
**INTEL: SURVIVAL OF THE FASTEST IN
SEMICONDUCTOR INNOVATION**

**INTEL IS THE LARGEST SEMICONDUCTOR MANUFACTURER IN THE
WORLD**

In 1971, Intel introduced the world's first microprocessor, the 4-bit 4004. Today, Intel is the largest microprocessor manufacturer in the world, so large that 80 percent of computers worldwide are running Intel processors (Kirkpatrick, 1997, pp. 60–72). Valued at \$100 billion, Intel is almost as large as the Big Three automakers combined (Port, 1996).

Intel annual revenues have grown phenomenally in recent years. Since 1991 annual revenues have climbed from \$4.8 billion, more than five-fold to \$25.1 billion in 1997 (shown in Figure D.1) (Intel, 1998). To continue this growth, Intel seeks to continue to be the preeminent building-block supplier to the computer industry worldwide. Intel supplies the computer industry with chips, boards, systems and software, which are used by the computer industry as “building blocks” to create advanced personal computing systems. Specific products categories are: processors (microprocessors (CPUs), chipsets, motherboards); networking and communications equipment; semiconductor products (flash memory, embedded control chips). Major customers are computer and peripheral manufacturers, PC users, and other manufacturers (Intel, 1996b, p. 1).

Intel is an international company with more than a dozen major facilities outside of the United States, located in eight countries. There are six sites in the continental United States—in Arizona, California, New Mexico, Oregon, and Washington—with multiple facilities at each and one site in Puerto Rico. Its oldest and smallest manufacturing facility, wafer fabrication facility (fab 4) on the Aloha campus in Oregon, was built in 1978 and was closed in 1996. In recent years Intel has been building a new fabrication facility, an investment of

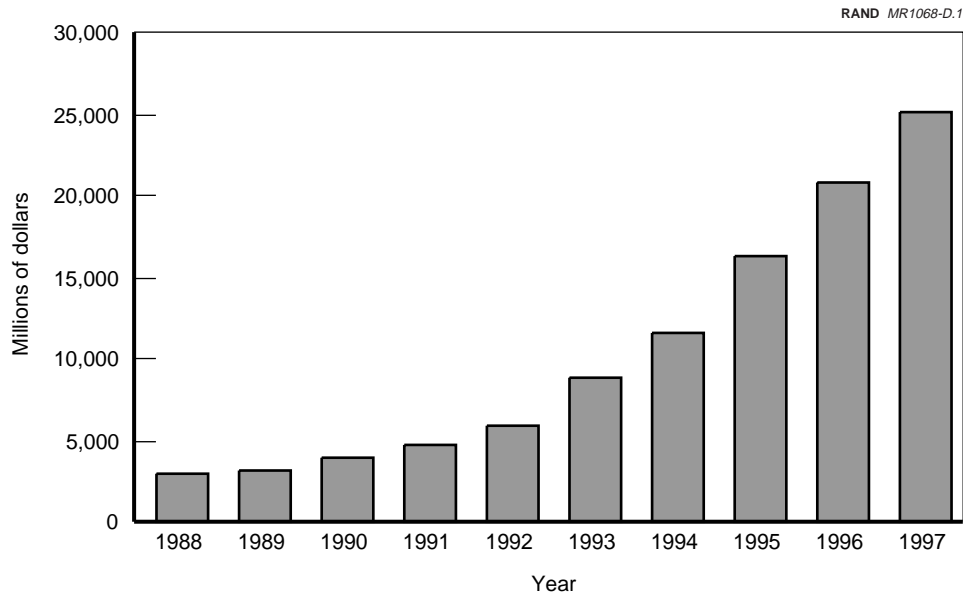


Figure D.1—Intel Revenues

\$1 billion to \$1.5 billion, every nine to twelve months (Kirkpatrick, 1997, p. 63; McManus, 1997).¹

The total number of Intel employees was 63,700 at 1997 year-end, up from 48,500 in 1996 (Intel, 1998). Worldwide EH&S staff number around 225 and are organized by site (McManus, 1997; Intel, 1996b). Intel appears to be a relatively flat organization—no product divisions; sales and product groups have a few engineers dedicated to support a specific product. While manufacturing operations are organized under one individual, employees are geographically dispersed. Specific manufacturing project teams are pulled from across the organization as required. Intel has a history of maintaining a fluid and flexible organization where “all such forms are ultimately transitory, and their purpose is to respond to the needs of the time.” (Nanda and Bartlett, 1994, p. 4.)

¹It takes between 18 and 22 months to construct a facility.

THE TECHNOLOGY TREADMILL AND SURVIVAL OF THE FASTEST

We will guard our intellectual property like a hawk, . . . but ultimately, speed is the only weapon we have.

—*Andy Grove, former CEO of Intel (Nanda and Bartlett, 1994, p. 14.)*

Intel is on a treadmill of new-product introductions fed by increasing demand for microprocessors.

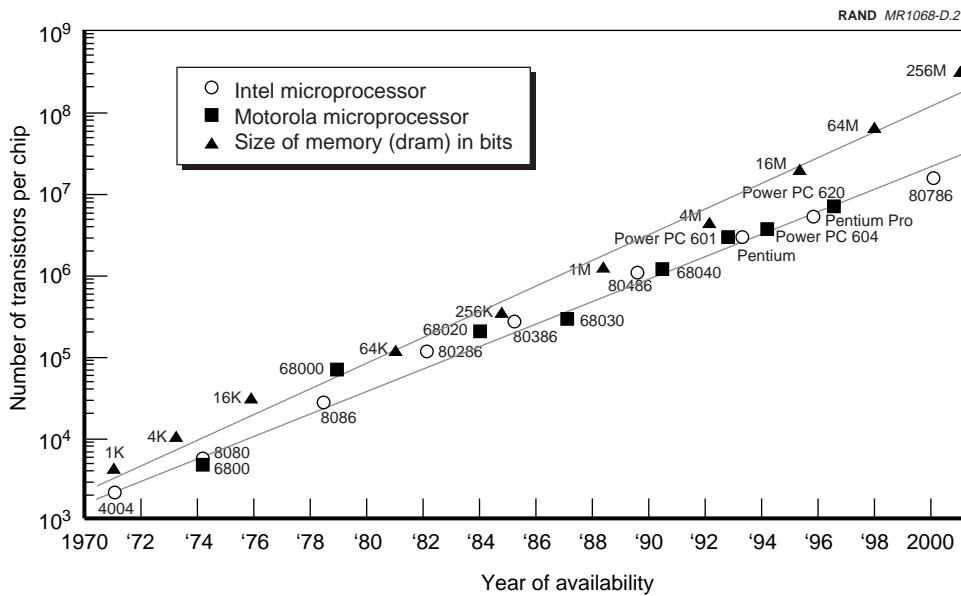
—*Scott Randall, SoundView financial security analyst (Kirkpatrick, 1997, p. 62.)*

A founder and chairman emeritus of Intel, Dr. Gordon Moore is famous for his 1965 prediction that the number of transistors on a chip will double every 18 months (Brandenburger and Nalebuff, 1996, pp. 168–175). This prediction has held true, Intel's primary product, the microprocessor, or chip, is seeing explosive technological change—product complexity has been increasing at an exponential rate. Improvements in two measures of semiconductor complexity, the number of transistors placed on a chip and the number of instructions processed per second, are shown in Figure D.2 below. As shown, the rates of increase in both of these measures have been exponential since introduction of the first semiconductor, the 4004, in 1971. The 4004 chip had 2,300 transistors on it that processed 0.06 million instructions per second. For comparison, the 1286 chip, projected to arrive in 2011, 40 years after the 4004, will have one billion transistors that processes 100,000 million instructions per second.²

This rapid series of incremental product improvements is referred to as the Intel “technology treadmill.” In the past their business strategy was to innovate faster than competitors, exploit leader advantages and then move on to the next generation of technology. The large profit margins from new semiconductors, usually around 60 percent and as high as 90 percent, fuel further innovation as well as capacity investments in new plant and equipment (Reinhardt et al., 1997, p. 70).³ According to a recent article, Intel is revising its overall strategy in response to market changes. For the first time it is creating semiconductors for

²Note: the personal computer was introduced in 1981.

³Intel's previous strategy was one of technology push and planned obsolescence. It relied on its ability to bring new technology quickly to the market to drive demand for better and faster computers. Once the technology became mature and competitors moved in, it was ready to introduce the next-generation technology and licensed production of the old to others. For example, in January 1996, Intel signed a technology licensing agreement with Rochester Electronics Inc. (REI), a company that specializes in manufacturing semiconductor products discontinued by the original manufacturers. Under this agreement, REI receives the rights, tooling, and technical data to manufacture 29 mature Intel products to include: 8088 microprocessors, the 82XXX series logic chips, and communication devices, most of which are based on the NMOS process. Intel plans to discontinue in-house manufacturing of these products (Intel, 1996c).



SOURCES: VLSI Research, Inc.; Integrated Circuit Engineering Corp.; Hutcheson and Hutcheson (1996, pp. 54–62).

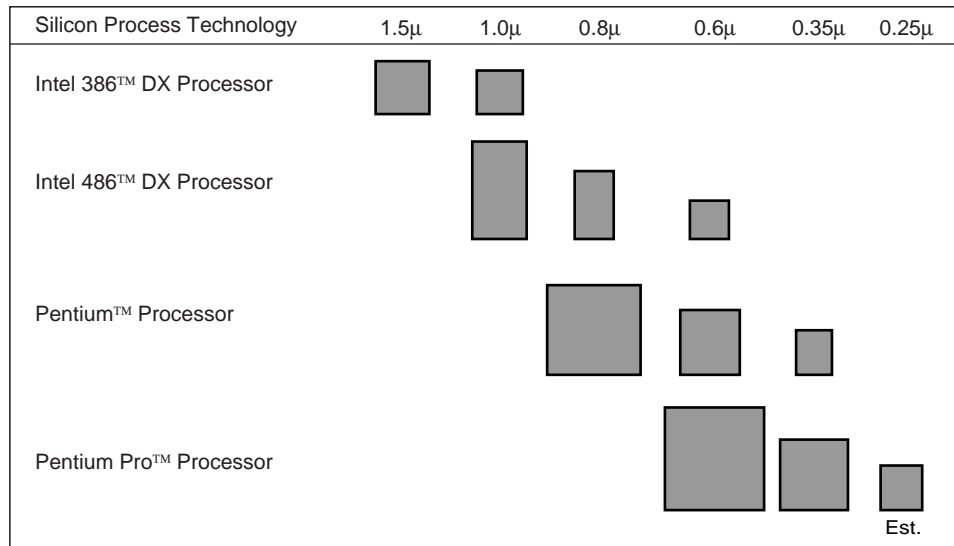
Figure D.2—Semiconductor Complexity Measure and Performance Improvements

the low-cost computer market, which is expected to grow dramatically in the next several years. In these markets, profit margins are typically lower. This may move Intel to diversify its strategy to address different markets—those that demand rapid product innovation and those that demand low-cost innovations (Reinhardt et al., 1997, pp. 70–77).

On average, new semiconductors take 31 months between generations to develop (Port, 1996, p. 150). In 1970, the R&D investments for a new family of memory chips were \$100,000; in 1980, these investments rose to \$2 million and on to \$100 million in 1985 (Nanda and Bartlett, 1994, p. 12).

Intel seeks these rapid, incremental technological advancements in a very structured development process. They accomplish this in part through concurrent development of product generations and their associated manufacturing processes. That is, new products (including semiconductor chips and software) and their new manufacturing processes are developed simultaneously. However, after a new chip is introduced, the design team does not stop there. Once the microprocessor is developed, the team works on a series of design modifications to miniaturize the feature size and chip size, increasing its processing speed and complexity (see Figure D.3). For example, after the Intel 486 proces-

RAND MR1068-D.3



SOURCE: Intel Corporation.

Figure D.3—Microprocessor Generations and Feature Size

processor was introduced at the one micron (1.0 μ) feature size level, the development team continued working to miniaturize features to the 0.7 μ level. These closer features increase the speed of the processor and also increase the number of functions that can be placed on a single chip. These feature sizes are very small. For comparison, bacteria are 8 μ in diameter and a human hair is 80 μ in diameter.

To accomplish rapid product innovation, Intel also employs two product development teams that “leapfrog” one another to speed the development process. In other words, the two separate product developments are continuously developing new products and when one design team finishes they pick up the follow-on to the other team’s chip design. Each chip design team performs a lot of product simulation and verification—including chip layout and functional analyses (co-processor, input/output, etc.).

Another practice employed to reduce the time-to-market is to include manufacturability and customers early in the design process. At the same time product design is underway, manufacturing processes are developed. Approximately one-third of a production line’s tool-set is turned over with each transition to a chip with feature sizes at a new micron level. Every two years at Intel, production capability is completely retooled to produce a new generation of semiconductor. Completely new fabrication facilities cost on the order of \$1

billion to \$1.5 billion dollars and could rise to \$10 billion for future facilities (Nanda and Bartlett, 1994, p. 150).

Manufacturing improvements are developed concurrently by a fluid or a virtual organization (Intel employees describe this as “amoeba-like”) that supports the entire corporation. These personnel are geographically dispersed and different groups are pulled together on a project basis. After project objectives are met, the organization will restructure to meet the next challenge. Personnel from Hillsboro, Oregon, and Santa Clara, California, generally handle R&D for fabrication, while in Arizona two different groups handle capital equipment planning and chip assembly R&D and fabrication issues. These locations have low-rate, developmental fabrication facilities. At these prove-out facilities, new techniques are developed and tested. Once new processes are sufficiently tested, they are copied exactly (in terms of equipment, procedures, and methodologies) and transferred to the full-rate fabrication facilities. This allows Intel to expand capacity to get out new products quickly, which is especially difficult for chip manufacturing because of the capital intensity of fabrication and the tacit knowledge required to get production yield up. Intel’s goal is to make its fabrication facilities identical around the world. In this way, manufacturing operations can be managed more easily and consistently, yields can be kept high, and most important, changes and new techniques can be diffused rapidly. This also gives Intel more flexibility to meet customer demand because identical manufacturing operations will eliminate the customer’s need to requalify products from different factories. Finally, the continuous change in products and processes affords Intel many opportunities to at least consider pollution avoidance and other environmentally conscious manufacturing improvements on an incremental basis.

R&D EMPHASIZES DEVELOPMENT

Investments in R&D have grown from \$618 million in 1991 to nearly \$2.4 billion in 1997 (Intel, 1998). Figure D.4 shows the growth in Intel’s R&D investments since 1986. Because much of Intel’s competitive advantage derives from its ability to bring new products to market rapidly, most of what Intel does in-house is development work. And for the most part, its development work is specific product development.⁴ Intel relies on universities for most of its

⁴Intel is not noted for performing original research on semiconductor design. Reduced Instruction Set Computing technology, the basis for the Pentium Pro chip, was originally developed at IBM and Motorola in the late 1980s. Only recently has Intel begun to invest a nominal amount (a few million dollars) into original, long-term computer chip design. This will be performed at its microcomputer lab. Its stated mission is to “keep the technology treadmill going.” (*Wall Street Journal*, 1996.)

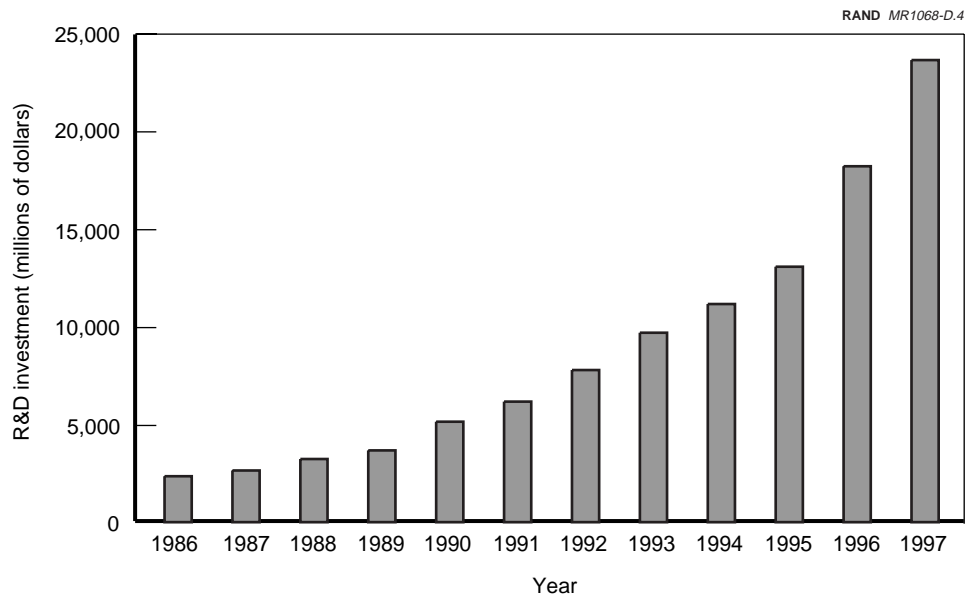


Figure D.4—R&D Investment Growth at Intel

“research,” or for projects with a longer-term focus than internal R&D. For example, the EH&S group is sponsoring university research on converting the gas form of xylene to liquid form so that emissions can be managed better.

Intel has a Research Council, consisting of committees organized by their various research labs, to promote and support higher education and research in areas that complement and augment their own programs. Examples of Intel research labs are the components research lab, microcomputer research lab, and applications research lab.

Each university-based project has an Intel sponsor, who is responsible for promoting it within Intel and for ensuring that results are transferred from the university to Intel. In addition to funding university research through grants and gifts, the Research Council can develop mutually supportive relationships in a variety of other ways. These range from participation in Intel research forums and seminars to sponsoring visiting faculty collaboration to one-on-one partnering on projects to hiring graduates.⁵

In order to ensure that environmental issues are integrated with general business-management activities, Intel does not identify environmentally oriented

⁵This information is taken from <http://www.intel.com/intel/other/rsearch/indesc.htm>.

R&D separately. R&D investments are made to meet internal objectives, and environmentally related objectives are a part of the overall set. They are not identified as a separate cost center. One environmental, health, and safety (EH&S) staff member is devoted full-time to the development and execution of the environmentally related objectives.

INTEL IS EXPERIENCED WITH FEDERAL GOVERNMENT COLLABORATIONS

Intel has been, and is, involved in numerous collaborations with the federal government. A sample of their activities follows.

- Intel has several CRADAs with national laboratories. They have several with the Sandia National Laboratory to develop better analytic methods and instruments to sample for one specific solvent when multiple solvents are present in the same tank (McManus, 1997). Another CRADA aims to reduce ultrapure water use during chip rinse (also with a university), and a third aims to develop chemical ionization mass spectroscopy to monitor air emissions with portable equipment. In the past, a Sandia rapid-response team worked with Intel engineers to solve a clogging problem in newly installed thermal oxidizers as well (Intel, 1996b, p. 7 and p. 17).
- Intel has identified a project during the Common Sense Initiative (CSI) implementation to develop better analytic methods to measure removal efficiencies for HAPs when the concentration is low, less than 1 ppm, but flow-through volume is high (such as in a wet scrubber).
- The Semiconductor Industries Association, the EPA, and Intel have signed a memorandum of understanding to identify the best methods to reduce perfluorocarbon emissions (Intel 1996b, p. 9).
- There is an EH&S staff member involved with SEMATECH (full time in 1995). They are developing ultrapure water conservation models and air emissions management systems with SEMATECH (Intel, 1996b, p. 12). However, SEMATECH-funded research is generally secondary to Intel's own research because its development times are just too fast to coordinate research with outside parties. In addition, there are some differences in priorities between Intel, a semiconductor manufacturer, and other industrial members of SEMATECH, most of whom are memory chip producers. Results from this collaborative effort are useful to Intel as alternatives to their own or as a way to refine a basic approach that they've initiated (McManus, 1997).

INTEL SEEKS TO ENGAGE ENVIRONMENTAL POLICYMAKERS

Intel is involved in several voluntary programs. For example, its Aloha, Oregon, facility participated in an experimental air permit program that included pollution-prevention activities. Its Chandler, Arizona, facility is involved in the EPA Project XL Program. As part of Project XL, Intel gains some regulatory flexibility in exchange for agreeing to superior environmental performance and extensive stakeholder involvement in priority-setting. Superior environmental performance is defined by the Project XL program as environmental performance that exceeds what would be achieved through routine compliance to current and reasonably anticipated future regulatory requirements. The specifics of the agreement are documented in an environmental master plan that includes both voluntary components for environmental improvements and two operating permits. This plan was signed November 19, 1996.⁶ Extensive stakeholder involvement is a part of priority-setting within this experiment (Intel, EPA, state and local authorities, tribes, and the community).

Intel's primary motivation for these activities is to improve the regulatory process as it relates to its business. Historically, environmental air permits have been issued for five-year increments. However, this is more than two Intel fabrication process "lifetimes." Because it has such a rapid product and process turnover, environmental regulations have become constraining. As a result, permitting times under the Clean Air Act Amendments of 1990 have created a huge opportunity cost for Intel.

At the international level, Intel has worked with the German government to develop the Closed Cycle Substance and Waste Act and the associated Electronic Waste Ordinance. In Israel, Intel worked with the Israeli Ministry of the Environment through the High Technology Industrial Zone to receive and properly dispose of chemical waste generated by the small companies near their facility (Intel, 1996b, p. 7).

Intel managers have suggested that the company pursue these opportunities for a multitude of reasons that range from a corporate emphasis on quality and continuous improvement to good corporate citizenship. According to these

⁶The environmental master plan is a comprehensive plan for the facility that includes voluntary actions, such as monitoring; water recycle goals; a single, integrated environmental report; and commitments on setbacks beyond legal requirements. The Intel Project XL final project agreement was signed after nine months of stakeholder discussions. Public comments on the Intel final project agreement were focused on two general areas: the tensions between provisions that provide the flexibility that Intel desires and assurances that superior environmental performance is achieved, maintained, and enforceable; and ensuring that the stakeholder decisionmaking process is as inclusive and equitable as possible. It appears that the lack of toxicological data and risk assessment methods and the inability to closely monitor actual environmental performance, particularly HAP emissions, have contributed to differing interpretations of Intel's plan to achieve superior environmental performance (EPA, 1997; NRDC, 1997).

managers, it is generally taken on faith as opposed to a rigorous calculation of return-on-investment that these activities will have some benefit to the corporate bottom line or to its employees (McManus, 1997; Mohin, 1997).

Intel's Environmental Goals

A large part of environmental management at Intel is employing design-for-environment practices to achieve its own environmental performance goals. These analyses will also help to determine the required investments necessary for achieving desired environmental performance.

Intel is focusing on four areas: air emissions, chemicals use, natural resource use, and solid-waste generation.

Air emissions. Intel's goal is to reduce air emissions to become a minor source at all locations (McManus, 1997; EPA, 1997). As a result, it is working to reduce volatile organic compounds (VOCs) and HAPs emissions through process redesign, chemical reuse and management, natural gas and boiler emissions reductions, and control technology development (Intel, 1996b, p. 6). Eliminating the need for an air permit under Title V of the Clean Air Act Amendments would save the company compliance expenses.⁷ Perhaps more valuable to Intel is the time spent negotiating permit modifications. We suspect that given such rapid product and process cycle times any delay can have huge opportunity costs.

Chemical use. Reductions in chemical use are being sought through careful management and Intel's "rent-a-chem" approach (McManus, 1997). They have a Strategic Chemical Council, established in 1993, that reviews chemical use at all sites. This executive-level council reviews products and process designs for improvements in chemical, water, and energy use (Intel, 1996b, p. 8). Ultimately, Intel seeks to close the material loop for chemicals either in an open or closed loop fashion—chemicals can either be completely incorporated into the product, with zero waste, or chemicals can be used, waste can be captured, and returned to the supplier for reuse or recycle. For example, Intel is working with its suppliers to capture PFCs for reuse/recycle and is also working with EPA and the Semiconductors Manufacturing Association to reduce PFC use overall.

Natural resource use. Water is an important issue in semiconductor manufacturing. The millions of gallons of water per day required by semiconductor

⁷Potential savings estimates were not provided by Intel. However, information for another semiconductor manufacturer, Lucent Technologies, suggests that the amounts can be large. It makes as many as 50 manufacturing process changes per year at its Allentown, Pennsylvania, semiconductor plant. Almost every one of these changes requires a permit modification, which can take hundreds of thousands of dollars to negotiate (Sanders, 1996, pp. 75–76).

manufacturing generated community concern over local water supplies at its plant in Rio Rancho, New Mexico. An Intel spokesperson was quoted as saying that controversy over water usage at the plant in New Mexico, was “the most intense the industry has faced.” (Labate, 1995, p. 32.) At Intel’s Chandler, Arizona, facility, which is the one participating in the EPA’s Project XL Program, stakeholder discussions uncovered community concerns about water use at this plant as well. While water is not reflected in environmental regulations, its use was of ultimate concern to the community surrounding the plant.

Semiconductor manufacturing requires a lot of water in the various chip cleaning and cooling processes. According to Intel, its Chandler, Arizona, fabrication facility (fabrication facility 12) was estimated to require three to six million gallons of water per day before several water use modifications were introduced. After these modifications are made, water use is expected to drop to one million gallons per day (Intel, 1996b, p. 13).

Two areas have been targeted to reduce water use—chip cleaning and wastewater operations. Chip cleaning operations require ultrapure water. Ultrapure water is required since even with a trace of organics in the water—less than 1 ppm—bacteria could grow and cause plant shutdown for weeks (recall feature sizes are currently in the $.7\mu$ to $.35\mu$ range while bacteria are 8μ in diameter). Efficient conversion processes require roughly 1.5 to two gallons of potable water to produce one gallon of ultrapure water. Current technological options to the use of ultrapure water for wafer cleaning, such as “no-clean,” have been reported as too costly (Labate, 1995, p. 32). Intel’s manager for Corporate Environmental Affairs suggests that there are unresolved technical issues as well. Intel is working with its equipment suppliers to develop new wet benches that clean silicon wafers more efficiently and increase ultrapure water recovery. It anticipates that the new benches will reduce ultrapure water use by 40 percent, reducing total water demand by 300,000 gallons per day at each facility (Intel, 1996b, p. 12).

Wastewater is the second area that has been targeted for technological improvement. Intel has developed two models for dealing with wastewater issues, an internal recycle approach (employed at fabrication facility 11 at Rio Rancho, New Mexico) and an external reuse approach (employed at fabrication facility 12 at Chandler, Arizona). Intel will transfer these approaches from its prove-out facilities to its other production facilities, just as it does with general fabrication techniques. The internal water-recycling approach uses process effluent for other purposes, primarily the cooling towers. Since water is internally recycled, management tends to focus on total dissolved solids content, which can accumulate with reuse. In contrast, the external approach involves buying municipal wastewater for use in cooling towers and Xeriscaping. The effluent from chip rinsing and ultrapure water production is

treated at a city-facility built specifically for Intel wastewater and funded by Intel. Reverse osmosis is used to treat the wastewater, and then it is injected back into the ground water. Separate lines must be run by both the city and Intel to take in both fresh water and wastewater as well as to discharge treated and untreated water. The external approach is only economically feasible because Chandler, Arizona, is a zero discharge city. That is, Chandler has invested in the infrastructure required to reuse wastewater citywide. Intel personnel could not identify another city that has invested in this infrastructure. Even with the city's preexisting infrastructure investments, Intel had to invest an additional 2 percent, or more than \$20 million, more than no-recycling approaches. If it used the no-recycle approach, Intel could have designed its water system to discharge all wastewater to the city for treatment at a cost to Intel of approximately \$5 million. Instead, Intel designed its system for external recycling using the city's existing infrastructure. However, Intel spent approximately \$28 million for a dedicated water treatment plant that will be owned and operated by the city to process its wastewater by reverse osmosis. Once processed, the water either will be used to replenish the aquifer or will be reused by the water district (McManus, 1997).

According to Intel, the stakeholder process is a useful way to incorporate community priorities, which vary across the nation, into environmental decisionmaking. In the Project XL process, Intel and the community were able to agree upon a mutually beneficial plan—Intel gained the flexibility to make process changes more quickly and the community gained water-use reductions, environmental emissions reductions, one emergency plan, and one consolidated report with all environmentally related information (Mohin, 1996 and 1997).

Solid-waste generation. Intel is addressing solid-waste generation through design-for-environment. These efforts concentrate on reducing and recycling packaging as well as the recycling of scrap silicon wafers generated during fabrication (Intel, 1996b, pp. 10–11).

INTEL'S RECOMMENDATIONS FOR THE FEDERAL ROLE IN ENVIRONMENTAL R&D

Right now regulations send the primary signal to industry about national environmental priorities. From Intel's perspective, regulations have emphasized technology objectives over environmental performance objectives. For example, in the San Francisco Bay area, regulations mandate a 98.5 percent VOC removal efficiency rate. The only way to do this is to use burners, which shift environmental impacts to another form (from VOCs to NO_x and CO₂ emissions because of the increase in natural gas use). In contrast, at another location Intel

can use carbon absorbers to mitigate VOC emissions. While these absorbers achieve a 90 percent and not a 98.5 percent removal efficiency rate, they also do not have any associated NO_x and CO₂ emissions. Another example are CFC emissions. These emissions reductions are at the point of diminishing returns—for Intel to eliminate the last 200 pounds of CFCs it may have to invest \$5 million to \$10 million. At some point cost-effectiveness should be incorporated into regulations.

Intel environmental, health, and safety personnel would also like to see greater allowances for community input into regulatory policy since there are regional variations in priorities and resources. They would also like to ensure that regulations are focused on the appropriate outcomes by improving the way in which rigorous scientific analyses are incorporated into regulatory policy.

Intel environmental personnel would like to see sustainability concepts used for environmental policymaking. In their view, sustainability has a special meaning.⁸ It is “when all companies and communities achieve their design-for-environment and these systems are integrated.” (McManus, 1997.) They envision a process by which regional or local planning and goal setting will allow companies and communities to establish their own environmental priorities and performance levels. The tricky part of this process then becomes establishing these goals.

Intel personnel’s specific recommendations for federal actions to promote environmental R&D are as follows:

- Improve regulatory policy to allow regional approaches and priority-setting (the Dutch model of including communities in priority-setting is a good one) and establish cross-media, performance-based criteria rather than single-medium, technology-based criteria.
- Invest in scientific research and ensure that the new knowledge is incorporated into regulations. Because regulations drive industry’s focus it is vital to ensure that they are addressing the right problems. Incorporating new knowledge gains into regulations is just as important as funding the research itself. An area of particular concern to Intel is water quality. In some cases regulations now drive industry management to focus attention on intermediate goals (such as dissolved salt content) rather than the ultimate objective (water use).

⁸Note that sustainability is not a well-defined concept. Intel, however, appears to be describing a slightly different process because its description makes no mention of using resources at rates that can be regenerated. However, this could simply be an omission made in the interview process.

- Use federal investments to improve monitoring technologies and measurement standards. Disseminate information and technologies on new analytic techniques and instrumentation. Past experience with EPA suggests that information dissemination and technology diffusion should be given more attention.
- Support the science and technology infrastructure, especially higher education and university-based research.
- Educate the citizenry on environmental issues for two important purposes—one, to generate market demand, and two, so that communities will be better equipped to establish their own environmental goals and targets.
- Promote sustainability and systems thinking to close material loops among all stakeholders.
- Use federal investments to help municipalities provide the necessary infrastructure.
- Intel did not recommend public-private R&D collaborations for its primary technologies, because Intel's technology treadmill is set for a fast pace.

SUMMARY AND OBSERVATIONS

Intel's business strategy is to introduce rapid product innovations more quickly than its competitors. In the past, its business strategy generated large profit margins, which were invested into new product development and manufacturing capability for the next product innovation. This strategy means that every management process, including environmental, must minimize the time-to-market of new products.

Environmental management is geared toward reducing the regulatory burden on time-to-market, primarily by reducing air emissions below permit thresholds. Public comments on the Intel final project agreement for the Project XL experiment suggest areas for environmental R&D. The inability to define superior environmental performance precisely, the lack of toxicological data and risk-assessment methods, and the inability to closely monitor actual environmental performance, particularly HAP emissions, has contributed to differing interpretations regarding Intel's plan to achieve superior environmental performance and its enforceability.

Involvement of stakeholder groups is also a part of Intel's environmental management. The Intel Project XL final project agreement was signed after nine months of stakeholder discussions. Community concerns about water use have led to investments in research and equipment to reduce it.

Regulations are the only existing signal to industry, and, according to Intel, they include single-medium technology objectives not performance objectives. They also do not allow enough flexibility for regional variations in priorities. Intel has its own view of sustainability that it would like to use to plan environmental investments. It is “when all companies and communities achieve their design-for-environment and these systems are integrated.” This view includes regional priority-setting to allow for local variability in priorities and stakeholder involvement. Investments in science and technology will ensure that communities have the expertise available to establish scientific environmental priorities. Infrastructure investments will also be required.

R&D collaborations with the federal government have limited application because Intel’s technology cycle times are too fast to coordinate with outside entities very well.