



## **Topic Hub: Semiconductor Manufacturing    Subsection : Reasons to Change**

Given the semiconductor industry's inputs and waste streams, there is potential for cost savings, reduction in emissions and greenhouse gases, improved efficiencies and worker safety, reduced waste, and possible expanded markets. The principles of pollution prevention and source reduction are opportunities and continue to be implemented by leading semiconductor manufacturers.

### **Energy**

Motivation to conserve energy is especially relevant with current high fuel and electricity costs. According to a 2005 study by the International Sematech Manufacturing Initiative (ISMI), the global semiconductor industry could save nearly \$500 million per year in energy costs by making modest improvements to its tools and facility support systems [1].

Cleanrooms are an important target for energy savings. The combination of high air-recirculation rates and energy-intensive processes makes cleanrooms 20- to 100-times as costly to operate on a per-square-foot basis as conventional commercial buildings. They operate around the clock, which means their electricity demand is always contributing to peak utility system demands.

Beyond direct cost savings, in many cases, improved energy efficiency can increase product yield through time savings and improved productivity, and reduce emissions of greenhouse gasses from fuel combustion. Energy efficiency can also provide more flexibility over competitors who do not address efficiency issues, by reducing susceptibility to price changes in resources and industry downturns.

### **Water**

Water-related costs result from obtaining water, producing deionized and ultrapure water in large-scale volumes, and treatment and disposal of wastewater. More water-efficient equipment and processes, along with recycling and reclamation, reduce cost and environmental impact.

Water is becoming scarcer in many areas where semiconductor fab plants are located. Reducing water consumption makes a facility more desirable in a community.

Water recycling systems are initially capital-intensive, but offer great cost savings many times over depending on how many times the water can be recycled. Typically 60-70% of the UPW used in fabs can be recycled cost-effectively [2]. Effective recycling systems offer a great return on investment (ROI). In fact, a Texas study showed a return on capital investment of five to seven months [3].

Other benefits of reducing water use are the conservation of water for flora and fauna in the region, as well as subsequent reduction of effluents and groundwater contamination.

### **Use of Toxic and Hazardous Materials**

The industry uses many chemicals to produce semiconductors, including hazardous materials. The Chemical Strategies Partnership estimates that conventional chemical management methods can cost up to \$1 for every \$1 of chemical purchased [4]. Hazardous wastes generated costs more than \$2 per pound to manage, according to the PPRC Measurement Project.

Minimizing use of chemicals reduces purchase, management and disposal costs. It also cuts staff exposure to hazardous and toxic materials. One example is reduction in use and protection of workers from exposure to known or suspected carcinogens including toluene, cadmium, arsenic, benzene, and trichloroethylene. Another example in semiconductors is the effort to eliminate lead components and interconnects. Some companies are reducing lead for numerous reasons including worker exposure, end-of-life waste containing lead, and global markets.

### **Emissions and Effluents**

Reducing emissions and effluents containing hazardous constituents diminishes liability, and cuts the cost of treatment and pollution abatement. Some previous semiconductor fabs and operations are believed to have contributed to groundwater contamination.



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Greenhouse gas emissions contribute to global warming and climate change. The semiconductor industry has successfully and significantly reduced emissions of perfluorocarbons (PFCs), potent greenhouse gases, since 1997. A viable replacement has not yet been found or invented, so PFCs are still in use. Any additional reductions of these gases are important for the climate.

### Compliance

Regulatory pressures, both federal and state, have led many manufacturers to significantly increase investments in more efficient, less polluting production techniques and technologies. Some applicable federal statutes include the following:

- **Emergency Community Right-to-Know Act (EPCRA) and its Toxic Release Inventory (TRI)** reporting requirements. (See list of <http://www.epa.gov/tri/chemical/index.htm#chemlist> <http://www.epa.gov/tri/chemical/index.htm#chemlist> TRI reportable chemicals and hazard information).
- **Clean Air Act (CAA) and National Emission Standards for Hazardous Air Pollutants (NESHAP)**. The CAA regulates air emissions of 189 toxic chemicals called hazardous air pollutants (HAP). To control emissions of these chemicals, EPA issued [NESHAP standards for the semiconductor industry](#) in 2003. NESHAP contains standards that cover emissions limits, work practices, initial performance testing, ongoing compliance monitoring, recordkeeping, and reporting.
- **Resource Conservation and Recovery Act (RCRA)**. RCRA regulates treatment, storage, disposal, and recycling of hazardous materials and wastes, as well as solid waste. RCRA wastes pertaining to semiconductor manufacturing include (but are not limited to) sludges and still bottoms containing heavy metals or other hazardous compounds, spent solvents, spent process solutions, reactives, and solvent-laden rags.
- **Clean Water Act (CWA) and National Discharge Pollutant Elimination System (NDPES)**. Spent solutions and wastewater must meet local, state, or federal discharge limits or limits set by the local publicly owned treatment works. 40 CFR Part 469 applies to all discharges associated with semiconductor manufacturing, and covers total toxic organics, fluoride, arsenic, total suspended solids (TSS), and pH. Fluoride is a byproduct of hydrofluoric acid used as an etchant and cleaning agent. Arsenic is generated at only those facilities that manufacture gallium or indium arsenide crystals. 40 CFR Part 433 applies to electroplating, vapor deposition, and sputtering, which covers total toxic organics, many metals, total cyanide, oil and grease, TSS and pH.
- **Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH)**. OSHA and NIOSH set occupational safety and health guidelines for chemical hazards and summarize information on permissible exposure limits (PEL), chemical and physical properties, and health hazards. Many semiconductor material inputs and wastes fall under OSHA and NIOSH (and/or additional state) guidelines.

In addition, states may enforce their own set of related regulations at the state level, and may have certain regulatory or voluntary energy and water efficiency provisions.

### Global Markets/Public Relations

Meeting the Waste Electrical and Electronic Equipment (WEEE) and the Restriction of Hazardous Substances (RoHS) directives is important for continued business and strong markets. Other environmental improvements, initiatives, and efforts are attractive to certain customers.

One example is via the Semiconductor Industry Association's Environment Committee, which has established an Environmental Metrics Program. The program has 17 participating companies and 40 facilities, that are employing environmental best practices benchmarking against others in their industry. The parameters being measured are:

- Total water supplied
- Total ultrapure water used
- Hazardous waste generated
- VOC emissions
- Electricity used

Employing the best environmental practices is important for maintaining a good image with the public and stakeholders, as well as attracting new customers and maintaining competitiveness.



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**Solid and Hazardous Waste**

Minimizing solid waste and maximizing recycling conserves resources and reduces landfill loading.

Reducing hazardous waste quantities can lessen permitting requirements, and cut cost and future liability. A conservative estimate of handling hazardous wastes is \$2 per pound, developed by the Pollution Prevention Resource Center's Region 10 Measurement Project, so it behooves any company to address its hazardous waste streams.

*Sources:*

- [1] International Sematech Manufacturing Initiative (ISMI). 2005. [ISMI Study Finds Significant Cost Savings Potential in Fab Energy Reduction.](#)
- [2] SEMATECH. 1998. [Ultrapure Water: Rewards of Recycling.](#)
- [3] Texas Agricultural Experiment Station at Texas A&M University. 2002. [Efficient Water Use for Texas: Policies, Tools, and Management Strategies.](#)
- [4] Claussen, J. Chemical Strategies Partnership. [Presentation] Undated. [Chemical Management Services: A New Strategy for Pollution Prevention.](#)

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