



Summer Camp XXVIII Twenty-Eighth Westford Symposium on Building Science

August 3, 2026 to August 5, 2026

I would like to invite you to the thirtieth Westford Symposium on Building Science. In continuing with past tradition, “building science summer camp” features intensive discussions on building science in both a formal and informal setting.

Westford XXVIII – features numerous presenters/facilitators. In keeping with tradition, the lead presenter/facilitator for each of the subject areas is one of the foremost practitioners in the subject area.

Course Dates

Monday, August 3 through Wednesday, August 5, 2026.

Course Outline

Presentations begin each day at 8:30 am

Lunch will be provided each day between 12 noon and 1:00 pm

Presentations will end Monday and Tuesday at around 5:00 pm

Symposium will close Wednesday at 3:00 pm

MONDAY AM SESSION



Introduction/Welcome

8:30 am to 8:45 am

Joseph Lstiburek

Approximately 400 attendees will be in the Orchard Church Community Center for 3 days. Note that it is acceptable to wear a mask. Also note that mask wearing is not compulsory. For those that wish to remain off site they will be able to remotely connect to the zoom link where the speakers can be heard live and the power points can be watched. The evening events at the “clubhouse” are all outdoors...except inside the “barn” where masks are acceptable but not compulsory.



Fluorocarbon Technologies: Environmental Considerations and Contributions to Building Energy Efficiency

8:45 am to 10:15 am

Mary Bogden

Fluorocarbon technologies have played a critical role for decades across a range of applications, including refrigeration, air conditioning, thermal insulation, solvents, blowing agents, and medical propellants. Over time, these materials have evolved from chlorofluorocarbons (CFCs) to hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and most recently hydrofluoroolefins (HFOs), with each generation reflecting substantial reductions in environmental impact, particularly with respect to ozone depletion and global warming potential. Throughout these transitions, the underlying performance advantages of fluorocarbon chemistry have been preserved.

In the context of building systems, fluorocarbon-based technologies continue to deliver industry-leading energy efficiency. High-performing refrigerants enable efficient HVAC and refrigeration systems, while fluorocarbon-based insulation materials contribute to superior thermal performance and long-term energy savings. As the building sector seeks to reduce operational energy use and carbon emissions, these attributes remain highly relevant.

At the same time, fluorocarbons are the subject of ongoing discussion regarding environmental considerations, including global warming potential (GWP) and emerging regulatory focus on PFAS. This presentation aims to provide a technically grounded overview of these topics, clarifying current research, regulatory perspectives, and risk frameworks. In addition, the discussion will examine the broader sustainability context by addressing operational energy efficiency, embodied carbon, and lifecycle performance of fluorocarbon-based solutions. The goal is to equip designers and engineers with balanced, evidence-based information to support informed decision-making in high-performance building design.

BIO: Mary Bogdan is a Research Fellow for Solstice Advanced Materials, formerly Honeywell working at the Buffalo Research facility for over 35 years. She earned a BS in Chemistry/Biochemistry and an MBA from Canisius University. Mary supports the blowing

agent business, leading application research projects and providing technical services to the global foam insulation industry covering technology from CFC to HFO technology. She is a Six Sigma Black belt. She has over 30 US patents and has published numerous technical articles on the development and use of fluorocarbons as foam blowing agents. She is actively involved in industry trade associations and standards organizations. She is a member of the SPFA Board of directors and has received industry recognition for leadership and excellence in technology.

----- **MORNING BREAK 10:15 AM TO 10:30 AM** -----



Healthy Living in Tight, Compact Homes - A Firsthand, Holistic, Cross-Disciplinary View
10:30 am to 12:00 Noon
Ashley Murphree

Once upon a time, Ashley dreamed of designing and building sexy, cutting-edge passive homes — until being humbled by a personal experience with chronic complex illness. Unsettled by new concern for risks in tight and compact buildings, she deeply examined what we might be missing— beyond the same ol' mold talk— as we forge ahead with current building science best practices. This discussion follows from her unique lived experience that seems most likely to be a paradox of attempting to escape her own fate:

- A residential Passive-House-trained mechanical engineer, general contractor, and building scientist
- Living off-grid in a self-built tiny house
- Amateur student of functional medicine theory and healthy living

This is a holistic, cross-disciplinary look at putting the human back into the building science, especially in high-performance homes and retrofits. We'll zoom in to the cellular level and then connect the broader (and changing) context to inform our evolving best building science practices. Outdoor and indoor micro-climates demand nuance in enclosures and mechanical systems. Membranes—biological and architectural— are stars of the show. Ashley shares her personal moments of revelation and astonishment that build a storyline of takeaways on staying punk, passive, and confidently healthy.

BIO: Ashley Murphree, P.E., is the founder of Alchemech Engineering in Northern California with undergraduate degrees in Mechanical and Civil/Environmental Engineering from the University of Michigan. A habitual contrarian and haunted by the Big Questions of life, she relieves her rumination through crafting jewelry, art, and leatherwork.

----- **LUNCH 12:00 PM TO 1:00 PM** -----

MONDAY PM SESSION



Building Science Moisture True Crimes: When Good Intentions Go Felonious

1:00 pm to 2:30 pm

Nikki Krueger

A forensic exposé of how the very codes, "best practices," and cutting-edge technologies we rely on to make buildings tighter, more efficient, and healthier are secretly committing moisture crimes behind closed walls.

Using real case files from the field — complete with crime-scene photos and forensic proof— Nikki prosecutes the usual suspects:

- **The Closed Crawlspace Felony** — Dilution vs. removal: when code lets you choose how to "condition" a sealed crawl space, the jury rarely likes what's hiding underneath
- **The Variable-Speed AC Misdemeanor** — Systems engineered for peak efficiency that quietly sabotage dehumidification the moment they drop to part-load. Doing less work never felt so costly.
- **The Ventilation Overdose Assault** — Bringing in "fresh" air that floods tight homes with more moisture than they can handle. The road to mold is paved with good airflow intentions.
- **The Dehumidifier Sizing Double Homicide** — Too big: short-cycling chaos. Too small: perpetual failure. Both ignore real latent loads — and neither checks what the equipment can actually deliver.
- **The Botched Install Burglary** — Poor ducting, gravity-defying drains, and integrations gone wrong that turn well-intentioned systems into moisture accomplices.

These aren't rare mishaps — they're patterns born from good intentions colliding with real-world physics. Nikki delivers the verdicts: field-tested, common-sense solutions that close the gap between modeling perfection and buildings that perform.

BIO: Nikki Krueger is the Senior Marketing Director for Santa Fe Dehumidifiers and AprilAire, where she's spent over 20 years trying to convince the world that dry, fresh indoor air is actually exciting (spoiler: it is). She is a RESNET-certified Home Energy Rater, a member of the ACCA Manual Low Load Homes (LLH) Advisory Committee, holds the ACCA Residential Design for Quality Installation Certification, and recently served on the 2024 National Green Building Standard update committee. Nikki educates builders, HVAC contractors, architects, engineers, and others, acting as the translator between the physics of building science and the professionals we count on to keep our homes comfortable, healthy, and not rotting apart.

----- **AFTERNOON BREAK 2:30 PM TO 3:00 PM** -----



Going Tropical- Building, Cooling and Ventilating in Climate Zone 0A

3:00 pm to 4:30pm

Kimberly Lewellyn

Our latest building science adventures have taken us south, not Texas south but 13° North of the equator. Barbados is a beautiful ~170 mi² (440 km²) island whose coralline limestone subsoil provides natural water filtration. The tropical climate stays within a tight dry bulb range of 72-87°F (22-21°C) and dewpoint of 70-74°F (21-23°C).

The historical building vernacular works: leaky wall assemblies, designing for cross-breezes, including ceiling fans and occasionally installing spot cooling in bedrooms suffices to keep spaces comfortable and building assemblies in good shape. However, all bets are off when you introduce drywall, over-sized ducted systems and have no bulk water detailing.

In tune with the theme of balancing practice and theory, we'll look at the reality of our building dissections, work force and materials availability AND walk through the loads, ventilation, material properties and go hygro-fricking thermal on the building assemblies. We'll take a close look at 62.2 ventilation rates and the risk associated with those latent loads.

The topic is ripe for fun- what happens when you put Canadian clients in equatorial environments, when Dutch engineers design a tropical roof system and when you put an exacting Bostonian Italian on that roof? Want to know what a water injection port into a wall assembly looks like? Come find out!

BIO: I trained as an engineer at university, earning my MS Engineering degree working in a thermodynamics lab. Cut my teeth in the field as a RESNET energy rater in TX. Learned loads and mechanical design from Kristof Irwin in Austin. Swam in the corporate pond working for Mitsubishi for almost 10 years in high performance buildings and product management. Service to the greater industry is important to me and my technical committee and board work for ASHRAE, ICC, ACCA, BPI and Phius totals >25 years. Consistently, my focus has been high performance buildings, moisture forensics, IAQ and HVAC design.



Are We There Yet? A Brief Update on Progress Towards Better Indoor Environments for All

4:30 to 5:00PM

Bill Bahnfleth

The Covid-19 pandemic got people talking about the need to improve indoor air quality and more broadly about indoor environmental quality. After six years, how far have we come? How far do we have to go? Bill offers some personal perceptions and prognostications from the frontlines about what's been happening in society, research, policy, and standards.

Bio: Bill is a professor of architectural engineering at Penn State where he teaches a variety of undergraduate and graduate HVAC course and does research mainly focused on controls for airborne respiratory infection transmission. He's also made an honest living as a consulting engineer in the distant past. He has served the professional community and public for more than 40 years through his ASHRAE activities, which include a term as President, chair of the ASHRAE Epidemic Task Force, and chair of Standard 241 *Control of Infectious Aerosols*. When left to his own devices, he would rather spend time riding his bicycles, playing the piano and organ, and reading.

TUESDAY AM SESSION



Drain, Drain Go Away

8:30 am to 10:00 am

John Straube

Drainage has gone from being largely ignored in historical documents to forming the core performance requirement of many systems. Drainage behind cladding, within curtainwall framing, along hidden flashing, through weep holes, down precast panel joints, and within foundation drainpipes is now required for the successful performance of many parts of modern buildings. This presentation will examine how much drainage can be expected in each of these systems based on physical measurements and theoretical calculations. Different drainage strategies for different building components will be assessed, recommendations provided, and risk factors identified.

BIO: Dr. Straube holds a joint appointment as Associate Professor in both the Civil & Environmental Engineering Department and the School of Architecture at the University of Waterloo where he teaches courses in building science, structural design, material science, and design. He is also a Principal and Senior Specialist at RDH Building Science, a North American engineering consulting firm.

John's research and practice have focused on the design of durable, energy-efficient, and healthy buildings, and the development of new building systems and products. He has worked around the world on forensic investigations, iconic buildings, new product development, and education. He has developed expertise in heat, air, and moisture physics, building products development, field and laboratory performance monitoring, and environmentally conscious buildings. Retrofit of existing building enclosures, often historically significant, and managing rainwater leaks and moisture damage has been a focus.

Before joining RDH, he was a Principal at Building Science Corporation from 2006 to 2013, and is the author or co-author of over 100 published technical papers, dozens of articles on the highly acclaimed buildingscience.com website, author of the book *High Performance Enclosures* and co-author, with Eric Burnett, of *Building Science for Building Enclosures*, recently released as a 2nd Edition.

----- MORNING BREAK 10:00 AM TO 10:30 AM -----



APARTMENT BUILDINGS: NEW DISSECTIONS, INTERVENTIONS AND CONNECTIONS

10:30 am to 12:00 Noon

Chris Benedict

Chris' talk will focus on two projects, the first is a recently completed 13 story 153-unit modular apartment building in Brooklyn, NY that has just received Passive House Certification. Chris will talk about the realities of building a building that needs an air barrier, drainage plane and compartmentalization put together from little pieces delivered by truck from Canada! Spoiler alert, it worked, but it wasn't always easy.

She will also share her currently proposed net zero water intervention for a 147-unit Passive House retrofit in Boston, MA where toilet waste and grey water will be separated via a vacuum toilet system and both waste streams will be reclaimed for food production, closing the nutrition loop and connecting the building with food forests throughout Boston!

BIO: Chris Benedict is a registered architect with over 30 years of professional experience. Her office, Chris Benedict, R.A., was founded in 1995 and specializes in the design of exceptionally energy efficient buildings. A leader of the Passive House movement in the United States, Chris has designed over 100 apartment buildings in New York City, including a new thirteen story modular Passive House and nine existing buildings that use her ground breaking strategy for meeting Passive House with tenants in place. Chris is a graduate of the Cooper Union where she was inducted into the Cooper Union Hall of Fame. Chris teaches internationally about her groundbreaking work and is a thought leader in the building industry.

----- LUNCH 12:00 PM TO 1:00 PM -----

TUESDAY PM SESSION



Buildings Move, Buildings Leak: Revisiting the Critical Link Between Engineering Mechanics and Enclosure Performance

1:00 pm to 2:30 pm

Jon Porter

"Systems thinking" is a term that is discussed at times in Building Science. But what all does systems thinking require us to consider for the long term viability of enclosure integrity? While the relationship between structural movement and a structure's usefulness to its intended purpose has been well developed throughout the history of design and construction, that understanding has not always translated well into satisfactory enclosure performance.

Drawing on experiences from post-construction forensic investigations, troubleshooting during construction, and efforts to influence design detailing, this presentation will discuss key factors in applying engineering mechanics for the benefit (or detriment) of enclosure performance. Specific aspects to be shared will include the cross-party dynamics in design and construction that give rise to current challenges, case studies of failures as a result of insufficient consideration, and areas for improvement across the design and construction industry.

BIO: Jon Porter is a recovering Structural Engineer who tracks the path of air and water as they wander in places where they don't belong.

For the past 12 years he has been on a quest to perfect his omelet making skills, despite still being mediocre at best.

----- AFTERNOON BREAK 2:30 PM TO 3:00 PM -----



Taking Passive Building to New Heights: Scaling from Single-Family Homes to Multifamily Housing

3:00 pm to 4:30pm

Greta Tjeltveit

Greta's professional journey began in single-family new construction in the Pacific Northwest, shaped by an education in architecture and hands-on construction experience with Habitat for Humanity. This early foundation led her to work as a HERS Rater focused on green building certifications and high-performance homes throughout Western Washington. Over time, her career evolved into building enclosure consulting on new and existing multifamily, senior housing, healthcare, institutional/educational, office, commercial, and high-rise projects. This presentation traces that transition through the lens of her passion for passive building, comparing single-family and multifamily projects across key enclosure and systems considerations, including shape and compactness, airtightness strategies, insulation and thermal bridging, ventilation approaches, owner goals, performance metrics, and risk management.

A central theme of the presentation is how scale, form, and occupancy density influence enclosure and mechanical system design. As buildings become larger, internal heat gains and surface-area-to-volume ratios decrease. This changes the need for aggressively efficient enclosure design. Passive house/building has often been associated with exceptionally robust enclosures—particularly in custom single-family homes where exposure and lower internal gains demand it—but these assumptions can shift as buildings scale up.

Through this lens, the session explores how strategies evolve on larger projects, including changes in airtightness testing methods, lessons from framing factor studies on real-world thermal bridging, and the advantages and challenges of different multifamily ventilation approaches. The discussion also highlights how performance metrics and risk management strategies differ between single-family and multifamily

projects, offering practical insights into how passive building principles translate—and sometimes transform—when moving from houses to high density housing.

BIO: Greta Tjeltveit (“Chelt-vayt”) works as a Building Science Specialist at 4EA Building Science in Seattle, focusing on the design, site review, and performance testing of building enclosures—often aligned with passive building concepts. She collaborates with project teams to develop simple, constructible solutions, performs site testing to verify performance, and has helped verify some of the first Phius-certified multifamily apartment buildings in Washington State. Greta continues to champion passive building throughout the region through her consulting work and service on the Passive House Northwest board.



Clustering Stuff: The Many Benefits of Architecturally Compact Mechanical Infrastructure

4:30 pm to 5:00 pm

Gary Klein

What if it was possible to reduce the volume of water in a building’s plumbing system by 90%? What are the various benefits of doing this? How can this concept be applied to the rest of the mechanical systems in the building? This session will explore the concept of architecturally compact mechanical systems in a variety of occupancies. Share your best examples in advance of Summer Camp so they can be discussed during the session.

BIO: Gary has been in “hot water” since the early 1990s. And he is married and has four children. Any other questions?"

Gary Klein, President of Gary Klein & Associates, Inc. has been intimately involved in energy efficiency and renewable energy since 1974. One eighth of his career was spent in the Kingdom of Lesotho, the rest in the United States. Since the early 1990s he has led the effort to incorporate “hot water as a system” into the core principles of building science. After serving 19 years with the California Energy Commission, he has provided consulting on sustainability since 2008, with an emphasis on the water-energy-carbon-health connection. The benefits of right-sizing premise plumbing and water heating systems, and the building science aspects of installing air-source heat pump water heaters are currently at the top of his list. Klein received a BA from Cornell University in 1975 with an Independent Major in Technology and Society with an emphasis on energy conservation and renewable energy.

The International Association of Plumber and Mechanical Officials (IAPMO) recognized his efforts in 2014 presenting him their Green Professional of the Year award. In 2015 the Department of Energy awarded him the Jeffrey A. Johnson Award for Excellence in the Advancement of Building Energy Codes.

WEDNESDAY AM SESSION



Back to the Future – Installing hydronics and air-to-water heat pumps to get fossil fuels out of buildings

8:30 am to 10:00 am

Galen Staengl

Does it make sense to bring water back into buildings to get fossil fuels out? What are the implications and best practices for hydronic systems? What equipment is available, and what capabilities are available with new and old refrigerants? As engineers try to decarbonize the built environment, we are turning back to hydronics with new air-to-water heat pumps to get the job done. We'll get into the thermodynamics and system issues associated with old approaches and new equipment. Bring your calculators and your propeller hats!

BIO: Galen Staengl is a Mechanical Engineer with a passion for sustainable design. Galen has more than 25 years of experience designing cutting-edge energy-efficient mechanical systems for green building projects. Galen is the founder of Staengl Engineering, a Virginia based MEP consulting firm that provides design and energy analysis for Passive and Net Zero energy buildings around the country. Galen is also a member of the Technical Committee for the Passive House Institute U.S..

----- MORNING BREAK 10:00 AM TO 10:30 AM -----



Designing a Cold Temperature Heat Pump for Air Quality and Comfort Management

10:30 am to 11:15 am

Ty Newell

"Cold climate" heat pumps are relatively new. What technologies allowed us to develop cold climate heat pumps? Do all cold climate heat pumps work the same? This talk will provide a brief historical perspective on today's cold climate heat pumps, and how they are changing today's HVAC systems.

Today's high-performance residences and multi-family units require active air quality management in addition to comfort conditioning, with air quality being the more dynamic and important environmental parameter to control. We'll discuss how the technologies behind Build Equinox's new CERV3 air quality management and comfort conditioning heat pump system meets these challenges.

BIO: Ty Newell is so old his EPA Universal Refrigerant Technician certificate is a cuneiform tablet. He is an emeritus mechanical engineering professor at the University of Illinois and Vice President of Build Equinox, a company dedicated to technology development for healthy, energy efficient, and sustainable living.



Replacing a hydro-air boiler with an air-source heat pump

11:15 am to Noon

Bruce Harley

Bruce was just leaving San Antonio when he got an urgent email from Betsy: "Can you help me decide what heat pump I need to replace a broken gas boiler?". The good news: Betsy had a lot of detailed information about the house. The bad news: "I thought it should be a rather easy exercise"... not. Lots of people who consider a heat pump find a deluge of complex, confusing and conflicting advice. Once you call an engineer, of course, it gets even more complicated. A further twist is that the old boiler fed two hydro-air handlers, and we're trying to heat the house with one air-to-air heat pump. We muddled through and came up with a solution that worked before Bruce even landed. Along the way we discussed the trade-offs in performance of different products the risks of capacity shortfall at cold temperatures, which Bruce will share with you. Hopefully it will help reduce complications in your life.

BIO: Bruce Harley is an engineering consultant focusing on heat pumps, decarbonization and efficient building enclosures. He's been learning to understand heat pumps for over a decade, and translating that experience to help design professionals, policymakers, researchers, utilities, and homeowners understand heat pumps. He thinks heat pumps are cool because they are also air conditioners... and he has an engineer's sense of humor.

----- LUNCH 12:00 PM TO 1:00 PM -----

WEDNESDAY PM SESSION



The Sound of Sausage in Swollen Standard Casings

1:00 pm to 2:00 pm

Nick Hurst

Nick has first-hand experience in the harmony of radon and moisture control. He also thinks we *agreed* about ventilation principles (among other things) long before we *argued* about them. With a little help from his friends, Nick will croon about the flavorful history of ventilation standards and how the building industry can find a unified voice to dispel the hot air we inhale in our perpetual sausage making.

BIO: Nick is a recovering carpenter, serial remodeler, and community-trained musician who has circulated health-seeking institutions (US EPA, ASHRAE, HVI, et.al.) for the last two decades, investigating building science and indoor air.



“The History of the Perfect Wall.....”

2:00 pm to 3:00 pm

Joseph Lstiburek

Joseph Lstiburek will go through a short history of the evolution of the “perfect wall” over the last half century...and where it is going. New products, old products, new thinking, old thinking.

BIO: Joseph is an old Toronto Maple Leaf fan and was alive when they last won the Stanley Cup. Lord Kelvin and Isaac Newton might have been still alive and at the game....