

GROWERTALKS

Features

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Better Crops With a Smaller Energy Bill

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Energy remains one of the largest operating costs in greenhouse production. At the same time, growers face increasing pressure to improve crop quality, maximize yields and operate more sustainably. Fortunately, lowering energy costs doesn't have to come at the expense of plant performance.

Figure 1. Before investing in equipment upgrades, growers should ensure they're capturing as much natural light as possible during the heating season.

All greenhouse operations can improve their energy usage efficiency to reduce energy bills—either mom-and-pop or enterprise scale operations. Everyone can move up on the greenhouse management ladder no matter whether their operations are primarily manual or fully automated. The process begins with sound cultural practices and energy conservation measures that support crop growth while managing disease and insect pressure. It then advances through environmental optimization and, increasingly, data-driven and AI-assisted control systems. The goal is straightforward: Maintain the optimum growing environment while using the minimum amount of energy required to meet production objectives.

Maximize free light first

Sunlight is the least expensive energy source available to greenhouse growers. Before investing in equipment upgrades, growers should ensure they're capturing as much natural light as possible during the heating season.

Dirty glazing, algal growth, condensation and dust accumulation can significantly reduce light transmission and limit photosynthesis. Regular cleaning, anti-condensation treatments and proper maintenance of double-poly structures help maximize crop exposure to sunlight. Maintaining adequate inflation pressure with clean outside air improves insulation while reducing condensation problems.

Because light directly drives photosynthesis and plant growth, improving light transmission often increases production without requiring additional energy inputs.

Moisture management saves energy

Many greenhouse energy losses are tied to excess moisture. Water vapor must eventually be removed from the greenhouse environment and dehumidification requires energy.

One gallon of No. 2 fuel oil is required to evaporate 10 gallons of water. Excess leachate, runoff on greenhouse floors and condensate accumulating on glazing and structural surfaces all increase heating costs. As this water evaporates, relative humidity rises, creating conditions that favor plant disease development. Reducing unnecessary surface moisture is, therefore, one of the simplest and most cost-effective ways to improve energy efficiency. Practical measures include minimizing irrigation runoff, eliminating standing water and applying anti-condensation coatings to facilitate drainage from glazing surfaces.

Figure 2. Let more free light in—dirty glazing and water droplets reduce light level.



When managing humidity, growers should remember that the crop micro-climate matters more than conditions measured several feet above the canopy. Temperature and humidity within the crop canopy can differ significantly from greenhouse averages. Rather than focusing solely on reducing overall greenhouse humidity, efforts should be directed toward preventing condensation on plant surfaces. Two principles are especially important: Humidity within the canopy is often higher than in the surrounding air and condensation occurs whenever surface temperatures fall below the dew point.

A practical hierarchy of moisture-control strategies, from low to high energy use, includes:

- Keeping the greenhouse dry
- Improving air circulation
- Maintaining warmer plant surfaces
- Using root-zone heating when appropriate
- Actively removing moisture

Air movement reduces pockets of high humidity within the canopy. Energy curtains help limit nighttime radiative heat loss and keep plant surfaces warmer. Root-zone heating can further reduce condensation risk by warming plants and lowering relative humidity within the crop's micro-environment. Active dehumidification, whether through ventilation or mechanical systems, is considerably more energy-intensive and should be used strategically.

Heat plants, not the entire greenhouse

During the heating season, one of the most efficient strategies is delivering heat directly to the crop rather than heating the entire air volume of the greenhouse.

Floor and root-zone heating systems warm plants more directly than overhead heating systems. Benefits include improved temperature uniformity, reduced canopy condensation, enhanced root growth and lower heat loss through the greenhouse roof. In Ohio conditions, overhead-heated greenhouses can lose approximately 50% more energy through the roof compared with systems that supply heat closer to the crop.

For maximum effectiveness, floor heating should be integrated with space-heating systems. Floor heat provides efficient baseline heating, while unit heaters respond quickly to sudden changes in dynamic weather conditions.

Reduce structural heat loss

If maintaining adequate temperatures during severe winter conditions has become increasingly difficult, the most economical solution may be reducing heat loss before adding heating capacity.

Double glazing remains one of the most effective energy-conservation investments available to greenhouse growers. Properly maintained double-layer systems can reduce heating requirements by 40% to 50% because the trapped static air layer acts as insulation. Attention to sealing leaks is equally important.

Energy curtains provide another proven strategy. They reduce radiative heat loss, decrease the volume of air that must be heated and improve the insulating value of the greenhouse structure. Depending on greenhouse design and climate, energy curtains can reduce energy consumption by 20% to 50%. These improvements often deliver some of the fastest payback periods available in greenhouse energy management.

Data-driven environmental control

Modern greenhouse management increasingly relies on data rather than fixed temperature setpoints and grower intuition alone. The foundation of data-driven control is the collection of accurate, reliable environmental and crop data. Key measurements include air temperature, relative humidity, vapor pressure deficit (VPD), photosynthetically active radiation (PAR), carbon dioxide concentration, root-zone temperature, growing media moisture, weather conditions and crop growth responses.

Data quality is critical. Poor sensor performance or inaccurate measurements can lead to costly management decisions. Proper sensor placement, calibration, maintenance and validation are, therefore, essential components of an effective control system.

Once reliable data are available, greenhouse management can move beyond monitoring to active optimization. Rather than maintaining fixed setpoints, modern control systems continuously evaluate crop requirements and environmental conditions to determine the most appropriate control actions. Examples include:

- Adjusting ventilation based on VPD rather than relative humidity alone
- Scheduling irrigation according to accumulated light and crop demand
- Coordinating heating, ventilation and dehumidification to reduce energy consumption
- Managing CO₂ enrichment based on anticipated photosynthetic activity

These approaches help maintain fixed environmental setpoints for crops while reducing unnecessary use of energy, water and labor.

Smart control and artificial intelligence

The next step in greenhouse environmental management is AI-assisted control. Researchers have demonstrated that machine-learning systems can improve temperature prediction and environmental regulation by anticipating changes rather than merely reacting to them. These systems integrate weather forecasts, greenhouse sensor data and crop models to optimize control decisions.

AI-assisted Model Predictive Control (MPC), developed by a research team led by Dr. Murat Kacira at the University of Arizona, has demonstrated improved temperature regulation compared with conventional on-off control systems, particularly under unpredictable operating conditions.

Greenhouse tomato trials led by Dr. Chieri Kubota at The Ohio State University have also shown promising

production benefits. In side-by-side comparisons, AI-managed tomato crops produced approximately 9.6% higher yields than conventionally managed crops, although the long-term economic implications continue to be evaluated.

Building the energy management ladder

Reducing energy costs while improving crop performance doesn't depend on a single technology; rather, it can be achieved with a systematic, stepwise approach:

- Maximize free sunlight
- Control moisture effectively
- Deliver heat directly to plants
- Reduce structural heat loss
- Collect accurate environmental data
- Apply data-driven control strategies
- Adopt AI-assisted management tools when appropriate

Growers who combine sound energy-conservation practices with data-driven environmental control can achieve two critical goals simultaneously: greater crop productivity and lower operating costs. As greenhouse technology continues to evolve, the ability to collect meaningful data and translate it into precise management decisions will increasingly distinguish the industry's most efficient and profitable operations. **GT**

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