

Advanced Energy's Powerful Innovation Cuts Electricity Consumption

Precision power solutions enable the next generation of energy-efficient technologies

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Introduction

The world's net electricity consumption grew by 76% between 2000 and 2018 - from 13,281 terawatt hours (TWh) to 23,398 TWh¹. In terms of emissions, 27% of the estimated 51 billion tons of greenhouse gases added to the earth's atmosphere every year come from generating electricity². As the global population grows and as companies, cities and countries seek to meet commitments to net zero emission targets³ it is clear that we (1) need to make better use of the electricity we generate and (2) increase the energy that comes from renewable resources.

Making better use of electricity has been at the core of advanced power conversion and management development for applications as diverse as indoor farming, semiconductor manufacturing, data centers and industrial manufacturing.

As a leader in power conversion innovation, Advanced Energy delivers highly engineered, precision power solutions that can also reduce electricity consumption and enable the creation of more efficient applications and support technologies needed to accelerate the adoption of renewable sources.

Table of Contents

Reducing Consumption by Design	2
Enabling Solutions for a Lower Power World	7
A Relentless Pursuit of Innovation	8
References	9

Reducing Consumption By Design

Indoor Agriculture: Less Electricity for an "Artificial Sun"

Consider the trend towards indoor horticulture or Controlled Environment Agriculture (CEA) that enables higher yields and more predictable all-year-round growing conditions. Driven in part by growing consumer awareness of the benefits of consuming fresh, locally produced food, this market is predicted to expand at a compound annual growth rate (CAGR) of 10.9% from 2021 to reach a value of over \$75 billion⁴ by 2028.

Energy costs are a key issue for indoor growers, frequently second only to labor. Controlling and reducing electricity is critically important to both commercial feasibility and meeting sustainability objectives.



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CEA uses many hundreds of high-power lights, typically LEDs, to deliver optimal lighting conditions to grow crops indoors. At present, around 100 watts of LED power is needed per square meter and lamps operate between 12 to 18 hours a day. While the exact power requirement depends on a number of factors, including the crop being grown, the power usage from these LEDs can account for well over 50% of the total electricity bill. Advanced

Energy has developed solutions that bring these costs down by reducing both the electricity needed to power the LEDs and the requirements for cooling the growing area.

The challenge with conventional approaches to CEA lighting is that the power conversion circuitry supporting the LED luminaires has inherent inefficiencies. While LED drivers may achieve power conversion efficiencies in excess of 90%, converting the power in many small increments for each lamp rather than in one go results in a lower power factor (PF) and higher total harmonic distortion (THD). Furthermore, with traditional designs, the fixtures operate from a single-phase supply. Without careful planning, this can lead to imbalances on the three-phase supplies that typically feed the grow facilities. These factors result in less efficient and more expensive electricity use, even before considering any levies that the utility company may impose for imparting poor power quality on power feeds.

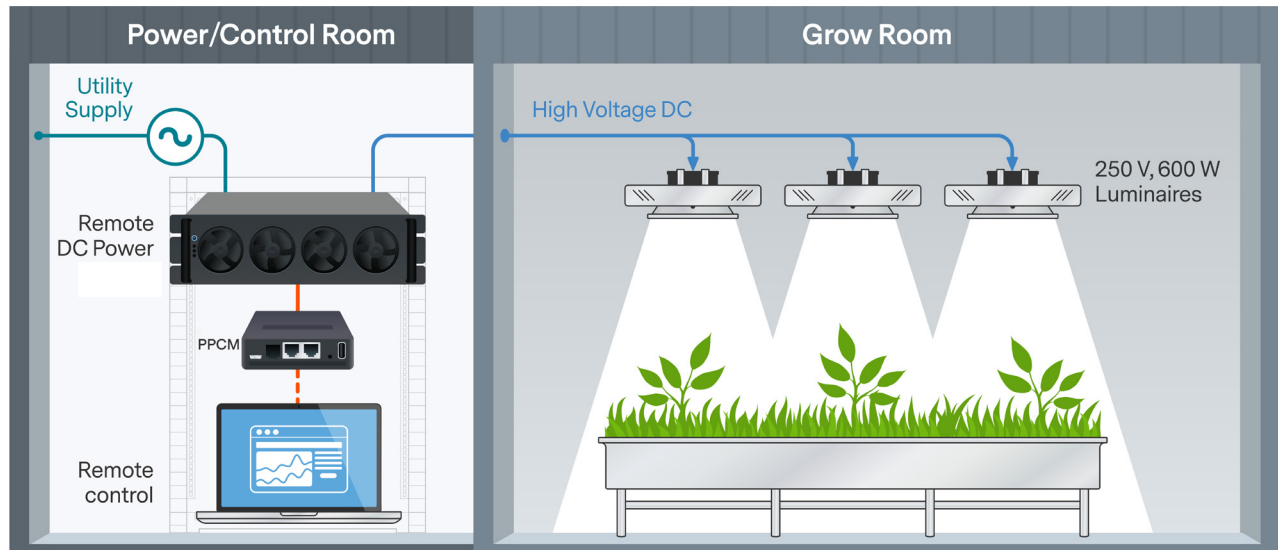


Figure 1. An improved approach to CEA lighting power conversion, which results in lower electricity consumption and less heat.

Figure 1 illustrates a novel approach to LED lighting that improves energy savings by as much as 12%. In this system, power is provided via a three-phase power conversion subsystem in a control room outside the growing area and connected directly to the incoming three-phase supply. The subsystem, which is driven by Advanced Energy's Artesyn iHP and LCM4000HV scalable AC-DC power supplies, provides a single point of power conversion that distributes DC power, rather than AC, directly to the individual LED lamps. A high PF and a low, grid-friendly THD signature improve efficiency.

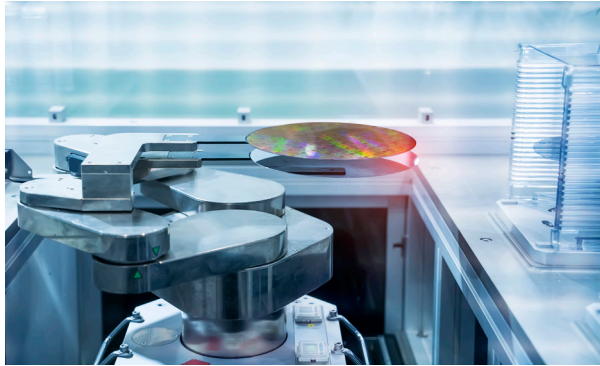
In addition, no matter how efficiently they operate, LED drivers give off heat. Assuming a power rating of 30 W per driver, a typical driver efficiency of 95% and around 1800 LED lights per acre then a significant 2,700W (9212 BTU/hr) per acre will be dissipated as heat. In the past, growers have employed air conditioning and other cooling solutions to remove the heat from the grow environment.

Now, by doing away with individual drivers, the monolithic remote DC power solution minimizes the need - and, therefore, reduces the energy required - for cooling. Depending on installation, these further savings can contribute to reductions in HVAC electricity requirements by up to 5%.

Finally, in addition to the cost savings resulting from lower energy use, by placing all of the key power conversion electronics in a single location, the Advanced Energy power solution can also deliver a 38% saving to the cost of lighting power and control installation.

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Semiconductor Manufacturing: Faster / Deeper Etch with Less Electricity



From new automobile delivery delays⁵ to the overall reduction of global GDP⁶, the impact of the worldwide semiconductor shortage has delivered dramatic proof of just how many global industries rely on semiconductors. As integrated circuit (IC) designs become ever-more complex with each new architecture and technology node, so too does the processing of the semiconductor wafers used to fabricate those ICs.

Making the Most Advanced ICs Requires Ultra-Precise Power Conversion and Control

IC fabrication relies upon plasma deposition and etching of thin films to create 'nano-circuits'. These techniques have become so complex that multiple radio frequency (RF) power supplies and matching networks are required to generate and control the plasma used to etch and deposit the patterns on the wafers. At the same time, IC manufacturers are under pressure to maximize throughput and keep process power consumption as low as possible.

Advanced Energy is a technology leader with innovative RF power supplies and match networks that transfer the RF power to the plasma, responding nearly instantaneously to changes in the etch or deposition process steps. Better power transfer means less wasted power, enabling the lowest possible power to be consumed.

AE also pioneered plasma power beyond RF. AE innovations have enabled manufacturers to re-think how power is delivered and managed in plasma-based applications for process characterization and control. Advanced Energy created its eVoS™ asymmetric bias waveform generator technology for a huge step forward in power transfer efficiency. AE's Navigator II digital match networks have also set the standards for fast and highly capable RF delivery for the least reflected and wasted RF power.



Designed to provide more accurate process control and more targeted and efficient power delivery, eVoS delivers the precise bias plasma performance for high-aspect-ratio (HAR) structures at high speeds. eVoS features customizable and direct ion energy selection. Unlike traditional sinusoidal RF power sources, eVoS enables the production of near mono-energetic ion energy distributions (IEDs) that deliver power only where the plasma needs it. This, in turn, delivers maximum efficiency with the least wasted energy.

eVoS breaks a trend that has been pushing RF power requirements up to 100 kW per plasma chamber and as much as 1 MW per etcher for HAR applications. Using eVoS results in half or even a third of the power consumption. Employing eVoS in a NAND fab with 180 etchers has the potential to reduce overall power consumption by as much as 120 MW.

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In addition, for equivalent etch conditions, the precision ion energy distribution control that eVoS delivers can reduce the thermal load to the wafer by an estimated 15% when compared to traditional RF bias techniques. This reduces the potential for wafer thermal damage during etch and makes it that much easier to cool the wafer.

Being Idle Can Be Ideal

Precise control of plasma power is not the only way that Advanced Energy is helping to reduce the energy consumed in semiconductor fabrication. AE also adds functionality to its family of RF generator and matching systems that allow them to reduce or turn off power and cooling water when not actively processing. AE's Paramount RF power generators and Ascent DC now offers "idle" state options to reduce energy.



While creating low-power or "idle" states may sound straightforward, in reality it is very challenging, not least with respect to maintaining performance and throughput, which demands high levels of stability and the ability to provide instant response to rapidly changing conditions. Representing a significant shift in the way the industry views RF and DC power management, these advances (depending

on specific fabrication requirements) can help drive down RF and DC system power consumption per plasma chamber by up to 50% during idle time.

Data Centers: the Hidden 3% of Global Electricity Consumption



The need to process, store and share ever-larger volumes of data demands ever-greater cloud computing power. As a result, the global market for data centers is expected to grow from \$59.3 billion in 2020 to \$143.4 billion by 2027⁷. This growth will be met both through increased server proliferation and adoption of next-generation, high-performance ICs.

ADVANCED ENERGY'S INNOVATION SUPERPOWER CUTS ELECTRICITY USE

Among these are Intel's Sapphire Rapids with power requirements up to 450 W, AMD's Milan with up to 300 W, Nvidia's A100 GPUs with up to 400 W and other custom-designed, high-power xPUs, FPGAs and ASICs. These power-hungry devices are one reason that average data center power-per-rack is expected to rise from the current 10-15 kW to between 20-40 kW.

From the data center operator's point-of-view, continual growth and increased power requirements present two fundamental challenges. Firstly, as capital investments range from hundreds of millions to billions of dollars, the focus must be on keeping costs as low as possible. Secondly, data centers already account for at least 3% of worldwide electricity use⁸ and there is intense pressure to drive up processing capacity without significantly increasing electrical consumption. This highlights the need to choose efficient power distribution networks that not only minimize the energy needed to power servers, storage and networking equipment but also reduce heat dissipation and, thus, the energy needed for cooling.

Data centers already account for at least 3% of worldwide electricity use.

With power supplies capable of operating at up to 97.5% efficiency and power densities as high as 75 watts per inch³, Advanced Energy is already enabling hyperscale and data center customers to efficiently deliver high-performance IT infrastructures. AE has now developed its next-generation of power supplies that support the transition from conventional 12 V power schemes to 48 V architectures. Increasing rack voltages from 12 V to 48 V significantly increases efficiencies as the current draw for the same power level is reduced by 4x, which translates to 16x lower power distribution losses.

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Load	12 V, 3 kW PSU	48 V, 4 kW PSU	Efficiency Improvement
100%	94%	96.3%	2.3%
50%	96.5%	98.1%	1.6%
20%	95.5%	97.3%	1.8%
10%	93.5%	95.1%	1.6%

Figure 2. Efficiency of 12 V architectures and 48 V power schemes.



It is estimated that half of the leading hyperscalers will use 48 V architecture in their data centers by the middle of this decade. Advanced Energy is leading the 48 V adoption with a range of AE's Artesyn 48 V power supply solutions, which include a family of ORv3 power shelves featuring 97.5% efficiency and total power output levels from 18 to 36 kW.

Furthermore, as a key contributor to the Open Compute Project (OCP) ORv3 standard, Advanced Energy is collaborating with major OCP users and leaders in the hyperscale data center segment to create a common power platform for customers across deployments.

Another area where 48 V architectures deliver benefits over 12 V counterparts is by providing power savings for battery backup (BBU). Integrated BBU at 48 V can deliver power savings up to 6% when compared with 12 V output and uninterruptible power supply (UPS) technology. The requirement for AC-DC conversion with inline BBU as opposed to the AC-DC conversion associated with UPS technology provides a highly efficient approach both in terms of required energy and space. Alongside its power shelves, Advanced Energy offers a number of advanced backup power options including an 18 kW 48 V ORv3 BBU shelf comprising five, hot swappable BBU modules.

Enabling Solutions for a Lower Power World

As with semiconductor manufacture, many complex industrial processes involving the deposition of thin films and coatings on a substrate require the precise and efficient control of power. Such processes can be found in the growth of thin films for the LEDs that support sustainability targets by using just a fraction of the energy of traditional incandescent bulbs. It is also used in the manufacture of the latest energy-efficient LED monitors, flexible/foldable OLED, WOLED and micro-LED, as well as Low-E coatings for architectural windows. Thin film deposition is also critical to the production of the photovoltaic (PV) cells that make up the solar panels that play a vital role in increasing the amount of energy we derive from renewable sources.



By ensuring reliable, stable precision process power, manufacturers can increase yields and reduce downtime when developing durable coatings and customizable films, cost-effectively produce crystalline and thin-film silicon PV, and create advanced anti-reflective coatings that meet legacy and evolving market needs.



For example, Advanced Energy's Ascent® Arc Management System (AMS) and Ascent DMS minimize arc energy while maintaining a stable, repeatable process for flat panel displays, glass coatings, industrial coatings and solar PV applications. Leveraging Advanced Energy's Dynamic Reverse Pulsing (DRP) power configuration lowers the heat load and increases the deposition rates compared to traditional AC power delivery. DRP has been shown to double the deposition rate of traditional dual magnetron sputtering, increasing the productivity and economics of depositing advanced thin films.

ADVANCED ENERGY'S INNOVATION SUPERPOWER CUTS ELECTRICITY USE

In solar PV manufacturing, Advanced Energy's Ascent MS optimizes power delivery by supporting up to five independent chambers of PERC PECVD deposition processes in a single unit. An increase from traditional 1 to 2 output chambers in a production line, the Ascent MS also helps lower capital costs, which in turn helps accelerate the transition towards solar energy. The ability to power five chambers with a single unit also reduces cooling water consumption and lowers the amount of power wasted in facilities.

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Alongside the power supplies themselves, Advanced Energy also offers technologies that provide the high-accuracy measurements needed to ensure accurate process control and optimum power delivery. Take, for example, the need for accurate thermal monitoring for a wide range of applications ranging from silicon wafer processing to glass production. Technologies such as optical temperature pyrometers and thermal imagers support thermal processing precision, repeatability, and reliability. When integrated into a closed-loop solution, they deliver exact heat measurement and regulation.

A Relentless Pursuit of Innovation

For the last forty years, Advanced Energy has been at the forefront of developing highly efficient power solutions. But AE does much more than simply build ever-more efficient power supplies. By shaping and transforming the way that power is used, delivered, and managed, AE creates and enables the technologies that are critical to making better use of global energy resources, reducing the world's reliance on fossil fuels and minimizing greenhouse gas emissions.

With engineering know-how and responsive service and support around the globe, AE builds collaborative partnerships to meet technology advances, propel growth for customers and innovate the future of power.

As demands to make better use of electricity and increase energy from renewable resources grow, Advanced Energy is positioned to help customers meet their energy efficiency and productivity goals.

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ABOUT ADVANCED ENERGY

Advanced Energy (AE) has devoted more than four decades to perfecting power for its global customers. We design and manufacture highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes.

Our products enable customer innovation in complex applications for a wide range of industries including semiconductor equipment, industrial, manufacturing, telecommunications, data center computing, and medical. With deep applications know-how and responsive service and support across the globe, we build collaborative partnerships to meet rapid technological developments, propel growth for our customers, and innovate the future of power..

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