Powering LED Lighting for Horticulture

Lowering costs and improving results with the right power supply for your horticultural lighting

Introduction

The rapid growth in the use of LED lighting for horticulture has been a driver in the power supply industry.

Experts at Advanced Energy have created this white paper to provide growers and farmers with the information they need to define a power strategy that could have a significant impact on capital and operating expenses for controlled environment agriculture. This includes greenhouses, and indoor and vertical farmers.

Application examples and financial models included in the paper provide you with the background you need to select the right power strategy for your application or installation.

Table of Contents

The use of LED technology in horticultural lighting systems is playing a fundamental role in cutting-edge farming and growing practices that are increasingly seen as a potential way of addressing production challenges for food, pharmaceutical ingredients, plants and flowers.

LED-based horticultural lighting is one of the largest and fastest growing markets.

Lighting for horticulture is quite distinct from other lighting applications. Light, in the wavelengths useful for horticulture, is called photo-synthetically active radiation (PAR) and falls within the 400-700nm range.

Photosynthetic Photon Flux, or PPF, measures the total amount of PAR photons generated by a luminaire. A higher PPF means the lighting system is more efficient at creating PAR.

As researchers continue to establish the impact of specific wavelengths of light on different plants and stages of growth, broad-spectrum sources such as high pressure sodium (HPS) lamps, popularly used in greenhouses, are being outperformed by LED lights due to their flexibility in producing different PAR wavelengths.

Other compelling benefits of LED lights for horticulture include:

- Spectral output control: LED lights offer greater control over the light output across different wavelengths, so growers can more closely match spectra to the needs of their plants, plus their luminosity can be adjusted to manage production depending on plant species and growth stage.
- More precise targeting: The availability of smaller LED lights improves control over where the light goes, increasing efficiency and reducing energy consumption.
- Less radiated heat: LED lights operate cooler than traditional HPS bulbs so can be placed closer to plants, resulting in more dense farms. This also lowers water consumption.
- Life cycle savings: LED luminaires typically have a longer lifetime, lower energy consumption and lower maintenance costs than traditional horticultural lighting options

The benefits outlined above combine to make LED lighting the ideal choice for supplemental lighting in greenhouses as well as vertical and indoor farms that depend on artificial light.

Market Drivers

- **Population growth and limited availability of agricultural land**
- **Ability to grow a steady supply of crops regardless of weather conditions**
- **Increased, higher-quality yield**
- **Reduced water usage**
- **Reduced use of pesticides and herbicides**
- **Government initiatives**
- **Legalization of cannabis for medicinal and recreational purposes**
- **Technical advances in LED technology**

TYPES OF HORTICULTURAL LIGHTING

Top lighting – greenhouses

- Illumination of the hall and plants from ceiling level
- Retrofitting old HPS, modifying spectral content of light
- Challenges: light concentration on plants, uniformity and constant quality of light spectrum, high amount of power needed

Top lighting – vertical farming

- Illumination from top of the plants at close distance
- Challenges: uniform intensity and spectral distribution, plants shading each other, photosynthetic efficiency (PPF/W), heat

Intra-canopy

- Illumination on the side or in between the plants
- Possible with LEDs (HPS too hot)
- Challenges: uniform PPFD, good color uniformity (if continuous/wide spectrum), spectrum fit to the rest of lighting, light direction

APPLICATIONS

Traditional greenhouses have been the primary adopters of horticultural LED lighting for many years, typically supplementing natural light. LED lighting supplementing natural light in large greenhouses or 'growing warehouses' improves control over the nutrient balance and growth cycle of a wide range of plants.

New types of farming are poised to lead the future growth of the industry, such as indoor and vertical farming. Whereas greenhouses mainly use LEDs in addition to the sun, indoor and vertical farming use LED fixtures as the primary or sole light source.

Indoor farming

Indoor farming covers a variety of growing techniques, including horizontal flood trays to vertical towers, warehouses to basements, and micro-greens to heirloom tomatoes. Indoor farms depend on artificial light and are mostly hydroponic, aeroponic, and/or aquaponic, which is one of the reasons why this type of facility uses less resources.

Even though it needs to be set up entirely with horticultural lighting, which increases the initial CAPEX investment, operational cost is relatively low thanks to reduced irrigation, chemical and labor expenses. Using LED-based grow lights brings down the cost even further.

Vertical farming

With vertical farms, shipping containers or similar structures are used to house shelves of plants, with lighting and nutrients supplied and carefully controlled to manage the growth of the crop.

Advocates of this type of agriculture argue that this method of growing crops can be done closer

to consumers (reducing food miles), without pesticides or other chemicals thanks to the contained environment, and using less water than conventional outdoor agriculture.

Using up to 99% less water, no pesticides or herbicides, reducing food miles by up to 93%, and having unrivalled control over the crops means that vertical farming may be the future for many communities around the world and off the planet.

But many growers are not reaping the full benefits of LED efficiency due to energy losses incurred in the schemes that provide power to the LEDs.

POWERING HORTICULTURAL LIGHTING

A survey by the Lighting Research Center (LRC) found that the majority of growers did not know their monthly electrical costs for lighting. 64% of growers reported that they pay a flat energy rate or a combination rate (energy rate and demand charges) for their electricity. 20% of growers did not know how they were billed for electricity.

Source: The Lighting Research Center (LRC)

For individual luminaires and lower power applications (ranging from 300 W to 3000 W), the key criteria are size and weight for a given power rating. Heavier and larger power supplies require more substantial and therefore more expensive rigging, usually from the ceiling of the greenhouse.

Power Factor and Total Harmonic Distortion

With large farms, the use of individual luminaires is not efficient. The way that energy is used affects costs. If the current and voltage are not in phase, then an additional load is created that does no useful work but incurs charges from the energy supplier. Engineers know this as power factor (PF), which, along with waveform distortion or total harmonic distortion (THD), should be minimized to control costs.

Total harmonic distortion is a measurement of how much of the distortion of a voltage or current is due to harmonics in the signal. A lower THD typically means higher power factor, lower peak currents and higher efficiency - all of which are desirable in a power system and beneficial to the application.

Many utility companies now use smart meters to measure THD and, depending on the level, will set billing rates associated to THD. Advanced Energy's Artesyn iHP system and LCM4000 series provide a much lower THD than many integrated LED drivers

The Cost of Air Conditioning

Any power conversion generates an amount of heat. By reconfiguring how energy is delivered to the LEDs, operators can achieve energy savings in excess of 10% over conventional setups, which locate power conversion in the growing area and deploy fans or air conditioning to regulate the grow area temperature, thus incurring additional capital and operating costs.

Centralized Source Approach

Using a large centralized current source outside the environmentally controlled growth areas and distributing power directly to all the luminaires can help eliminate the need for individual drivers and the associated costs.

In a centralized approach, the power conversion from AC to DC is located outside the growing area. Excess heat can be vented to the outside world in the summer or channelled into the growing area in the winter. Furthermore, distributing DC to the LED fixtures delivers a grid- and budget-friendly solution with high PF and low THD. When high voltage is used,

wires can be thinner, reducing costs and weight on the structure. And when currents are lower, wiring losses are significantly reduced.

A configurable front-end power solution can deliver up to 24 kW of DC power in a three-unit rack. In this type of modular supply, the outputs are configured using plug-in modules that are flexible and can be rapidly reconfigured should the needs of the application change. Generally, control of the power solution can be digital or analog, and configuration and monitoring is done through a supplied software graphical user interface (GUI). Some vendors offer additional scheduling and control software specifically tailored for horticultural applications.

One benefit of using 19-in. rack-mount power is the simplicity of maintenance. Replacing a ceiling luminaire in a conventional setup requires technicians to enter the growing area with ladders and tools, working around and over planting areas. However, in the unlikely event of an issue with a rack-mount power solution, workers can pull the unit out, often without needing tools, and push in a new one. In many cases, they wouldn't need to cut off power to the entire facility to perform this swap. Indeed, it is very similar to opening and closing a drawer.

Another benefit of the centralized power source approach, as identified by one of Advanced Energy's customers, is that the same cabling that is used for HPS lights can be used for power LED luminaires using an iHP or LCM4000 system. The added complexity of individual control systems on each luminaire and the additional cabling required adds to the installation costs. A simpler cabling approach can simplify and significantly speed up the installation time for new grow operations or the time to convert an existing facility.

One pioneering creator of vertical farming solutions has adopted Advanced Energy's Artesyn iHP series configurable digital high power system to provide the DC power for their custom-engineered horticultural LED lights. These provide specific photon wavelengths and intensity, enabling the customer to create customized "light recipes" for each crop.

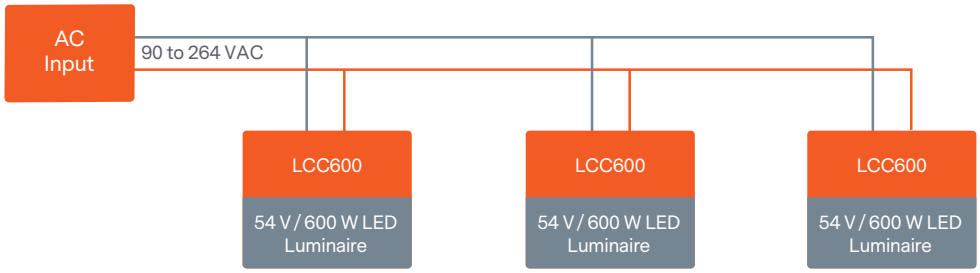
The iHP series provides up to 24 kW in 3 kW increments and can be configured for up to 8 outputs using a wide variety of plug-in modules that address a large range of voltages and currents. It provides the user with analog and digital control as either a programmable voltage or current source.

POWER ARCHITECTURE EXAMPLES USING ADVANCED ENERGY POWER SUPPLIES

Conventional Power Distribution with Integrated Luminaire + Driver

Example shown using Advanced Energy's Artesyn LCC600 supply/driver integrated into a 600 W luminaire.

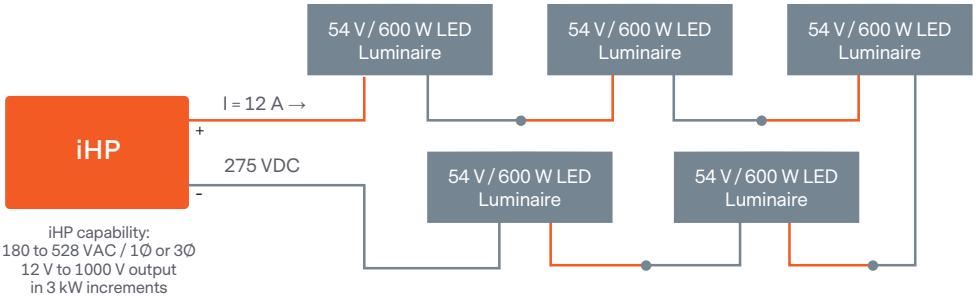
- Easily adaptable for retrofit (can utilize existing power/wiring infrastructure) and new installations
- Dimming Control: 0-10V or resistive Dimming (0-100% output current)
- Heat generated by both luminaire and driver/ power supply needs to be considered in energy/cooling calculations



Centralized Power with Distributed Lighting using 54 V LED String in Serial Configuration

iHP example shown using one (1) 3 kW module set to 275 Vdc, 12 A constant current output.

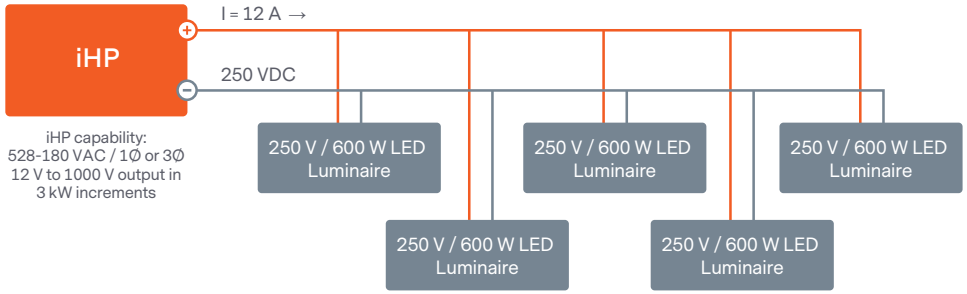
- Centralized power source and the associated conversion/heat losses can be managed separately outside the environmentally controlled growth space, lowering cooling and energy cost
- Higher voltage distribution can help reduce total installation cost (e.g., reduced wire sizes)
- Faults in serial configuration can shut down all the luminaires connected in the same loop



Centralized Power with Distributed Lighting using 250 V LED String in Parallel Configuration

iHP example shown using one (1) 3 kW module set to 250 Vdc, 12 A constant current output.

- 347/600VAC 3-Phase input
  Analog: 0-5V or 0-10V dimming Control (0-100% output current)
  Digital: Cloud-Based Ethernet or LAN control
- Centralized power source and the associated conversion/heat losses can be managed separately outside the environmentally controlled growth space, lowering cooling and energy cost
- Higher voltage distribution can help reduce total installation cost (e.g., reduced wire sizes)
- Faults in parallel configuration will not shut down all luminaires connected on the same power rail



Advanced Energy's Artesyn iHP 12KW

Advanced Energy's Artesyn LCC600

600W LED Luminaire

APPLICATION EXAMPLE: LARGE WAREHOUSE FARM REQUIRES 126.3 KW OF LED LUMINAIRES

SCENARIO 1: STANDARD DIRECT INTEGRATED LIGHTING

AC Hook-up Wiring	Integrated Power, Driver and Thermal Management	Annual A/C Cost Due to Power Dissipation	Relative Installation and First Year Cost
$21,000	**$54,400**	**$9,281**	**$80,681**
Hook up to 240 integrated lights	Cost of conversion, driver and thermals for 600 W (240 pcs)	Based on 8.8 KW power loss requiring 30,133.5 BTUs/ Hr cooing	

SCENARIO 2: DISTRIBUTED LIGHTING USING LED STRING CONFIGURATION IN 48 V CONFIGURATION

DC Hook-up Wiring	Remote Power Supply	A/C Cost Due to Power Dissipation	Relative Installation and First Year Cost
$56,808	**$16,116**	**$0**	**$72,924**
Installation requires 2 AWG to rack, 4 AWG to distribution point, 12 AWG to fixture	Cost of remote CC mode precision power supply (iHP) using 48 V configuration	All power dissipation is external to the installation	

SCENARIO 3: DISTRIBUTED LIGHTING USING LED STRING CONFIGURATION IN 250 V CONFIGURATION

DC Hook-up Wiring	Remote Power Supply	A/C Cost Due to Power Dissipation	Relative Installation and First Year Cost
$12,108	**$16,116**	**$0**	**$28,254**
Installation requires 2 AWG to rack, 10 AWG to distribution point, 16 AWG to fixture	Cost of remote CC mode precision power supply (iHP) using 200 V configuration	All power dissipation is external to the installation	

Notes:

1. A/C cost calculation used: $\frac{\text{(Operating hours x BTU per hour) x 0,293 = kWh}}{1000}$ x Electricity costs per kWh

2. Hook-up wiring requirements are estimated and costs are relative based on low volume online prices

CASE STUDY: ONE ACRE OF INDOOR GROW AREA

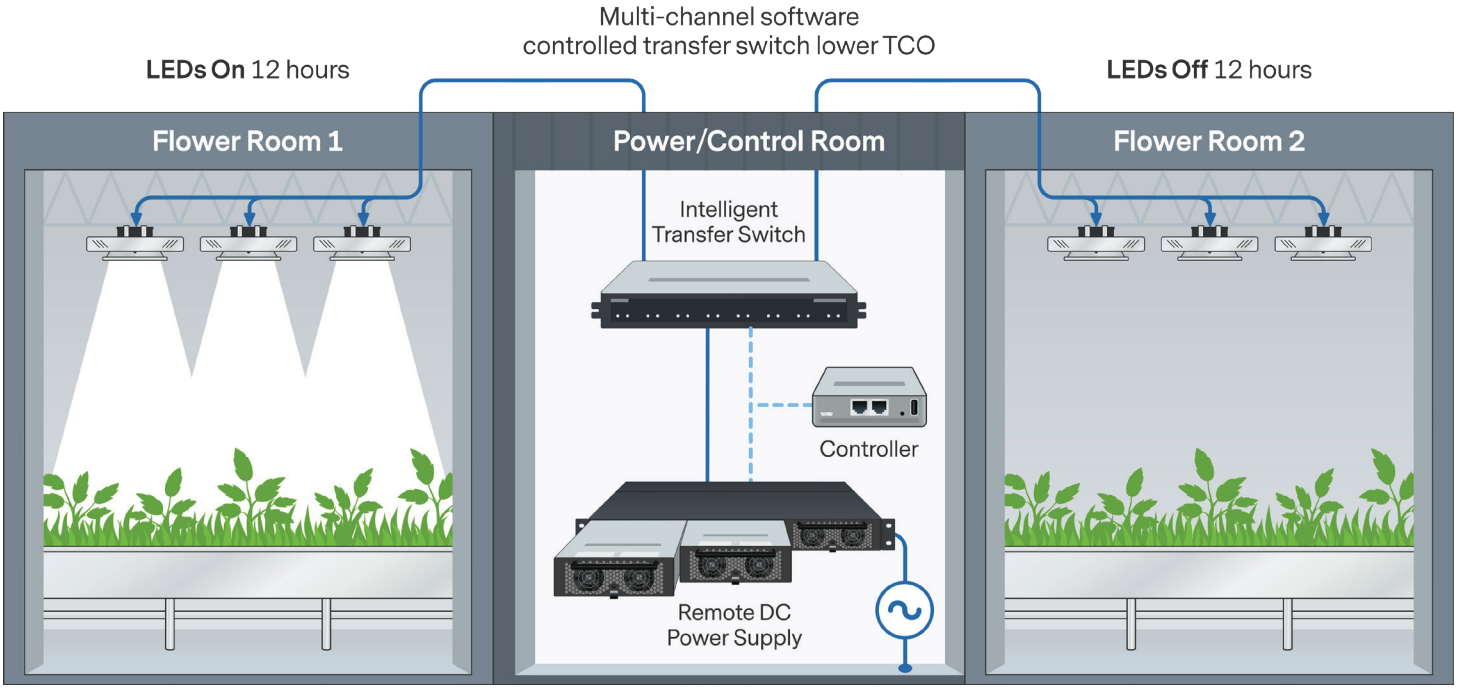
Based on over 44 customer engagements across the USA, we have prepared this case study to compare the traditional local LED driver approach with the centralized driver approach using a 208 feet by 208 feet (1 acre) grow area, illuminated by 1000w LED lights that each handle a 5 x5 ft area. These calculations compare the Advanced Energy Artesyn LCM4000 centralized driver with a typical local driver and reveals an ROI within approximately 2.6 years.

Traditional Local LED Driver	Centralized Driver
■ 1 centralized driver can power many light fixtures, typically set up as a zone per driver ■ Driver use 3 phase AC, higher PF, lower utility cost ■ Uses DC voltage to connect lights ■ No extra wiring for on/off & dimming control ■ Can use digital control or analog, 0 to 10V, 0 to 5V, 0 to 24V ■ Simplified installation lowers the labor cost ■ Hot swappable drivers – easy to change	■ 1 light fixture needs 1 driver ■ Drivers use single phase AC, lower power factor, higher utility cost ■ Need to run AC power to all the lights ■ Need use many AC circuit breakers and panels ■ Need extra wiring for on/off & dimming control ■ Produces unwanted heat that will need a HVAC to control
CAPEX Summary: 24% Saving	
■ Cost of 1743 LED Drivers (1000W) = $313,740 ■ Cost of Lighting Control 1743 lights = $37,145 ■ Cost of wiring, CB & CB Panels = $28,992 (872 CB, 21 Panels) ■ Cost of HVAC & structure update = $21,500 ■ **Total Capex = $ 401,377**	■ Centralized Driver = $ 284,700 ■ Cost of Lighting Control = $4160 ■ Cost of wiring, CB & CB Panels = $15,250 (146 CB, 15 Panels) ■ **Total Capex $ 304,110**
OPEX Summary: 9% Saving per Year	
■ Energy Cost plus HVAC cost per year = $1,098,504	■ Energy Cost per year = $982,872 ■ GrowINsight yearly cost = $5,928 ■ No additional HVAC needed in the grow area with the centralized driver ■ **Total cost = $988,800**

Advanced Energy has detailed calculations to support these summaries as well as worksheets to help growers decide the best option based on their specific circumstances, please contact us for more information.

FLOWER ROOMS

The centralized driver approach enables you to use the same rack power source for two different grow rooms through the flowering stage of certain crops. With each room illuminated for 12 hours a day or less, the LCM4000 centralized driver rack would be 100% utilized.



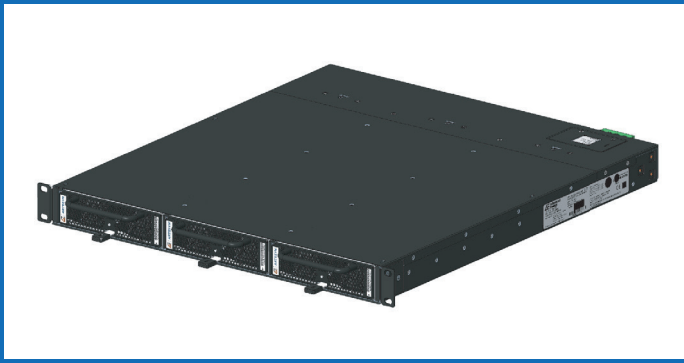
With this approach, Advanced Energy has calculated even higher CAPEX and OPEX savings, with the capital expense saving being up to 38% and the operating expense saving at 12% per year. Detailed calculations are available from Advanced Energy on request.

INNOVATIVE MODULAR AND SCALABLE POWER SOLUTIONS

By offering single conduction and IP rated solutions up to large distributed external systems, Artesyn can help scale power for various power distribution architectures in practically any installation.

LCM4000HV Series

Optimized for horticultural LED lighting



- High voltage power modules (100 – 300 VDC) combine with 19” 1U rack mount shelf (LCM12K) to create a centralized current source for medium- to large-scale LED lighting installations
- Each hot-swappable module rated for up to 4000 W, 12 KW per 1U shelf
- Cost and functionality optimized for horticultural LED lighting
- Compliant with DesignLights Consortium (DLC) technical requirements (v2.1)
- Up to 95% efficient
- Traditional 0-10V (0-24V) analog dimming – compatible with any PLC controllers and dimmers
- Digital control via Modbus RTU interface
- Drive any LED luminaire
- Digitally controlled loop compensation eliminates flickering throughout the operating range
- Compatible with GrowInsight™ cloud control software

Intelligent Transfer Switch (ITS)

- Patented solution for switching or sharing a single power source between two different grow rooms
- Reduces installation costs by reducing the number of power supplies needed
- Substantially reduces ongoing utility costs
- Designed to operate with two phases of a three phase input mains up to 480VAC nominal, or standard phase and neutral of single-phase mains

iHP Series

Configurable Intelligent High Power System

- Can drive any LED luminaire
- Customized grow cycle lighting control by setting scheduler (using calendar)
- Dimming Control: 0-5V or 0-10V (output completely off to full max output current)
- Removes driver heat from grow area to save on HVAC costs
- High level of scalability – multiple racks per cabinet can scale up to megawatt levels (in 3 kW increments up to 12 kW in small rack or 24 kW in large rack)
- Highly flexible input (180-528 Vac, single or 3-phase) and outputs (12-1000 Vdc) allows high voltage distribution, saving copper wiring costs
- Intelligent current and voltage source control (local or via Internet) eliminates the need for individual luminaire drivers
- Digitally controlled loop compensation eliminates bothersome flickering throughout entire operating range
- Compatible with GrowInsight digital cloud control software

LCC600 Series

600 Watts total power

- Dimming Control: 0-10V or resistive dimming
- 600 watts from -40°C to 85°C baseplate operating temperature
- High efficiency design in a 4” x 9” x 1.57” compact IP65 enclosure under 2 kgs
- Fanless design uses conduction cooling for thermal management – can utilize the same luminaire heatsink for thermal heat transfer
- 90-264 Vac or 180-305 Vac operating input
- Digital control: Constant voltage (default) or constant current mode of operation; programmable constant current limits through I2C/PMBus®
- External voltage or resistance dimming capable
- Active share/parallel operation for higher power

GrowInsight™

GROWINSIGHT™
by Advanced Energy

Advanced Energy's GrowInsight™ is a flexible, controlled environment agriculture control and monitoring system:

- Fully integrated with Advanced Energy's remote driver distribution
- Digital dimming control
- Create lighting schedules for any type of LED lighting system
- Cloud control and monitoring, local controller manages schedule execution
- Access lighting schedule information from anywhere
- Set alerts using text messages or email
- Monitor grow room sensors – CO2, humidity, temperature, PAR
- Camera integration

CENTRALIZED DRIVER: LOWER TOTAL COST OF OWNERSHIP WITH ENHANCED CONTROL AND MONITORING

CAPEX Reduction between 24% and 38%		OPEX Reduction between 9% and 12%	
Lower cost of lighting control system	Eliminates expensive lighting PLC and IO controllers No extra dimming control wiring needed	**Reduced energy cost**	High power factor and low THD Lower HVAC energy cost
Smaller HVAC system and structure cost	No additional heat within the grow area Less weight per light reducing lighting structure	**Easily controlled**	Optimal setting for efficient light Web based controls and monitoring
Lower installation costs, simpler electrical connection	No special junction boxes Fewer circuit breakers Lower ship weight	**Lower maintenance cost**	Power all in one location vs. spread out Hot swappable power modules for quicker replacement of failures
Scalable	Grow as needed	**Very reliable, high MTBF**	Power not in the grow area environment Longer LED life due to no extra heat from the driver
		'Sea of Green'	More evenly distributed plant heights

ABOUT ADVANCED ENERGY

Advanced Energy (AE) has devoted more than three 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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