E-GROW

Empowering Greenhouse Resiliency
with an Optimized Workforce

Gaps in CEA Education Report

May 2025

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Acknowledgements

Numerous stakeholders were engaged in the production and review of this Gaps in CEA Education report. The Empowering Greenhouse Resiliency with an Optimized Workforce (E-GROW) project team acknowledges the contributions of the following organizations:

- Agritecture (New York)
- Commonwealth Charter Academy (Pennsylvania)
- Cornell University Greenhouse Lighting and Systems Engineering consortium (New York)
- Great Opportunities in Technology and Engineering Careers (Virginia)
- Hargrave Military Academy (Virginia)
- Harrisburg University of Science and Technology (Pennsylvania)
- High School for Environmental Studies (New York)
- Institute for Advanced Learning and Research (Virginia)
- John Adams High School (New York)
- John Dewey High School (New York)
- Lyman High School (Wyoming)
- New York Sun Works (New York)
- Ten Sleep Schools (Wyoming)
- University of Wyoming (Wyoming)
- Virginia Tech (Virginia)
- Wind River Middle School and High School (Wyoming)
- Albany County School District (Wyoming)

Executive Summary

This *Gaps in Controlled Environment Agriculture (CEA) Education* report was developed by the project team for the Empowering Greenhouse Resiliency with an Optimized Workforce (E-GROW) project funded by the U.S. Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA) through the Food and Agricultural Non-Formal Education (FANE) program. The E-GROW project focuses on expertise and careers in the controlled environment agriculture industry (greenhouses and indoor farms) and agricultural technology (AgTech) for efficient domestic food production.

This report explores the scope of formal and non-formal CEA and AgTech education available to U.S. middle and high schoolers in 2025. The development of this report included literature review and a survey of our project's initial Advisory Group. These research mechanisms highlight the largest gaps in CEA education across the four U.S. states addressed by the E-GROW project: New York, Pennsylvania, Wyoming, and Virginia.

While some programs, such as New York Sun Works, Virginia's GO TEC, and Pennsylvania's AgWorks have introduced CEA and AgTech concepts into classrooms through courses for credit and workforce pathway programs (WPP), efforts remain fragmented, teacher-dependent, and geographically uneven. In rural areas, barriers include a lack of certified educators, limited access to resources like funding for on-campus infrastructure or tools, and the absence of standardized curricula and certification programs to prepare youth for CEA and AgTech careers. In some cases, educators must create their own materials with little centralized support or coordination.

To prepare youth for jobs in the CEA field, it is important for CEA educational solutions developed by the E-GROW project to:

- Expand existing CEA workforce pathway programs to reach more middle and high schoolers in each E-GROW state (New York, Pennsylvania, Wyoming, and Virginia)
- Democratize access to standardized CEA curricula integrated into middle and high school education, and
- Coordinate national efforts across higher educational institutions, government agencies, and industry.

About E-GROW

The Empowering Greenhouse Resiliency with an Optimized Workforce (E-GROW) project is developing youth interest and competency in agricultural technology (AgTech) for food production in controlled environment agriculture (CEA) by creating non-formal agricultural educational content and activities to foster curiosity and competency of tech-savvy STEM students in disciplines like automation of vegetable greenhouse climate control systems, robotics and AI for crop science, and energy and economic benchmarking of vertical farms. E-GROW will pilot a CEA certificate for youth at ten middle and high schools in New York, Pennsylvania, Virginia, and Wyoming for integration into a future CEA workforce credentialing program. E-GROW pilots expect to reach 500-1,000 youth and reach student populations underrepresented in STEM including rural youth, students from low-income households, young women, ethnic minorities, and persons with disabilities. Seven project partners from higher education and youth development will collaborate to accomplish the aims with assistance from a mentoring network of industry professionals, academics, and researchers facilitating and amplifying accomplishments of students. Progress toward four distinct aims with milestones over four years will be evaluated by an Advisory Group of pilot school stakeholders. E-GROW non-formal educational modules, experiential learning activities, and modeling tools tailored for grades 6-12 will build on existing youth development strategies to increase understanding of the benefits of CEA AgTech. Student-produced capstone projects and outreach materials will demonstrate competency and build public confidence in AgTech in food systems by showing their communities how AgTech enables CEA operations to produce fresh food and support local jobs. Learn more about the project at [*https://glase.org/about-glase/e-grow*](https://glase.org/about-glase/e-grow)*.*

Background

Emerging technologies accelerating agricultural productivity improve the economics of horticultural crop production and can ensure global food security and environmental health (1, 2). Greenhouses allow for year-round crop production, including in areas where crops otherwise could not be grown due to unfavorable environmental conditions, which are predicted to be more widespread in the future (3). The greenhouse production of specialty crops (fruits, vegetables, and floriculture) is an important part of U.S. agriculture, with a $6.9 billion annual wholesale farmgate value (4). High-tech CEA businesses, like greenhouses and indoor farms, implement automation and environmental monitoring to enable higher crop yields, but a qualified workforce is crucial to maintain cost-effective and sustainable operations. The U.S. greenhouse vegetable industry requires skilled labor, but the supply of a qualified domestic workforce is not available; in many cases relies heavily on temporary worker visa programs and imported subject matter experts from the Netherlands (5). CEA jobs offer a pathway to rural prosperity as site selection for new CEA facilities strategically targets food deserts, locations in between multiple metropolitan areas, or areas with available land, inexpensive real estate, favorable zoning, and skilled local labor (6). While the U.S. K-12 educational programs are not producing enough students to prosper in Science, Technology, Engineering and Mathematics (STEM) fields, the number of STEM-related jobs has increased. It is critical to humanity's biological needs that the number of students entering the STEM career pipeline be increased by focusing attention on increasing student interest/attitude toward pursuing future work in the STEM field (7). Timing is key; generating interest in STEM careers during middle and high school connects the dots between science and students' lives to keep them engaged and interested while they form opinions about their career paths (8). Communities underrepresented in STEM education include rural youth, students from low-income households, young women, ethnic minorities (Blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives), and persons with disabilities (9–12).

CEA offers a vehicle for STEM education and presents an interesting career opportunity for youth to envision for themselves. CEA operations offer interdisciplinary agricultural work that supports multiple economies, including food production and cultivation of specialty horticultural crops. CEA facilities need diverse technical staff with various STEM backgrounds: Growers, engineers, and scientists all have a role to play to maximize production and efficiency of greenhouses and vertical farms using high-tech systems and approaches (5).

Workforce development in the CEA industry has been concentrated on professional continuing education (13–15). Youth education focused on careers in the CEA industry has been implemented in limited regions of the U.S. and must be expanded to build the pipeline of future workers needed to run high-tech greenhouses and indoor farms. New York Sun

Works builds hydroponic science labs in urban schools and currently partners with over 300 schools in New York City. Virginia's GO TEC program supporting youth talent development reaches students in 52 middle schools across the southern part of the state, and some have in-classroom CEA demonstrations. Pennsylvania's largest cyber charter school delivers an AgWorks program reaching 24,000 students. In Wyoming, the University of Wyoming advances youth understanding of AgTech by training K-12 teachers on TeachEngineering.org to deliver hydroponics curriculum.

Workforce pathway programs (WPP) are structured educational and training initiatives designed to prepare individuals for specific careers or occupational fields, like the U.S. Department of Labor's Workforce Pathways for Youth (16). WPP often include a combination of classroom learning and experiential or on-the-job training. These programs are critical for equipping individuals with the skills, knowledge, and practical experience they need to meet industry demands, thereby contributing to economic growth and reducing unemployment rates. WPP programs often involve partnerships between educational institutions and businesses to ensure that the training is aligned with industry needs. Existing youth development strategies include soft-skill development, career exploration, vocational training, job readiness and certification, summer jobs, year-round jobs, residencies, and apprenticeships in out-of-school time. In WPP programs, businesses partner with local workforce boards and youth-serving organizations to connect their existing activities and prepare youth to enter the workforce by exposing youth to career-related services.

There are four major gaps in current WPP: Underrepresented industries, geographic disparities, demographic underrepresentation, and emerging career paths. Currently, these programs predominantly serve industries like healthcare, manufacturing, and information technology. There is limited focus on emerging sectors like renewable energy, CEA, and digital media. WPP are often concentrated in urban areas, leaving rural communities underserved. There is a lack of initiatives aimed at engaging underrepresented groups, including women and minorities, in STEM fields. The focus of existing WPP is predominantly traditional career paths, often missing skill development required for careers in emerging fields. Recently-launched WPP focused on emerging technologies are novel and have limited reach (10, 17–19).

Climate-smart CEA practices (activities that result in additional, measurable, and verifiable carbon reductions and sequestration) can contribute to food security and are in line with sustainable development goals (1–2). CEA is a big sector of the U.S. agricultural industry and is key to year-round domestic food production (3–4). The 'green industry' (which includes greenhouses, nurseries, floriculture) is limited by labor availability, and one solution is workforce development and a full talent pipeline of new workers from high schools to colleges to industries, similar to what the manufacturing industry has done with WPP. The horticulture industry needs a great volume of talent but is facing record-low unemployment rates, and other sectors offer more comfortable working conditions and

often higher pay for entry-level jobs (20). It is critical to use AgTech to drive awareness and interest in CEA so youth see CEA as a viable career with growth opportunities.

There is a need for CEA WPP focused on youth underrepresented in STEM. Apprenticeships and residencies in CEA offer the dual advantage of providing both theoretical knowledge and practical, hands-on training in a growing industry with diverse applications of emerging technology. This allows students to learn, work, and earn, contributing to persistence towards a credential/degree while fulfilling workforce needs. Companies in the CEA sector report a lack of adequately trained workers, leading to unfulfilled positions and slower expansion in the U. S. or a reliance on temporary worker programs (5). There is an insufficient number of educational programs focused on CEA to satisfy demand, despite the industry's rapid growth; in some states, there are no existing youth development partners focused on CEA. The shortage of skilled workers in the CEA sector potentially leads to a loss in revenue estimated in the millions and hinders innovation (21).

Initial Findings

The following sections describe state-level findings from the literature review and discussions with Advisory Group members.

New York

There are notable geographic disparities between urban and rural programs related to Controlled Environment Agriculture (CEA) in New York. Urban areas, especially New York City, have more established programs like New York SunWorks, whose 'hydroponic classroom' initiative has expanded AgTech education to 320 public schools across the five boroughs, though this still represents only 20% of schools (22.). Meanwhile, rural areas face unique challenges, and while some issues overlap between urban and rural students, rural students often encounter additional barriers. Programs like Career and Technical Education (CTE) schools, which could benefit from CEA certifications for high schoolers, face high barriers, including certification requirements for teachers and difficulty in getting CEA programs approved.

There is also a lack of central coordination in these efforts. For instance, organizations like the Future Farmers of America (FFA) are present in over 100 rural and urban school districts, but CEA and AgTech education often rely on the passion of individual teachers rather than a standardized, coordinated curriculum (27). While FFA offers a wide range of Career and Leadership Development Events (CDEs and LDEs),

including areas such as livestock evaluation, agricultural communications, environmental and natural resources, food science, and veterinary science, there is limited programming and events specifically focused on controlled environment agriculture (CEA) or hydroponics (25).

This decentralized approach makes it difficult for instructors with the interest, knowledge, and bandwidth to teach hydroponics and AgTech to connect and share resources, forcing them to "reinvent the wheel" at their respective schools. While Cornell Extension offers some support, it does not always provide the necessary subject matter expertise, particularly for newer topics like hydroponics. Programs outside the school system, such as 4H, sometimes rely on outdated materials, further highlighting the need for updated and coordinated resources (27).

Pennsylvania

With Pennsylvania's size and diverse population centers, there are also struggles with public interest in agriculture, as many people do not see it as a viable career due to low profit margins. To overcome these challenges, there is a need to demonstrate clear career pathways for students interested in CEA.

There are several promising developments in CEA education in the state, including the Southwestern region's commitment to introducing aquaponics and tower gardens in many of its schools. However, one of the biggest challenges is the lack of institutionalized CEA education; much of the work is driven by individual teachers rather than being integrated into standardized curricula (26). Pennsylvania's efforts have gained attention, with the Department of Education's CEA Accelerator spotlighting the state for its stakeholder interest and capacity-building readiness. Harrisburg University features a strong CEA learning lab, and is also breaking ground on new CEA research facilities. The state is looking to address agriculture with its focus on advanced robotics and manufacturing. Harrisburg University is also breaking ground on new CEA research facilities, and the state is looking to address agriculture with its focus on advanced robotics and manufacturing (33).

Despite these efforts, CEA education in Pennsylvania faces hurdles. The sector lacks comprehensive data to support its inclusion in economic development strategies, and workforce development boards lack a standardized certification pathway for CEA. There is an active Future Farmers of America (FFA) program with about 13,000 students and good communication among its participants. However, the FFA does not have a specific curriculum focused on Controlled Environment Agriculture (CEA). There is also an active 4H program, though its focus remains informal, often centered around livestock rather than greenhouses or indoor farming CEA. While some schools, like Milton Hershey School and Commonwealth Charter Academy (CCA), have built their curriculums incorporating

CEA topics, there is no standardized approach across the state. CCA has developed CEA 101 and 102 courses for which students can earn credit. Philadelphia schools struggle with a lack of resources, though several schools have pre-committed to adopting CEA into their curriculums and plan to build a CEA AgTech hub (26).

Wyoming

Wyoming's climate and geology make traditional farming less prevalent, creating a unique opportunity for CEA to thrive. The agriculture sector is a significant focus, with strong support from the government, the University of Wyoming (UW), and school districts (35). The state's Department of Education is particularly enthusiastic about developing a Controlled Environment Agriculture (CEA) program. The University of Wyoming plays an active role with its Center for Controlled Environment Agriculture spearheading outreach activities, including K-12 education for teachers on hydroponic systems through a "train the trainer" model (31).

While Wyoming has an active 4-H program (34), there is limited focus on CEA within it. Wyoming faces geographic and socioeconomic challenges, particularly in its many small towns, where resources for both students and educators are scarce. Socially and economically disadvantaged communities experience significant disparities in access to these programs. A few major industry partners, such as Plenty and Vertical Harvest, built their research and development facilities in Wyoming. An emerging consideration is whether educational CEA programs will engage homeschooled students, who make up a significant portion of Wyoming's student population (32). Despite these challenges, the state is well-positioned to expand CEA through its existing initiatives and industry partnerships.

Virginia

Agriculture is Virginia's largest private industry, and is working toward leading in the controlled environment agriculture (CEA) industry (24). CEA's growth in the commonwealth is due to many factors, including support from the commonwealth to recruit companies, increase formal K-12 - college educational opportunities in AgTech, increase workforce development opportunities, the state's position in the middle atlantic, and an extensive interstate system that situates operations near major population centers along the East Coast and Atlantic Seaboard (37). There are many AgTech programs currently in Virginia. These include the statewide programs that have historically been the main access to agriculture education across the U.S.: 4-H and FFA. Several of these programs across the state are offering educational opportunities in CEA, although not uniformly. Many agricultural education and FFA programs have greenhouses for horticulture classes, which traditionally focus on ornamental horticulture and may need updates (37). Outside of the

ornamental horticulture focus, Floriculture Career Development Event, and a few classroom vertical farming units, there is not a standardized program focused on CEA. Several programs around the state focus on STEM education that incorporate agriculture at some level. These include Governor's School, Career and Technology Education programs, and Fairfax County Public Schools Get2Green.

There are several other educational programs that have a focus or a subfocus on CEA ranging from K12 through college level. These include schools that have created a hydroponic lab, utilized a greenhouse, or added another AgTechnology system opportunity to incorporate hands-on learning into engineering, biology, statistics, career, and technology programs, etc. across the state. More formalized programs in the state include the GO TEC program based out of Danville which includes vertical farming/urban agriculture in their curriculum. They are focused on the middle school population in 52+ schools total (all these schools may not have a vertical farm component). Other formal education programs include Farm Bureau's Agriculture in the Classroom program that tends to focus on pre-school through middle school education.

Virginia is home to two companies that have classroom vertical farming systems that include curriculum for the classroom. This includes Babylon Micro-Farms and AeroFarms Community Farms. These programs are not grade or age-specific. There are also several programs and projects outside of 4-H that Virginia Tech, Virginia Cooperative Extension, and/or IALR lead that include agriculture technology education and in some cases, CEA-specific education. Non-CEA specific programs include the Farm to School Program which is a project with Extension and the Department of Education that has the dual purpose of education and providing nutritious meals. Another non-CEA specific example is the IALR Summer Internship Program. Primarily undergraduate students, each summer intern with the Applied Research division at IALR explores a range of agricultural research topics. Specific to CEA education, a recent CEA Strategy and Roadmap in GO VA Region 3 was released that outlines the need and plan to develop community college-level CEA education programs, among other economic development and workforce training strategies (23). Specific to K-12 CEA education, the Virginia Seafood Agricultural Research and Extension Center has recently hired a new K-12 Outreach Coordinator who is working with schools to develop educational opportunities related to aquaculture, aquaponics, and other agriculture-related topics. In addition to these, the VT and IALR CEA Innovation Center offers non-formal educational opportunities through having K-12 students and educators participate in field trips through the CEA Innovation Center Demonstration Farm to coincide with their curricula. Another CEA-specific K12 Outreach activity in Virginia is part of the USDA-funded project I2GROW which is focusing on greenhouse gas removal with CEA. Dr. Kaylee South is leading the K12 outreach efforts which includes internships, field trips, and vertical farm classroom use.

Through reviewing the known programs related to AgTech and specifically to CEA, there is a need for additional formal CEA education programming for the middle to high

school level. There are many agriculture education programs throughout the state, as agriculture is very important to the state's economy. There are also several initiatives within the state that have a focus on elementary or college-level CEA-specific educational programming. A recent study that included focus groups in VA to determine CEA education and workforce training needs which was conducted by South et al (publication in preparation), gathered data on needs related to four-year universities, Extension programming, and employee training. The largest, formal education program that has a specific CEA module is the GO TEC program, which is specific to middle schools that fit within the GO TEC educational module curriculum. There is a need for additional work to understand the state's need for middle to high school AgTech educational programming and to develop the resources that provide teachers with the tools to implement CEA educational programs across the state.

Stakeholder Survey Findings

A survey shared with the E-GROW Advisory Group (a 22-member panel of youth development partners and pilot school instructors and staff) had 15 respondents in April 2025. See Figures 1 and 2 for demographic distributions of survey respondents. Teachers instructing grades 6 - 12 were 45% of the respondents. Virginia programs were represented by 45% of the respondents.

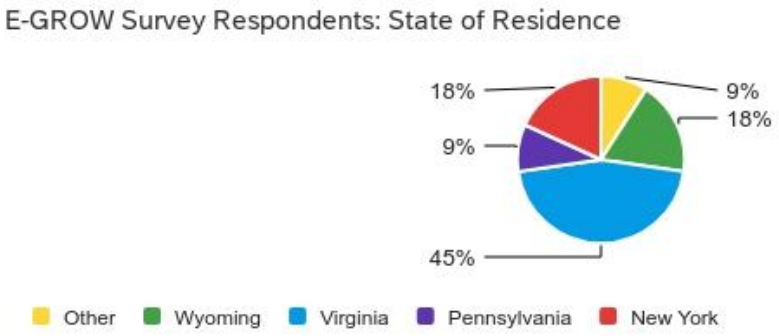

Figure 1: 2025 E-GROW Survey Respondents by State

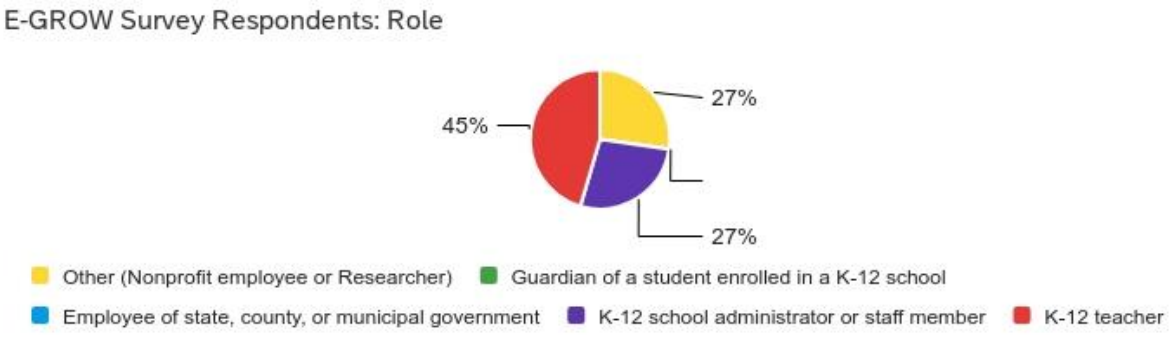

Figure 2: 2025 E-GROW Survey Respondents by Role

The survey findings help the E-GROW team confirm what existing youth development strategies exist and are succeeding at the middle and high schools in New York, Pennsylvania, Virginia, and Wyoming.

A majority of respondents' middle and high schools provide plant science, food production, and/or agricultural technology (AgTech) infrastructure and youth development programming.

- 91% of respondents indicated K-12 schools within their school district currently offer formal and/or non-formal educational opportunities for students to develop knowledge and skills related to plant science, food production, and/or AgTech.
- 78% of respondents indicated that their school offers formal and non-formal educational opportunities for plant science, food production, and/or AgTech at their local K-12 schools via Future Farmers of America programs and courses for credit. Five survey respondents shared that their local schools offer courses like Plant Science, Horticulture, Floriculture, and Agriculture Production Technology while only two respondents shared that courses specific to Controlled Environment Agriculture were available.
- 68% of respondents indicated that career and Technical Education pathways are available. 4H, student clubs, and internship programs were also shared as examples of formal and non-formal educational opportunities.
- 53% of respondents indicated that students attending their local K-12 schools have access to on-campus or in-classroom facilities or infrastructure for teaching skills related to greenhouse production or indoor farming like greenhouses or hydroponic growing systems.
- 18% of respondents indicated that there are no IT resources and infrastructure that are available in their local K-12 schools to support a plant science, food production, and/or AgTech educational program.

Currently available youth Agtech programming grows a wide range of CEA crops in schools. Respondents to the survey indicated a variety of CEA crops grown in commercial greenhouses are grown on-campus or in-classroom equipment at their local K-12 schools, including basil, lettuce, tomatoes, herbs, kale, arugula, chard, tatsoi, parsley, oregano, dill, cilantro, stevia, lavender, borage, marigold, sunflower, nasturtium, snow peas, cucumber, pepper, eggplant, calendula, rosemary, thyme, lemon balm, mint, sage, beans, pak choy, mustard greens, spinach, sorrel, hibiscus, okra, beans, kohlrabi, parsley, marigold, and microgreens.

An AgTech certification program focused on CEA is a gap identified by most respondents.

- 80% of respondents indicated that there is a very high or high level of interest among local K-12 students in preparing for a plant science, food production and/or AgTech career.
- 70% of respondents indicated that students at their local K-12 schools would benefit from a certification program in Controlled Environment Agriculture (CEA) that would prepare them for a career in plant science, food production, and AgTech.
- 67% of respondents indicated that a CEA-focused curriculum could spark greater interest in plant science, food production, and/or AgTech careers among your students.

Conclusions

Controlled Environment Agriculture (CEA) is a rapidly growing sector vital to the future of food production, sustainability, and workforce development in the United States. Many workforce development efforts in CEA are geared toward continuing education for professionals, leaving gaps in youth engagement, particularly among rural communities and underrepresented demographic groups in STEM. The number of STEM jobs continues to grow, yet K-12 educational systems are not adequately preparing students for careers in these fields, especially in emerging industries like CEA. Structured and accessible WPPs that integrate classroom learning with hands-on experience are limited in scope and availability, and CEA is often overlooked in national and state workforce strategies.

There is a lack of standardized curricula and recognized credentials in CEA. Without formal certifications, it's harder for students to demonstrate their skills or transition into careers.

Underrepresented Industries	Geographic Disparities	Patchwork Curriculum
Demographic Underrepresentation	Emerging Career Paths	Nascent Certification Pathway

There is a critical and growing need for a skilled CEA workforce. The industry faces a severe labor shortage, and without intentional youth education and workforce development efforts, growth may stall.

CEA is underrepresented in existing youth workforce pathway programs. Most programs prioritize industries like healthcare, IT, and manufacturing, leaving agriculture behind.

Educational efforts related to CEA are fragmented and inconsistent across regions. Programs often depend on individual initiative, and there is a lack of coordination, especially in rural and underserved communities.

Partnerships are important for delivering strong CEA education, but many are ad hoc and lack coordination. More support is needed to connect schools, businesses, and higher education.

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