Bringing energy efficiency to the fab

Large semiconductor fabs use as much as 100 megawatt-hours of power each hour, which is more than many automotive plants or oil refineries do. In some markets, electricity can account for up to 30 percent of fab operating costs, so there is significant opportunity in rethinking power usage and management.

Steve Chen, Apoorv Gautam, and Florian Weig

A typical semiconductor fabrication plant, or fab, will use as much power in a year as about 50,000 homes. In fact, the larger "megafabs" can consume more electricity than auto plants and refineries. Some facilities have even built their own captive power plants.

While the power consumed by semiconductor chips has been reduced significantly in the past decade, improvements in the energy used during the chip-production process have lagged behind. Energy costs can account for 5 to 30 percent of fab operating expenses, depending on local electricity prices. High-tariff markets include semiconductor hot spots like Japan and Singapore.

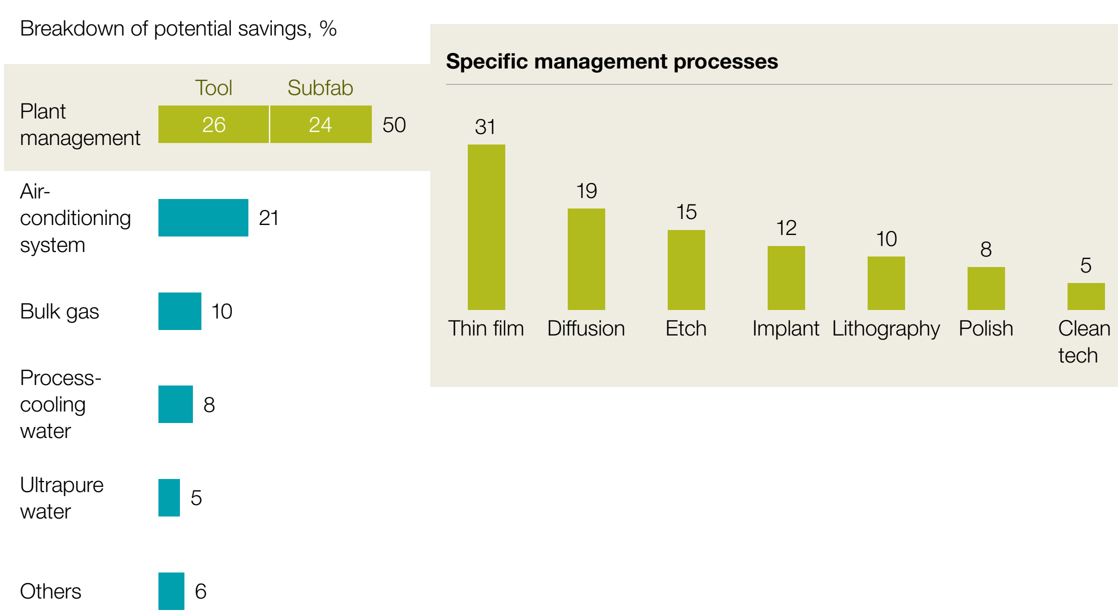
Given the competitive intensity of the industry, it is not surprising that integrated device manufacturers and foundries have invested to achieve energy-efficient solutions (sometimes in collaboration with "green" nongovernmental organizations). We often find, however, that less work has been put into ensuring that the company's infrastructure is run in the most efficient manner. Instead, reliability is frequently the primary, and sometimes the only, consideration when it comes to utility requirements. Few measurements are taken, and at many fabs, there is only one power meter for the entire clean room, despite the dozens of power-intensive tools contained therein. About $20 million to $30 million in electricity flows through that meter each year, but engineers, plant managers, and even fab executives often treat it as a free commodity. Our experience shows that most fab engineers focus on process technology, and the few facility engineers on staff are asked to maintain the status quo. As a result, compressors and exhaust fans run above specification, and chillers often overcool water for the air-conditioning systems.

In boom times, many companies treat energy conservation as a low priority. But the issue becomes more critical when chip volumes fall. Despite reduced production, energy costs remain relatively stable since the plant environment must be maintained regardless of the number of chips made. This puts upward pressure on the ratio of energy costs per wafer and can quickly eat into profit margins. In addition, governments worldwide are putting increasing pressure on energy-intensive businesses to reduce consumption. So semiconductor companies are facing both financial and political pressure to rationalize their energy use.

We have analyzed the energy usage of leading-edge and lagging-edge fabs of several companies in different regions. We consistently found that by applying energy-efficiency lessons from other power-hungry industries, fab energy costs could be cut 20 to 30 percent, half of which can come from changes in plant-management processes. A few modest investments would be required to capture the rest of the savings (exhibit).

Exhibit

A 300-millimeter fab could cut up to 30% of its energy costs.



Realizing significant efficiency potential

Our approach draws on methodologies and tools used for other power-intensive industries, such as in steel and paper plants and oil refineries. We also apply insights from other McKinsey work to identify the types of equipment and processes that consume the most power in a fab. In most cases, we found potential energy savings of 25 to 30 percent with no loss of quality or worker-safety compromises and little new investment.

How is this possible? Most facilities we inspected are overengineered. Consider the thousands of exhaust pipes circulating scrubbed air and removing hazardous fumes from a modern fab to provide a safe, clean environment. Manufacturers of these exhaust systems recommend certain airflow specifications for this equipment. Our analysis showed that most exhaust volumes were running 20 to 50 percent higher than the equipment specifications called for. This was because most semiconductor companies focus on maintaining a certain level of air pressure in the ventilation system, rather than focusing on a manufacturer's recommended airflow volume, which is the more relevant metric. (It is possible to achieve correct pressure with either a low flow or a high flow.)

By reducing the volume of air pushed through the network of exhaust pipes and sent through the scrubber to the manufacturer's recommended volume, a fab could save 20 to 30 percent of air-conditioning costs, or 4 to 9 percent of total electricity expense. Of course, there is potential to reduce volumes further, because there are minimum and maximum specifications. To reach beyond the initial improvements would take several months of additional testing, but the first steps could yield significant improvement in just weeks.

Another area we found that is always able to generate quick wins is the process-cooling water system. Pressure, flow, and temperature are three critical parameters and cost drivers of the system, and our analysis and experience shows that the efficiency of each could be improved significantly. Take pressure: most tools require pressure of less than 4 bar (for context, normal home water pressure is 1 to 2 bar). Most fab systems, however, supply process-cooling water at 5 to 7 bar for perceived reliability or because one or two tools call for extra-high pressure. But there is another way to provision cooling water. Some 15 to 30 percent of the power used to pump water could be saved by reducing pressure from, say, 6 bar to 4.5 bar. And small-boost pumps could be added for specific tools that require higher pressure.

Putting a new approach in place

While process-cooling water systems and air-conditioning are two big users of electricity, semiconductor companies should consider carrying out a comprehensive review of fab operations and an analysis of energy consumption at the tool level. This may lead to a change in metering. Most fabs would benefit from installing meters, if not for every tool then at least at the module level, thereby creating more visibility and accountability. While it could cost $200,000 to install 200 meters, the transparency created can produce rapid savings. In our work, we have found the payback for installing new meters comes in one or two months. The visibility into which modules are using how much power changes behavior faster than any policy memo could.

From there, the challenge shifts to ensuring that functions such as the exhaust system are running within the specified parameters and then to see if additional improvement potential exists. This often requires the creation of a dedicated, professional energy-management team. Many fabs have only one part-time engineer assigned to the energy-management role, even though they might spend tens of millions of dollars each year on electricity. We suggest building an energy-management organization comprising at least one manager, three to five system experts, and additional part-time specialists. Their goal would be to find, implement, and sustain gains in energy efficiency.

Several months into the program, with all processes adhering to specifications and all quick wins either implemented or close to being implemented, managers should undertake a more comprehensive review and develop an energy-efficiency road map across the entire fab network. System experts and specialists should investigate the theoretical limit of power consumption by each tool type and major piece of equipment. From that point, they can develop a list of new efficiency ideas and evaluate each based on a formal business case.

For example, there may be an opportunity to install an additional loop of "high temperature" process-cooling water (77 degrees Fahrenheit versus the 55- to 65-degree water that is commonly used). This water could be produced by ambient air flowing through a cooling tower—a process that is essentially free—compared with traditional (and expensive) chill-generated cooling water. Assuming electricity costs 18 cents a kilowatt-hour (not unusual for Japan or Singapore), a fab could reduce makeup system costs by 50 percent, with a positive return on investment in less than one year. A fab could also install idle-time controllers to reduce tool power consumption by 30 percent. Even this technology investment would generate a positive return on investment in less than two years.

• • •

Energy efficiency is not a common topic within the fab community, but with the fierce competition in many segments of the industry, ratcheting up efficiency efforts and taking a 20 to 30 percent bite out of annual energy costs can offer a competitive advantage and also improve profit margins. As such, semiconductor companies have a big incentive to analyze the opportunity and look for ways to economize across their fab networks. ○

The authors wish to thank Abhyuadaya Shrivastava and Karen Sim for their contributions to this article.

Steve Chen (Steve_Chen@McKinsey.com) is a consultant in McKinsey's Shanghai office, **Apoorv Gautam** (Apoorv_Gautam@McKinsey.com) is a consultant in the Delhi office, and **Florian Weig** (Florian_Weig@McKinsey.com) is a director in the Munich office.