Reimagine Labs Retrofit Insight Briefs

Reimagine Buildings Collective–FALL 2025

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Introduction

This collection brings together our latest set of Insight Briefs created inside the Reimagine Buildings Collective. These briefs emerged from the Reimagine Retrofits iteration of our Reimagine Labs, which took place in the fall of 2025—small, practitioner-led "think and do tanks" where members organized themselves around some of the most urgent questions in deep energy retrofits.

Across these briefs, you'll see a shared focus on delivering high-performance retrofit outcomes at scale, with each Lab bringing a distinct lens to the challenge and remaining grounded in building science and the realities of practice.

Some briefs explore emerging tools and workflows, including the promise (and limits) of AI in retrofit decision-making—especially the need for better shared datasets, clearer governance, and professional judgment to keep outputs accurate and responsible. Others focus on durable, field-ready strategies for resilience, like fire-risk retrofits, passive survivability, and moisture-tolerant, vapor-open assemblies using bio-based materials, with one brief in particular offering a notably thorough treatment of nature-based performance in retrofit assemblies. And some address the constraints practitioners face every day: phased retrofits, sequencing, homeowner education, and the craft of helping clients prioritize comfort, health, safety, and long-term performance alongside energy and carbon.

My hope is that these briefs do two things at once: offer practical takeaways you can use immediately, and invite deeper collaboration so that what we're learning in individual projects becomes shared knowledge the whole field can build on.

What stands out to me most in this work is the quality of attention it reflects. These briefs show a community thinking carefully, questioning assumptions, and testing ideas against real projects and real constraints.

I hope you enjoy reading—and that what's here helps inform your next conversation, your next decision, or your next retrofit.

– Zack Semke
Host, Reimagine Buildings Collective

AI-Enhanced Practice Lab Insight Brief

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AI-Enhanced Practice: Passive House Retrofits

The application of Artificial Intelligence (AI) to Passive House retrofits is a complex and multifaceted field that requires careful consideration of several key areas. First, it is essential to understand the capabilities and limitations of AI, including its potential for natural language interaction, brainstorming, pattern classification, and data analysis. However, AI also has limitations in terms of deterministic calculation and critical judgment, which must be taken into account when applying it to Passive House retrofitting projects.

Large Language Model (LLM)-enabled tools such as Notebook LM and ChatGPT can be useful for tasks like data analysis, information retrieval, and content generation related to Passive House retrofits. For example, Mike prototyped a "field guide to occupied building retrofits" in Notebook LM, which includes information on air barrier products and specific products. Similarly, Sandra uploaded a building assessment report to create a podcast, and Randy developed a video tutorial on 'Recursive Prompting' to describe a method for prompting by successively building on previous results.

When applying AI to Passive House retrofitting projects, it is crucial to consider multiple factors, including energy efficiency, sustainability, and unintended consequences. The group emphasized the need for collaboration, data sharing, and foresight to drive innovation and improvement in the field of Passive House retrofits. Members discussed how AI can help in decision-making processes by analyzing data on various materials, systems, and designs to suggest the most effective retrofits that aspire to Passive House standards. For instance, using data science and AI models to find patterns and relationships in large datasets can be a valuable approach.

To leverage AI effectively in Passive House retrofits at scale, it is necessary to organize and categorize large datasets related to building energy usage, environmental impact, and retrofitting strategies. This could involve creating a database of successful retrofit projects including Passive House using tools like Typeform surveys and Airtable, as well as developing a framework for organizing and evaluating data that includes features like building typology, upgrade recommendations, and output metrics such as carbon savings and energy consumption. Additionally, AI can be used to create synthetic data to help with data management and organization, while addressing privacy concerns.

However, there are also challenges and ethical considerations surrounding the use of AI in Passive House retrofit projects. The group discussed the need for better data organization and integration, as well as the importance of understanding client objectives, climate zones, and building science when retrofitting buildings to address Passive House standards. Professionals must be aware of the limitations of AI models and validate their results to ensure accuracy and reliability. Moreover, there is a concern about AI-generated content being out of context, which highlights the need for nuanced understanding of applicable knowledge areas and liability issues.

Collaboration and knowledge sharing are essential for driving innovation and improvement in the field of AI for Passive House retrofits. The importance of sharing knowledge, experiences, and findings related to AI applications in Passive House retrofits was stressed, including the potential for creating a 'sandbox' for conducting research and trying out different AI tools within the collective. Digital online workshops using net-native tools like Miro and Notebook LM could enable collaborative learning and knowledge sharing, using synthetic or anonymized data to comply with privacy rules.

Ultimately, the effective application of AI in Passive House retrofits relies on understanding its capabilities and limitations, managing and organizing data, and addressing ethical considerations and governance. By acknowledging these aspects, community members can better harness the potential of AI to create more sustainable, energy-efficient buildings that promote Passive House standards and environmentally responsible practices. As we move forward, it is essential to continue exploring the possibilities of AI in Passive House retrofits, including advancing collaborative learning, promoting responsible research and development, and curating a shared platform for enhancing AI and digital literacy across the community of PH professionals.

Fire-Resilient Design Lab Insight Brief

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Blaze Busters - Fire Retrofits

Challenge

To discuss ideas for retrofits to structures as it relates to fire, using varied backgrounds and past experiences.

Top Takeaways

- Statistically ±90% of homes that burn are from wildland fires, ±10% from the inside (cooking, electrical, heating).
- Ideas for protecting the home from the exterior
    - Roofs - thick gauge metal, slate, clay tile, green/live roof
    - Gutters - add a screen over the top of the gutter to protect from material buildup.
    - Windows - tempered glass, aluminum clad, steel.
    - Exterior blinds - protect the windows with metal exterior blinds
    - Siding - non combustible materials, plaster, compressed earth blocks,

ect..
    - Venting - use something like Vulcan vents to help protect structure from sucking in embers. Use this for rainscreens, roof venting, etc.
    - Shape - when designing try to think about ways to design that will not trap or accumulate embers such as inside corners.
    - Sprinklers (exterior) - these have been reported to save homes from burning as they use a foam/water that protects the home when a fire is approaching.
    - Protection Zone - Wildfire defensible buffer zones. Look at fencing and other items that might carry the fire to the structure.
- Ideas for protecting the home from the interior
    - Cooking - maybe think of using induction cooking
    - Sprinklers - use interior sprinklers even if they are not required.
    - Area of refuge - explore ideas about folks exiting structure and if they need more time to get out how might you reinforce the exit path for folks?
- Materials
    - Use natural materials / non-toxic materials as much as possible. If there is a structure fire this will help with mediation and soil toxicity.
    - Avoiding foams- solid gasoline at 27 min

What's Next?

Our group sees clear next steps: creating standardized fire-resilient Passive House assemblies, guidance for integrating biobased + mineral systems, Construction for Deconstruction and insurance-ready documentation packages that help owners demonstrate lower risk.

We look forward to continuing this collaboration with all of you, across the Collective, as webuild a safer, healthier, and more resilient built environment.

Resources

Cascadia Windows and Doors Component Spotlight https://passivehouseaccelerator.com/articles/cascadia-windows-doors-component-spotlight-recap-wildfire-resistance-window-strategies-for-wui-design

Manufacturer spotlight and some pro upvc organizations:
https://livingdesigndoubleglazing.com.au/wp-content/uploads/assets/fire-properties-of-upvc_may-2008.pdf
https://www.vinyl.org.au/pvc-fire
https://threecountiesltd.co.uk/are-upvc-frames-fireproof/

Guidelines and training:
https://www.fire.ca.gov/dspace
https://surefirecpr.com/infographics/california-wildfire-home-safety-checklist/
https://www.upvcwindows.org.au/fire-safety.html

Nature-Based Performance Lab

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Why Bio-Based Materials Create Safer, More Forgiving Retrofit Assemblies

One of the key advantages of bio-based materials in retrofit work is their ability to maintain vapor openness and hygroscopic behavior within wall assemblies. Many existing and historic buildings were originally built with materials that could absorb, store, and release moisture. This inherent moisture flexibility allowed their walls to tolerate imperfect detailing, variable wetting, and the gradual effects of aging, seasonal expansion and contraction, and shifting moisture conditions over the life of the building.

When used appropriately, bio-based materials can make retrofit assemblies less sensitive to sequencing challenges, material mismatches, and partial upgrades. Their vapor-open and moisture-buffering characteristics do not solve every problem, but they can expand the margin of safety in assemblies where maintaining drying potential is important.

Compared with more moisture-restrictive systems, bio-based materials often integrate more naturally with the hygrothermal logic of older walls. This can be especially useful when retrofits must proceed in stages or when only certain walls are accessible or permitted for upgrade. These advantages still depend on appropriate analysis, careful detailing, sound installation, and appropriate indoor humidity management.

This document outlines where bio-based materials offer meaningful advantages, where their benefits are incremental, and how their characteristics interact with the realities of existing buildings. The goal is to give practitioners a clear and practical understanding of how these materials can reduce moisture-related risk when applied thoughtfully.

1. Assessing the Building Before Choosing Retrofit Strategies

Before selecting materials or strategies, every retrofit should begin with a thorough assessment of the building and its context. Existing buildings vary widely in construction methods, moisture behavior, deterioration patterns, and modification history, so understanding current conditions is essential.

A comprehensive assessment typically includes:

Building condition and history: existing materials, previous repairs, visible or concealed water damage, alterations, and past failures.

Exposure and climate: wind-driven rain, freeze-thaw potential, solar exposure, interior humidity loads, and microclimate conditions.

Hygrothermal properties: material permeability, moisture content, capillarity, and drying pathways.

Structural considerations: condition of structural components, including any embedded or concealed elements that may be moisture-sensitive.

Site constraints: access, staging limitations, adjacent structures, and drainage patterns.

Regulatory constraints: historic preservation requirements, code compliance, fire-rating needs, and permitted materials.

Intended use and interior conditions: expected occupancy, ventilation strategy, moisture generation, and mechanical system performance.

Only after understanding these factors is it possible to select appropriate interventions. In some cases, vapor-open, hygroscopic, or capillary-active systems offer meaningful advantages; in others, different approaches may be more suitable. Assessment informs, but does not replace, the selection of an appropriate retrofit strategy.

Addressing Bulk Water Issues First

Before any performance retrofit work begins, all bulk water problems must be identified and resolved. No insulation system, regardless of type, can perform safely if bulk water is entering the building envelope. Common bulk water issues that must be addressed include:

Roof drainage failures: Failing, damaged, or clogged gutters, downspouts, and rain leaders that allow water to cascade down exterior walls or pool near foundations.

Flashing and edge details: Improper or deteriorated copings, drip edges, window head flashings, and parapet caps that direct water into the wall assembly rather than away from it.

Grading and site drainage: Improper exterior slope or grade that directs surface water toward the building rather than away from it, inadequate foundation drainage, or improperly placed downspout discharge.

Wall penetrations: Unsealed or improperly flashed wall penetrations including exhaust vents, electrical conduits, hose bibs, and through-wall mechanical equipment.

These issues cause orders of magnitude more moisture than vapor diffusion or air leakage. Addressing them is not optional preparation for retrofit work; it is a prerequisite. Vapor-open, hygroscopic assemblies can manage incidental moisture and improve drying, but they cannot compensate for ongoing bulk water intrusion.

Interior Moisture Management

While vapor-open assemblies are more forgiving than vapor-closed systems, they are not immune to excessive interior moisture loads. Proper interior moisture management is essential for all retrofit assemblies:

Mechanical ventilation: In cold climates, heat recovery ventilators (HRV) or energy recovery ventilators (ERV) should maintain winter indoor relative humidity below 40-50%. In very cold conditions (outdoor temperatures below 0°F/-18°C), indoor RH should be reduced further to prevent condensation at cold surfaces.

Spot ventilation: Bathrooms and kitchens require dedicated exhaust ventilation regardless of assembly type, as these are the primary sources of interior moisture.

Moisture source control: Address any interior moisture sources such as basement dampness, plumbing leaks, or inadequate drainage before insulating.

These measures apply to all retrofit strategies but are particularly important when using vapor-open assemblies, as excessive interior humidity can overwhelm even the most forgiving moisture management systems.

Repointing and Parging: Essential First Steps for Masonry Buildings

For masonry buildings, repointing deteriorated mortar joints is often one of the most critical preparatory steps before any insulation work begins. Repointing restores the weather barrier, reduces air leakage, and helps prevent bulk water intrusion. In some cases, adding a parge coat—a thin layer of mortar applied to the interior or exterior face of the masonry—can provide additional benefits.

Interior parging can:

- Strengthen deteriorated or soft masonry

- Provide an air barrier layer that improves overall airtightness
- Create a more uniform substrate for insulation installation
- Improve moisture distribution across the wall surface

Mortar compatibility is essential: the repointing mortar and parge coat must be compatible with the existing historic mortar in terms of strength, permeability, and composition. Using mortars that are harder, denser, or less permeable than the original can trap moisture, accelerate masonry deterioration, and cause spalling. Lime-based mortars are generally preferred for historic masonry, as they maintain vapor permeability and allow the wall to continue drying.

Insulating parge coats: When parging on the interior, vapor-open renders with cork or hemp mixed in can add modest insulating value while maintaining breathability. These insulating plasters typically provide R-1 to R-3 per inch, which may be sufficient for mild climates or as part of a hybrid approach. They also help moderate the thermal transition between the masonry and any additional insulation layers, reducing the risk of interstitial condensation.

When insulation isn't feasible: In cases where there is no space available to add insulation on the interior or exterior (due to historic preservation restrictions, ceiling height limitations, narrow lot lines, or other constraints), an airtight insulating parge coat can provide a surprising improvement over doing nothing at all. The combination of reduced air leakage and modest insulation value can meaningfully improve comfort and reduce energy use, even without achieving modern insulation levels. This approach may be the only viable option for some constrained buildings, and represents a practical middle ground between full insulation retrofits and leaving the building unimproved.

Repointing and parging should be completed and fully cured before hygroscopic insulation systems are installed, particularly capillary-active interior insulation.

2. Historic Buildings Were Designed to Dry in Multiple Ways

Traditional buildings (brick, stone, early timber framing, and lime plaster) performed well for centuries because they relied on:

Vapor permeability: assemblies dried in multiple directions.

Hygric buffering: wood, clay, and lime moderated humidity swings.

Air-leakage drying: not ideal by modern standards, but highly forgiving.

Heat-driven drying: older buildings also benefited from a lack of insulation combined with generous winter heating. This allowed heat to move freely through the assembly, effectively "baking out" any accumulated moisture. The combination of air leakage and high heat flow provided a powerful, if energy-intensive, drying mechanism.

When modern retrofits introduce vapor-closed membranes, rigid foams, acrylic renders, impermeable interior finishes, or low-permeance WRBs, they disrupt the building's original moisture pathways. Adding insulation also dramatically reduces heat flow through the assembly, eliminating the heat-driven drying that these buildings historically relied upon. This double disruption is a leading cause of retrofit moisture failures and makes it critically important that retrofitted assemblies are designed with careful attention to air and moisture control, maintaining drying pathways through vapor openness, capillary redistribution, and two-way drying potential.

3. Bio-Based Materials Work With the Building's Original Moisture Logic and Offer Thermal Advantages

Bio-based materials (such as wood fiber, cellulose, cork, straw, hemp, clay, and lime) share the same hygrothermal behavior as historic materials:

- High vapor permeability
- High moisture storage capacity
- Hygroscopic properties that distribute and disperse moisture through the material volume, allowing faster drying than concentrated moisture at a single surface
- No abrupt vapor-control transitions that can trap moisture

- Ability to buffer moisture without creating mold-friendly zones

Because these materials behave like the original structure, they help keep assemblies stable even when work is performed room-by-room, over several seasons, only on certain walls or orientations, or during long, multi-stage retrofit plans. Bio-based materials can help maintain continuity in the building's moisture behavior, potentially lowering risk during staged or partial work when properly designed.

Material Compatibility and Air Barrier Placement

In vapor-open assemblies, the air barrier can be located at the interior surface (service cavity approach), at the sheathing (if using a vapor-open WRB), or distributed across multiple layers.

The key is continuity and compatibility with drying direction. Unlike vapor-closed assemblies where air barrier and vapor barrier are often the same layer, vapor-open systems separate these functions, allowing the air barrier to control airflow while maintaining vapor permeability throughout the assembly.

Critical Limitation: Ground Contact and Capillary Wetting

Bio-based hygroscopic and capillary-active materials must be protected from ground contact and rising damp. While controlled capillary action within insulation materials can help redistribute incidental moisture, the same property becomes a significant liability when materials are exposed to continuous liquid water from below. Capillarity will draw (wick) ground moisture upward through continuous contact, leading to persistent saturation. For exterior continuous insulation (typically wood fiber board), the insulation should be held at least 12 inches (30 cm) above grade, or above anticipated seasonal snow accumulation, whichever is higher, to prevent capillary uptake of ground moisture, splash-back wetting, and prolonged contact with snow melt.

For interior applications, capillary-active insulation must be installed only above the damp proof course (DPC). If installed below grade or in a building with water intrusion in walls, moisture can wick continuously into hygroscopic materials, leading to persistent saturation, salt migration, and potential mold growth.

Before installing hygroscopic materials, assess the condition of walls near grade. Address any rising damp issues through appropriate damp-proofing measures, and ensure proper drainage and grading around the building. Additional detail on this limitation is provided in Section 10.

Beyond Moisture: Thermal Performance Benefits

In addition to moisture compatibility, bio-based materials provide thermal advantages rooted in their physical properties:

Lower thermal diffusivity: Bio-based materials tend to have higher density and specific heat than many common insulation materials, including petrochemical foams, fiberglass, and mineral wool. As a result, they generally exhibit lower thermal diffusivity (meaning they store more heat and release it more slowly), so heat moves through them more slowly. Practically, this can delay and reduce peak heat gain during hot weather, improving comfort and reducing cooling loads.

Improved summer comfort and cooling loads: Because heat flow is slowed, assemblies using higher heat-capacity bio-based insulation experience smaller afternoon temperature spikes, reduce peak cooling demand, and shorten air-conditioning run times. A practical framing: "Same R-value, less AC run time."

Mechanical system impacts: By moderating peak heat flow, these assemblies can:

- Reduce required HVAC capacity
- Decrease equipment and duct sizing
- Potentially help avoid electrical service upgrades

Temperature stability during outages: Slower heat transfer can keep indoor temperatures within a safe range for longer during power outages, reducing risks associated with extreme heat or cold events. The magnitude of this benefit depends on climate, assembly design, and air sealing.

Wildfire resilience: In wildfire-prone regions, the low thermal diffusivity of dense bio-based continuous insulation can provide a protective effect during radiant heat exposure. The high heat capacity and slow heat transfer help shield more sensitive components of the assembly (such as wood framing, sheathing, and membranes) from rapid temperature rise during wildfire events. This thermal mass effect can delay ignition and reduce the likelihood of assembly failure under radiant heat conditions. The degree of protection depends on material density, thickness, and the intensity and duration of heat exposure.

Practical installation benefits: As rigid boards, some bio-based products offer improved support for cladding compared to softer foams, creating flatter siding surfaces and fewer interior disruptions when used as exterior insulation.

Carbon benefits: Bio-based materials typically have significantly lower embodied carbon than petrochemical foams or mineral products. Additionally, many bio-based materials store biogenic carbon that would otherwise be released through decomposition if the biomass were not preserved in buildings. This carbon storage, combined with reduced manufacturing emissions, supports both building durability and climate goals.

Core concept: R-value measures steady-state heat flow. It does not account for heat storage or timing. Bio-based materials, due to their density and heat capacity, can slow heat transfer and shift peak loads without changing nominal R-value. These thermal benefits complement (rather than replace) the moisture management advantages that are the primary focus of this document.

4. Vapor-Open Assemblies During Construction Sequencing

Real-world retrofits rarely proceed linearly. During construction, assemblies may experience temporary conditions that would be problematic in moisture-restrictive systems:

- Incomplete air-seal layers
- Rooms insulated before adjacent spaces are treated

- Elevated indoor humidity before HVAC systems are commissioned
- Portions of the assembly temporarily exposed during sequencing
- Temporary cold bridges
- Uneven moisture loads between construction phases

Bio-based materials can moderate some of these transitional risks because they:

- Offer resilience when portions of the assembly are temporarily exposed or unevenly insulated
- Tolerate short-term moisture imbalances better than assemblies dependent on strict vapor control
- Reduce sensitivity to brief periods of elevated indoor humidity before mechanical systems are fully operational
- Absorb short-term moisture spikes
- Redistribute moisture laterally, avoiding wet spots
- Dry inward and outward, preventing cold-side condensation
- Buffer interior humidity, keeping RH below mold thresholds
- Avoid sharp vapor control transitions

Comparatively:

- Mineral wool + membranes + acrylics: very unforgiving during construction
- Wood fiber + lime + cellulose: more forgiving under certain conditions

5. Common Questions: Why Allow Moisture Into a Wall, and What Keeps These Materials Safe?

A frequent concern with vapor-open, hygroscopic, or capillary-active materials is the idea that they "draw moisture into the building". It is important to clarify what actually happens and why these systems are designed to remain safe under normal conditions.

Do these materials intentionally draw moisture inward?

Not in the sense of encouraging wetting. Instead, they allow moisture that is already present in the assembly (from vapor diffusion, solar-driven inward vapor, or incidental wetting) to move and redistribute rather than accumulate at a single cold interface. This mobility is central to preventing cold-surface condensation and reducing long-term moisture loading.

How much moisture can they safely hold?

Bio-based materials do not remain dry, nor are they intended to. They absorb and store moisture within their pore structure, then release it as conditions change. Within their normal operating range, they can safely take on a considerable amount of moisture without supporting mold growth, because:

- They buffer humidity by spreading moisture through a larger volume
- They remain vapor-open, allowing drying in multiple directions
- They avoid concentrated wetting at discrete surfaces
- The materials used have high safe moisture storage thresholds when not deprived of drying potential

Importantly, mold growth generally requires sustained surface relative humidity above 80%, with higher risk above 70% RH for extended periods. By distributing moisture volumetrically rather than concentrating it at surfaces, bio-based materials help keep local RH below these thresholds.

Will they mold?

Any material can mold if kept wet with no drying pathway. The key difference is where moisture ends up. In vapor-closed or foam-based assemblies, even a small amount of concealed wetting can remain trapped at cold interfaces, creating ideal mold conditions on hidden surfaces such as sheathing, joist ends, or masonry interfaces.

Bio-based materials instead disperse and buffer moisture, reducing spikes in local relative humidity that would otherwise allow mold to grow. They are not immune to mold, but their moisture behavior generally reduces the likelihood of mold-friendly microclimates when assemblies are properly detailed.

What about bulk water?

Bulk water is a problem regardless of insulation type. No material performs safely if bulk water is getting into the assembly. The difference is what happens when moisture intrusion is small, incidental, or unavoidable during sequencing. In restrictive assemblies, even minor wetting can remain hidden and cause significant damage.

In vapor-open, hygroscopic assemblies, minor wetting can be redistributed and dried more safely.

Bulk leaks must still be prevented, but forgiving moisture behavior helps reduce the damage from small, temporary, or unavoidable wetting events.

What about ground moisture and rising damp?

Hygroscopic and capillary-active materials should never be in contact with ground moisture or used in areas affected by rising damp. While these materials safely manage vapor diffusion and minor incidental wetting, capillary action will draw liquid water upward when materials are in continuous contact with ground moisture, causing persistent saturation.

For exterior wood fiber continuous insulation, maintain at least 12 inches (30 cm) clearance above grade, or above anticipated seasonal snow accumulation. For interior applications, install capillary-active materials only above the damp proof course. Rising damp must be addressed before installing hygroscopic insulation systems.

Reservoir claddings: Bio-based exterior insulation should also be avoided or carefully detailed when used behind reservoir claddings (such as brick veneer or stucco) in areas subjected to high wind-driven rain. In high-exposure conditions, these claddings can absorb and hold significant moisture, which may then be driven inward through the insulation during solar heating cycles. When bio-based exterior insulation must be used with reservoir claddings, ensure adequate drainage and ventilation space between the cladding and insulation.

Why accept a material that holds water at all?

Because all assemblies contain moisture, whether through diffusion, air leakage, rain exposure, or interior humidity. The question is not whether moisture is present, but whether the system can manage it safely.

Bio-based materials offer predictable, measurable moisture storage and release behavior, which can support safer moisture management when assemblies are properly detailed. When integrated into assemblies designed for two-way drying, they help maintain stability rather than creating hidden wet zones that are difficult to detect and expensive to repair.

6. Bio-Based Materials Excel in Permanently Hybrid Retrofits

Many retrofits result in permanently hybrid assemblies due to constraints such as:

- Historic partitions that cannot be opened
- Only certain facades accessible for insulation
- Basement and attic work proceeding separately or never completed
- Budget limitations that leave portions of the building unupgraded indefinitely
- Some walls repointed but not insulated
- Others insulated fully inside or outside
- Mechanical upgrades progressing unevenly

Bio-based insulation can offer useful advantages across these conditions when assemblies are detailed and managed appropriately. They can tolerate:

- Uneven air barriers between upgraded and non-upgraded zones
- Differing vapor profiles across the building
- Variable drying rates in different orientations
- Thermal asymmetries between treated and untreated assemblies

This can improve moisture tolerance during incomplete or asymmetrical retrofit conditions, though performance still depends on correct detailing and boundary conditions.

7. Synthetic Materials Require Complete, Well-Coordinated Retrofits

Foams, membranes, acrylic systems, and vapor-closed boards rely on:

- A continuous, perfect airtight layer
- Consistent insulation thickness
- Full thermal enclosure
- Controlled mechanical ventilation
- Uniformly dry masonry

Historic buildings and phased retrofits rarely meet these conditions.

When modern synthetic systems are inserted into uneven, aging assemblies, the risk of hidden condensation, freeze-thaw damage, salt migration, plaster or masonry spalling, and moisture accumulation in voids can become more likely under these conditions. Bio-based assemblies can mitigate some of these pitfalls when they are compatible with the building's original hygrothermal behavior, but they are not a universal solution.

8. Why Bio-Based Materials Are Safer: Moisture Risk Moves Into the Material, Not Onto a Surface

Bio-based systems move moisture into the volume of the material, where it can be stored and re-released. Foams and membranes create single, vulnerable cold surfaces where condensation is likely. Bio-based insulation:

- Absorbs moisture into its bulk
- Redistributes it safely
- Releases it slowly as conditions change

Example: What "Moisture in Volume" Looks Like

Consider a masonry wall with interior insulation during a cold winter day when indoor humidity is elevated:

With closed-cell foam: Vapor drive pushes moisture toward the cold masonry. When it hits the back face of the impermeable foam, it condenses as liquid water on that single surface (the coldest point in the assembly). This hidden surface can accumulate several pounds of water per heating season with no drying pathway, remaining wet for weeks or months.

With wood fiber insulation: Vapor diffuses into the insulation volume, where it's absorbed and distributed through thousands of wood fibers. The moisture is held within the material itself rather than condensing on a surface. As conditions change (outdoor temperature rises, indoor humidity drops), the stored moisture is gradually released and dries inward and outward. No single surface stays saturated.

This is the difference between surface condensation and volumetric buffering.

Why This Matters

Assemblies often fail when a single surface reaches:

- Dew point
- Freeze-thaw thresholds
- Salt crystallization levels
- Sustained high RH

Assemblies perform more reliably when moisture is:

- Stored in a distributed way
- Buffered rather than concentrated
- Able to move toward drying pathways

These characteristics do not eliminate moisture risk, but they can reduce sensitivity to localized failures that might otherwise lead to long-term damage.

9. Phased Retrofits Benefit Most From Bio-Based Materials

Many retrofits proceed in stages due to budget, occupancy, or logistics. Vapor-open, hygroscopic materials can make these transitional periods more forgiving by maintaining some drying potential even when the enclosure is not yet complete. They can be particularly useful when:

- Only parts of the building are ready for upgrade
- Interior spaces must remain occupied
- Exterior work is delayed or weather-dependent
- Certain walls or details will be upgraded later

These benefits still depend on protecting assemblies from bulk water, managing indoor humidity, and ensuring that temporary conditions do not persist longer than intended.

10. Capillary-Active IWI: Safest Path for Interior Insulation of Mass Masonry

Insulating mass masonry from the interior changes the thermal gradient and reduces the temperature of the exterior masonry during winter. This can increase risks such as freeze-thaw cycling, interstitial condensation, moisture retention, and salt accumulation. Capillary-active interior insulation systems can help manage these risks by absorbing and redistributing liquid moisture while remaining vapor-open.

It is important to clarify what "capillary-active" means in this context: these materials can absorb small amounts of liquid water (such as from localized condensation) and redistribute it through their pore structure, allowing it to dry in multiple directions. This is different from bulk water transport; capillary-active materials are not intended to manage significant liquid water intrusion or act as drainage layers.

Recognized capillary-active IWI materials include:

- Calcium silicate boards

- Mineral foam capillary boards
- Dense, plaster-ready wood fiber interior boards
- Autoclaved aerated cellular mineral (AAC) boards

When properly installed, these systems can support inward drying, improve moisture distribution, and moderate humidity at the masonry-wood interface. By maintaining more even moisture distribution, capillary-active systems reduce the concentration gradients that drive salt crystallization at discrete interfaces. This helps reduce the risk of decay in embedded wood members such as joist ends, beams, and ledger boards by maintaining more stable moisture conditions. These advantages depend on inward drying not being blocked by low-permeance finishes. Actual performance depends on climate, masonry condition, detailing quality, and installer familiarity with vapor-open assemblies.

Capillary-Active IWI in North America

Capillary-active interior insulation remains largely unknown in North America, likely due to the historical lack of appropriate materials and limited practitioner experience with vapor-open retrofit strategies. Most North American guidance on interior insulation of mass masonry has focused on preventing inward vapor drive through vapor control layers, rather than managing moisture through capillary redistribution and controlled drying.

With the recent establishment of domestic wood fiber board manufacturing in North America, practitioners now have access to materials suitable for capillary-active IWI applications. This development makes it timely to study and adapt the extensive European research and field experience with these systems. European building science has developed detailed design protocols, monitoring data, and failure analysis for capillary-active interior insulation across various climates and masonry types. Adapting these lessons to North American climate zones, building typologies, and construction practices could expand the range of viable retrofit strategies for the existing masonry building stock.

Critical Limitation: Ground Contact and Rising Damp

Capillary-active and hygroscopic materials must be kept away from ground contact and avoided in areas affected by rising damp. While these materials are designed to absorb and redistribute small amounts of moisture such as from localized condensation, this same property becomes a severe liability when exposed to continuous liquid water from below.

Capillary-active interior insulation should be installed **only above the damp proof course (DPC)**. In buildings without an effective DPC, or where rising damp is present, these systems can wick moisture upward continuously, leading to:

- Persistent saturation of the insulation
- Salt migration and efflorescence
- Damage to interior finishes
- Potential for mold growth in chronically wet conditions

Before installing capillary-active IWI, the condition of the masonry below grade must be assessed. If rising damp is present, it must be addressed through appropriate damp-proofing measures before hygroscopic insulation is installed. In some cases, a capillary break or transition to non-hygroscopic materials may be necessary at the base of the wall.

This limitation applies to all hygroscopic and capillary-active bio-based materials in contact with or near grade, not just interior insulation systems.

11. Conclusion

Bio-based materials are not a universal solution, but they offer meaningful advantages for many retrofit situations, especially when working with older or moisture-sensitive assemblies. Their vapor-open and hygroscopic properties align with the way many historic buildings manage moisture, providing a buffer against the imperfect conditions common in phased or constrained retrofit work.

When NOT to Use Bio-Based Materials

Bio-based hygroscopic materials may not be appropriate in the following situations:

- Buildings with active bulk water intrusion that cannot be resolved
- Contact with or proximity to ground moisture or rising damp (below DPC)
- Behind reservoir claddings subjected to high wind-driven rain without adequate drainage
- Situations requiring very high R-value in minimal thickness, though this is rare in retrofit applications
- Where required fire ratings cannot be met with available bio-based products
- Locations where qualified installers familiar with vapor-open assemblies are unavailable

Cost Considerations

Bio-based materials may have higher upfront material costs than some conventional options, but this can be offset by reduced mechanical system sizing, fewer callbacks, and improved long-term durability. The value proposition is strongest when moisture tolerance, thermal mass benefits, and carbon considerations are factored together.

Importantly, developing demand and building the market for these products will enable producers to scale manufacturing and increase the pool of qualified installers. Market development is the most effective path to bringing costs down while improving product availability and installation quality across regions.

Monitoring and Verification

Where feasible, monitoring temperature and relative humidity at key interfaces during the first heating season can verify assembly performance and provide early warning of moisture issues before damage occurs.

Adapting International Experience

In the United States, availability of bio-based, vapor-open insulation systems has historically been limited compared to Europe, where these approaches have been integrated into research programs and monitored field projects for decades. Dense-pack cellulose has been widely available in the United States, but other vapor-open bio-based products such as wood fiber boards and capillary-active panels have seen far more limited availability until recently. The recent establishment of domestic wood fiber manufacturing and growing interest in lower-carbon, moisture-tolerant retrofit strategies creates an opportunity to adapt proven European practices to North American climate zones and building typologies.

The effectiveness of bio-based retrofit systems still relies on careful detailing, realistic assessment of moisture loads, and an understanding of local climate and building conditions. Successful use depends on evaluating masonry characteristics, expected moisture loads, and the specific constraints of each project. When applied thoughtfully, bio-based materials can expand the margin of safety, reduce the likelihood of hidden moisture accumulation, and support more durable retrofit outcomes.

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Passive Survivability Lab

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In our Lab's Summer Insight Brief, Passive Survivability: No power, no problem? The team defined passive survivability as "the ability of a building to maintain safe thermal conditions in the event of an extended power outage or loss of critical services like heating or cooling."

Threats to occupant health and safety may include:

- Extreme heat or cold
- Fire and particulate matter pollution from smoke
- Flooding
- Wind events
- Electrical grid outages
- Energy shortages

While the problems and challenges with retrofit are similar to those of new construction, the solutions are more challenging; one must work with what is existing, even though the building form or fenestration may not be optimized.

Measures for passive survivability in extreme cold are well-known in the Passive

House community, and have been touted since the polar vortex of 2014: Passive House designs act as thermal batteries and keep the occupants warm for days or even weeks. A retrofit to EnerPHit standards will not hold the heat as long as new construction, but is still going to be obviously better.

Measures for dealing with fire and particulate matter are not dissimilar from new construction: air tightness and heat or energy recovery ventilators with MERV 13 filters.

The major difference may come in the ability of retrofits to manage the threat of extreme heat.

Most of our existing houses and buildings were designed for cooler environments, in a time where the threat to occupant health tended to be extreme cold; they are poorly suited for dealing with extreme heat. In many cases, extreme heat has been discounted as a cause of death; according to Kristie Ebie of the University of Washington:

“The CDC’s estimate of heat deaths, about 1,200 Americans a year, is probably at least a tenfold undercount. An estimate from several years ago was that, in the U.S., there are actually in the range of 10,000 to 12,000 heat-related deaths, and that is likely higher today.”

A recent study also notes that because of climate change, what might have been considered a tough heat wave a few years ago will be far worse in the future. “While mitigating further global warming can reduce heat mortality, mass mortality events remain plausible at near-future temperatures despite current adaptations to heat.”

Our team was concerned that in many retrofits, the risks of extreme heat are not being given enough consideration. More thought should be given to:

- Exterior shading devices can reduce heat gain. Active exterior shading, as is often used in Europe, can also protect windows from flying objects in storms.

- Color and material selection can reduce heat gain. Certain roofing materials can promote radiative sky cooling.
- Envelope materials and system replacements should prioritize supporting energy generation system and anticipate future climate impacts NYC Climate Resiliency Design Guidelines (i.e. windows, roofing materials, elevating mechanical equipment, increased wind speed)
- Attic and roof venting should be examined to ensure that firebrands cannot enter.
- Consideration should be given to battery backup for ERV systems to ensure a fresh air supply.
- "Safe rooms" or refuge spaces equipped with active cooling or dehumidification may be an option, as air conditioning the entire dwelling may draw too much power.
- Local policy, building code regulations and zoning restrictions that support addressing these concerns

The key conclusion of the group was that passive survivability is a well-understood benefit in a retrofit when it comes to cold and smoke, but the challenges from excessive heat have not been given enough consideration, and may well become the dominant issue in the future.

Resources:

In Warming World, Global Heat Deaths Are Grossly Undercounted
https://e360.yale.edu/features/kristie-ebi-interview

Increasing risk of mass human heat mortality if historical weather patterns recur
https://www.nature.com/articles/s41558-025-02480-1

NYC Climate Resiliency Design Guidelines
https://www.nyc.gov/assets/sustainability/downloads/pdf/publications/CRDG-4-1-May-2022.pdf

Phased Retrofits–Single Family Lab 1

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Guideline for Retrofitting Single Family Homes

Goal

Enable homeowners to achieve comprehensive, high-performance retrofits through strategic phasing that maintains building science principles while working within real-world constraints.

Challenge

How to help homeowners understand and implement phased retrofits that address critical building science requirements while balancing budget constraints, avoiding costly sequencing mistakes, and navigating complex interdependencies between building systems.

I. The Assessment-First Process

Key Principle:

Comprehensive building assessment must precede any retrofit planning. Understanding existing conditions is the foundation for all successful phasing decisions.

Critical Pre-Retrofit Diagnostics:

- Moisture and bulk water control evaluation (highest priority)
- Blower door testing to measure air leakage
- Wall assembly inspection and insulation assessment, including thermal imaging to identify thermal bridging and insulation gaps
- Window and door evaluation
- Attic and roof inspection
- HVAC system assessment
- Radon testing (especially critical when tightening the envelope)
- Building systems and equipment end-of-life and replacement cycle

Priority #1: Moisture Management

Before any other retrofit work begins, moisture and bulk water control issues must be addressed. Tightening a building envelope without first resolving moisture problems can create serious health and structural issues.

In a retrofit, use modeling to verify the effect of adding air infiltration control and insulation to the existing building envelope. Verification of proper design will avoid creation of future moisture problems in wall and roof assemblies.

II. Framework for Phasing Decisions

Establish the Complete Vision First

Create a comprehensive retrofit plan for the entire building before determining how to phase the work. This complete roadmap ensures that each phase builds logically toward the final goal, early decisions do not create obstacles for later work, and homeowners understand the full scope and cost trajectory.

Key Factors Affecting Phasing Strategy

- **Equipment End-of-Life Timing:** Assess when major building components and systems will need replacement regardless of energy improvements. Retrofit work should align with these natural replacement cycles when possible.

- **Budget Constraints and Flexibility:** Understand both current budget limitations and potential future funding sources. However, avoid letting short-term budget pressures force sequencing that will create higher long-term costs.
- **Sequencing Dependencies:** Some improvements must happen before others to avoid rework and wasted investment. Most critical: envelope work creates dependencies for all mechanical systems.
- **Lifestyle Considerations:** Homeowner tolerance for disruption varies significantly. Some prefer to complete work quickly; others need to phase over many years.
- **Physical Constraints:** Existing building geometry, structural limitations, and site access may constrain what can be done and when.
- **Regulatory Constraints:** Local historic preservation requirements, code restrictions, and permitting processes may dictate certain approaches or timing.
- **Homeowner Priorities:** While homeowners initial priorities may not align with building science best practices, understanding their concerns helps frame the education process.
- **Standards Evolution Risk:** For multi-year retrofits, building codes and certification standards may change during the project timeline.

III. The Envelope-First Principle

Critical Finding:

For most single-family retrofits, Phase 1 should focus on completing the ENTIRE building envelope.

Why Complete the Envelope First?

- Envelope improvements dramatically change heating and cooling loads
- Partial envelope work makes it impossible to accurately size mechanical systems
- Installing new HVAC before completing envelope work often means replacing or modifying that HVAC later—a costly double investment
- Envelope work creates the sealed, insulated shell necessary for efficient

mechanical system operation
- Completing envelope work establishes accurate performance baselines for future phases
- Ventilation system sizing, layout, and installation should be coincident with envelope remediation to avoid air quality issues.

Systems That Cannot Be Effectively Phased:

- HVAC equipment (load calculations depend on final envelope performance)
- Ventilation systems (require complete envelope air-sealing to function properly)
- Some window and door configurations (partial replacement creates air-sealing challenges)

IV. Professional Engagement Strategies

The Integrated Team Approach

Successful phased retrofits require coordination among multiple professionals:

Lead Designer/Consultant Role:

- Architect or building science consultant should lead overall planning
- Conduct or coordinate comprehensive diagnostics
- Develop the complete retrofit plan
- Create phasing strategy based on building science principles
- Educate homeowners about performance implications
- Coordinate contractor input during planning

Contractor Engagement:

Challenge: Contractors may be reluctant to provide input without guaranteed work

Solution: Consider paying for contractor consultation during design phase

Benefit: Early contractor input identifies constructability issues and refines cost estimates

Independent Assessments for Critical Issues:

For issues like mold, use independent licensed inspectors with building science expertise:

- Avoid conflicts of interest—inspection and remediation should be separate companies
- Proper inspection tools include thermal cameras, moisture meters, and borescopes
- Mold assessment requires understanding of building systems, not just visible growth

Finding Qualified Professionals:

Vet contractors and consultants through professional organizations (such as Passive House professionals, building performance associations), specialized certifications, references from similar projects, and demonstrated understanding of building science principles.

V. Homeowner Education

Bridging the Knowledge Gap

Homeowners typically have superficial priorities based on visible problems or immediate comfort issues. Professional consultants must educate them about hidden performance problems revealed through diagnostics, long-term implications of poor sequencing decisions, cost-benefit analysis of different approaches, and when phasing may not be appropriate.

The Role of Diagnostic Reports

Comprehensive assessment reports serve as educational tools that make invisible problems visible through data and imaging, establish baseline performance metrics, demonstrate the interconnected nature of building systems, and justify recommended approaches with evidence.

When to Recommend Against Phasing

Be prepared to advise homeowners that phasing may not be appropriate when:

- Critical moisture or structural issues require immediate comprehensive action
- Budget constraints would force sequencing that creates higher long-term costs
- Building conditions make partial work impossible without major rework
- Homeowner goals cannot be achieved through incremental improvements

VI. Critical Safety Considerations

Ventilation and Indoor Air Quality

Tightening the building envelope without addressing ventilation creates serious health risks, including increased indoor pollutant concentrations, elevated moisture levels leading to mold growth, potential for backdrafting of combustion appliances, and radon accumulation.

Therefore: Envelope air-sealing work must be coupled with ventilation strategy, even if full mechanical ventilation installation is phased to a later stage.

Mold Prevention

Phased retrofits create special mold risks: partial insulation can create new condensation planes, changed vapor profiles may activate moisture problems in un-retrofitted assemblies, and improved airtightness without ventilation increases moisture levels. Mitigation requires careful attention to moisture management throughout all phases.

VII. Measuring Progress

Performance Verification

Each phase should include performance testing:

- Blower door testing after air-sealing work
- Thermal imaging to verify insulation effectiveness
- Indoor air quality monitoring
- Moisture readings in critical assemblies

Documentation

Maintain detailed records of baseline conditions and diagnostics, work completed in each phase, performance testing results, lessons learned and adjustments needed, and updated plans for remaining phases.

VIII. Conclusion

Successful phased retrofits in single-family homes require:

1. Comprehensive assessment before any planning
2. Complete retrofit vision established upfront
3. Envelope-first sequencing in most cases
4. Professional leadership from building science experts
5. Homeowner education about long-term implications
6. Careful attention to moisture, ventilation, and safety
7. Performance verification at each phase
8. Flexibility to adjust plans based on findings

The key insight: Phasing is about SEQUENCING complete work, not about doing incomplete work in pieces. Each phase should leave the building in a stable, functional state while setting up success for the next phase.

retrofits over time without the costly mistakes that come from improper sequencing or inadequate planning.

Phased Retrofits–Single Family Lab 2

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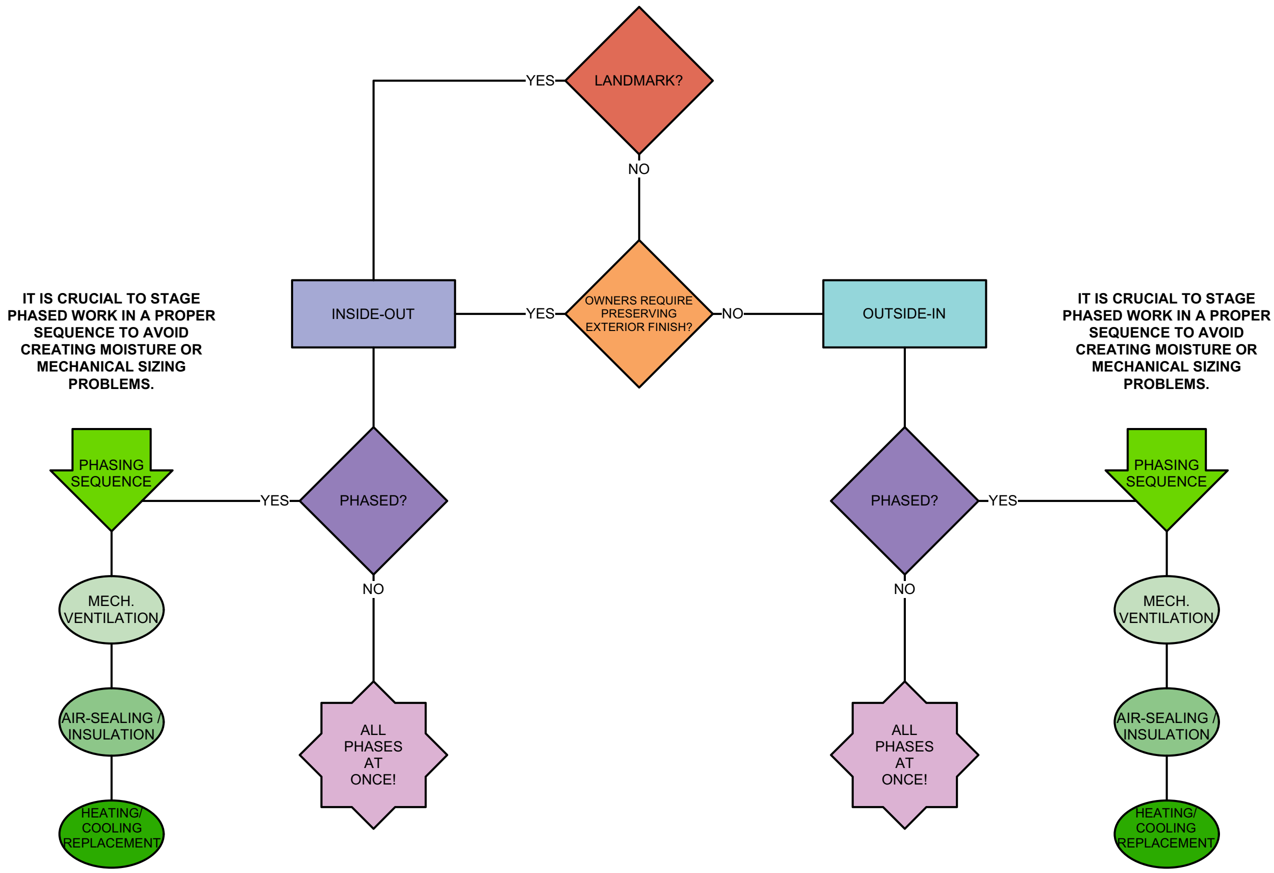

Selling Passive House Lab

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- *Paul Herron - Principal and Founding Member of Sage Craftsmen, LLC*
- *Michael Ingui - Architect, Artist, and Founder of the Passive House Accelerator*
- *James Turner - Marketing Consultant and host of the Marketing Passivhaus podcast*

The Challenge

Our culture has trained people to believe they can have whatever they want; all they need to do is throw more money at it. People are being told (by realtors, for example) that if they don't include features like a gas range and a wood-burning fireplace, they won't be able to sell their house.

The biggest challenge we face in selling Passive House Retrofits is that the metric most people focus on is Return on Investment (ROI). If we want to sell Passive House, the ROI cannot be measured in just dollar terms; we've got to include the client's priorities.

And so, the issue is not so much about Selling Passive House as it is about determining what Selling is. The premise of "finding the pain" is that people buy emotionally and justify intellectually. As proponents of Passive House, we tend to come in passionate, leading with our selling points in an intellectual way. We don't typically take the time to first find out the true emotional reasons why our potential customer is sitting in front of us.

Top Takeaways

1. Clients don't come into the project knowing the benefits of a true, fabric-first Passive House retrofit. Once they do, and they realize that upgrading systems without upgrading the envelope will result in less-than-optimal comfort and high heating or power bills, they don't push back.

2. If you're fixing something in your home, that's the ideal time to improve it. No one who has done a major renovation wants to do it again. The trick is to build it back better. Don't just bring it back to how it was; make it so you won't have this problem again.

3. No client is going to come to you asking to solve their carbon footprint problem. They all have pain points in their existing homes and buildings. To find out what they do want, you have to LISTEN! And then, when it's your turn to talk, speak in clear, plain language – the language your customer uses – not too technical and without any industry jargon.

4. Comfort is generally the top driver. Show clients what they can have – fresh air, quiet, and no bugs. Do this by painting a picture, like Michael does in a recent article for Green Building Advisor:

> "It's a frigid November morning in New York City, during an early-season polar vortex event sweeping down the Atlantic coast. The outside air temperature is a chilly 38°F. At 7:30 a.m., it is still dark, with no solar heat streaming through the glass. Inside my Passive House townhouse in Brooklyn, however, the temperature sits comfortably at 68°F.
>
> The part that still feels magical, even after nearly a decade in the home, is that our thermostats are off. We haven't had to turn on the heat, despite the low exterior temperature."

5. When clients are fixated on getting exactly what they want, the best we

can hope for is to incorporate as many energy-saving and health-improving elements as possible. (As opposed to just saying “find another architect, sorry.”)

What’s Next?

Selling Passive House, whether new or retrofit construction, is more about the art of listening combined with the patience to ask questions that help a customer express their true desires, beyond the initial references to cost, style, and even “sustainability”.

The quality of life, security, and comfort that Passive House can provide is of universal appeal. People don’t need to be sold on these points. They already want them. Our job, then, is more about connecting the dots. It’s about counseling, facilitating, and, finally, educating. We have the goods. The field is built. They will come.