RESOURCE INNOVATION INSTITUTE

Automation & Controls Key Terms

for Cannabis Cultivation and Controlled Environment Agriculture.

TERM	DEFINITION	IMPORTANT NOTES	TIPS FOR APPLICATION
LIGHTING CONTROLS			
Sole source	Lighting designs utilizing only electrical lighting, no sunlight. Indoor facilities use sole-source lighting solutions.	The operation of sole-source lighting systems is critical to ensure plants receive proper photoperiods, light intensities, and daily light integral (DLI).	Sole source lighting controls systems can create photoperiods and dial in DLI without the influence of sunlight.
Supplemental	Lighting designs utilizing electrical lighting in addition to sunlight. Greenhouse facilities use supplemental lighting solutions.	Supplemental lighting systems (along with light deprivation systems) should account for the variation of solar exposure to ensure plants receive proper photoperiods, light intensities, and daily light integral.	Adaptive lighting controls solutions can respond to real-time changes in solar radiation to dim supplemental light fixtures and save energy.
Daily light integral (DLI) controls	The number of photosynthetically active photons (photons in the PAR range) per square meter per day (mols/ m2/day); equal to the sum of PPFD over the course of the photoperiod.	Daily light integrals (DLI) can vary from 2 to 50 mols/m2/day for cannabis cultivation. DLI targets guide lighting design in both sole source and supplemental situations. Utility energy efficiency programs can offer financial incentives for DLI controls.	Achieving constant DLI does not require having a constant PPFD. Control lighting systems in all cultivation environments to DLI targets to reduce peak demand by strategically scheduling and dimming light fixtures.
Spectral quantum distribution (SQD)	Illustrate the polychromatic spectrum of horticultural lighting. SQD graphs the distribution of photon flux per photon wavelength over the photosynthetic and far-red range wavelengths (400 – 800 nm) for a given light fixture.	Also referred to as a 'light recipe'. Understand the SQD that suits your crop and the level of control necessary to maintain light levels and photoperiods.	LED light recipes are made up of different LEDs with specific red:blue (R:B) and red:far red (R:FR) ratios. LED lighting system SQD are customizable by manufacturers.
Spectral tuning	Lighting controls to select certain light recipes by modulating the output of diodes like red and blue to affect photomorphogenic qualities. These qualities include biomass production and phytochemical responses like secondary metabolite production.	Spectral tuning is combined with modulating light intensity in some LED applications with some cultivars. Academic and manufacturer research with cannabis producers is helping the industry understand how different light recipes affect plant traits.	Spectral tuning is only possible with LED technology. Some LED light fixtures can produce a variety of light recipes from one fixture and can be spectrally tuned throughout the course of the day or the plant growth cycle.
Phytochemicals	Biologically active compounds including secondary metabolites, terpenes, and flavonoids.	These chemicals affect desirable and undesirable quality characteristics of cannabis that affect product value.	Lighting controls like dimming and spectral tuning can affect phytochemical responses. Production and quality goals impact which phytochemicals operations prioritize.
Secondary metabolites	Phytochemicals present in cannabis cultivars can be broken down into two basic families of compounds: cannabinoids, of which THC and CBD are just two of more than a hundred; and terpenes, a large family of compounds associated with aroma and taste.	Light treatments can affect secondary metabolite production. Increasing light intensity induces production of various secondary metabolites in plants as a form of protection. The effect of spectral quality on cannabinoids has been shown to be small in studies of medical cannabis.	Prioritize dimming controls above spectral tuning to affect secondary metabolite production in cannabis. Note that secondary metabolism diverts resources away from plant growth.
Photoacclimation	The ability of plants to adjust the structure and function of their photosynthetic apparatus in response to changes in light. Photoacclimation lighting control sequences allow plants to acclimate to higher light intensities, such as when cannabis is moved from vegetative to flowering stage of growth.	If you expose plants to high light intensities too early in the crop cycle, you can damage chlorophyll pigments causing photo-oxidation (photo-bleaching). It is recommended to slowly increase your light intensity as plants develop.	How fast and by how much you increase light intensity can depend on the cultivar and the cultivation approach. As a general rule of thumb, increasing by 50 μmol/m2/s or less per day, with frequent observation, is a good place to start.
Dimming	Modulation of light fixture input voltage (0 - 10 V), resulting in modulation of light fixture output and associated light intensity (PPFD).	LED light fixtures are directly dimmed while high pressure sodium light fixtures are dimmed at the ballast. 0-100% dimming is only possible with LED technology, and not all fixtures can dim across the entire 0-100% range.	As LEDs dim, light fixture photosynthetic photon efficacy (PPE) can increase, saving energy. Utility energy efficiency programs can offer financial incentives for dimming.

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Granularity	In lighting controls, this refers to how finely a light fixture's light intensity can be tuned.	Dimming with high granularity allows growers to dial in PPFD precisely to provide target light levels for plant growth and development.	LED generally have much more granularity in lighting levels over more traditional lighting systems.
Total Harmonic Distortion	The distortion present in a current or voltage waveform signal of equipment powered by electricity.	Low total harmonic distortion means more efficient and long-lasting equipment. High total harmonic distortion can mean unintentional interference with other devices as well as internal wear and tear on electrical components.	High intensity discharge lighting systems like HPS struggle with total harmonic distortion when dimming below 50%. LEDs do not have this issue. Not considering this factor when designing lighting systems can be problematic where dimming is concerned.
Pyranometers	Devices that measure solar radiation across a broad spectrum of wavelengths.	This is an important baseline for understanding what supplemental lighting needs a greenhouse may need throughout the year.	Measurement methods should be standardized and regularly conducted.
CLIMATE AND AIRFLOW CONTROLS			
Trend data	Historical data records from environmental control systems used to find patterns in data.	Monitoring systems for lighting, HVAC, and water controls can quickly generate a lot of trended historical data and should be analyzed by fault detection and diagnostic (FDD) systems. Determine how long you want to store your historical logs of lighting, HVAC, and water trends.	Control systems typically contain hundreds of sensors measuring various conditions and collecting data at regular intervals to track historical trends, generating tens of thousands of data points from a cultivation facility every single day. Designing data storage, analysis, and visualization is just as important as deciding what points to monitor so your team can take informed action steps.
Aspirated	Aspirated environmental sencors use integrated fans to provide continuous air movement around the sensor and remove humidity accumulated from the grow environment.	Aspiration and shielding prevents radiation from affecting temperature and humidity readings. Sensors should be in aspirated boxes shielded from light.	Sensors for recording environmental parameters should be in aspirated boxes to ensure accurate readings.
Air changes per hour (ACH)	Describes supply air volume of HVAC systems and is used as an input for climate and airflow controls. Measures how many times the air within a space is replaced each hour.	Determine approprioate supply air volume setpoints for your facility during design. Consider reducing supply air volume setpoint during dark periods.	Controls Working Group members report sizing 10 to 20 ACH for cultivation, with some cases as high as 30 - 40 ACH.
WATER CONTROLS			
Substrate	The medium a plant grows in, including soil, rock wool, coconut coir, peat mixed with amendments, or water culture.	Growing media impacts the effectiveness of irrigation. Select substrate during design to inform HVAC and water controls. Consider leachate percentage to prioritize different substrate options.	When selecting a substrate, consider properties such as water retention, recommended irrigation approach, watering rate, leachate percentage, commonly used amendments, and implications for water recapture and reuse to find the right growing media and fertigation methodology.
Leachate	A leachate is any liquid that, in passing through matter, extracts either soluble or suspended solids, or any other component of the material through which it has passed.	An excess of water with fertilizers provided beyond saturation. Understanding your substrate is a vital part of designing water controls.	Leachate can also be called drain and greater amounts of leachate can mean greater needs for water treatment before recirculation and reuse.
Leachate percentage	Describes the amount of irrigation water that drains through substrate and leaches out some of the nutrients. Leach percentage % = (volume of runoff / total irrigation volume) * 100	Depending on watering techniques used, 25% of irrigation water may drain through substrate and become runoff water (drained irrigation water).	Choose substrates with lower leach percentage to manage less runoff. Lower leach may be achieved with water culture approaches that recirculate irrigated water.

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Watering rate	Describes the volume of water applied per irrigation event (ie 150 ml per dripper), or rate of water application or over a time period (ie gallons per day).	Watering rate affects HVAC loads and the operation of dehumidification equipment. Lighting levels affect transpiration and may impact target watering rates.	Watering rate can inform HVAC and lighting controls responses and be a helpful feedback loop to ancipate changes in humidity from irrigation and transpiration. Use water controls that integrate information to maintain consistent environmental conditions and avoid plant stress.
Recapture and reuse	Save considerable operational expenses by reducing use of source water. Reclaim, test, and treat recaptured water for irrigation, and rebalance nutrients for fertigation.	There are two types of recapture and reuse: recapture of irrigation runoff water and recapture of HVAC condensate (water in the air from evapotranspiration). Both require treatment before recirculation and reuse; different treatment methods are used depending on the source of the recaptured water.	Irrigation water treatment focuses on nutrient management. HVAC condensate recapture focuses on treatment for heavy metals and other minerals that may have entered the water from the HVAC system. Determine water reclamation priorities during design and assess costs and benefits depending on facility water source and quality of reclaimed water.
Bio-accumulator	Plants can deal with heavy metals by allowing absorption and sequestering the heavy metals where they can do less physiological harm. Bioaccumulation is the gradual accumulation of substances, such as pesticides or heavy metals, in an organism.	In cannabis, this means that things such as heavy metals that may be contained in water used for fertigation will be absorbed into the plant and remain even after harvesting.	Awareness of this is important when considering water recapture and reuse from the HVAC condensate system. Using that water without appropriate treatment results in dangerous heavy metals in the plant which cannot be flushed or otherwise removed.
Fertigation	Injection of fertilizers, water amendments and other water-soluble products into irrigation water.	Many cannabis production facilities use fertigation to provide nutrients to plants and fertigation methodology depends on irrigation approach and water controls.	Determine how irrigation water will be mixed with nutrients to fertigate plants. Consider how source water might be mixed with treated reclaimed condensate and/or runoff water to rebalance pH and nutrients.
Deep water culture (DWC)	A water management approach that recirculates fertigation water. Plants roots are suspended in a nutrient solution which is oxygenated with an airstone to allow for root growth.	Deep water culture will produce more runoff than soil. Well managed hydroponic systems can be purpose-built to reclaim and reuse water, but also run the risk of microbial or pathogen outbreaks and oxygen depletion.	It is vital to test and actively manage fertigation water in facilities using DWC to avoid extensive disease outbreaks and substantial crop loss.
Aeroponic	A water management approach that recirculates fertigation water. Plant roots are suspended in the air (under some cover to prevent light infiltration). The roots are misted extremely frequently with small pulses of nutrient solution.	Aeroponic growing systems can be resource efficient but extremely sensitive to system problems. Water controls with monitoring and alarms are especially important for these systems.	Since roots are suspended in air not directly in soil or water, fault detection and diagnosis systems linked to back-up equipment standing by for emergencies are crucial for aeroponic systems.
HARDWARE/SOFTWARE			
Headend controller	Centralized command center receiving inputs from light, climate and airflow, and water controls systems (and other facility systems) and communicating with these systems to automate sequences based on facility standard operating procedures.	Facilities using decentralized controls may not have a headend controller. Facilities with centralized controls should determine what communication protocols are used by systems to ensure compatibility and avoid expensive translation protocols.	The headend is the controls conductor orchestrating facility processes. Headend controllers may not directly control all systems in a facility, but may monitor outputs to inform other systems in the facility to respond appropriately.
WiFi	An internet connection that's shared with multiple devices via a network for communication and control.	WiFi control of lighting or HVAC systems may seem like an easy solution, but with many competing needs on your network, as well as possible cybersecurity concerns, it can be a short-sighted controls communication solution.	It is important to follow best practices when setting up IOT devices for control through WiFi systems to mitigate security concerns as well as make sure that WiFi control is right for your space. As more devices connect to a WiFi network the data transfer rate decreases, which can be problematic.

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LoRa WAN	Long Range Wide Area Network. A standard for wireless communications that allows devices to communicate over a long distance.	This is a common standard utilized for controls. It avoids many of the concerns for WiFi systems but does come with its own considerations.	While LoRa WAN has benefits including long communication ranges, low power needs, low costs, and cybersecurity benefits, there are drawbacks including data transfer being not instantaneous or continuous. Data is sent as as packets sent at regular intervals.
Sensitivity	A measure of change in system response with regards to the change in other parameters. For example, greenhouse lighting controls sensitivity describes how fast and how much supplemental lighting systems respond to changes in light levels from sunlight.	A higher sensitivity indicates that the system will respond to even the smallest input. A greenhouse lighting system with lower sensitivity will not ramp up lighting equipment in response to small changes like clouds passing over sensors.	A highly sensitive control system will be highly affected by small changes in inputs, causing frequent equipment responses, fatigue to components, and higher resource use.
Microgrid	An independent power network that uses local, distributed energy resources to provide grid backup or off-grid power via a variety of energy sources such as natural gas combined heat and power (CHP) and renewable energy sources like solar.	Microgrids allow cannabis producers to flexibly use different sources of energy to save money and reduce environmental impact of resource consumption and demand.	Benefits of microgrids can include mitigation of the risk of escalating energy prices, demand management capabilities, and resiliency of power supply to the facility.
AUTOMATION			
Environmental control system	A computer or controller that collects data from other systems in the facility for central display and command control. The systems can include HVAC, lighting, water management, and other essential systems in the cultivation facility.	This is traditionally set up by a third party controls company, so it is important to define the scope of environmental controls and how they will be centralized during facility design.	Growing spaces like greenhouses or indoor grow rooms may make use of a separate system for environmental controls than the climate control systems serving spaces for people.
Zones	Region of space separated for control of lighting, HVAC and/or watering.	Zone division may be done by room, by growth stage, by a certain canopy area etc.	Different systems may have different divisions of zones, it's important to document which systems are divided into what zones to the team.
Functional performance tests	A step in the commissioning process to verify your new equipment is ready before moving plants into your growing spaces. This type of testing runs through every possible condition for the system to experience in order to identify potential issues with equipment or set up.	Functional testing includes quality assurance activities performed by a third party that reveal conflicts between trades, installation errors, and functional performance failures. After equipment start-up, commission equipment to catch these types of issues before they cause damage to equipment or crops.	Some functional performance tests for cultivation spaces could include overriding actual temperature or relative humidity readings from sensors and observing whether your HVACD equipment responds appropriately to bring conditions back into target ranges. Other tests can include: ensuring sensors are calibrated, running equipment in lights on and lights off conditions, and checking that generators come online during power outages.
Peak electric demand	The highest facility power demand during a utility billing period.	For commercial cannabis growers, peak electric demand charges can account for 30 to 70 percent of monthly electric bills. Lower peak electric demand to reduce operational expenses.	Use lighting and HVAC controls to lower power consumption during peak hours to reduce overall energy costs. Many utilities and energy efficiency programs work with customers to lower peak electric demand and provide financial incentives for voluntary load reductions.
Packaged controls	Systems shipped complete with programmed automatic controls.	Understand what systems can be directly controlled with your environmental control system and what systems are controlled by packaged controls.	Use your environmental control system to send setpoints to packaged controls equipment performing HVAC, lighting, and water management processes.

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AUTOMATION			
Application Programming Interfaces (API)	A connection between computers or computer programs, a software intermediary that allows two applications to talk to each other.	API allows for different systems to exchange information as well as data to be sent to a centralized readout or unite data at a headend controller.	Partner with vendors who make it easy to integrate hardware and software and build their equipment to enable data integration through open API so you can add your own automated sequences.
Fault Detection and Diagnostics (FDD)	Software that analyzes historical trend data, finds problems within systems, and offers guidance about resolving identified issues.	This software can significantly reduce costs and improve operational efficiency by automating the identification of unusual data and suggesting action steps.	FDD systems make sense of data and alarms coming out of environmental control systems and present clear and actionable insights to growers in a user-friendly way.