WHITE PAPER

Semiconductor Manufacturing
Environmental Sustainability

# Reducing Carbon Through Energy Conservation in Manufacturing

## Strategies to enable capital investment to reduce operational energy use


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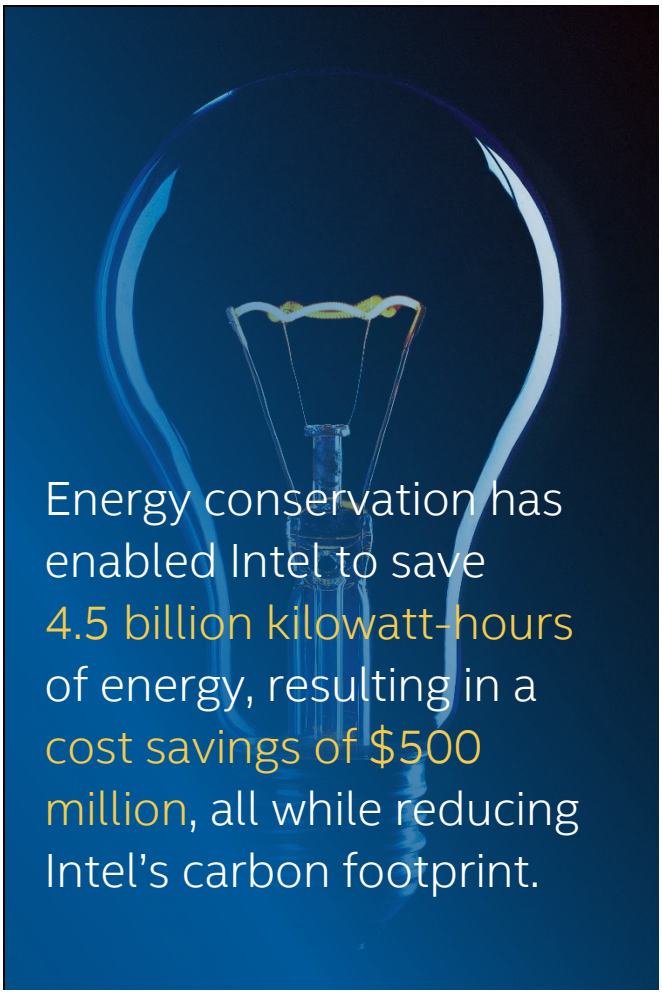




### Executive Summary

Semiconductor manufacturing is an energy-intensive industry due to the demand for technology products to deliver an ever-evolving user experience and the complexity of the manufacturing process. Over the last decade, Intel has completed more than 2,000 energy conservation projects for a total savings of 4.5 billion kilowatt-hours, or enough electricity to support more than 400,000 average American homes for one year.[i] In this paper, we describe the strategies used and focus areas that enabled us to achieve this milestone, with the goal of encouraging other manufacturers to invest strategically in energy conservation to reduce their carbon footprint.


### Energy Management

The semiconductor manufacturing process requires thousands of steps involving hundreds of tools in a temperature and humidity-controlled cleanroom environment. These tools use electricity to process the semiconductor wafers and indirectly drive energy use because of multiple support systems: the heat created by the equipment and the people within the cleanroom is removed by cooling systems, and environmental control systems such as exhaust abatement or scrubbers and waste treatment require energy to reduce impact on the environment.

Given the energy-intensive nature of semiconductor manufacturing, energy conservation has long been a priority for Intel and is documented in our Environmental Health and Safety policy. Today, reducing operational energy use is core to Intel's overall climate strategy and 2030 goal to drive an additional 10% reduction in our absolute Scope 1 and 2 carbon emissions from a 2020 baseline and to save an additional 4 billion kilowatt-hours of energy.

## Institutionalizing Energy Conservation

Key to the success of any energy conservation program is support from senior management. Additionally, we are guided by our Intel Energy Policy, which recognizes our responsibility to minimize the use of energy in our buildings, factory, and supply chain.

Our energy management systems follow the international ISO 50001:2018 Energy Management System standard and we have multisite registration for several sites.

From an organizational perspective, our corporate Sustainability team guides a global network of dedicated energy managers, champions, and subject matter experts who partner with local operations teams to identify, design, and implement innovative energy conservation projects. These experts share cross-site learnings and offer technical expertise to guide project managers and system-level engineers through the process of scoping, resourcing, funding, and delivering these energy efficiency and conservation projects.

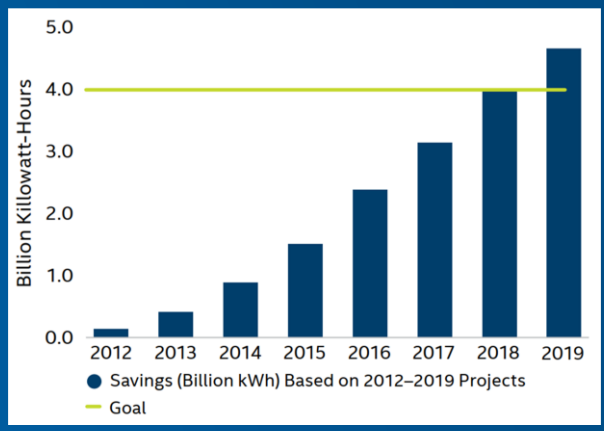
## Financial Considerations

Although there is typically a cost associated with energy conservation projects, many projects have a strong return on investment and deliver additional benefits such as improved

## How Energy Conservation Can Reduce Carbon Emissions In Manufacturing

Reducing our energy use is core to Intel's climate change strategy.

And since 2012, we've completed more than 2,000 energy conservation projects for a total savings of 4.5 billion kilowatt-hours.




Here's what we've learned:

1. Remove roadblocks for action: Make it easier for employees to participate and take action to save energy.
2. Set a goal for each facility: Make it visible, and actively track your progress towards it. Consider a goal that motivates action.
3. Take a program approach to asset energy efficiency improvement: Develop a repeatable action plan to get to an ideal state efficiency for all similar assets.
4. Create a network of fellow travelers: Working with passionate people builds momentum within the organization to save energy.

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asset reliability and lower cost of operation. Financial investment is required to drive energy conservation at scale, and structuring the financial portion of your energy conservation program with intent is a must. At Intel, a dedicated, centrally allocated annual capital budget for energy and water conservation enables results and alleviates local operational constraints. Site engineers and facility managers engage directly with the corporate Sustainability team to access the funding, which includes an allocation to enable feasibility studies for the development of local opportunities.

Projects that will deliver sustainable, year-over-year energy savings are funded once they meet criteria of 8-year positive net present value. The projects Intel has completed over the last decade, ranging in size from $10,000 to $15 million, represent a total investment of approximately $200 million, resulting in cost savings of more than $500 million.

## Strategic Investment Areas

Although energy conservation opportunities are present across the spectrum of Intel's manufacturing operations, we have identified strategic investment areas to enable identification of best solutions, shared learning, and increase speed of implementation:

**Efficient lighting:** Lighting is one of the first areas to consider for improvement. Oftentimes, lighting is on when not truly required, and advances in lighting technology can deliver substantial savings. Upgrading lighting can be a good way to demonstrate early success for an energy conservation program, especially longer lifetime warranty for LED lighting products and solutions. In Intel cleanrooms, custom lighting fixtures are required for integration into the ceiling grids. Recently, an electrical engineer, worked with factory process engineers and a specialist lighting manufacturer to develop and test an LED solution that delivers operational energy savings of 80% to 95% compared to the previous lighting system. The cleanroom LED solution replaced every four fluorescent fixtures with two LED fixtures with integrated control, occupancy and light level sensors, and increased light output.

**Chilled Water Cooling:** Given the heat removal required in semiconductor manufacturing facilities, chilled water systems are significant energy users, accounting for up to 20% of total

## Smart Lighting Gets Smarter

Smart and efficient lighting can make a difference nearly anywhere – not just in manufacturing. At our warehouse in Malaysia, we upgraded the lighting system, resulting in a 111% brighter floor space, and 62% lower energy bills.

The custom-designed Internet of Things lighting solution, which includes 400 dimmable lights, is powered by Intel Atom® processors and Intel® Quark™ Microcontrollers, which feed data into an energy management unit. Calf-level motion sensors at the entrance and exit of each warehouse aisle trigger overhead parabolic lights. When warehouse employees walk or cruise by in carts to collect items from storage bins, the lights turn on. The lighting solution is now commercialized and available to customers worldwide.

electricity use. Chiller technology has evolved significantly with the use of low global warming-potential refrigerants, magnetic bearings, medium voltage frequency drives, and improved control modes of operation. Intel conducted a detailed assessment of all our chilled water systems to understand their configurations, modes of operation, overall system health, and opportunities for improvement.

By comparing baseline energy performance with new technologies and potential performance improvements, Intel identified an opportunity for an average of 20% energy performance improvement. Based on these findings, we initiated an effort to begin converting existing chilled water systems to new full variable primary flow systems. These conversions also present an opportunity to integrate Internet of Things-based controls with online remote system experts to provide operator support and optimize energy savings.

## Energy Conservation and Employee Engagement

Since 2008, we have linked a portion of our executive and employee compensation to corporate responsibility factors in our Annual Performance Bonus. In 2020, we redesigned our operational goals to include metrics related to climate change, meaning every employee – from manufacturing technician to CEO – has a stake in our commitment to sustainability and energy conservation.

**Compressed air:** Semiconductor manufacturing has always required the use of clean, dry air. The production of this air requires dryer systems and compressors, both of which use energy.

Typically, over 80% of energy used to generate compressed air is lost as heat. As such, implementation of a centralized heat recovery system allows productive use of that heat. The impact of allowing the compressors to run slightly warmer to use the available heat requires additional cooling of the air. While there is energy required to cool this air, it has an additional benefit of allowing removal of moisture with a water separator before the drying process, reducing its energy intensity. These measures, including variable frequency compressors, have allowed Intel to improve energy performance by up to 20%.

In some cases, it's possible to replace the use of compressed air for air conditioning and humidification with evaporative or high-pressure humidification, reducing energy use further. To assist in the evaluation of compressed air systems, we recommend identifying and challenging the end user's need of compressed air, the distribution systems, and the generation and treatment efficiency.

**Heat Recovery/Electrification:** For manufacturing facilities where heating is required, the available heat from equipment lends itself to a holistic factory approach to reduce dependence on fossil fuels. Intel commenced the journey of heat recovery first with chiller condenser water providing heat for incoming city water while reducing cooling tower load. In the late 1990's, we began using chillers to provide heating, and what followed was a move to standardize specifications, dedicating heat recovery chiller/heat-pumps for cleanroom makeup air low temperature heating. This shift reduced boiler fossil fuel heating by over 30%. New developments in higher

temperature heat pumps allow for the increased possibility of boiler replacement. In addition, the electrification of heat provides for a more immediate route to using renewable energy where biogas is not available.

## Right the First Time

While the strategic investment areas identified in the section above are primarily focused on retrofit of existing facilities, energy conservation must be considered in the design of new systems, buildings, and factories. The incremental investment cost (if any) is much less than the cost to deliver equivalent energy efficiency improvements through retrofitting.

Intel's approach is to include energy efficiency requirements in construction specifications, which supports changing building codes that increase energy efficiency requirements through directives such as Near Zero Energy in the European Union.

We also partner with companies and nonprofits to expand the number of manufacturers implementing green building practices. For example, Intel is a founder of Leadership in Energy and Environmental Design user groups that have driven cross-company and industry collaboration with the U.S. Green Building Council.

## Technology as an Enabler

Technology can enable understanding of where and how energy is used to improve energy management, develop more robust solutions and verify impact of energy conservation actions.

Intel-based Internet of Things-enabled sensors, devices, and data analytics give intelligence to equipment and deliver operational insights to lower maintenance costs, enable new lines of business, and improve overall productivity.

Additionally, organizations can leverage on-premise and cloud data historians for building management systems or factory supervisory systems to support the identification of operational efficiency opportunities and enable automatic fault detection.

Technology has also enabled the delivery of Intel's own sustainability programs through better virtual collaboration, goal tracking, and a multitude of virtual tools that reduce workload, facilitate decision-making, and increase the delivery speed of energy projects.

"For decades, Intel has worked to reduce our carbon footprint through energy conservation, which is core to our overall climate strategy. Combined with our investments in green power and alternative energy, Intel's focus on energy conservation will help us reach our 2030 goal to drive an additional 10% reduction in our absolute Scope 1 and 2 carbon emissions from a 2020 baseline."

Todd Brady
Director, Global Public Affairs & Sustainability
Intel Corporation

## Encouraging Industry Action

For decades, we have worked to advance progress on complex issues together with our customers and other stakeholders. Acting alone, Intel cannot achieve the broad, societal impact we aspire to. Our 2030 corporate responsibility strategy and goals reflect even greater ambition for ourselves, as well as a growing sense of urgency to work with others to address challenges no one can tackle alone. Intel's commitment to environmental sustainability has 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.

We are committed to applying our deep experience as a leader in global manufacturing and leverage our unique position within the technology ecosystem to embark on a number of collaborative initiatives to help our customers achieve their own sustainability goals and accelerate progress in key areas across the entire technology industry.

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



1020/WP/GPAS/LLQ/PDF

[i] (U.S. Energy Information Administration, 2020)