Committee on Controlled Environment Technology and Use

Controlled environments such as growth chambers and greenhouses are used to produce a wide variety of crops. Precise control of temperature, humidity, light, and other environmental conditions is particularly useful for growing crops under specific parameters that cannot be achieved otherwise. Controlled environments are also essential for research and education.

For 40+ years, a committee of land-grant university researchers, Extension specialists, industry members, and international partners has worked to advance the design and operation of controlled environments with an eye on responsible consumption of resources such as energy, water, and nutrients. Optimizing controlled environments is key to ensuring crop production, especially in the face of climate change and population growth.

Bringing together members from multiple states and disciplines, this committee has been able to coordinate research and share diverse expertise, information, technology, and other resources, driving innovation and impact. Led by land-grant universities, the committee provides unbiased assessment of controlled environment technologies and practices. The committee structure also enables professional development and networking opportunities for members.

This project is supported in part by USDA NIFA through Hatch Multistate Research Fund allocations to participating State Agricultural Experiment Stations at land-grant universities and other partners, which include: University of Alaska, University of Arizona, Brigham Young University, University of California, Clemson University, University of Connecticut, Cornell University, University of Delaware, Duke University, University of Florida, University of Georgia, University of Guelph, University of Hawaii, University of Illinois, Iowa State University, Kansas State University, University of Maryland, McGill University, Michigan State University, University of Minnesota, NASA - Ames Research Center, NASA - Kennedy Space Center, North Carolina State University, Ohio State University, Penn State University, Purdue University, Rutgers University, University of Tennessee, Texas A&M University, USDA-ARS, Utah State University, West Virginia University, University of Wisconsin, University of Wyoming. Previous and ongoing cycles of this project may include additional participants. **Learn more: controlledenvironments.org/members/**

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Multistate Research Fund IMPACTS

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LAND - GRANT UNIVERSITY RESEARCH

Research Highlights (2020-2024)

The committee's efforts have improved controlled environment resource use efficiency, sustainability, and production costs.

- Researchers demonstrated how to leverage artificial intelligence to automate climate controls and optimize other operations in greenhouses.
- A University of California, Davis, study showed the differences in energy requirements for greenhouses with different shapes, orientations, and locations.
- Growers who used findings from Rutgers University to properly design greenhouses and to update operational strategies have been able to realize energy savings of 5-30%. These reductions save an average-sized (one-acre) greenhouse business an estimated $25,000 in annual operation and maintenance costs.
- Experiments with LED lamps generated new spectra with increased energy efficiency. Adopting these LED lamps for commercial horticultural crops could reduce energy use by 50% compared to traditional high-pressure sodium lighting.
- University of Georgia studies showed that lettuce can tolerate daily light sum fluctuations. If greenhouse growers could cut back on lighting, they could save $6,000-9,000 per acre per year.
- Texas A&M University experiments suggested lighting strategies that can boost red leaf lettuce quality while also reducing energy consumption by 15-25%.
- Arizona State University demonstrated that luminescent film helps greenhouses use sunlight more efficiently, benefiting strawberry production in low light conditions.
- Applying black cloth is often required to induce chrysanthemum flowering, but it is labor-intensive. The University of Delaware developed lighting strategies that allow growers to reduce black cloth use, reducing labor costs by 43%.
- Floriculture growers can use Michigan State University findings on light intensity to boost growth and time plant flowering more precisely for specific market dates.
- Spinach typically can't be grown during the summer season in the southern U.S. even in a greenhouse, but Texas A&M University findings on root zone cooling and heat tolerant cultivars will allow greenhouse growers to extend the season through early summer.
- Percival researchers designed new humidification/dehumidification technology, which is especially important for seed storage and mycology research.
- Auburn University showed that poultry slaughterhouse wastewater can be an effective source of irrigation for hydroponic lettuce as long as specific nutrients are supplemented.
- Other Auburn University research suggested a method for growing vegetables in brackish water, which would allow aquaponics systems to cultivate higher-value fish while still producing vegetables. This would vastly improve the economics of aquaponics.
- Chemical fertilizers are costly and associated with high greenhouse gas emissions and energy demands. An Arizona State University study demonstrated that food waste fertilizer could be a sustainable alternative to chemical fertilizer for growing leafy vegetables in a vertical farm.
- Researchers at JR Peters are working with an industry partner to determine optimal phosphorus application rates for cannabis production to minimize runoff.
- Lettuce tipburn can lead to serious economic losses in controlled environments. Working with an industry partner, University of Delaware identified the optimal concentration of a chemical biostimulant that can decrease tipburn by 88% without affecting yield.

The committee circulates calibrated instruments and has developed widely used protocols, standards, and guidelines for controlled environments. Standardization is essential for accurate, reliable research and optimal operation.

Committee members have helped NASA develop advanced plant growth chambers that meet the performance and quality needs for long duration space applications.

- Data from University of Delaware hydroponics studies facilitated spectral customization for space crop production.
- A plant growth chamber designed at the Kennedy Space Center has successfully grown rockcress, dwarf wheat, radishes, and chile peppers on the International Space Station, some of which were harvested and eaten by the crew.

A researcher adds water and nutrients to plants grown in the International Space Station environment simulator chamber at Kennedy Space Center. Photo credit: NASA/Cory Huston.

The committee has supported the expansion of the controlled environment agriculture industry, leading to increased demand for equipment, production, and retail. Controlled environment-related industries collectively contributed $77 billion to the U.S. economy in 2024.

- Active participation of industry members, some of whom are direct competitors with each other, illustrates the committee's ability to bring key stakeholders together. This ensures research priorities are in step with industry needs and enables quick implementation of research-based recommendations.
- University of Arizona scientists were instrumental in developing the technology for and building the Marana, Arizona Greenhouse Complex, which has revolutionized how Bayer develops new corn varieties for animal feed. The year-round, highly automated hydroponic system requires 80% less water and nutrients and allows scientists to develop new breeding lines up to three years faster than with field production. This helps ensure farmers have feed corn with much-needed attributes like drought and salt tolerance. Building the greenhouse complex also created around 40-60 new local jobs, including engineer and biologist positions.

Committee members have published research, prepared educational materials, organized symposia, conferences, and workshops, and shared expertise with other scientists, commercial users, and the general public.

- Committee members have published over 800 peer-reviewed papers and technical reports during the last five years.
- During workshops and events hosted by committee members, thousands of growers improved their knowledge about controlled environment agriculture. After a 2023 climate control short course led by Cornell University and Rutgers University, more than 80% of surveyed participants planned to implement new practices in their operations.
- The Indoor Ag Science Café webinar series led by The Ohio State University has become a popular platform for sharing controlled environment research updates with the general public. Enrollment in the webinars increased from 138 in 2018 to 1,607 in 2024. Recorded presentations on YouTube received 48,407 views between 2018 and 2024.
- Committee members at the University of Delaware created the YouTube channel Grow Anywhere and publish educational videos about hydroponic setups for growing food crops at home, in a greenhouse, or in an indoor facility. The channel has amassed 752 subscribers as of 2024, and two recent videos have gained over 12,000 views.

This committee's efforts have been key to educating the next generation of controlled environment researchers, engineers, managers, and growers.

- Over the years, the committee's work has influenced the expansion of controlled environment agriculture programs at multiple academic institutions.
- Multiple members first participated as students and are now leaders in the field.
- Controlled environment research has been used to reach out to K-12 and college students and spark interest in STEM fields. For example, the University of Guelph's Tomatosphere™ has engaged over 4 million students.
- Committee members wrote a book that is used by most academics teaching controlled environment agriculture courses. Over 1,000 copies have been sold since 2017.

Committee member Neil Mattson demonstrates the new light emitting diodes and lighting control systems used in greenhouse strawberry growth trials at Cornell University. Photo by A.J. Both.

NCERA-101 committee members tour the Des Moines Botanical Gardens. Photo by A.J. Both.