Harvesting energy savings in indoor agriculture facilities

Quick wins for cannabis cultivators and utilities

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Summary

With the recent legalization of cannabis in some states, cultivation facilities have rushed to increase production and gain market share, and they have often overlooked energy considerations in the process. Indoor cannabis cultivation facilities are huge energy consumers with year-round loads; each marijuana plant consumes more energy than seven refrigerators, and each cultivation facility may contain upward of 400 plants. In Washington State, analysts anticipate a load growth of 80 to 160 average megawatts of power over the next 20 years due to cannabis production—the equivalent of a small city. (An average megawatt is equal to 8,760 megawatt-hours; see Megawatt on the Northwest Power and Conservation Council website.) And cannabis production is already estimated to consume roughly 1 percent of national electricity use, or $6 billion each year. Furthermore, facility operators often fear a change in legislation will make their product illicit once

again and are thus inclined to think short-term, forgoing investments in facilities designed with energy efficiency in mind. Even if facility operators do have energy efficiency at the top of their minds, there is so little information about this sector available that many HVAC contractors wouldn't know the most efficient way to configure equipment. All of these factors have left cultivation facilities with heaps of low-hanging fruit, ripe for energy-efficiency picking. Here we present nine tips for quickly and easily reducing the energy consumption of these facilities.

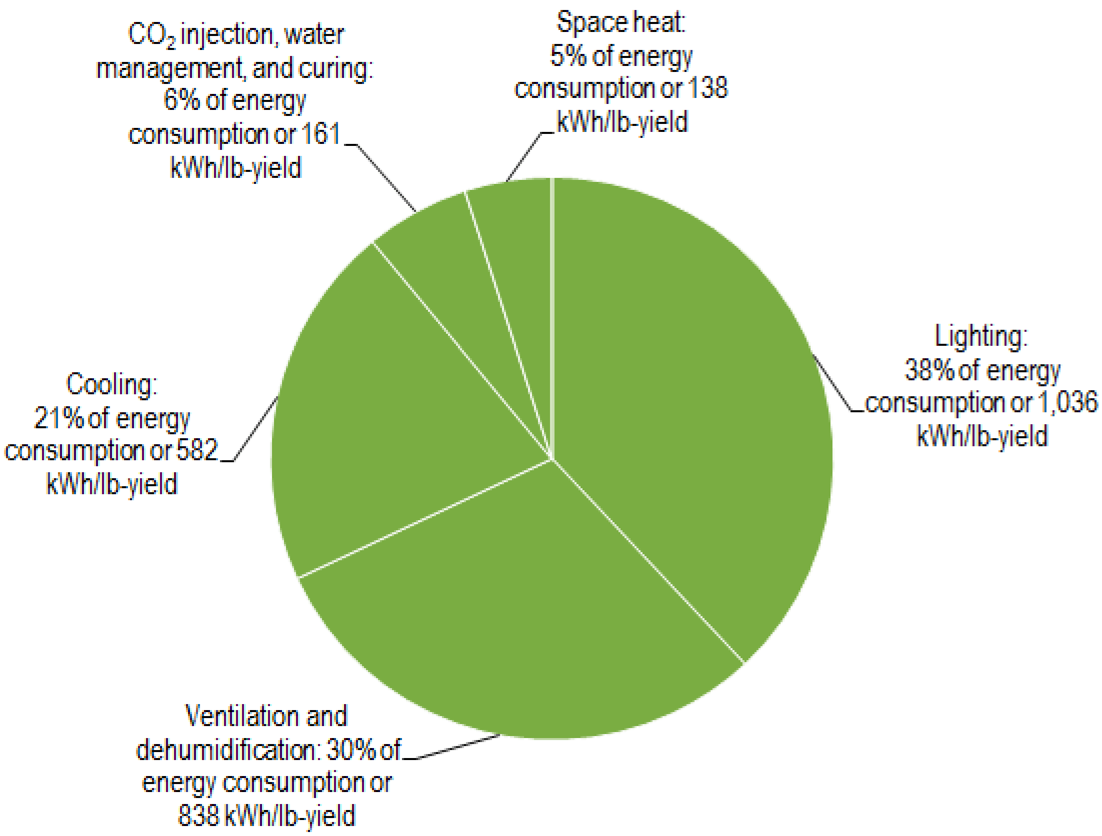
Characterizing a typical cultivation facility

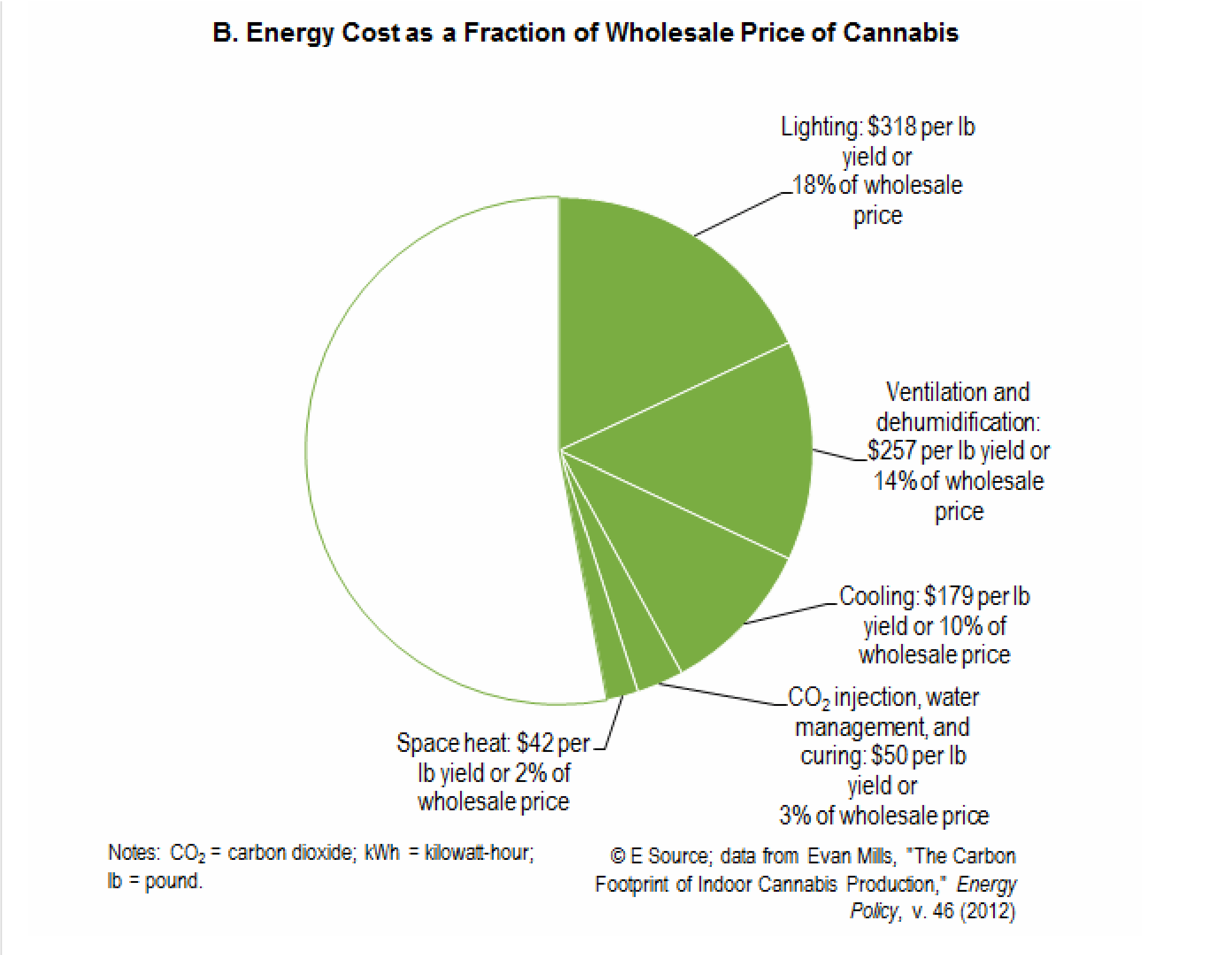
To identify where energy can be saved, it's necessary to know where and how energy is being used. Although there is no "typical" cultivation facility, these facilities are often built in old warehouses. According to a national survey of legal growing operations by *Marijuana Business Daily*, 92 percent of legal cultivation occurs indoors and only 1 percent in greenhouses, although the number of greenhouse cultivation facilities is increasing. Indoor growing allows for more crop cycles per year, greater control of environmental conditions, improved security, and, as some believe, a higher-quality product. But it comes at the cost of greater energy consumption. Indoor facilities consume much more energy than greenhouse facilities due to the large lighting and space conditioning loads, and those facilities will be the focus of this report. The breakdown of energy consumption in indoor facilities is shown in **Figure 1**.

FIGURE 1: Lighting, cooling, and dehumidification dominate the energy costs of an indoor cultivation facility

Lighting constitutes the highest portion of the energy consumption of an indoor facility (A) and is also the main contributor to the cooling load, making the combined effects of indoor lighting the vast majority of load in indoor cannabis facilities. Energy costs make up almost 50 percent of the total wholesale cost of cannabis production (B), according to Evan Mills.

A. Energy Breakdown of a Cultivation Facility





Energy use in indoor cannabis cultivation facilities can often be characterized by the following traits.

Grow lights galore. Typically, there are three lighting stages for indoor growing: seed, vegetation, and flower. Plants are moved from room to room as they reach different stages of growth. In the earliest stage of growth, the seeding stage, plants are most commonly lit with tubular fluorescent lamps 24 hours per day for 2 to 4 weeks.

During vegetative growth—the growth of stems and leaves—lighting is commonly provided by metal halide (MH) lamps for 18 hours per day for the next 2.5 to 5 weeks. MH lamps offer a broad spectral output and high light intensity with typical wattages of 400 W or 1,000 W each.

In the flowering stage, lighting time is reduced to 12 hours per day to invoke a circadian response for blooming. The flowering stage typically lasts 60 days. Flower growth also requires higher-intensity light, with a portion of red spectrum for stimulation. As such, 400-W or 1,000-W high-pressure sodium (HPS) lamps are typically used because of their intensity, orange/red spectral peak, and low cost per light.

Year-round cooling with oversized packaged rooftop air conditioners. The heat generated from the agricultural lighting used for cannabis production dwarfs any external (outdoor) weather conditions, resulting in a need for year-round cooling. And the swift ramp up of production has typically led to facility operators “slapping on” a number of oversized packaged rooftop air conditioners (RTUs) to compensate for these internal heat gains. Again, there is no typical cultivation facility, but many use packaged RTUs to meet their cooling needs. Others use mini-split heat pumps or even window air-conditioning (AC) units.

A constant need for dehumidification. Because plants produce water vapor as they grow, there is a constant need for dehumidification in indoor cultivation operations. Although ACs provide some dehumidification, it’s not usually enough to fully dehumidify the space while keeping temperatures within the desired boundaries. (ACs equipped with reheat control avoid this problem at the expense of additional energy consumption.) Therefore, many cultivation facilities use separate, dedicated dehumidification equipment. Some use numerous energy-consuming residential dehumidifiers.

Furthermore, ACs only provide dehumidification when they’re running, and they’re mostly running when the grow lights are on. Thus, separate dehumidification equipment is often needed to accommodate the lights-off periods.

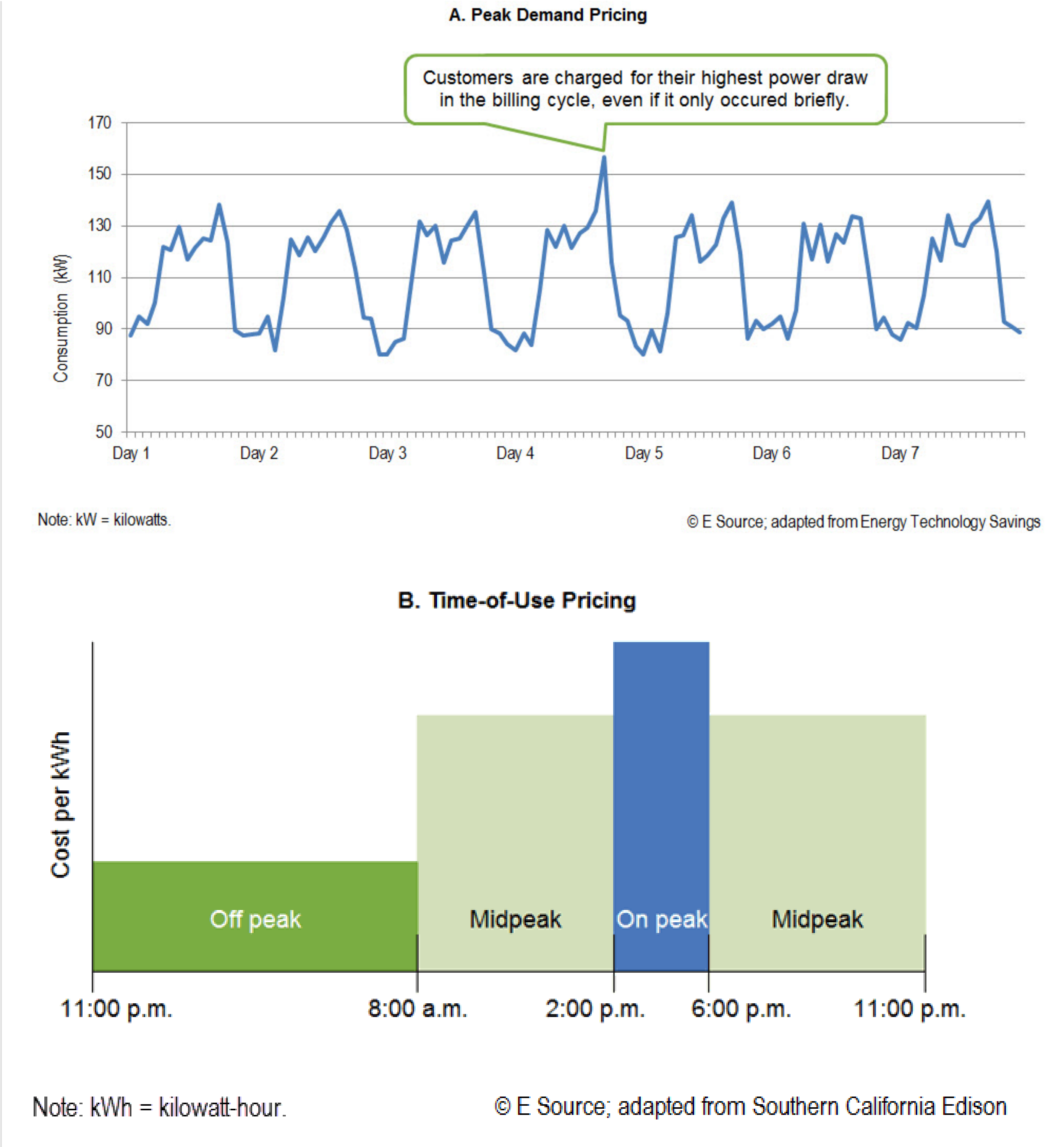
Water management, curing, space heating, and CO_2 injection. Pumps and water-management equipment are needed to feed the plants; curing equipment is needed to produce the final product; space heating is required during the colder months when the grow lights are turned off; and carbon dioxide (CO_2) injection helps feed the plants.

Not all facilities use CO_2 injection, but the idea is to let the plants “breathe” as much as possible. Because plants consume CO_2 and produce oxygen, without fresh air ventilation or another source of CO_2, they would have a dwindling supply of CO_2 to consume.

High utility demand charges. Utilities charge commercial customers for energy consumption, which is the total amount of energy consumed during the billing cycle; but utilities also charge for demand, the highest consecutive 15-minute power draw during the billing period (**Figure 2A**). Furthermore, utilities often have time-of-use pricing in place, where they charge more for electricity consumed during peak times of the day—usually between 2:00 and 6:00 p.m. (**Figure 2B**). The demand charges of a grow facility can be as high as 60 percent of the overall utility bill, according to one industry professional.

FIGURE 2: Time-of-use and demand pricing significantly add to facilities’ utility bills

Demand pricing (A) charges customers based on their highest power draw during the billing cycle, whereas time-of-use pricing (B) charges customers more for energy consumed during peak times of the day.



Top energy-saving measures

The following energy-efficiency measures are the easiest to implement with the quickest payback periods that we're aware of. Every cultivation facility will be different, and not all measures will be applicable to every facility or in every climate. Meters show the relative expected simple payback period for each measure: either short, medium, long, or immediate.

1. Change the facility's schedule to reduce utility demand charges

When the grow lights are on, the ACs are on, and the power draw of the facility is at its greatest. There are two ways that facilities can save on energy costs simply by rescheduling their operations: avoid peak time utility rates and reduce their peak demand.

Scheduling the lights-off period during the time that utilities charge the most for electricity—usually between 2:00 and 6:00 p.m.—may save on peak-time usage charges. Not all utilities use time-of-use pricing, however, and those that do may vary their rates to different degrees.

Utility demand charges are often calculated based on the greatest consecutive 15-minute power draw during the billing period. Reducing a facility's power draw, even without reducing its overall energy consumption, can save on demand charges. Scheduling the lights-on and lights-off periods in different rooms at different times can avoid having all the lights, and ACs, on at the same time, which could reduce overall demand charges.

2. Perform a lighting upgrade

Most cultivation facilities use single-ended HPS or MH fixtures. Newer, double-ended HPS (DE-HPS) fixtures designed for horticultural applications can provide roughly 30 to 70 percent more usable light per watt than standard HPS lamps with electronic ballasts. The savings are likely even greater when compared to HPS lamps using older magnetic ballasts.

Newer ceramic metal halide (CMH) technology offers a slightly broader spectrum, roughly 25 percent greater efficiency, and greater lamp life compared to standard MH fixtures. However, CMH fixtures still fall behind the efficiency of DE-HPS by about 20 percent, according to one study in the journal *PLOS ONE* (PDF).

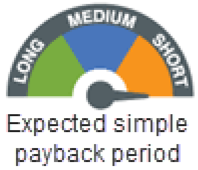
There's a lot of hype surrounding the use of LEDs in the growing industry, and a lot of variation in performance among different products. Because LEDs can cost several times more than DE-HPS fixtures, it's imperative that cultivators do their homework. Anecdotal evidence suggests that the best-in-class LEDs outperform DE-HPS, but one independent research study (documented in the 2014 *PLOS ONE* journal article) found that best-in-class LEDs only matched the efficiency of DE-HPS lamps. At the worst, LEDs are no more efficient than standard HPS or MH systems.

But LEDs offer two distinct advantages over standard high-intensity discharge (HID) lamps: First, they can get more of the light onto the plant canopy, reducing light waste. LEDs are a point light source with directional output, whereas HID lamps emit light in a 360-degree sphere and require a reflector to provide direction. Because light "bounces around" inside the reflector, some of it is prone to leave the reflector at an angle and miss the plant canopy (**Figure 3**). This is exacerbated by the fact that HID lamps need to be placed farther away from the plant canopy than LEDs because they radiate more heat. HID lamps are generally recommended to be placed 3 feet above the canopy, whereas LEDs are generally recommended to be placed 1 foot above the plant canopy.

FIGURE 3: High-pressure sodium lamps cast a wide angle of light

High-pressure sodium (HPS) fixtures, placed roughly 3 feet above the canopy, waste a good portion of their light output, as can be seen by the light reflected off the wall. LED fixtures can be placed 1 foot above the canopy and waste little light, as seen in this YouTube video comparing LED and HPS lighting.

Second, LED manufacturers are able to tune the light output to specific parts of the spectrum, which they claim makes them more efficient for plant growth. Researchers claim that not all wavelengths of light used for photosynthesis are created equal: Certain wavelengths are better for plant growth than others. Each plant has a different "light recipe" that will deliver optimal growth. Some LED products can also be tuned to vary spectral content in the course of the day or year. We're not aware of any independent research specific to cannabis, however.



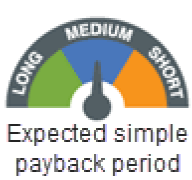
3. Get the light on the plants, not the floor or walls

Growers should be sure that as much light as possible is reaching the plants. For example, they can move the plants together without any gap between the leaves to form a solid canopy, fix damaged reflectors, and adjust lamp height to ensure good light distribution without being so close that the plants get burned. Measuring the light incident on the canopy can be very informative: It can locate darker spots that need more light and help inform operators of uneven light distribution that isn’t visible to the naked eye. This may seem obvious, but many growers don’t follow these guidelines.

Trellising can also be used to make the most of the light output. Trellising is the process of securing the upper portion of the stalk to a lattice. Branches, leaves, and flowers can be then be arranged to allow for an even canopy and maximum light absorption.

4. Use variable-frequency drive retrofit devices for packaged RTUs

Variable-frequency drive (VFD) retrofit devices allow variable-capacity operation of single-zone packaged RTUs. When the cooling demand is lower than the capacity of the equipment (which is likely all of the time because equipment is often oversized to begin with), VFD retrofit devices slow the supply-air fan and/or the compressor to reduce energy consumption. This technology has been shown to reduce total HVAC energy consumption in typical commercial buildings by roughly 50 percent, which would equate to roughly $15,000 per year for a facility with 120 plants. Many VFD retrofit devices also offer economizer controls and fault detection and diagnostics (FDD). Economizers are described in tip 6, below; FDD notifies facility operators if their equipment isn’t operating properly, potentially avoiding unforeseen surprises on a facility operator’s utility bill. For more information on VFD retrofit devices for RTUs, see the E Source Answer What information can E Source provide on variable-frequency drive technology for rooftop units?



5. Remove heat from the source rather than from the room

Capturing and removing lamp heat directly from the fixtures before it spreads into the room may be a big energy saver. Once the heat is in the room, it takes a large amount of energy to move air around for cooling and dehumidification. As an example, as previously mentioned, simply slowing down the supply-air fan in typical commercial buildings has been shown to save roughly 50 percent of total HVAC energy consumption.

Air- and water-cooled lighting reflectors for CMH and DE-HPS lamps are available from Surna, Sunlight Supply Inc. (now Hawthorne Gardening Co.), SunGro, Fresca Sol, and Liquid Lumens. Although we haven't yet seen any evidence of energy savings from these devices, the mechanism for savings is sound. Surna also claims that its devices have other benefits such as more directional light output to reduce light waste (see the previous section Get the Light on the Plants and Not the Floor or Walls).

6. Use economizers

Economizers are devices integrated into RTUs that draw in outside air for "free," nonmechanical cooling when the outside air is cool enough. In warm months or climates, this will have less of an impact, but in cold months or climates, when most other buildings are being heated to stay warm, the huge internal heat gains of the grow lights can be mitigated with cold, free, outside air. In dry climates, this has the added benefit of providing free dehumidification. In humid climates, care must be taken to ensure that outside air isn't adding additional moisture to the space.

There are many different algorithms used to determine when the economizer should let in outside air. Our analysis of recent research indicates that combined fixed enthalpy and fixed temperature control, when calibrated to the return-air conditions, is likely the best control algorithm for cultivation facilities.

Cultivators should be sure to commission the economizer when it is installed and at least twice a year thereafter. Commissioning is the process of ensuring that building systems are designed, installed, functionally tested, and capable of being operated according to the owner's needs. Economizers are notoriously faulty, with as many as 60 percent of newly installed devices not functioning properly. The problems grow worse as they age, and malfunctioning economizers can likely waste much more energy than they were intended to save.

Additionally, because plants consume CO_2 and produce O_2, bringing in outside air increases the CO_2 concentration in the facility, which is beneficial for plant growth. Conversely, care must be taken to disable economizers when facilities are operating CO_2-enrichment systems. When air is being drawn into the facility, an equal amount of air must also be exhausted; running CO_2-enrichment systems during this time risks generated CO_2 being exhausted.

7. In dry climates, use indirect evaporative cooling in parallel with direct expansion cooling

An economizer draws in outside air for free cooling when conditions are cold enough, and in dry climates, for free dehumidification. But in hot months or climates, the economizer won't engage because the outside air is too warm. Adding an indirect evaporative cooler in parallel with the existing cooling system will provide cool, dry air to the space with extremely low energy consumption. Indirect evaporative coolers from Munters and Seeley have been shown to be roughly six times more efficient than standard RTUs, potentially reducing cooling energy costs by about 80 percent (assuming an energy-efficiency ratio of 75 for the evaporative cooler versus 12 for a code-compliant RTU). An indirect evaporative cooler essentially provides "cheap" cooling and free dehumidification. However, some industry professionals have concerns about bringing in outside air; see the sidebar above.

When installing these systems, care must be taken on two fronts: First, because these devices are operated in tandem with other HVAC equipment, the controls should be set up to prioritize the most energy-efficient operating mode of either device at any given time.

Second, the supply and exhaust airflows should be designed in such a way that cool air moves to where it's needed and hot air is exhausted.

8. Use combined conventional and desiccant dehumidification for energy-efficient moisture management

Desiccants are materials that readily attract water and can thus dehumidify air without mechanical cooling. Desiccants can potentially reduce HVAC electricity use by 30 to 60 percent and peak electricity demand by 65 to 70 percent. The most efficient dehumidifiers that we're aware of combine both mechanical and desiccant systems. Outside air is first mechanically cooled to the dewpoint—the stage in which it is saturated with water vapor, but the vapor has not condensed. Saturated air is then fed to a desiccant system where the vapor is removed chemically, avoiding the energy-intensive condensation process. The desiccant system is recharged with the heat from the condenser or another source. The benefits of this are twofold: The mechanical cooling runs very efficiently because it’s not cold enough to condense any water vapor, and the desiccant system runs very efficiently because the air enters in a saturated state.

Some combined conventional and desiccant dehumidifiers, such as the Munters HCU, even have economizers built in, which will draw in outside air when it is dry enough to offer free dehumidification. This is a great option for facilities that are cooling with equipment that can’t be equipped with economizers. This one device can efficiently dehumidify and economize and then leave the remaining sensible cooling to other HVAC equipment, which will likely consume much less energy because it no longer needs to provide the same amount of dehumidification, if any.

9. If not using desiccant dehumidification, use commercial dehumidification equipment

Dehumidification systems vary widely in their efficiency. Residential dehumidifiers that are available at retail stores are very inefficient, only removing roughly 2.5 liters of water per kilowatt-hour (kWh) of energy consumed. Energy Star models boost the efficiency to roughly 4 liters/kWh, but they are still well behind the efficiency of commercial models. High-quality commercial dehumidifiers are available that can remove roughly 6 to 8 liters/kWh, saving a facility with 120 plants roughly $12,000 annually. (This calculation assumes 30 grow modules, 4 plants per module, 1 pound of yield per module per cycle, 4.7 cycles per year, and 50 percent of cooling and heating energy.

Additionally, operators should ensure that water is properly drained from the facility. Water left in standing pools or on the floor will evaporate and increase the humidity levels of the space.