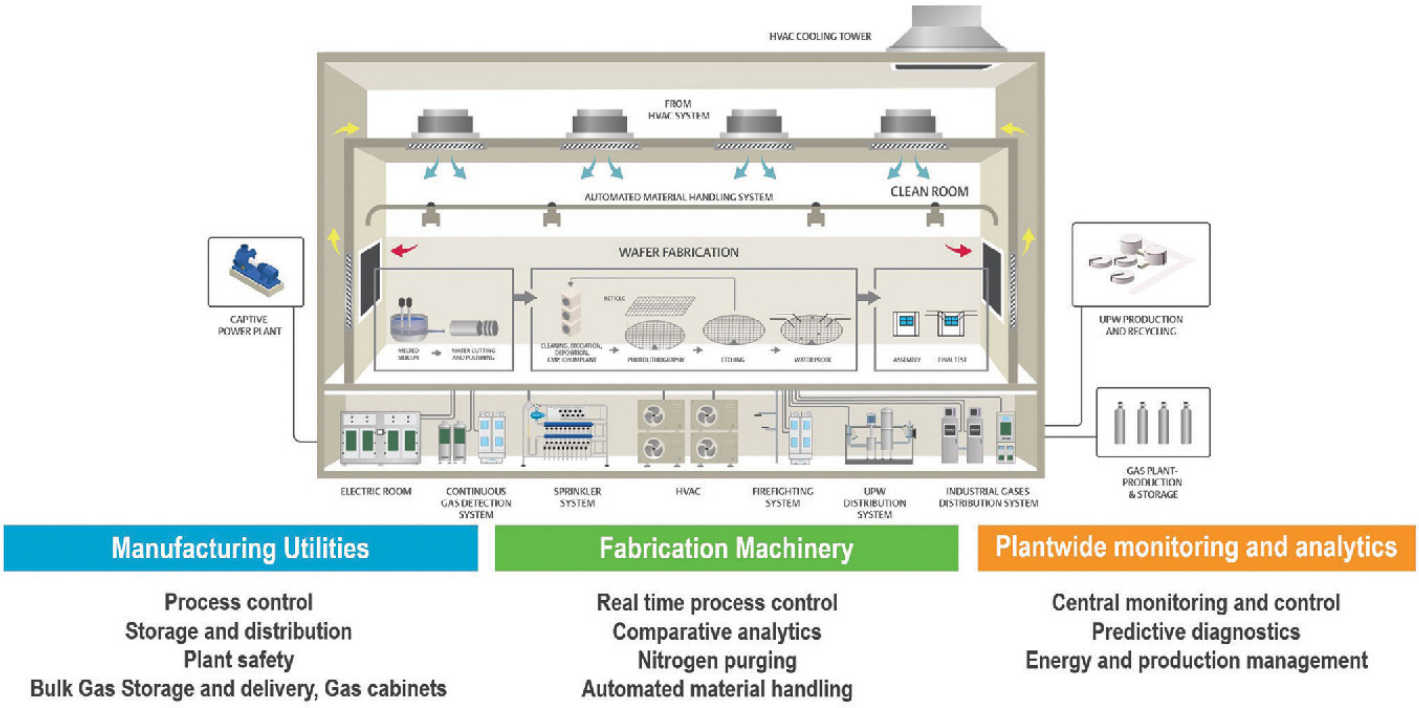


**Figure 3.** Digitalization of semiconductor manufacturing utilities and fabrication machinery provides visibility and control that can achieve sustainability and production goals. (image *courtesy of Emerson)*

centimeters) of microchip requires about 12 gallons (46 liters) of ultrapure water, and the typical foundry can consume about the same amount of water daily as a midsized city.

A foundry's sustainability initiatives include operational continuity as well as resource reduction.

Multimedia monitoring can provide greater visibility into and control over resource consumption while ensuring operational continuity. For instance, BOP process monitoring, such as energy consumed per gallon of ultrapure water production, gas consumption and water recycling metrics can identify critical opportunities to reduce waste and related costs. Reduced waste lowers operating expenses and improves sustainability while maintaining throughput and yield rates.

Power, gas and water OEMs can receive and pass along benefits through foundry solutions equipped with edge technology. For example, water skid OEMs can remotely manage a widespread skid fleet using edge controllers and an advanced human machine interface (HMI), and system integrators can include control solutions in their systems. It's important to look for solutions that provide a combination of performance, availability, cybersecurity, backward integration and a singular configuration toolkit for faster switchover.

## Address talent shortages

With the growth of the U.S. semiconductor industry, talent shortages may become more pronounced. Floor to Cloud solutions can automate manual processes and provide detailed guidance in the form of insights and alerts that provide relief to a strained workforce.

Digitization and remote monitoring mean that personnel can make fewer field trips for data collection or visual inspection. This increases staff availability for plants as well as OEMs and allows for less dependency on personnel with process-specific knowledge.

Predictive diagnostics paired with alarm capability can help personnel detect equipment wear in its early stages. Operators and maintenance personnel can receive detailed guidance about what to check and do, which allows for proactive, schedule maintenance based on equipment condition rather than schedule-based maintenance. This equips staff with the right information at the right time. By making quick decisions and confidently addressing issues before they become critical, foundry personnel can help prevent failures and unplanned downtime.

## Improve foundry OEE

As the semiconductor industry grows more competitive, productivity will become even more critical. There's a tremendous amount of pressure on foundries to meet contractual obligations, satisfy new demands and gain market share. And everything in a foundry — from raw material inventory availability to equipment availability — can affect plant uptime. As a result, semiconductor foundries operate around the clock and, in an ideal state, their machines and processes run nonstop.

While some foundries may rely on built-in system redundancies at the machine level to maintain uptime, these

redundancies can cost millions of dollars each and are simply not practical. Instead, it's in a new foundry's best interest to address the availability of their individual processes and machines using a Floor to Cloud approach that enables sophisticated systems control. These solutions can improve OEE values by ensuring higher utilization and availability, as well as optimized performance that can result in low rejection rates, reduced process breakdown and fewer manufacturing line resets/restarts.

Scalable PLC/PAC and edge controller hardware platforms with easily configurable redundancy provide fast changeover times that ensure uninterrupted control and monitoring that can help prevent production losses and delays. Highly available, these PLCs can provide process continuity even during firmware and hardware updates.

At the same time, there is HMI/SCADA software and off-the-shelf software modules specifically engineered to address OEE. HMI/SCADA software can provide central monitoring and control with alarm dispatching that helps predict and prevent failures. This level of diagnostics allows foundries to schedule machine maintenance based on condition, which can keep equipment running and minimize downtime. Foundries can even develop customized edge analytic applications that provide equipment insights and frequent faults, along with energy consumption, waste and resource utilization trends.

When foundries adopt control strategies at the machine and process levels, it helps improve plant utilization and OEE. In fact, semiconductor machine OEMs might find that IPCs with integrated advanced edge technology are beneficial to running core proprietary processes and edge connectivity between machines. When machines can connect to the cloud and interact with other machines and processes, it allows for greater visibility into machine health and deeper understanding of root cause issues as well as comparative benchmarking. All this can help manufacturers optimize machines and processes, leading to better outcomes.


**Figure 4.** The ER5000 electropneumatic PID controller paired with a TESCOM regulator, both from Emerson, reduce exposure to hazardous gases with remote control without jeopardizing yield reliability. The ER5000 controller can be used as a stand-alone regulator or pilot regulator where precision and accuracy are critical to reach true repeatability. *(Source: Emerson)*

## Enhance safety

While all business goals are critical, worker safety is paramount. Floor to cloud solutions enable remote monitoring and automation, which put distance between people and machines. This minimizes the need for people to enter hazardous areas and can reduce the risk of incidents. At the same time, the reduced footprint of maintenance personnel inside clean rooms reduces the chances of contamination.

For instance, Emerson offers a solution that reduces exposure to hazardous gases. Its ER5000 electropneumatic PID controller, paired with its TESCOM™ regulators, provides remote control without jeopardizing yield reliability (FIGURE 4).

In addition to people, it's important to protect equipment. Cybersecurity is also a form of safety. As foundries become more connected, it's critical that control systems are equipped to thwart potential cyberattacks. Systems must provide built-in security protocols and a wide range of cybersecurity technologies and tools. Robust technologies can resist breaches that can affect production or introduce safety concerns and possibilities for data theft or loss.

## Achieving success

To provide a new generation of chips, machines — and foundries themselves — must become more sophisticated. A Floor to Cloud approach to fab design can help foundries solve multiple challenges and achieve ambitious goals — simultaneously. It's important to remember that, even with new foundries, digital transformation is a unique journey. To get the right infrastructure in place and achieve the desired outcomes, it's critical to start by identifying business insights from the floor up and to receive buy-in from the people who will be using the technology.

Manufacturers can begin the journey by partnering with a supplier that offers a wide portfolio of high/low-flow and high/low-pressure regulators and solenoid and pneumatic valve systems along with controls hardware and software. Expert support and an easy-to-configure, intuitive platform that is backward- and future-compatible can ensure new foundries are prepared for the road ahead and ensure that road is as smooth as possible.

## About the author

**Manish Sharma** leads the industry marketing segment for semiconductor, energy and water industries at Emerson. He has 20 years of experience in marketing, product management and control systems research and development. Manish has been with Emerson since 2011 and holds three U.S. patents for control systems solutions.