



Circularity in Intel's Semiconductor Manufacturing: Recovery and Reuse

Intel has long been committed to recycling and circular economy strategies, with a focus on recovering and regenerating resources.

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Intel is a world leader in the design and manufacturing of essential products and technologies that power the cloud and an increasingly smart, connected world. Unlike many other semiconductor companies, we primarily design and manufacture our products in our own facilities and view our in-house manufacturing as a unique advantage.

Intel has made significant capital investments in semiconductor manufacturing facilities at three locations in the United States—Arizona, New Mexico, and Oregon—as well as in China, Ireland, and Israel, forming a responsive and resilient global technology manufacturing network. Approximately one fifth of Intel's employees around the world support these manufacturing operations, producing an estimated 10 billion or more transistors every second.

Responsible Waste Management

A large fraction of the waste Intel generates is tied to product manufacturing. Major semiconductor manufacturing-related waste streams include lithography-related solvents, metal plating waste, specialty base cleaners, spent sulfuric acid, ammonium sulfate, and calcium fluoride. Our operations also generate plastic waste, metal waste, kitchen waste, and general office waste. We sent just 6% of total waste generated to landfill in 2018.



275%

Increase in percentage
of Intel manufacturing
waste reused and
recovered since 2015

Intel has long been committed to environmental sustainability, strategies, with a robust focus on finding ways to recover materials and regenerate resources. Since the mid-1990s, Intel has voluntarily disclosed key environmental metrics, including waste generation and recycling, and proactively set goals to improve our performance in this space. Over that time, the company has increased its recycling rate from 25% to 90%, all while Intel's business and production continued to grow, and total waste generated has increased.

Transitioning from traditional disposal methods of incineration and landfill to materials recovery and reuse methods is where we are today, resulting in circular economy solutions that reduce costs and environmental impact.

Early Reuse Efforts

Intel began manufacturing in Oregon in 1976, its first wafer manufacturing plant outside of its California headquarters. Since then, Intel's Oregon operations have grown to become an important development facility in addition to manufacturing.

In 1999 during the conversion to 130 nm transistors and metal interconnects, Intel began generating copper plating waste. Initially the plating bath was managed offsite by our waste hauling suppliers, but eventually Intel manufacturing sites began electroplating the metal on-site, generating scrap copper for sale.

As the technology advances, Intel has continued to investigate the recovery of other plating metals. In 2019, Intel's Oregon facility is expected to send more than 600 tons of metal plating bath waste to supplier facilities where these metals will be recovered and returned to the metals commodity market, closing the circular economy loop.

DISPOSAL METHODS

Direct Reuse

Material is reused in its existing form

Recovery

Material is purified to its original form for reuse

Recycle

Material is transformed into another substance

Fuel Blending

Material is substituted in place of virgin fuels

Treatment

Material is neutralized to allow for disposal

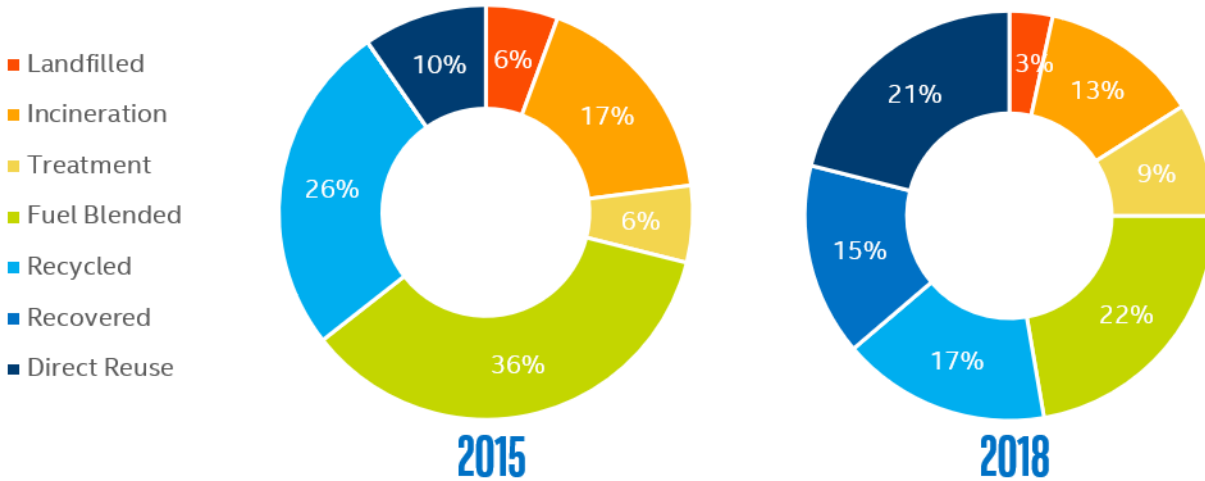
Incineration

Material is safely burned without energy recovery

Landfill

Material is sent to an Intel-approved landfill

INTEL MANUFACTURING WASTE BY DISPOSAL METHOD



In 2018, 75% of Intel's manufacturing waste was fuel blended, recycled, recovered, or reused. Over the past three years, Intel's direct reuse and recovery of manufacturing waste has increased by 275%. Data includes hazardous and non-hazardous waste associated with manufacturing processes at Intel's wafer fabrication manufacturing sites (Ocotillo, Chandler, Ronler Acres, Hudson, Jerusalem, Qiryat Gat, Ireland, Rio Rancho, Dalian, and Bowers).

In the early 2000s, Intel began treating ammonium wastewater to reduce nitrogen sent to local waste water treatment facilities. The waste byproduct, ammonium sulfate, was initially directed towards offsite waste water treatment—but beginning in 2013, both Oregon and Arizona facilities began directing this byproduct to fertilizer manufacturing in partnership with our waste supplier. This effort, which was Intel's first U.S. reuse program has resulted in over 35,000 tons of ammonium sulfate being directed toward fertilizer manufacturing.

Spent Sulfuric Acid Waste Recovery

Intel established a presence in Arizona in 1979 and began operations in Chandler the following year. In 1994, we expanded our operations with high-volume manufacturing on our Ocotillo campus.

Intel began collecting sulfuric acid waste from our wet cleans process in 2017. Initially, the only available disposal method was stabilization and landfill. By 2018, we began

sending the Arizona site's spent sulfuric waste to an offsite facility where it is processed to technical grade sulfuric acid in partnership with our supply chain. A portion of this material is directed back to our manufacturing operations in Arizona, as well as our factory in New Mexico, to be used in our onsite wastewater treatment systems.

Implementation of the waste management and material recovery solutions required regular on-site testing and sampling, as well as investment from our waste management supplier. We estimate that the switch will save approximately \$700,000 in disposal costs over three years, supporting the first circular initiative in our manufacturing operations.

Since August 2018, when we began collecting the spent acid waste for recovery, we have managed to divert nearly 3,000 tons of hazardous waste from landfill and are on track to increase that number to more than 4,300 tons of material in 2019. These efforts are in line with Intel's 2020 environmental

Manufacturing Waste Stream	Traditional Disposal Methods	Current or Near Future Opportunities
Ammonium sulfate	Wastewater treatment	Fertilizer manufacturing
Calcium fluoride	Landfill; cement kiln recycle	Cement product; cement kiln recycle
Lithography-related solvents	Fuel blend	Cyclohexanone recovery; paint thinners
Metal plating waste	Landfill; wastewater treatment	Metal recovery
Specialty base cleaners	Incineration	Water recovery; organic high BTU fuel
Spent sulfuric acid	Wastewater treatment; stabilize and landfill	Recovery offsite

Major semiconductor manufacturing waste streams and traditional and progressive waste management methods adopted by Intel in recent years or planned for future environmental sustainability initiatives.

goal to send zero hazardous waste to landfill.

This example, which required close coordination with both Intel's manufacturing operations as well as several key suppliers, is a model that we look to replicate at additional manufacturing locations in the coming years.

Reuse and Materials Recovery at Intel Ireland and Israel

Intel's industrial campus in Leixlip, Ireland is one of the most advanced in Europe. Intel has had a presence in the country since 1989, and the site plays a central role in Intel's global manufacturing network. The site, which currently manufactures semiconductor products based on Intel's 14nm process node, has made tremendous progress in managing their manufacturing waste over the past several years.

In 2014, the Intel Ireland site generated 4,400 tons of manufacturing-related waste, and none of it was reused or recovered. In addition, approximately 30% of the site's chemical manufacturing waste was landfilled

or incinerated. That year, Intel's supply chain organization—in collaboration with the site and third-party waste management partners—began developing materials recovery and recycling disposal methods for a number of waste streams, driving our manufacturing waste up the waste hierarchy from incineration and landfill to recycle and materials recovery. Some examples include:

- Moving our calcium fluoride waste from landfill to an ingredient component in cement product manufacturing
- Distillation and recovery of a lithography solvent for resale
- Recovery of semi-precious metals for metal recovery rather than sludge generation.
- Converting our spent sulfuric acid and ammonium sulfate to inputs for fertilizer manufacturing.

Following strong collaboration between Intel and our waste supply chain, Intel Ireland's overall waste management costs decreased

by nearly 50%, and our per ton disposal costs continue to decrease—demonstrating that more sustainable disposal methods can generate cost savings.

By the end of 2019, we expect 80% of the site's manufacturing waste to be reused or recovered helping to mitigate the site's environmental footprint. In addition, none of the manufacturing waste is being directed to landfill or incineration any longer.

Through these multi-year efforts and strong supplier partnerships, Intel has significantly improved reuse and materials recovery for our Irish manufacturing waste.

At Intel's Qiryat Gat fabrication facility in Israel, a similar approach to managing manufacturing waste has been developed. In addition to distillation of lithography solvents fuel blending of specialty base cleaners, and metals and ammonium waste recovery, calcium fluoride waste from the site is used as an alternative daily cover for local landfills.

Addressing Electronic Waste

Managing electronic waste (e-waste) such as computers, monitors, and phones is a global concern. Most of Intel's products—including motherboards, microprocessors, and other components—fall within the scope of e-waste laws only when they are incorporated into a final product, generally by an original equipment manufacturer (OEM). As such, we work with OEMs, retailers, customers, and others to identify shared solutions for used electronics. We also take steps to integrate environmental considerations into the design of our products to minimize environmental impacts of electronics at their end of life. In some countries, our distributors provide recycling options for products covered by e-waste laws. Intel has a free mail back program for the Intel® NUC, Intel® Compute Stick, and Intel® Compute Card in the U.S., making it easier for U.S. customers to properly recycle these products.

Intel's investments in responsible waste management practices, including reuse and recovery, are a part of our broader commitment to environmental sustainability and corporate responsibility. These initiatives, many of which are driven by passionate employees, create value for our company, our customers, and especially the communities in which we operate.

Encouraging Industry Action

It is becoming more imperative to develop circular economy waste solutions to ensure a smaller environmental footprint in manufacturing and across all industries. Intel's implementation of waste recovery and reuse initiatives at multiple facilities around the world demonstrates that even industrial manufacturers of advanced technology can and should leverage these strategies in their businesses. Although investments are typically required to investigate potential avenues and implement solutions, the returns and rewards, including lower costs, reduced environmental impact, and reputational benefit should be weighed against these startup costs. In addition, suppliers and other strategic stakeholders can play a cooperative and important role in the success of these circular economy initiatives.

Intel's commitment to environmental sustainability and responsible waste management have supported our efforts to manufacture some of the world's most advanced technology. This technology is addressing some of the world's greatest challenges and helping secure, power, and connect billions of devices and the infrastructure of the smart, connected world—from the cloud to the network to the edge and everything in between.

Learn more about Intel's corporate responsibility and environmental sustainability efforts at www.intel.com/responsibility.

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