Passive Building Design Guide

Passive House Institute US

FOR DEVELOPERS, INVESTORS & CONSTRUCTION PROFESSIONALS

MULTIFAMILY CONSTRUCTION

ACKNOWLEDGEMENTS

We would like to thank the MacArthur Foundation for making this design guide and its associated website, the Multifamily Construction Resource Center (www.multifamily.phius.org), possible.

Through these new resources, they do vital work building a more just verdant, and peaceful world, specifically through slashing the effects of global climate change. We thank them for their investment and commend them for acting locally on issues with global implications.

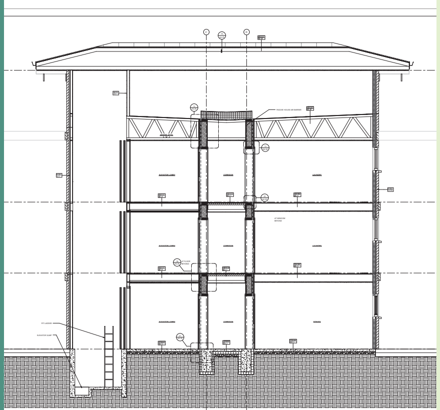
We would also like to thank all of the people who worked with us to put this guide together. Their help tracking down photos, photo credits, providing technical insight, and inside information was invaluable and has made this a better book. Among the people who dropped everything to help: Sam Rodell, Erin Cooperrider, Dylan Lamar, Matt Fine, HousingUp, REACH CDC, Community Housing of Maine, Tinsley Morrison, Vickey Rand, Ben Walter, Colin Schless, Michael Hindle, Steve Bluestone, Hammer and Hand, Ben Bogie, James Hartford, Hank Keating, and last—but not least—Sloan Ritchie.

Passive Building Design Guide: Multifamily Construction

PHIUS
Passive House Institute US

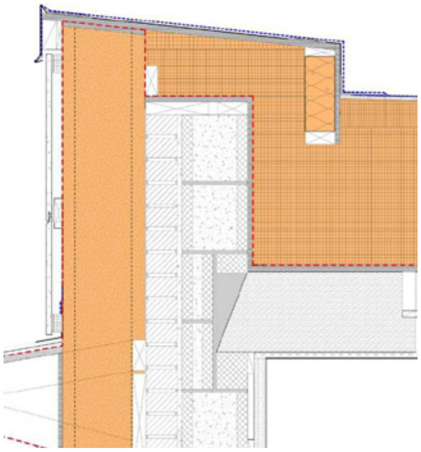
CONTENTS

10 *Great windows make rooms bigger.*



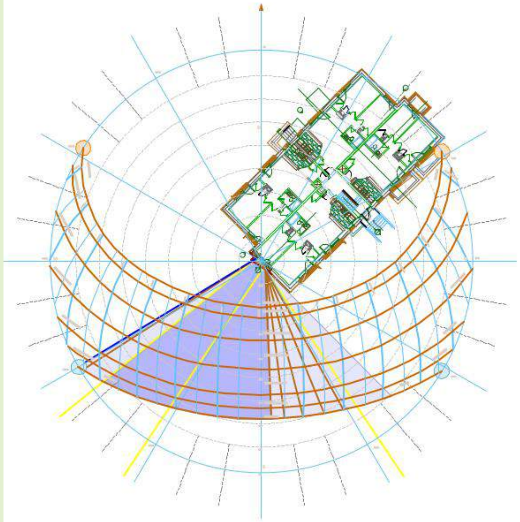
28 *A tight envelope with an elevator inside.*

44 *Cost, certification, resilience, and ventilation are top queries.*



6 *Detail drawings eliminate weak links.*

13 *There are many paths to high performance.*



42 *Choose your windows early in the process.*

INTRODUCTION

Welcome to the Passive Building Design Guide for Multifamily Construction

When we began the Passive House Institute US in 2007, we focused primarily on houses, because that's primarily what we designed and built for a living. As we moved into multifamily and commercial projects, we realized that it works much better on larger projects, especially after closely tailoring the building to the climate it sits in. The 2015 Climate Specific Passive Building Standards are the result of deep research and improvements to the old passive-house model of construction. The standards represent the most cost-effective way to extremely low energy use.

This guide is loosely divided into three sections. Chapters 1 and 2, Passive Building Fundamentals and Passive Building Benefits, cover the basics. The second section explores real-world experiences of developers, architects, and building owners. In Passive Building Works for All Building Types, we dispel some notions about whether passive building can scale to multifamily (it can). Next, we look more closely at examples of PHIUS+ buildings in the real world: a retrofit project for formerly homeless and at-risk of homelessness people; a new development focused on community integration , affordability, and carbon responsibility; and an affordable housing apartment complex with an unconventional hoop to jump through. The last part of the guide walks you through the pathway to PHIUS+ certification (Six Steps to PHIUS+ Certification) and answers any of your lingering questions (Frequently Asked Questions). Of course, if your question isn't answered in this guide, there is an easy way to get it answered: Contact us at multifamily@passivehouse.us.

I hope you'll consider incorporating PHIUS+ into your next building project. As you'll learn in this guide, the result is a superior building for occupants and owners that does not necessarily cost more to develop and build.

Data that is coming in from completed projects shows the accuracy of the modeling software to be remarkable—energy use is frequently within about 10 percent of what the model predicts, which is substantially more accurate than other energy-use predictions that you may come across.

For more info on passive building, at the end of the guide is a substantial resource list, but don't stop there—you can also dig into the Multifamily Resource Center, the Commercial Construction Resource Center, and phius.org. In the meantime, subscribe to the PHIUS newsletter for breaking news, info, and new certified projects.

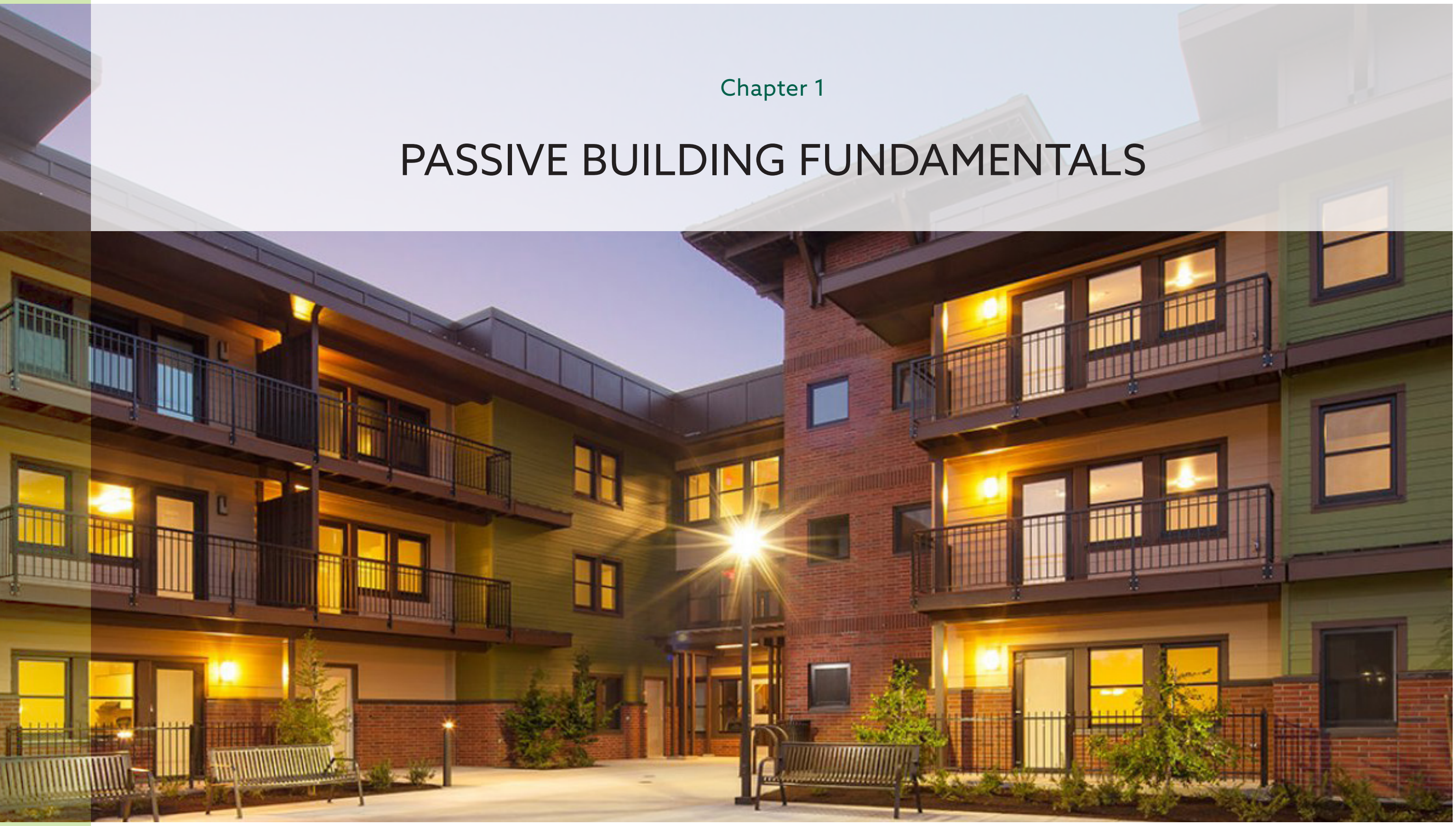
Thank you for your interest in PHIUS.

Sincerely,

Katrin Klingenberg
Executive Director, Passive House Institute US

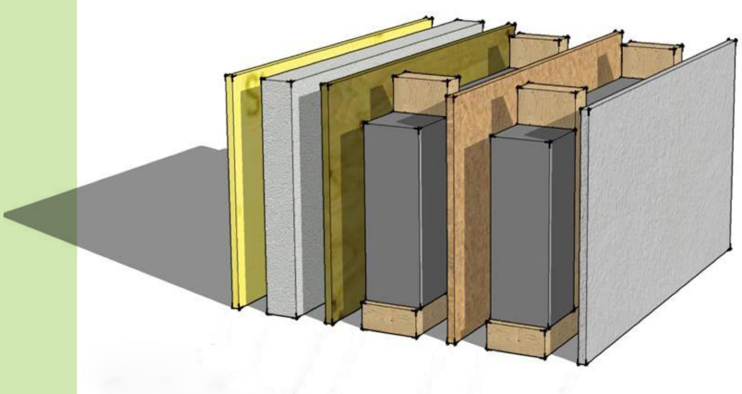
Chapter 1

PASSIVE BUILDING FUNDAMENTALS



Passive building is based on science and experience

The building blocks of passive building come from the same building blocks as North American energy standards like Energy Star, LEED, and the Department of Energy's Zero Energy Ready Home designation, because you can't argue with physics. Those individual programs move buildings incrementally closer to energy efficiency. Passive building certification though PHIUS is a direct route to net-zero building that is substantially more comfortable, durable, healthful, and predictable than partial measures cobbled together. Fast-forwarding past the physics of passive building, it boils down to five building science principles:



An indoor/outdoor approach to thicker walls.
In this retrofit, Hammer and Hand added a stud wall inside the building and a layer of foam outside.

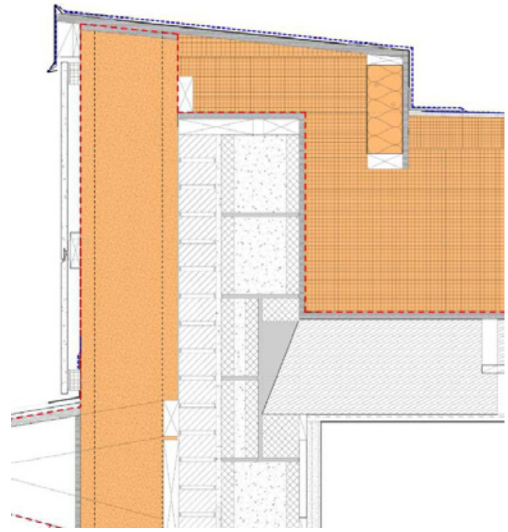
1 Continuous insulation interrupts thermal 'bridges' between inside and out

By completely wrapping a building with insulation, heat can no longer sneak out through framing, which has a lower R-value than the surrounding insulation. Masonry chimneys that connect inside and out are another often-overlooked thermal bridge. In multifamily housing, cantilevered concrete balconies inadvertently transform high-rise buildings into giant radiators. The simplest way to fix all of those energy sieves is to avoid building them in the first place. Continuous, thick insulation on the outside of a building keeps heat flow to a minimum.

2 Airtight construction stops heat and moisture

While thick, continuous insulation can stop a significant amount of heat loss through conduction, plugging air leaks can slow heat flow, too. Because temperature drives air movement—think about convection loops—the air moving through buildings usually carries a lot of heat with it.

And here's the rub: Warm air can hold more moisture than cold air. So when warm air leaks through electrical outlets into exterior walls, it dumps moisture into wall cavities when the moist air hits the cold wall sheathing. It happens in winter and summer, only in reverse. Air-conditioned buildings are cooler and drier than outside air, so hot, humid outside air is sucked into walls, where it dumps moisture on the paper backing of the drywall. Paper backing on drywall makes terrific mold food, by the way. There are a lot of holes, gaps, and cracks in typical buildings that can add up to cause a lot of hidden rot problems while also wasting energy.



Detail drawings eliminate weak links in logic. Plan sets that have extensive detail pages show tradespeople how to execute critical details in the field.

Swinging windows are tighter. Casement and awning windows seal more tightly against air leaks than double-hung windows do. Triple-glazing and low-e coatings keep heat where you want it.

3 Optimized windows keep heat in—and out

Windows have a terrible job description: Plug a hole in the wall; stop air, water, and heat; open and close; look good; and be transparent. Some are even supposed to be shatter-resistant. Of all these demands, stopping heat flow is the most difficult to achieve because glass has an extremely low R-value. Typical Energy Star windows do this with double-glazing and argon gas, but passive buildings usually use triple-glazing.

However, heat flow does not stop at conduction. A lot of heat can pass through windows by radiant transfer. Free heat in winter is welcome because it lowers the work a heating system must do. Free heat in the summer is the opposite: It makes the air-conditioning system work harder.

Low-e coatings applied to the surface of the glass can block radiant-heat transfer, keeping it in or out, depending on the temperature gradient. They can also be fine-tuned to allow a particular amount of heat gain. These coatings are categorized according to their solar heat gain coefficient (SHGC). High SHGC windows should be used on sides of the house where winter sun is wanted, generally on the east and south. Low SHGC windows should be used where summer sun will do the most harm, generally on west-facing windows.

The appropriate window depends on your climate zone; cold climates need well-insulated windows because the temperature extremes are significant. Hot-climate windows typically have strong radiant-heat blockage because the sun is intense in hot climates.

A tight line of mechanical equipment. When the money is spent overcoming the need for monstrous mechanical systems, the resulting systems fit in a corner of the basement and work as expected.

4 Balanced ventilation ensures fresh air—and controls moisture

Airtightening means that dirty, moist air isn't leaking into the living space from basements and loading docks, which is good. It also means that stale indoor air is not leaking out, which is bad. Air changes must be controlled with some sort of high-tech fan. One option is an energy recovery ventilator (ERV), which pulls new air in and pushes old air out while transferring heat and moisture in the process.

A constant flow of fresh air flushes the living space without pulling in hot, cold, or wet air that the HVAC system must then condition.

5 Minimal mechanical is all a super-tight building needs

Because the building is supertight and superinsulated, and has super windows, a super-size heating and cooling system is unnecessary. The mechanical system is where the upfront investment begins to pay off because mechanical systems can get expensive. Some of the money that was spent upfront on insulation and windows can now be recouped with a much smaller mechanical system. In single family homes, this can add up to attractive savings, and in multifamily and commercial buildings, the savings compound quickly. In fact, a 58-bed long-term health-care facility in Spokane, WA, cost less to build ($132/square foot) than typical built-to-code construction (see example 2, page 25).

LESSONS LEARNED Comprehensive stability for our residents

Our primary benefit is the health and comfort of the residents. The building envelope and continuous filtered ventilation provide the highest quality indoor environment.Lower operating costs make Weinberg Commons affordable both for us (the building owner) and for the residents. To continue to make truly affordable housing, we must cut residents' operating costs and the improve the healthfulness of the homes.

—Project team, Housing Up

Chapter 2

PASSIVE BUILDING BENEFITS

A living example of achievable excellence. Designed for comfort, affordability, and occupant health, the Elm Place apartment building in Milton, VT, is expected to use 60 percent to 70 percent less energy than a comparable building of the same type and size in the Northeast.

A better building that's more predictable and affordable to operate—at little extra cost

Passive-house certification is often cited as the most aggressive energy-efficiency standard available. That is correct. Passive building set out to define a rigorous energy-efficiency standard for buildings as a way to reduce the ecological footprint of the construction sector. This was achieved through superinsulation, super airtightness, super-efficient windows, meticulous control of plug and lighting loads, and some unconventional—and often overlooked—space heating (taking advantage of waste heat from lighting, appliances, and people).

All of this is great news for the people who pay the energy bills, but it's also a big plus for the planet: Buildings represent about 40 percent of carbon pollution, so buildings also represent about 40 percent of the solution. That's a lot of power in the hands of building professionals. PHIUS+ certification is the best way for building professionals to take control of the carbon footprint of their buildings.

Passive buildings have clean indoor air

Beyond energy efficiency and carbon reduction, passive buildings also deliver superior living conditions via indoor-air quality and comfort. Because outdoor air doesn't leak in and indoor air doesn't leak out, building operators have much more control over the interior conditions. Because tight buildings have dramatically less air exchange with the outside, they are frequently blamed for causing mold or indoor-air pollution. "Buildings need to breathe" is a common refrain in conversations about sick buildings, but it is a bad analogy. The thought behind the phrase is that buildings need fresh air that can replace polluted or moist air that cannot escape a tight building. Actually, buildings don't need to breathe; people do.

Buildings must be able to exchange old stale air for clean, fresh air so that the people inside can breathe.

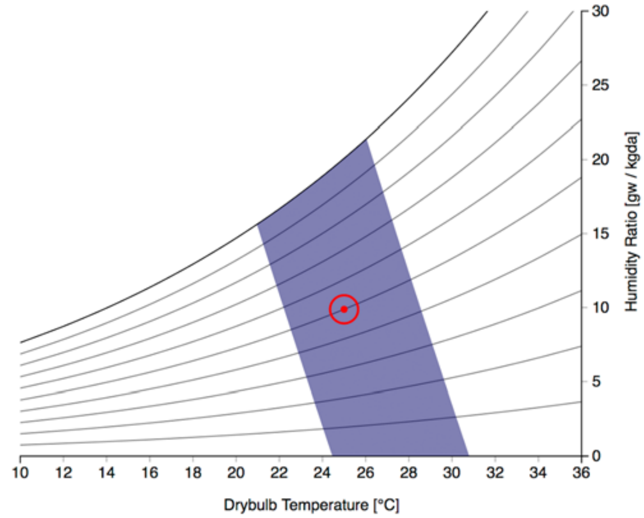
Leaky buildings exchange air accidentally through random holes in the walls, roof, or basements, where there may be soil gases, musty air, or even dead rodents. Tight buildings control where the fresh air comes from and how much of it is drawn in, allowing building operators to dial in indoor-air quality (IAQ) for people who actually breathe inside the building.

Superinsulation and tight construction make buildings comfortable to be in

Comfort can seem like a vague term, but there is actually a way to measure it. Not surprisingly, the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has a chart for it.

Comfort is highly subjective because every individual has slightly (or drastically) different tastes. Personal comfort zones can vary seasonally as well. ASHRAE's chart plots temperature against humidity to isolate a zone within which most people will be comfortable.

One thing everyone can agree on, though, is that a passive building delivers superior comfort. It is not too hot, cool, drafty, clammy, or humid. Many occupants find that indoor temperatures well below what they think they need are surprisingly comfortable in a building that doesn't leak. Because people are accustomed to thermal striations and drafts, they think 65 degrees is too cool in winter and are accustomed to keeping the thermostat at 70 or 72 degrees. But when experiencing interior air in a passive building



Comfort is relative, but not nebulous. This chart illustrates what 90 percent of people find a comfortable balance between heat and humidity. As temperature increases, people find humidity less tolerable. The test method is defined in the ASHRAE 55 Standard.

Hip, healthy, and high-tech. Marmoleum flooring and low-VOC materials are utilized throughout the project. The design and layout of the interiors are more modern and are influenced by the tech community in the area. Conditioning is by a wall-mount ductless minisplit.

Great windows make rooms bigger. Because the indoor temperature in PHIUS+ units is stable, people can enjoy the view by sitting close to windows without getting hot or cold. The 'usable space' within the 'living space' grows and occupant satisfaction goes up.

that is a consistent 65 degrees, they are surprised by how comfortable they are.

Passive buildings are extremely comfortable in all seasons, and yes, passive-building owners can open their doors and windows on spring days, just as they would in a conventional building.

Mold is bad for buildings. It's a good thing passive buildings are mold-free.

Many typical maintenance chores result from some sort of moisture damage—exterior painting or cleaning, bulk water leaks at windows and doors, high interior humidity that fosters mold or mildew growth—but floodwaters notwithstanding, it is not really liquid water that destroys buildings. It is the mold and decay fungi that follow it and deteriorate the building materials. Because of the careful hygrothermal (heat/moisture interaction) modeling and quality assurance and control that are central to PHIUS+ certification, moisture problems are never present in PHIUS+ buildings.

PHIUS+ certified builders understand the science behind the building, so bulk water problems from construction defects are equally rare. Buildings without water problems are more durable, require less maintenance, and last longer than conventionally built structures. This means lower operating costs, fewer disruptions for occupants, and fewer headaches in general for building owners and operators.

The premium for PHIUS+ is negligible

Early in the passive-building movement, it did indeed cost more to build this way. Eight percent to 10 percent premiums were commonly reported. These higher prices were quickly qualified with lower operating costs as a way to recoup the initial investment in the passive-building process. Also, passive building was never developed as a way to save money in the construction process. It was developed as a way to minimize the ecological footprint of the construction sector.

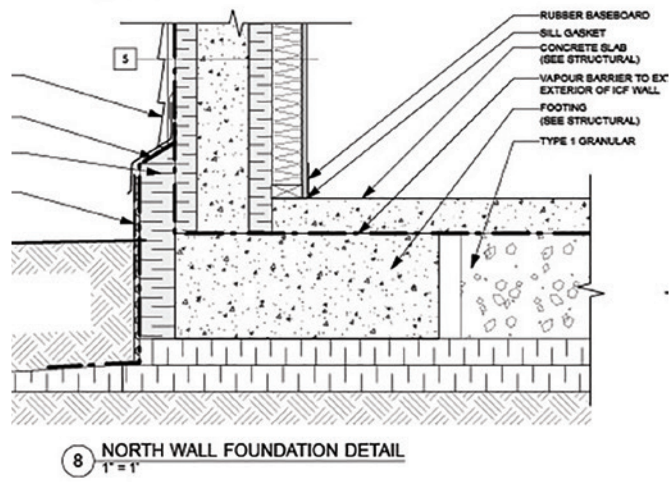
PHIUS+ 2015 tailors construction details to the climate zone. That means not spending money on things that are not needed to achieve the desired performance. The result is a building that is cost-optimized for its climate. One cliche is about how much insulation to put under a slab. Just because it makes sense to put 10 inches of insulation under a slab in Chicago (heating demand: 6.2 kBtu/sf/yr, cooling demand 3.2 kBtu/sf/yr), it does not make sense to put that much insulation under a slab in Houston (heating demand: 2.1 kBtu/sf/yr, cooling demand 13.3 kBtu/sf/yr). Consequently, builders in Houston can spend less on subslab insulation and retarget the money to cooling strategies, which is much more important in that climate zone. Buildings certified under the German PHI standard, which has not been cost-optimized for North American climates, still require the same amount of subslab insulation everywhere, so they cost about 8 percent more to build, while PHIUS has dropped to less than 3 percent.

Construction savings scale up extremely well in PHIUS buildings

Single-family homes tend to cost more to build to passive standards, but larger multifamily and commercial buildings can deliver much better results. The health-care facility mentioned earlier actually cost less to build to PHIUS+ than an equivalent built-to-code facility would have cost because of tremendous savings on HVAC equipment. “The payback,” architect Sam Rodell says, “is either spectacular or irrelevant, depending on how you look at it,” because the term “payback” implies some sort of extra investment.

Rodell is not alone. Many developers presenting at the 2017 North American Passive House Conference reported cost premiums in the 3 percent to 5 percent range, with some seasoned veterans coming in around 2 percent. A high-end 30-unit affordable senior living facility, Elm Place in Milton, VT, reported a 2 percent premium—mostly due to the fact that the construction team was very experienced in passive-building. Steve Bluestone, a developer in New York City who builds with insulating concrete forms (ICF), reports premiums of about 1.5 percent largely due to the intrinsic airtightness and continuous insulation of ICF construction.

Scaling efficiency is not just about magic products; it is also a product of simple math. As buildings get larger, surface-to-volume ratios decrease, and thermal envelope targets become easier to hit. Unintuitively, walls need less insulation in a large building than in a smaller one (if the insulation is continuous). Single-family homes built to Passive House



Subslab insulation is important, but... Different winter clothing is needed in Minneapolis and Houston. People choose clothing based on climate, just like PHIUS+ decides insulation levels based on climate zone.

A thermal cushion for a building to sit on. Six inches of insulation is installed along with plumbing rough-in before the slab is poured for Sunshine Health Facilities' new administration building in Spokane, WA.

People see the finishes first. When people are asked what they like about an apartment, you know they'll say the flooring, appliances, cabinets, tile, and so forth. Tailoring a building's envelope to the local climate can make room in the budget for upgraded fixtures and finishes.

Laundry rooms can be a black hole of energy use. Commercial washers and dryers use a lot of water and electricity while creating a pressure imbalance that can drive moisture. One solution is to move laundry rooms out of the passive building envelope.

standards often have R-40 walls, or higher. The previously mentioned ICF building in New York City has wall insulation that is just a little higher than the code requirement (R-22).

The best path to zero energy

The reason that code-specified R-values can deliver the performance of passive building is that continuous insulation—a thermal barrier that wraps all six sides of a building—is much more effective than intermittent insulation, which is interrupted by structural members, corners, and interior walls. This relatively simple concept, coupled with meticulous air-sealing and high-performance window glazing, means that PHIUS+ certified buildings are very close to net zero right out of the gate. Usually, adding a few solar panels can tip the scales to positive energy production.

In fact, through our work with the Department of Energy, all PHIUS+ houses qualify as net-zero ready homes (ZERH). The ZERH designation also converts to multifamily and commercial structures up to four stories. The bottom line is cost-optimized comfort and performance.

When the five passive-building principles are applied to buildings—apartment buildings, offices, skyscrapers, single-family homes—you get predictable performance. You also get unmatched comfort for the occupants, superb air quality, and resiliency in the face of power outages due to winter storms, summer blackouts, or extreme weather events.

Chapter 3

PASSIVE BUILDING WORKS FOR ALL BUILDING TYPES

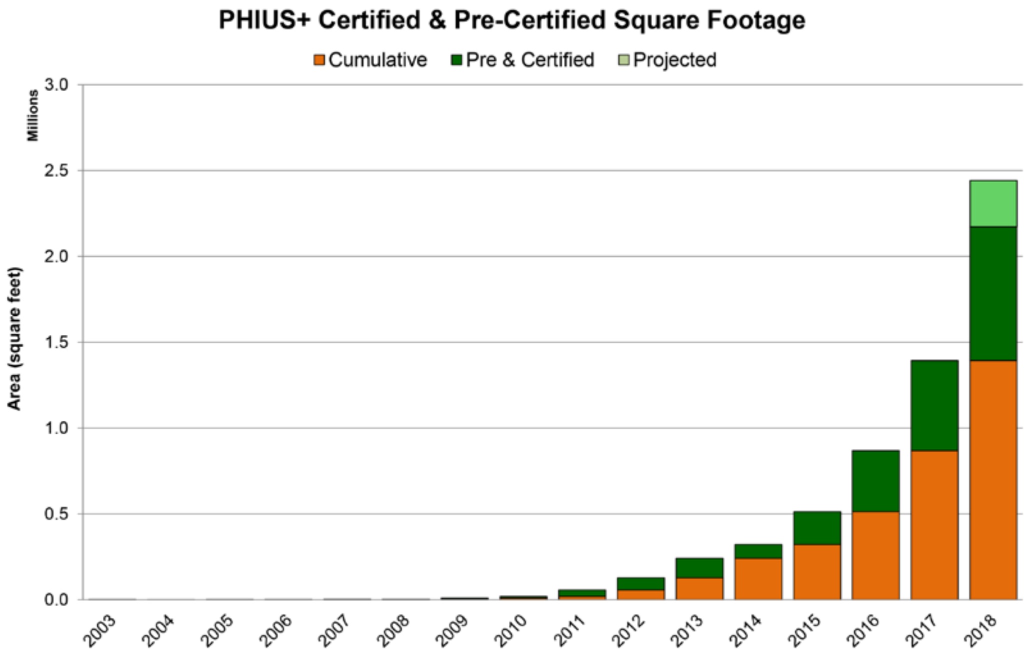
There are many paths to high performance. The 101-unit apartment building was built using insulating concrete forms (ICFs) for the foundation and the exterior walls. ICFs deliver continuous insulation and substantial airtightness along with structure.

As buildings get bigger, efficiency scales along with it

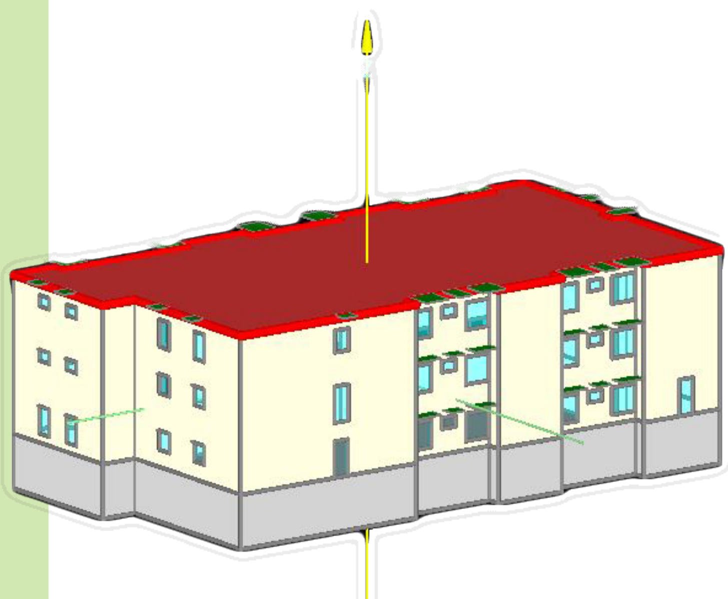
Passive-building principles were originally developed for houses. After decades of experimentation, we have dialed in modeling tools to the point where observed energy use is within 10 percent of expected energy use over the course of a year. One of our first observations was that mechanical systems small enough to heat and cool these aggressive little structures barely existed in North America. Swedish and German mechanical appliances, called “magic boxes,” existed, but their capacities were designed for Germany and Sweden. Unfortunately, they didn’t have enough peak capacity for the more extreme North American climates—and they were blind to our dehumidification needs. Besides, who could read the label?

A passive-house paradox is that larger houses can achieve certification more easily than smaller ones.

Old school update. A turn-of-the-century resort cabin at a conference center in Sharon, CT, was upgraded to PHIUS+ certification. The upgrade was done with off-the-shelf products. In this case, I-joists were used to overframe the walls and roof, making room for more insulation.



Big growth from bigger buildings. The number and size of certified passive projects in North America is soaring. Real estate experts expect this growth to accelerate. The number of buildings is on a steady rise, but the area of the buildings is shooting up even faster—because bigger buildings are easier to build to PHIUS+ than smaller ones are. Source: PHIUS data.



Modeling on a computer is better than designing on a hunch. WUFI Passive is the most potent passive-building modeling tool available. Developed by Fraunhofer Institute for Building Physics in collaboration with PHIUS and Owens Corning, WUFI Passive is a user-friendly software uniquely suited to North America's varying climate zones.

This seems unintuitive, but it explains why passive building scales up to multifamily and commercial so well. The smaller surface-to-volume ratio of larger buildings makes insulating the space more efficient. Not only do small-enough mechanical systems exist on this side of the Atlantic, but the people occupying the building actually serve as space heaters. This can add up in office buildings and multifamily/hospitality applications.

Passive building has grown exponentially over the past decade, partly because of how powerful the WUFI Passive modeling software is, but to a larger extent, it has been new business attracted by the economies of scale in multifamily and commercial construction. The project database is full of examples of certified, multifamily, and health-care facilities in all parts of North America.

PHIUS+ works in all climates because it is tailored to each climate zone

PHIUS+ certification includes intricate hygrothermal (moisture/temperature) modeling, which is based on local climate and weather data. The models dial in the building envelope to include exactly what it needs to achieve its specific goals—no more, no less. And this leads to another happy paradox: extreme energy efficiency does not always require extreme superinsulation. Many PHIUS+ multifamily buildings have wall and roof R-values only slightly higher than code.

The reason that PHIUS+ buildings perform so much better with similar insulation is answered in chapter 1. Continuous airtight insulation with great windows allows a small and efficient mechanical system. It begins with 3D energy modeling to tailor assemblies to their site.

Passive retrofitting is like regular retrofitting: messy and worth it

A fundamental truth of building—that new construction is easier and cleaner than remodeling—holds true for passive building, too. New buildings are undeniably easier to make perfect than existing buildings because you start with a bare lot instead of a leaky building. Retrofits, however, are positively possible and profitable.

WUFI modeling software can help designers and builders identify issues and opportunities for the retrofit, just as it does on new builds. There are many examples of successful passive-house retrofits in the certified projects database from single-family homes to mixed use to medical boarding facilities.

Successful retrofitting just requires a dedicated—and experienced—team and the motivation to get it right. Because retrofitting is trickier than new construction, an experienced team is critical. It is best not to cut your teeth retrofitting to passive-building standards (though it has been done).

Test the airtightness as construction progresses

The trickiest part of a PHIUS+ retrofit is making the existing building airtight. Multitasking materials, such as spray foam—which insulates and air-seals—can be valuable tools for tightening an envelope, which may be hard to define at first. Using a blower door as often as possible during construction lets you identify holes and leaks when sealing an old building. Blower-door-directed air-sealing drills can also help subcontractors stay focused on airtightness goals.

The first multifamily retrofit to earn PHIUS+ certification. The Harry and Jeanette Weinberg Commons, developed by Housing Up and completed in 2015, uses 75 percent less energy than a comparable code retrofit in the Washington, DC, area.

A historic landmark brought into the 21st century. This iconic YMCA building in McKeesport, PA, was retrofitted into single room occupancy housing for homeless people.

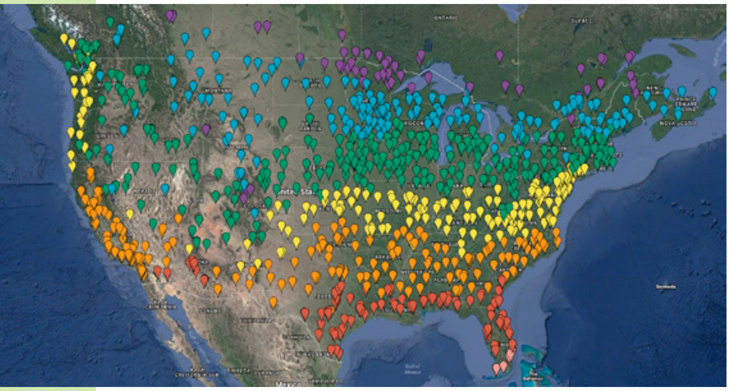
Adding insulation and airtightness to existing buildings changes the thermodynamics of how the building interacts with its environment. In other words, heat and moisture behave differently than they used to, and the consequences can be both surprising and unpleasant. For example, insulation added to the inside of an old masonry building can cause spalling, subfluorescence, and efflorescence because it changes how the masonry wall can dry after rain.

While retrofitting is more challenging than new construction, it can be rewarding (and tax advantageous) to restore old buildings. Because of the inherent risk involved with unknown thermodynamic changes, we believe the WUFI Passive modeling software is critical to success. In fact, it is central to PHIUS+'s quality-control and assurance guarantee.

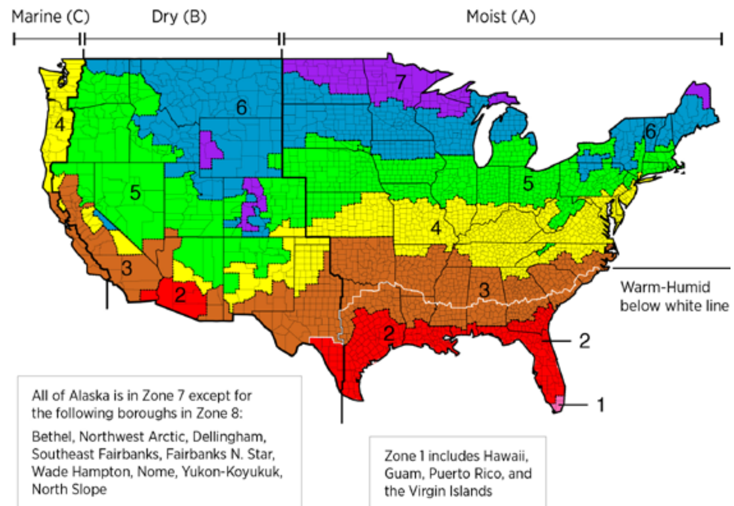
PHIUS+ is already integrated into North American building codes and standards

The move to tailoring PHIUS+ to North America's extreme climate zones led us to work with some of North America's leading engineers, architects, and policymakers. We partnered with Building Science Corporation, which had done extensive research through the U.S. Department of Energy's Building America program to identify affordable, effective energy-saving solutions for residential construction. BSC was excited to work with us on bringing affordability to extremely energy-efficient buildings that are also cost-effective, durable, reliable, and comfortable. This led to the climate map (next page) with data on more than 1,000 locations in North America. These data sets can be fed into the WUFI Passive modeling software.

A side effect of this collaboration and the evolution of climate-specific cost-effective energy solutions is that the PHIUS+ 2015 standard closely aligns with North American energy codes and energy-efficiency certification programs like ENERGY STAR. Because the International Residential Code, the International Building Code, and the International Energy Con-



PHIUS climate data overlay IECC climate zones. Data points for over a thousand locations are coordinated to the climate zone map on page to the right. When inspectors, planning commissions, or investors ask about codes and standards, you can tell them that PHIUS+ fits.



Seven zones of separation. From Miami—which gets its own climate zone— to California—which has five—there is a lot of climate variation in North America. Even within the climate zones, there are three humidity categories (dry, moist, marine).

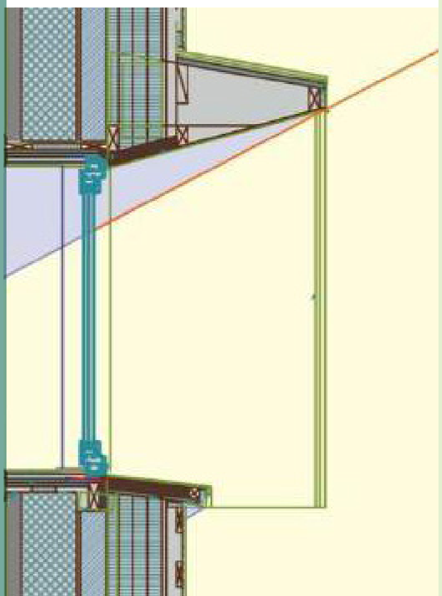
servation Code are based on Department of Energy research, the solutions we developed in the PHIUS+ 2015 Passive Building Standards are used for model codes. PHIUS+ 2015 integrates into building codes because the language—and climate-specific science—is consistent.

For example, the German Passivhaus standard may bump up against city or state ventilation requirements. A similar situation arose in a recent high-profile construction project in New York. The ventilation system did not align with what the building officials expected, so project managers had to obtain a variance from the city. This took multiple weeks and tacked cost onto the project. In such cases, you may need to obtain variances from city or county officials. PHIUS is aligned with ASHRAE standards and ICC requirements, so getting buy in from local building officials is a much more predictable process.

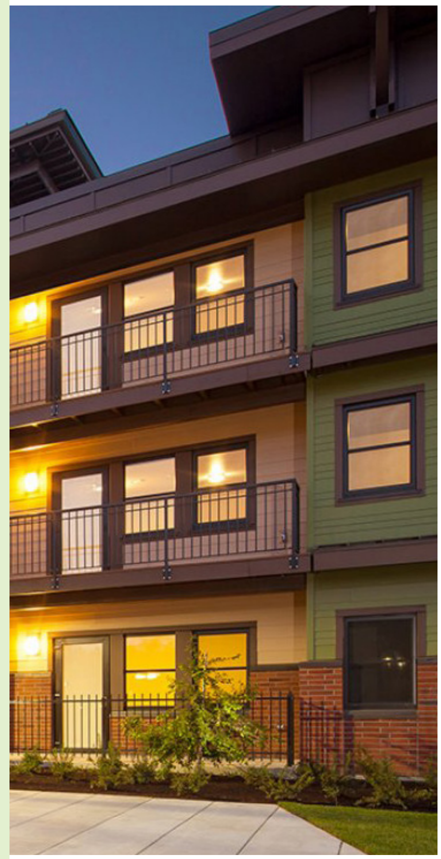
Ventilation requirements can vary vastly by region. Because PHIUS+ aligns with North American ventilation codes and standards, there are no construction delays or variances needed.

Chapter 4

THREE EXAMPLES OF PASSIVE BUILDING



20 *Design solutions mean significant utility savings, which are like a pay raise for residents.*



27 *Affordable housing with a tight connection to the community.*

31 *Bolting PHIUS+ onto a design should be a last resort, but in this case, it was the plan of action.*

Chapter 4: Example 1

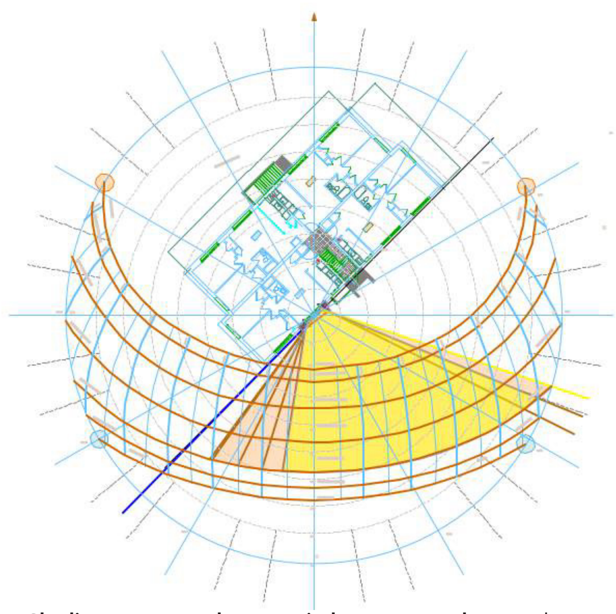
AFFORDABLE HOUSING RETROFIT: WEINBERG COMMONS

New design elements that solve existing problems with flair and frugality. The most visible solutions are the rust-colored exterior shading boxes that were site-built and mechanically fastened to the building after thickening the walls with a blanket of insulation. A larger challenge was creating basement living space on a historically wet site.

Significant utility savings are like a pay raise for residents

Weinberg Commons is the first multifamily passive building in Washington, DC, and the region, and is one of only two masonry multifamily passive-building retrofit projects in the country. This affordable housing project has three three-story brick and block apartment houses built in the 1960s. All 37 of the two-bedroom apartments were retrofitted using the same assemblies and systems. The renovations include new electrical distribution and lighting, fire detection and alarm, upgraded kitchens with new appliances, water-efficient bathrooms and new finishes on the walls, ceiling, and floors. Common amenities include converting one dwelling unit into a programmatic suite with computer workstations, conference space, upgraded common laundry rooms, barrier-free accessways, and an outdoor patio.

Specific Passive House design features include a superinsulated and ultraairtight building envelope, high-performance windows with external solar shading control "boxes," constant low-flow ventilation



Shading surveys make your window strategy clear. Looking at the path of the sun throughout the year, with existing vegetation, highlights the threats and opportunities of a site. Because the three buildings were already placed, the lighting/heating/shading strategy had to incorporate no-maintenance exterior shading.

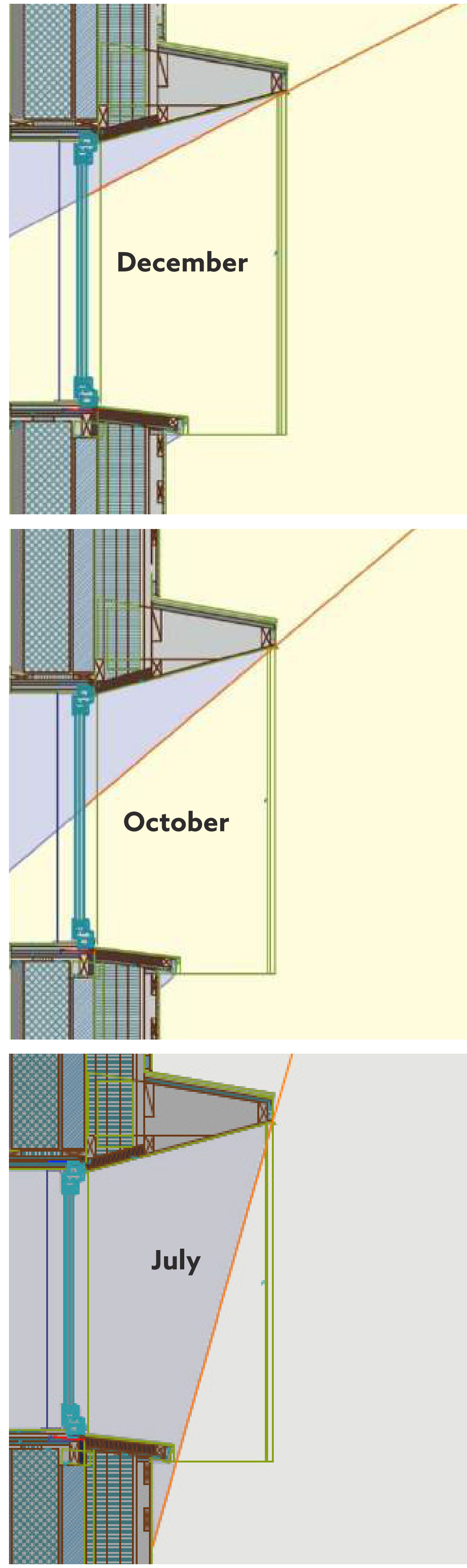
Quality of life is enhanced with natural light, fresh air, and comfort. Each apartment gets a steady stream of ventilation air from a shared ERV providing comfort and clean air. Finishes such as flooring and paint are pollutant-free.

with energy recovery, strategic and efficient heating and cooling equipment and distribution, and a moisture-sensitive assembly to mitigate the effects of the mixed humid climate. The development team also plans to add photovoltaic panels for on-site renewable energy generation.

Sidestepping poor orientation

Because the buildings were already standing, there was little the team could do to improve the energy performance of the site. Even more, operational shading, which is a common feature of passive buildings, was out of the question because the developer was concerned about maintenance and occupant interference. Despite these challenges, the team devised a way to create shading during summer and passive heat gain during winter: tapered external shading boxes that surrounded each window.

Fixed and tapered external shading boxes were designed to mitigate heat gain in summer and preserve heat gain in winter. The tapered boxes also preserved light apertures for daylighting. Across the three buildings on the site, five unique geometric aperture profiles were designed and distributed among the 12 primary facades.



Shading boxes manage the sun's heat all year. Geometric window frames are attached outside the thermal boundary. Custom angles are built for each of the 12 sides of the three buildings to allow heat to enter during winter and block heat in summer.

The first PHIUS+ masonry retrofit in DC. Brick and block buildings are solid, but can also be challenging to bring into energy superiority. Wrapping the building with insulation keeps thermal mass inside, keeping the indoor climate stable.

"You know this passive house design business, they tell me about it, and I am sure there are all these terrific explanations of what it is and how it works, but you know what it really means to these families that are going to live in these buildings? It means they will pay almost nothing for utilities! That is what it means to these people!"

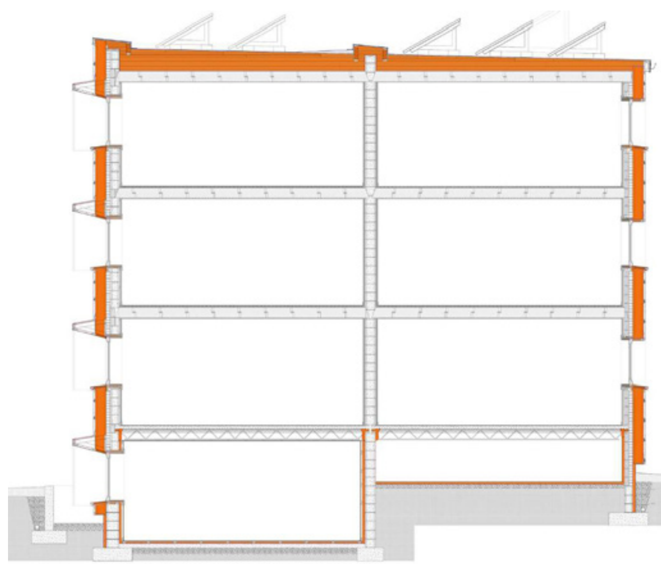
—DC Mayor Vincent Gray

The boxes were stick-built and framed in with an outrigged wood I-joist assembly, essentially eliminating thermal bridging back to the structure of the original building.

During the design phase, there was a question about how to make these boxes customizable to the variable building orientations and window size locations, while also durable, cost-effective, and complementary to the overall building's aesthetic. Extensive solar analysis and constructability details were critical to the process.

Mechanical advice: get the most out of ERVs

Because the small enclosed bedrooms can overheat quickly by the sun and occupancy, distributed heating and cooling are needed for comfort—despite the very low loads for each apartment. A ducted fan coil unit was chosen over a single wall-mounted mini-splits. Ventilation is provided by a common system using four ERVs, each serving a vertical stack of three or four apartments.



Vertical distribution. Mechanical ventilation is Distributed efficiently in three- or four-unit groups served by a single ERV. Keeping the duct runs vertical and direct also keeps the distribution system short and, therefore, efficient.

PROJECT SPECS

LOCATION *Washington, DC (Climate Zone 4A, mixed humid)*

BUILDER *Hamel Builders, Inc*

QA/QC RATER *Chris Conway, Conway Energy*

ARCHITECTURE *Matt Fine, project manager, ZA+D, LLC*

CPHC *Michael Hindle, Passive to Positive*

BUILDING TYPE, FUNCTION *Retrofit, Multifamily*

SIZE, LEVELS *33,096. sq. ft., four levels*

WALLS *Existing: Brick masonry on CMU backup, plaster/gyp/board on lath. New (exterior): 9 ½ inch wood I-joists, cavities filled with 2 lbs/ft^3 spray applied fiberglass. Solitex Mento Plus air barrier covered with fiber cement cladding over rain screen air gap using horizontal wood furring.*

ROOF *OSB roof sheathing taped to become airtight layer, 14 inches of polyiso board insulation and adhered EPDM roofing membrane*

FOUNDATION *Existing concrete slab: HDPE vapor barrier (airtight layer), 2x wood sleepers with SPF insulation, and plywood subfloor.*
Crawlspace: Graded soil with gravel course, 15 mil PE vapor barrier (airtight layer) with 2 in. stone wool insulation board

WINDOWS *Yaro PVCU Economy+, SHGC: 0.50; U-value: 0.182 BTU/hr, ft^2 deg. F*

HEATING/COOLING/DEHUMIDIFICATION *LG 12 ton VRF (serving 12 dwelling units each) with vertical 1 ton ducted AHU in each dwelling unit*

VENTILATION *Ultimate Air 200DX (serving 3 dwelling units each) with glycol ground loop heat exchanger pretemper*

An individual ERV in each unit can solve a lot of problems in one step, but in multifamily, it is costly, almost always mismatched to the actual load, and adds people's actions and judgment to the system. The Weinberg Commons solution was to split the buildings into vertical units, serving three apartments with one ERV, through a single vertical shaft, with minimal duct length within each apartment. This simple strategy allowed the team to limit disturbance to existing interior walls and ceiling finishes.

Because of the small apartment size and relatively low building height, stack effect was not as big a concern as it is in larger buildings. The equipment cost was about half of what individual units would have been, and the solution saved living space. In each apartment.

Ultimately, the interior spaces are very comfortable. Solar exposure on an hourly basis optimizes passive gain to more than adequately meet the PHIUS+ annual energy budget for heating and cooling while maintaining open views to the exterior. The assemblies have created a unique visual character to Weinberg Commons, where its function very literally informs its form.

Big ducts, short runs, and right-sized equipment. Rather than put a small ERV into each apartment—which would almost certainly be too big or too small—the design team matched one large ERV to four apartment units, stacked vertically. The duct runs are short and direct and the load is balanced to the equipment.

Moisture in the air and in the ground is another challenge

Washington, DC, is in a mixed-humid climate zone and is increasingly experiencing higher temperatures and relative humidity, along with a higher frequency of extreme weather events. Despite being a heating-dominated climate, though, cooling loads and humidity are the main design challenges in this climate zone (zone 4). The high humidity, along with high occupancy rates, causes unacceptable indoor humidity in many of the region's multifamily projects.

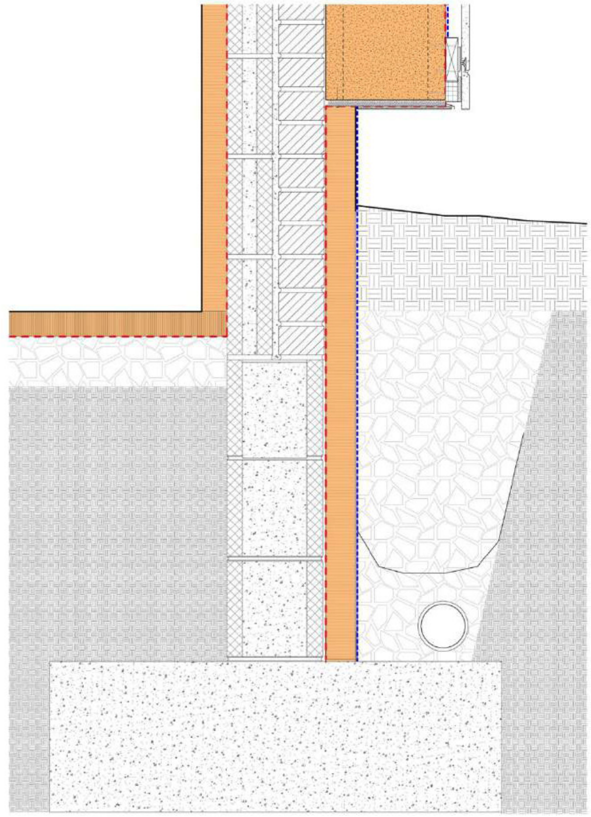
The buildings also had serious groundwater issues. When basement living space was included in the pro-forma, it meant that the team needed to design a long-lasting, low-risk assembly to ameliorate bulk water and provide plenty of drying potential. Establishing continuous thermal and air-control layers was very difficult in the brick and block buildings because it meant bridging interior control layers to exterior ones.

When excavating for drainage, they were able to easily insulate the foundation walls on the exterior with Rockwool Drainboard. Exterior insulation, air sealing, and waterproofing extend at least 3 ft. below finished grade, which is well below the finished first floor of the interior. Restricted head height in the basement spaces meant the team was limited in how thick the floor insulation could be. They used 1 ½ inches of spray foam over the slab with sleepers embedded for subfloor backing.

In order to retain interior space, insulation and air control layers were added to the outside of the buildings.

The affordable enclosure assembly consists of vertically hung wood I-joists wrapped with a vapor-open airtight membrane and dense-packed with fiberglass insulation, covered with a vented rain screen of fiber-cement cladding.

Domestic hot water is delivered by a common system primarily heated by a solar thermal array on the roof. Backup water heating is provided with electric resistance. Dedicated dehumidification was designed, and wiring and plumbing were installed in



Capturing living space from the bottom floor. To improve the pro-forma, a basement unit was added. Exterior trenches channel groundwater to keep moisture away from the building. Inside, insulation wraps the interior of the foundation and slab to keep finishes warm and dry.

the event that the VRF system does not adequately dehumidify the buildings in the shoulder seasons.

The original Weinberg Commons buildings are representative of much of the housing stock in Washington, DC, where affordable housing is desperately needed. This housing stock is, for the most part, performing poorly, is outdated, and is unhealthy. Mold and indoor air quality problems are common in typical retrofits because of a variety of design and construction issues that passive building addresses head on.

CPHC professionals are well aware of problems like part-load condition humidity, inappropriately placed vapor barriers, duct condensation, high cost of occupancy, and airborne moisture infiltration. These external liabilities represent a serious cost to the occupants, the city, and the world outside of the nation's capital.

Pursuing Weinberg Commons may have appeared to be an unwise application of passive building principles to some and may even stretch the simple energy-reduction cost-benefit premise, but projects like these must be completed on a broad scale to avoid the decimation of our existing urban fabric.

To the team, undertaking the Weinberg Commons project was a financial, environmental, and moral imperative.

LESSONS LEARNED

Meet with the subs early and often

This project revealed the importance of buy-in from all parties on the mission, goals, and budget of the project. Because of the intricacies of passive building design, this consensus is even more critical in terms of the preconstruction relationship with subcontractors. More time spent educating subcontractors on the project would mitigate learning curves and reduce the inaccurate pricing and multiple change orders that occur when subcontractors lack basic knowledge and context of the project.

Hire a couple of rock stars

Specifically, the team learned the importance of hiring experienced air sealing and insulation subcontractors and including concise passive building air sealing and sequencing requirements in all contracts to be agreed upon by all parties. In other words, if you cut a hole in the envelope, you seal it back up. Assembling a qualified and fully dedicated team that has delivered other passive building projects of the same scale and difficulty level is critical to completing the next such project on time and on budget.

—Project team, Weinberg Commons

Ordinary buildings undergoing an extraordinary makeover. Extrathick framing with I-joists was packed with insulation and covered with fiber-cement siding.

Chapter 4: Example 2

ORCHARDS AT ORENCO

Affordable housing with a tight connection to the community. Located on the MAX light-rail line in suburban Portland, OR, Orchards at Orenco has easy access to hospitals, airports, large employers (Intel, Kaiser), restaurants, shopping, parks, and schools.

A comprehensive multifamily model for affordable living

Orchards at Orenco is a multifamily housing development that proves that affordable, efficient, and beautiful design are not mutually exclusive. In fact, they can feed each other. Located adjacent to mass transit, the project builds on the New Urban community named after the original land owner, the Oregon Nursery Company (hence the name, Orenco).

In 2011, the developer, REACH Community Development, acquired a 6-acre parcel of land in Hillsboro to build approximately 150 units aiming to hit three main goals: access to mass transit; affordable housing to those earing less than $30,000 per year; and PHIUS+ certification.

Phase I, completed in June 2015, ticked all of the boxes. Containing 40 one-bedroom and 17 two-bedroom apartments, it is the largest certified multifamily passive building in North America, and it won Multifamily Project of the Year in the PHIUS design

No lot is perfect. The corner location and community covenants limited what could be done on phase 1 of the project. Despite the difficulties, Orchards at Orenco hit all of its community-centered targets: affordability, access to transit, and climate responsibility.

PROJECT SPECS

LOCATION *Hillsboro, OR (Zone 4C Mixed humid, marine)*

BUILDER *Walsh Construction Company*

QA/QC RATER *Ryan Shanahan, Earth Advantage*

ARCHITECTURE *Ankrom Moisan and William Wilson Architects*

CPHC *Dylan Lamar, Green Hammer*

BUILDING TYPE, FUNCTION *New construction, multifamily*

SIZE/LEVELS *42,584 sq. ft., 3 levels*

CONSTRUCTION *Wood frame over concrete slab. Walls: 2x10 wood studs with sheathing and 1 ½ in. of exterior mineral wool. Roof: 12 in. polyiso foam over open web wood truss with TPO membrane roofing. Concrete slab on continuous EPS foam. Second and third floors: Gypcrete over wood joists and sheathing*

WINDOWS *Euroline 4700 uPVC Tilt-Turn with Cardinal LoE 180/180 & 366/180 Triple Pane Argon*

HEATING/COOLING *Heat pump in parallel with ventilation air. Backup heat provided by electric resistance. Night cooling with residents opening windows at night. Some cooling from heat pump inline with ERV ventilation for dwelling units.*

VENTILATION *Central ERV units direct-ducted to each dwelling unit provide continuous supply to bedrooms and exhaust from kitchen and bathrooms. Heat recovery bypass with economizer to assist with night flush cooling in summer.*

competition. Located west of Portland, in the heart of the 'Silicon Forest,' these units fill the need for inexpensive but high-quality homes for people who populate the lower-income support jobs at large tech companies, such as Intel and Kaiser. The residents typically earn less than 50% of the median family income of the area.

Design challenges

It was important that the team set the goal of PHI-US+ certification early in the process rather than trying to layer it on top of a typical housing development. Setting the goal first meant making the most of solar orientation and massing while complying with the community design guidelines. The corner location and community design requirements limited the options for the site. Massing was kept as simple as possible within these constraints to maximize east-west building orientation, which allows the best use of the sun for passive heating, cooling, and daylighting.

The team looked at five wall assemblies before choosing the right one. Not only did the wall design need to eliminate thermal bridging and provide an acceptable R-value, but it also had to be cost-effective, constructible by local tradespeople, and be resistant to moisture problems. The design team adjusted the window-to-wall ratio to guarantee suf-

Wood is good. Common spaces respond to urban design cues such as the light rail and incorporate wood from trees removed from the original orchard.

ficient daylighting without significant energy loss or materials cost.

Air barrier detailing is challenging to those unaccustomed to it

One of the largest challenges we faced came in developing air barrier detailing that met the strict airtightness requirements on a large commercial building. The team scrutinized critical connections—such as the wall to roof connection—at the conceptual phase and then worked closely with the structural engineer and general contractor to execute this connection to maintain air barrier continuity within typical subcontractor sequencing.

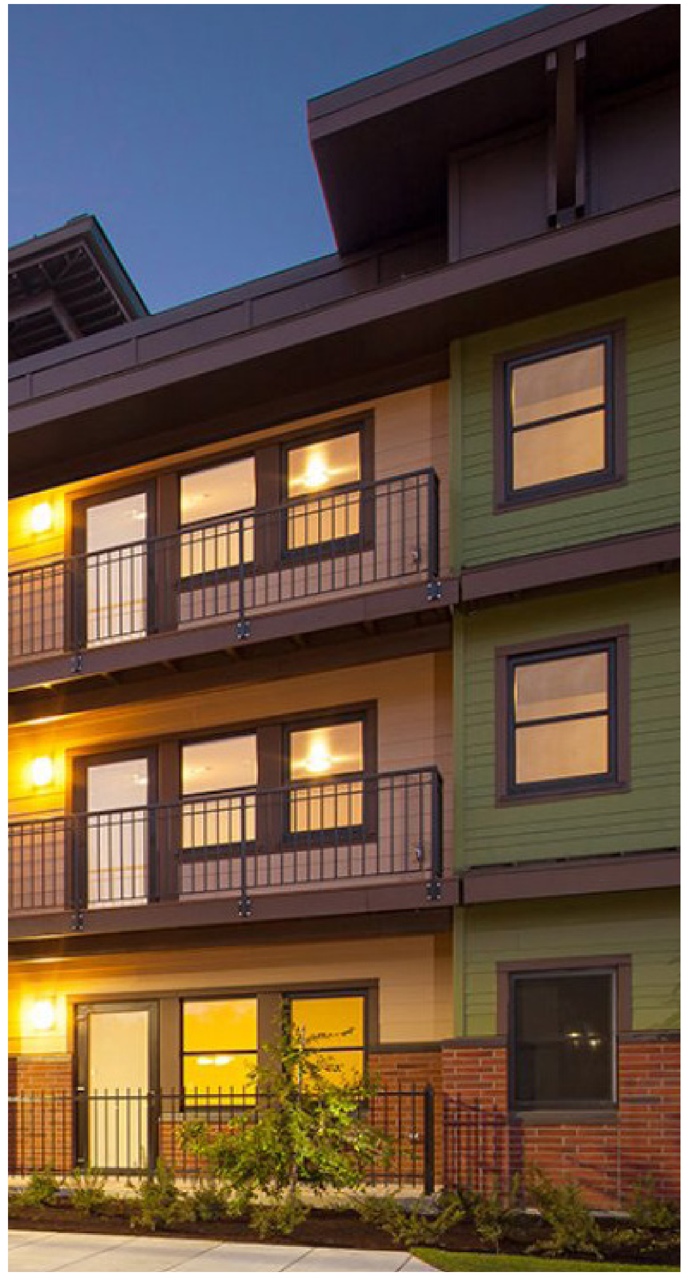
Another tricky detail was the exterior doors. The team needed to find commercial doors that met air tightness requirements, could accept electronic hardware (for security and accessibility), and had sills meeting federal accessibility standards. Because of the governmental housing dollars used in the project, the project also had to meet Uniform Federal Accessibility Standards (UFAS), which are stricter than ADA standards.

The team selected an American-made, thermally broken, triple-pane glass storefront door. The doors are not nearly as airtight as European models but will accept standard hardware and access controls and have a UFAS–compliant sill.

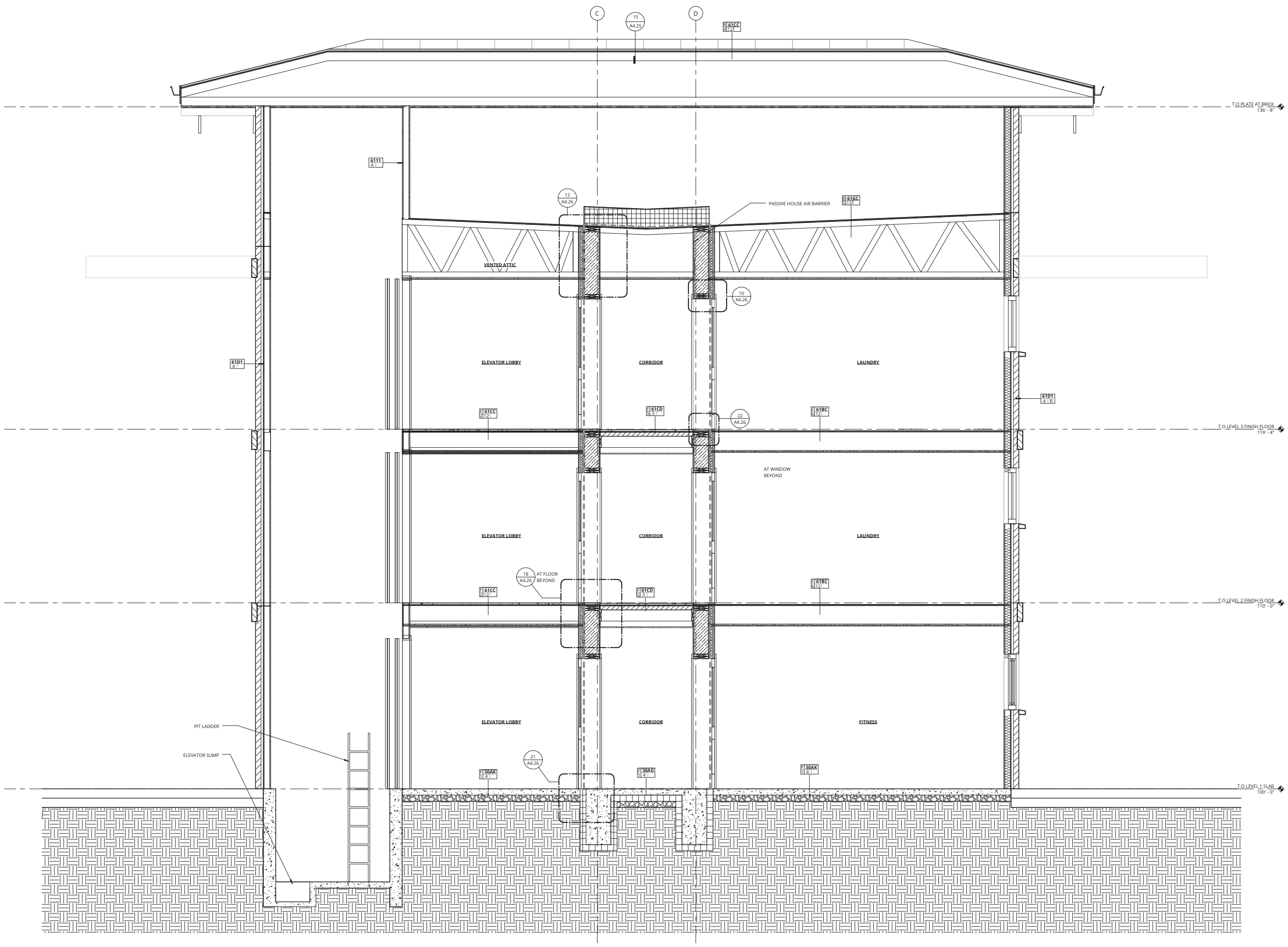
A selective envelope

The team chose to remove portions of the building from the PHIUS+ envelope—including the laundry and trash rooms—due to airtightness requirements and high ventilation rates. Initially, the elevator was also outside of the building envelope but was brought back in after preliminary blower testing determined that the air leakage at the elevator louver would not put the project over the limit.

The building is a three-story wood-fram structure atop a concrete slab-on-grade foundation. Typical enclosure walls have 2x10 framing with blown-in fiberglass insulation in the stud cavities and 1½ in. of rigid mineral wool exterior insulation. Mineral wool was chosen because of its permeability and capacity to dry out as needed.



Outdoor space is an extra amenity. Semipublic outdoor spaces—including benches at the main entry and an interpretive plaza near the light rail stop—commemorate the historical significance of the site. Garden spaces, picnic benches, and a play area provide outdoor gathering spaces for residents.



A tight envelope with an elevator inside. The ground floor slab sits atop a 4-in. layer of EPS insulation, which also wraps around and under the perimeter and interior footings. Plywood sheathing (with taped seams) is the primary air barrier. Capping the building is a wood truss roof with 12 in. of polyiso insulation and a fully adhered roof membrane. Because of the tight envelope, the elevator was able to remain within the envelope without typical problems associated with stack effect.

Decks and sun shades, designed for outdoor living space, add architectural interest, summer shading, and three-season living space. The team considered vertical shading, but the city's design commission vetoed the option.

A hybrid mechanical system

After reviewing the pros and cons of central versus local mechanical systems, the team took a "hybrid" approach, borrowing the best of both approaches. A central high-efficiency water heating system provides domestic hot water to all units quickly and efficiently. Three mechanical "pods" with large ERVs serve multiple units each, and an air source heat pump placed in-line on the supply air distribution tempers this ventilation air.

Each of the mechanical pods is within the building envelope at the roof level. The ERV in each pod serves 18 to 20 dwelling units, with direct 4-inch diameter "home run" duct runs. These home runs, collected into main trunk lines above the ceiling at the third-floor corridor, eliminate the need for fire-smoke dampers at each dwelling unit.

The air-source heat pump provides approximately 80 percent of the heating and some degree of tempered cooling during the summer. Two ultra-high efficiency boilers provide domestic hot water. The team determined that a temperature maintenance system with heat trace tape was more energy efficient than a recirculation pump.

Happy peeps make happy veeps. Doing good things for the community means that doing well financially is much more likely. Studies have shown that people who live in energy efficient houses have lower default rates than people who live in “normal” homes.

LESSONS LEARNED

Energy efficiency and IAQ go together

"It's uncommon for market-rate apartments to have fresh air ducted to each apartment; it's even less common in affordable-housing projects. So in addition to living in apartments with very low heating and cooling bills, Orchards' residents also will have 'really great' air quality."

—Mike Steffen, Walsh Construction Co.

Many benefits to passive building

Based on residents paying their own electric bills, the monthly savings are about up to $45. For a low-income resident, this is the equivalent of a 1 percent to 2 percent pay raise.

REACH is benefiting from the great press of this project and meeting our commitment to creating an affordable living environment for our residents in a beautifully designed building and in an amenity-rich neighborhood.

—Project team, REACH

Fluorescent lighting was designed to meet 0.4 watts per sq. ft. for the dwelling units. Lighting controls were used to reduce loads in corridors and stairs.

Energy savings are like a pay raise

“Every day I find a new reason to love it,” gushes George Hamlin, whose one-bedroom apartment is as noiseless as a recording studio. “It's cool, it's quiet, and I don't even hear the train. During the heatwave, my girlfriend came over to sleep because it was so cool.” The residents also benefit from the energy savings of living in a passive building; the $30 to $45 per month savings are equivalent of a 1 percent to 2 percent increase in the annual income of the average resident.

Mike Steffen of Walsh Construction Co. said, “It's uncommon for market-rate apartments to have fresh air ducted to each apartment; it's even less common in affordable housing projects. So in addition to living in apartments with very low heating and cooling bills, Orchards' residents also will have great air quality.”

Amenities include a community room/kitchen, food pantry, laundry room, and fitness room. The interior aspects strongly reflect the sustainable motivations of passive building requirements.

Chapter 4: Example 3

VILLAGE CENTRE APARTMENTS

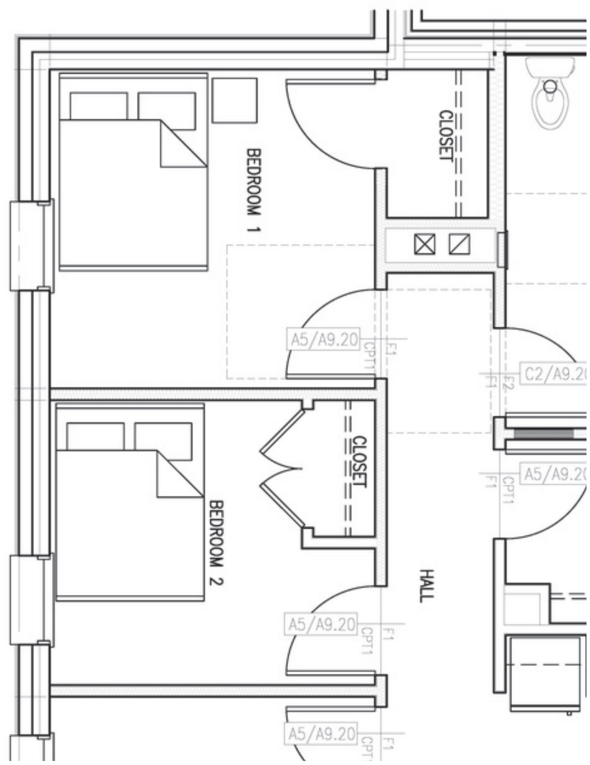
Unusual regulatory hoops meant creative jumping for the design team. Local government and building codes can impede affordable high performance. One solution was to design to code and then improve on it. Another involved a closer reading of the law.

Bolting PHIUS+ onto a design should be a last resort, but in this case, it was the plan of action

Usually, passive building and PHIUS+ certification are incorporated into the design process as early as possible. Usually. Sometimes, you have to take a different route.

After a 2011 controversy over the cost of affordable housing in Maine, all affordable housing projects in the state are subject to a hard cost cap. These spending limits forced the team to design and permit a conventional code building in order to receive a building permit and funding. With a fixed design, orientation, and budget in hand, the project team set out to achieve the PHIUS+ 2015 standard as an add-on.

This workflow is certainly not the optimal path, but it was necessary. After passing all post-construction testing, Village Centre opened in June 2016. The project has become a highly publicized example of the potential for high-performance affordable housing in extreme climates.



Thick walls that deliver comfort. An affordable way to boost R-value in a cold climate was an extra stud wall at the exterior. The cavity between walls is filled with insulation, making a 12-inch thick exterior wall.

PROJECT SPECS

LOCATION *Brewer, Maine (Zone 6A)*

DEVELOPER *Erin Cooperrider | Community Housing of Maine (CHOM)*

ARCHITECTURE *CWS Architects*

MECHANICAL ENGINEER *Bennett Engineering*

CPHC PROFESSIONAL *Colin Schless, Thornton Tomasetti*

QA/QC *Diane Schless | Horizon Maine*

BUILDER *Wright-Ryan Construction*

BUILDING TYPE, FUNCTION *New construction, multifamily housing*

SIZE/LEVELS *51,778 sq. ft.; 3 levels; 48 housing units*

CONSTRUCTION *Walls: Double-stud walls with cellulose infill and kraft-paper vapor retarder (R-37.5), Roof: Polyisocyanurate roof (R-57), Floors: XPS under slab (R-20)*

WINDOWS
Triple-pane, U-0.18 overall; SHGC 0.47 all non-west walls; SHGC 0.25 for west walls; 3 inches of horizontal exterior solar shading on south and west walls

HEATING
Electric resistance baseboard, 6 ft. per unit

COOLING
Split system, cooling only

VENTILATION
16 ERVs (1 ERV serves stack of 3-units) 73 percent sensible recovery

Design challenges: climate, cost caps, and bureaucrats

Village Centre Apartments is one of the largest multifamily passive building projects in North America. The building contains 48 units in a three-story elevator building, with one-, two-, and three-bedroom affordable apartments that include heat and hot water in the rent. This housing project is located in Brewer, Maine, where snowfall in May is not uncommon.

Brewer, Maine, averages over 7,800 heating-degree days per year, and after winter ends, the area quickly becomes warm and humid. June through September is muggy, with some days that peak over 100°F.

This heating load is approximately 280 percent that of the temperate western European climate for which the initial passivhaus standard was developed. Thus, the project team elected to pursue certification under the climate-specific PHIUS+ 2015 Passive Building Standard. Because of the cost cap, the team would

Public spaces offer healthy and productive environments. Low-VOC carpet, furniture, and finishes keep community spaces, such as this shared library, healthy and productive for the residents.

A connection to the community. A sheltered bus stop gives the community access to the nearby city of Brewer, Maine. Additionally, a curbed-pull off allows the city bus to pull over out of traffic from main traffic artery. Another outdoor amenity is a community playground for kids and parents to enjoy.

have to achieve the passive standards at little or no extra cost compared to a typical budget for an affordable housing development in Maine.

Modeling works better than 'rules of thumb'

The team experimented with a variety of wall constructions to determine which assemblies would fit within the budget while maintaining a 20 percent value-engineering buffer—which, considering the unconventional design process, was almost certain to occur as the project progressed.

Minimum window U-values were established early in the project as an occupant comfort concern. In order to maintain PHIUS' minimum temperature difference between the interior temperature of the glass and the ambient air temperature, the team determined that center of glass U-factors could be no higher than U-0.11, or about R-9 minimum.

For the rest of the envelope, the team was able to significantly reduce the 40/60/80 rule of thumb that many of Maine's passive building architects use (R-40 slab, R-60 walls, R-80 roof). By doing the hygrothermic modeling, the team specified a 20/40/60 envelope that maintains a 30% buffer below load- and demand-related metrics. Reducing underslab insulation to 4 inches provided some of the most significant cost savings to the team because it reduced both the first cost of the thermal envelope and the structural system.

Moving up to the walls, the team eliminated rigid insulation entirely, instead creating the thermal break with a double-stud cavity filled with cellulose insulation. The assembly saved first costs while avoiding the global warming impact of carbon-intensive blowing agents associated with rigid insulation. In the roof assembly, the team used exterior rigid foam because of interior moisture concerns, especially in areas directly above apartment bathrooms.

Reasonable ventilation can cut the heating requirements

Three main challenges required nearly a dozen mechanical design charrettes to solve: primary energy, budget, and code. While not obvious at first, each of these three concerns was intimately connected to the others. The core challenge was the ventilation rate. ASHRAE 62.2 (2007) required that the building remove nearly three times as much air from kitchen spaces than PHIUS' maximum suggested allowances. This would also remove conditioned air, which would significantly increase the amount of heating needed to condition the space.

Ultimately, the solution to the ventilation problem was found in the legal language that caused the problem in the first place, rather than the design of the actual system itself. In early January 2015, a close reading of Maine Uniform Building Energy Code (MUBEC) found that the state's building code had "adopted" ASHRAE 62.2 years ago; however, as opposed to ASHRAE 90.1, it had not established the ventilation requirements as "mandatory." A telephone call with the advisory board to the State of Maine Bureau of Building Codes and Standards confirmed the interpretation, allowing the team to establish their own ventilation rates for the project as they saw fit.

The team chose to adopt the International Mechanical Code (IMC) kitchen ventilation rates instead, allowing kitchen exhaust to be lowered to 47cfm provided that the

" ... It was a tremendous learning experience for our whole design team, and underscored our commitment to (and the need for) excellent communication, getting our team together early in the project, and paying careful attention to detail. At the end of the planning process, but before starting construction, we concluded that all the changes/improvements driven by the PHUIS certification were worthwhile and should be done in all new construction projects."

**—Erin Cooperrider,
development director,
Community Housing of Maine**

Energy misers and energy producers. Multiple minisplit heat pumps share the rooftop space with photovoltaic panels that provide 26 kW of free electricity–.

LESSONS LEARNED

Use existing data

The project team considers certification via the PHIUS+ standard an admirable feat and wouldn't change much about the path taken to get there. On the next project, the team will likely use the results of already available optimization studies rather than try to repeat the studies themselves. These time-intensive explorations yielded important results but required a lot of time from project team members.

Adjustable ventilation mollified concerns about low rates

The project team used a potentiometer to reduce the load of the sixteen 450-cfm ERVs down to around 150 cfm. This meant better heat recovery than published values and owner control of ventilation rates.

—Project team, Community Housing of Maine

design included recirculating filter hoods. Energy modeling and calculations determined that even a 10 percent increase in ventilation rates would still meet the PHIUS+ requirements. While the team doesn't anticipate this happening, it helped ease the concerns of the owner and mechanical engineer about reducing ventilation rates below ASHRAE 62.2's suggested rates.

After lowering ventilation rates and specifying a high-efficiency ERV unit, the team was able to provide space heating with simple electric baseboard units. Tunneling through the cost barrier like this allowed the team to achieve its aggressive budget targets. Careful cost analysis of every building material and system was considered to determine the lowest cost for the best benefit. In the end, the cost of this superior project came in at 3 percent higher than conventional construction costs.

Shading that lets the rain flow through. Aluminum shading with slats is bolted to the outside of the building to reduce the effect of unwanter sun during summer while allowing free heat in winter, dries easily, and is maintenance free.

Chapter 5

BREAKING DOWN THE NUMBERS

Ribbon-cutting day for 36 families. Weinberg Commons, developed by Housing Up, provides housing for low-income and formerly homeless families in the Washington, DC, area. This housing retrofit uses 75 percent less energy than comparable buildings—a boon to the tenants.

How much extra does PHIUS+ certification cost?

This question is hard to answer for the same reason that it is hard to say how much a bag of groceries costs. It depends on what's in the bag.

Almost everything in the process of passive building, design, construction, and development involves trade-offs. It's hard to quantify the cost of an enclosure system without considering what other things are being done—or not being done—that affect the total cost.

It depends on what's in the bag.

The grocery bag that developers use is a pro-forma document

All of the cash that flows through a project finds its way into a pro forma. Everyone's pro forma looks different, but it generally contains costs, financial resources, and revenue. Costs break down into hard costs (of which land is usually the biggest), soft costs (everything that the developer is paying for that isn't construction), and construction costs. Financial resources include equity investors (who expect a return over time) and debt from financial institutions, like banks, which expect a fixed-return rate on their loans.

Revenue comes in the form of rent, but also in the form of vacancy rate. Lower vacancy means higher revenue. Expected revenue may be 10 percent of the total cost in a year—that is a reasonable target. This revenue is then allocated to debt, property taxes, utilities, maintenance, and management. What is left over is called net operating income, or NOI.

Net operating income drives value

NOI of for-profit development is typically used to value the property at some sort of rate. If we expect a 5 percent return on that NOI, the value of the property is 20 times the NOI. Most developers aim for positive NOI, but some—such as affordable-housing projects—do not. Some properties are planned to be tax shelters, so the NOI is planned to be zero. For the most part, though, developers are looking for a positive NOI on their projects.

What happens when PHIUS+ is added to a market-rate grocery bag?

There is typically a premium for adding PHIUS+ to the plans. Experienced developers can do it for no premium, but first-time PHIUS+ developers report premiums around 5 percent. Adding it into the total land and soft costs, the premium is closer to 3 percent, but 5 percent makes the math easier. To fund it, you need more debt or more investors.

It's difficult to get the extra 5 percent from banks because the appraiser has to recognize the added value. Appraisers do not generally recognize added value for comfort, durability, and healthful indoor environments—yet. You can help things along by encouraging the bank to select the right appraiser. James Finlay, a former appraiser at Wells Fargo Bank, writes in *Building Energy Magazine*, "The owner should ask the banker (both in person and via email) to include the most vital high-performance property information when posting for bids to select a qualified appraiser." He also suggests communicating with the bank that you are willing to pay a little extra for the right appraiser, allowing more time. After hiring, immediately confirm with the appraiser the building's high performance features. If the appraiser doesn't get it, get a new appraiser.

At least until the market recognizes the value, you need to find the extra 5 percent through investors. There are other ways beyond investors to defray the passive-house premium. Utility incentives, state energy department incentives, municipal incentives, and grants can all bring in extra cash to offset the premium.

On the revenue side, it's safe to expect higher revenue for a passive building in the form of higher rents, lower vacancies, or both. The allocation is more favorable, too: Utilities will certainly be extremely low. Maintenance will likely be lower, too, but management, taxes, and debt will remain the same. Higher revenue and lower allocation expenses mean a higher NOI, which translates into value when the building is sold.

Developers are calculating risk takers

Developers like proven things that have worked in the past. They want to see a track record, and they look at data. In the end, though, they are risk takers.

Affordable and profitable. The 35-unit Kiln Apartments in Seattle has small individual units (350-sq.-ft. studios), which rent for $1,000 a month each. The rent at Pax Futura is considered affordable because typical rent is twice that in Seattle. An extra $50 per unit per month could translate to $400,000 when it is time to sell the building. It is easier to get the extra $50 if you offer superior IAQ, comfort, and extremely low energy bills.

A mixed-use experiment that cost less than 5 percent extra. Seattle's 13th and Pike is a six-story apartment building with 48 units, retail, and a parking garage. The total hard cost was $4.2 million; the PHIUS premium was about $200,000, or 4.75 percent.

Breaking ground on a new project is inherently a leap of faith. Bankers and underwriters are not risk takers.

"We depend on a lot of outside capital," said Sloan Ritchie of Cascade Built in Seattle, "because we do not have $50 million laying around, so we have to validate our model with investors, appraisers, lenders, underwriters, executive loan committees—if any one of them does not like the project, we are finished."

This is a major part of Ritchie's process: validating the model to outside people. All of these people are risk averse, whereas a developer's job is to take risks.

Ritchie presented a business case for PHIUS+ development at the 2017 North American Passive House Conference using a couple of recent projects as examples. Cascade Built is a general contractor and developer that builds for itself and other owners. The examples Ritchie highlighted included an affordable housing complex (previous page) and a mixed-use six-story apartment featuring retail and commercial space (above).

Lending, debt, and equity investors

Investors may not know much about passive building, but because you may have a lot of face time with them, you can usually get them on board with the program. You'll still need to show track record, data, and projections, because many investors are cautious, but you have more time to educate them and bring them around. Bankers are less easy to convince.

Ritchie's rule for communicating with bankers is "never to say 'passive house,' 'passive building,' or anything like that. They do not know what it is, so—by and large—it is a red flag." Rather, talk about comfort, air-conditioning, exterior shades, quiet, low energy, and futureproof. These things make sense and translate to bankers. You are unlikely to get the question "Have you built a comfortable building before?" Most likely, they're just going to think you're a good marketer with a good project. Investors may think passive house or PHIUS+ is really cool, but the bankers are writing you off as the words come out of your mouth.

The two markets in multifamily development: tenants and buyers

It's hard to estimate and prove how much extra a tenant will pay to rent space in a PHIUS+ building. If they are willing to pay more, will they be better

LESSONS LEARNED

Never say 'passive building' to a banker

"We had a project, and it went to the lender, and everyone said, 'It looks good, we agree with the numbers and the project and the market, so we want to get an appraiser.' The appraisal comes back over the projected value, so it moved to the underwriters, who got tons of data, approved the project, and completed the underwriting. It moved to the last step: the rubber stamp from the executive loan committee.

Someone on the executive committee asked, 'Isn't passive house where there's a rock pit underground for heating and cooling?' My vice president of banking was attending, and he didn't know the answer to that question. All of a sudden, the executive committee thinks there is going to be a rock pit underground to heat the building. They didn't know what passive house was, but that's what they thought it was, so guess what happened to that loan? It did not get rubber-stamped.

That's when we stopped ever saying 'passive house' to bankers."

—Sloan Ritchie, Cascade Built, Seattle, WA

If the banker thinks you're building an earth ship, you are sunk. Sloan Ritchie, a developer in Seattle, never says the words "passive building" to bankers. Bankers don't know what it is, so it raises questions. Instead he talks about comfort, durability, and energy efficiency.

tenants? Will there be less wear and tear? Probably, but you cannot really prove that to a banker. Even for the "affordable" $1,000 apartments, most people are willing to pay $20 extra. Maybe it breaks down to 10 bucks for thermal comfort, five bucks for indoor-air quality, four bucks for quiet. Add another buck for a lower carbon footprint.

The buyer really looks only at the NOI—all the income minus the expenses. So if passive house has an economic value, it has to end up in NOI somewhere. You either need more rent or less expenses. Otherwise, there's no economic value to it—in this model. Twenty bucks per month times 35 units times 12 months is $8,400 per year. Dividing by the capital rate (20 times the NOI) gives a value of $170,000 for adding PHIUS+ to the grocery bag.

Will people stay longer in a PHIUS+ building?

Five percent vacancy is a common rate to use for underwriting. Will tenants stay longer in your passive building? It is reasonable to bet that tenants will stay longer because PHIUS buildings provide a superior environment. This logic is backed up by statistical evidence. A study by University of North Carolina at Chapel Hill's Center for Community Capital and the Institute for Market Transformation (IMT) found owners of energy-efficient homes—designated by Energy Star certification—were one-third less likely to default on their mortgage. "...The odds of a mortgage default on an ENERGY STAR residence are one-third lower than those of a home in the control

Great teams build great buildings. Clear communication about goals, strategy, and milestones is the most effective way to excellence. The team at Community Housing of Maine had to overcome a difficult state law requiring all affordable housing projects to be designed to code. Using the lowest common denominator and back-calculating to excellence is not the straightest line, but was needed to achieve success

group. A mortgage holder on an ENERGY STAR residence is also one-quarter less likely to prepay. Since lenders consider prepayment a risk, these loans are potentially more valuable to them."

The study looked at 71,000 home loans from 38 states and the District of Columbia. The sample was restricted to single-family, owner-occupied houses, but it does not seem like a stretch to say that the psychology behind the data scales to people in multifamily buildings, too. The study goes on to say that "the lower risks associated with energy efficiency should be taken into consideration when underwriting mortgages."

If the tenants are more likely to stay in an energy-efficient building, then moving from a 5 percent vacancy rate to 3 percent on the 35-model unit that Richie cited earlier would create $183,000 of value.

Maybe you can change the vacancy rate to 4 percent. This extra income every year translates to a value. As you move from 5 percent to 3 percent on the 35-model unit pictured earlier, you create $183,000 of value. That $183,000 is pretty similar to the extra $200,000 you paid for passive house upgrades. So maybe the vacancy pays for the whole thing. But you don't know for certain. You cannot prove it to bankers.

Those apartments cost about $1,000 a month. How much more will tenants pay to live in a space with superior IAQ, comfort, and energy consumption? If people in affordable housing, like Pax Futura, will pay an extra $20 per month, tenants in larger and more luxurious accommodations will probably pay an extra $50 per month, so that's an additional $20,000 income per year, which translates to $400,000 in value. So when the building gets sold, someone's going to pay an extra $400k for your $50 bump in rent. Not only does that pay for the PHIUS+ certification, it also pays a nice return to the investor.

SIX STEPS TO PHIUS+ CERTIFICATION

Start early and sweat the details; construction will be smooth

The Department of Energy is now promoting PHIUS+ certification as the highest attainable level of energy efficiency as part of its program suites. PHIUS+ certification has risen exponentially over the past five years, with the affordable multifamily passive-building sector in particular multiplying. As of 2017, PHIUS has certified and precertified more than a million square feet of North American projects.

The PHIUS+ 2015 Passive Building Standards represent a sweet spot where aggressive carbon and energy reduction overlaps with cost-effectiveness. It's all about the bottom line.

There are six main steps in the process, with numbers one and six being the easiest.

1 Set the goal, and build your team

If you're not sure right out of the gate that you want to pursue PHIUS+ certification, a feasibility study can show you how close your current design is and what it will take to get to PHIUS+. After deciding on the goal, set up your team.

You'll need a CPHC professional and a verifier, both certified by PHIUS. It is wise to hire a PHIUS-trained builder, too, but some untrained builders can do it. It's important to get the PHIUS certification staff involved as early as possible. They have seen many of these projects unfold; they know what can go wrong in the field. They can help you sidestep landmines that others may not notice.

Request a PHIUS+ certification fee and project contracts. Depending on the project size, you either need to get a custom fee, or you can use one of the base fees listed on phius.org. Also, each project needs a project contract with the project name and owner.

2 Register for certification and create the project in our database

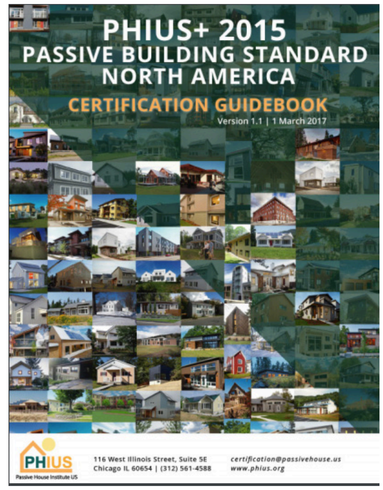
The contract and payment are submitted by the consultant or the project owner. After registration, we send the CPHC professional a login to our database so they can create the project and begin uploading information and documents. Upon precertification, the project will be visible in our project database, so upload a lot of great photos and as many details, notes, comments, and lessons learned as you can. After the project is created in the database, we create a project Dropbox folder for your team to submit documents. This folder is used throughout the certification process: design review, precertification, and on-site quality-assurance/quality-control checklists and documentation.

LESSONS LEARNED

Collective experience matters because individual experience is limited. The reality is that on a standard build, everyone has done 20 or 30 projects. On a PHIUS project, the experience is not nearly as deep. Everyone may have done one or two projects. Check your ego at the door because you're probably going to be wrong about most things that you would normally do on a project. Hopefully at the end, you'll get something that really works.

Team is a huge part of how to get it done.

—Sloan Ritchie



PHIUS Certification Guidebook. The comprehensive guide has a section up front to help tailor your certification packet to the particular requirements of the building type, such as commercial, multifamily, or industrial.

3 Submit your package

After registering for PHIUS+ certification, you should prepare your PHIUS+ submission package. Submit a set of plans (including elevations, sections, and details) along with a preliminary energy model (built by your CPHC professional). Before creating the model, though, study up on the prescriptive requirements. The design team should pay particular attention to the moisture design guidelines for building assemblies in your specific climate zone.

Look through the quality-assurance/quality-control checklist, too. Although these checklist items are for the rater or verifier at the end of the project, the design team should be aware of them at the beginning. In addition to plans and an energy model, we like to see performance data for windows, a shading study, and performance data for mechanical systems and appliances. The PHIUS+ certification packet lists all the documentation you need to submit.

The CPHC professional will then create the initial energy model using the modeling protocol in the PHIUS+ certification guide. The guide follows the order of the energy-modeling software, so while it is technical, it is also intuitive. This first energy model is like an advanced feasibility study. The team learns where the building stands as designed and what you need to do to get to PHIUS+.

4 Earn precertification

With plans and a model ready, the CPHC professional will prepare all other documentation for the first round submission. There are almost always three rounds of design review, with the first round taking the longest.

Round one: 4 to 8 weeks

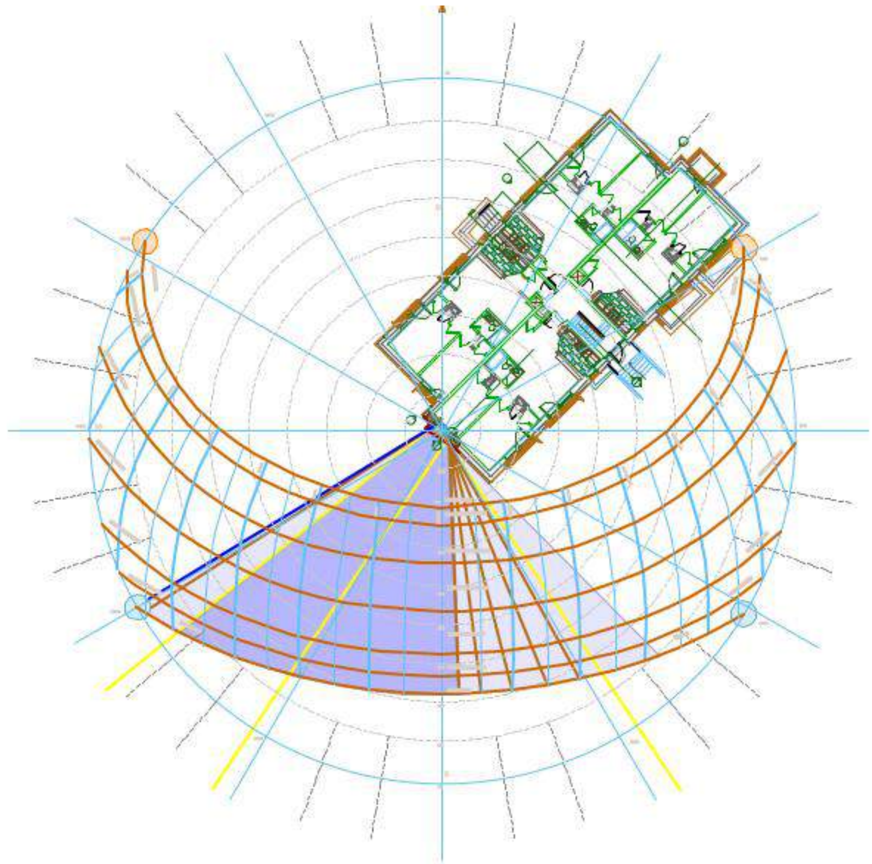
The more documentation we get, the more we can comment on, and the more accurate your round-two design will be. We will scrutinize every input of the energy model, review all the submitted drawings and specifications, and comment. We'll address areas of concern in the design and thermal-bridging analysis that may be required, and we'll ask for supporting documentation if it's missing. We recommend hiring a verifier early in the design phase.

Round two: 2 to 4 weeks

You may want to sit down before you open the first review—especially if you didn't go over the prescriptive requirements. In the first design review, you will learn what's missing and what concerns us, for example, about moisture, comfort, or other problems.

This is why we recommend that the design team look at the certification guide in detail—or email us with questions as you're modeling—so that you're not surprised by our first round of feedback. Teams that work closely with us during round-one reviews typically get feedback covering smaller-scale items; if the design team does not go through the guide, large-scale issues could push the design out of certification range.

The CPHC professional works with the design team to incorporate this first round of feedback and then submits a second-round package for review—ideally with all the supporting documentation asked for in round one.



Sun and shading affect how a building performs. A shading study is one piece of the package analyzed by PHIUS for precertification.

Round 3: 2 weeks or less

The CPHC professional receives our round-two feedback and adjusts the design and the energy model if needed, and submits a package for round-three feedback, the last submission. Our round-three feedback will have minimal comments.

With everything marked up on the feedback form, the project is approved to move forward, and PHIUS will award the project as PHIUS+ Precertified. Now, we send a precertification letter to the team, and the project becomes publicly visible on phius.org; this is the official hand-off to the building team.

5 Build and verify: the QA/QC process

At this point, construction documents can be completed, and the baton is passed from the design team to the construction team. As the project breaks ground, you can be confident that you are on the path to meeting the PHIUS+ certification standard.

6 PHIUS+ certification

After construction and verification, PHIUS adjusts the project's final energy model to match the results confirmed by the verifier. We then review final documentation and issue a PHIUS+ Certified Passive House Certificate to the CPHC professional and design team. A PHIUS+ Certified project plaque is available for purchase to show your commitment to higher quality construction.

LESSONS LEARNED

"As an architect, to suddenly learn that everything I knew was wrong was surprising. You can't unlearn this stuff, and once you're aware of it, everything around you seems negligent."

—Sam Rodell

Rodell does not blame negligence on people who don't know what they don't know. He notes, however, that it seems negligent that within the design and construction sector of this vast economy, passive-building techniques are so foreign to so many.

Chapter 7

FREQUENTLY ASKED QUESTIONS

The fastest path to net-zero energy use. Because extreme energy efficiency, indoor-air quality, comfort, and construction quality are built into the PHIUS+ process, the U.S. Department of Energy, awards PHIUS+ certified buildings with the DOE's Zero Energy Ready status.

Cost, certification, resilience, and ventilation are top queries

We hope this guide has answered most of your questions, but in case it hasn't, we've assembled a collection of common questions we've received over the years.

Of course, you can find more information at phius.org, at multifamily.phius.org, on the Klingenblog, and listed on the resource page at the end of this guide.

Q Does it cost more to build to the PHIUS+ standard?

A Of course, it does. Quality always costs more.

For commercial and multifamily construction, expect to pay about 5 percent or 6 percent more if your design and construction team is not experienced in passive building and/or PHIUS certified.

Experienced teams report about 2 percent to 3 percent cost premium over code construction. Depending on the project, you may be able to do it for even less. A 58-bed boarding facility in Spokane, WA, was able to do it for less than code standard by practically eliminating the heating system. With extra-thick insulation and 70 people generating heat every day, not much supplemental heat is needed. Because insulation is cheaper than mechanical equipment, the team was able to come in under the cost of a standard-code building.

Also, as more large-scale window and door manufacturers bring high-performance products to market, economies of scale drive down costs.

Q Are PHIUS+ buildings resilient?

A Yes.

One of the best things you can do for a building in an area that's prone to power outages is to build it tight and well-insulated. When the power goes out, a building's internal temperature should not plummet (or skyrocket) to match the outside conditions.

During the recent wave of hurricanes in Houston, Florida, and Puerto Rico, there were many cases of nursing homes with patients who were suffering—and dying—because without power, the building could not be air-conditioned.

Contrast that with a 58-bed medical facility in Spokane, WA, built to the PHIUS+ 2015 standard, which is completely buffered from power outages. When the building loses power, the temperature remains stable inside. In fact, during winter, the building is often in cooling mode because of the internal heat generation from people and computers.

When the owners of the facility add a PV array, the building will be energy independent and net zero.

Q Do tight buildings cause mold?

A No, tight buildings do not cause mold.

Moisture, suitable temperatures, and organic material that mold can eat "cause" mold. Actually, they "allow" mold to live and reproduce. If one or more of those ingredients is not present, then mold won't grow. Because leaky buildings could dry quickly (with air readily moving between inside and out), moisture was the limiting factor to mold growth in leaky buildings. Because buildings are made from organic material, it is very difficult to limit potential mold food, and because mold is an organism with similar physiological tolerances to humans, temperature will rarely be a limiting factor.

Because tight buildings have less air exchange with the outside, they are often blamed for causing mold. Internal moisture—in the form of humidity—can build up in tight buildings and provide the third ingredient listed above.

Passive buildings have an airtight building envelope and superinsulation, which combine to drastically reduce temperature variations and prevent condensation and mold issues. The constant, low-level ventilation also found in passive buildings further prevents moisture problems while maintaining excellent indoor-air quality.

That said, potential moisture issues must be carefully addressed at the design stage. That's why it's important to work with a certified passive-house consultant (CPHC). CPHC professionals are trained to accurately model building performance and to identify and address potential moisture issues from the onset.

Tight buildings are good because they use very little energy and they deliver clean indoor air, comfort, and sound control.

Q Where do I find windows for my project?

A www.phius.org.

PHIUS has certified window data available for a number of manufacturers, as well as recommendations by climate zone. Visit the PHIUS Certified Data for Windows Program resource page to learn more: www.phius.org/phius-certification-for-buildings-products/phius-verified-window-performance-data-program/find-compare-windows

Q What's the difference between passive-house certifications?

A Plenty.

Only one certification is tailored to the climate that the building is in. We think that's pretty important.

There are a lot of organizations with the words "passive house" in their title. Most of these are loose affiliate organizations, clubs, or groups of like-minded building professionals who want to design and build better buildings. They often want to combat climate change in their daily lives, and they recognize passive-house certification as the most stringent energy standard available. To smooth the learning curve, they form these support groups.

Despite the many "groups" and "networks" sporting the passive-house name, there are only two standard-certifying organizations: Passivhaus Institute (PHI) in Germany and Passive House Institute US (PHIUS) in North America. Through most of their early existences, the passive-house standard was similar for both, and you could certify a building with either or both—depending on where the building was located or your personal preference.

Around 2012, that began to change, as PHIUS looked to improve the performance of buildings for North America's many climate zones. We learned that designs for Germany's climate don't exactly work in Chicago, Houston, or Las Vegas. To improve building performance in hot, humid, cold, and mixed climates, PHIUS worked with Building Science Corporation (under a grant from the U.S. Department of Energy) to write the Climate Specific Passive Building Standard. This is an actual standard, available for jurisdictions to use as a model for building codes. We also worked with the Fraunhofer Institute of Building Physics to modify their WUFI hygrothermal modeling software into a design and verification tool for passive buildings tailored to North American climate zones and weather data.

The three-year study yielded a formula that we used to generate cost-optimized performance targets (annual heating demand, annual cooling demand, peak heating load, peak cooling load) for more than 1,000 North American locations. The results are remarkable: Early test cases show that observed energy use is extremely close to the expected energy use predicted by the model.

In the early days of passive house, there were fewer differences between PHIUS and PHI because we both used a spreadsheet to predict the energy use. The WUFI passive three-dimensional energy and moisture modeling software has created a large-enough gap in performance that PHIUS+ 2018 will no longer support the PHPP spreadsheet that is central to PHI certification.

PHIUS+ certification is the best, most efficient cost-effective, climate-specific path to a zero-energy building.

Q Can PHIUS scale to multifamily?

A Yes.

Passive house is orders of magnitude more efficient and easier to achieve than single-family residential. OK, maybe not orders of magnitude more efficient, but certainly much more.

Although plenty of single-family homes have been built to passive-house standards, the approach has been applied recently to multifamily apartment buildings and large-scale multifamily buildings. The results are spectacular because meeting the energy codes gets easier as the surface-to-volume ratio goes down. Less insulation is needed in large buildings, and because more people occupy commercial and multifamily space than single-family residential, more heat is generated, which can drastically reduce the size of the heating system.

Even though there are a few things in your favor, there is still a learning hump for new designers and builders. Continuous insulation, airtightness, and balanced mechanical ventilation are less common in standard construction and may be challenging to scale up on the first project with a new team.

Large buildings are a great fit for PHIUS. Large buildings are easier to make energy efficient, so the cost premium for PHIUS diminishes, too. This apartment building cost about 2 percent more to build than a comparable code building on Long Island, NY.

Q How long does certification take?

A Longer than you think, but less if you're experienced.

The length of the certification process varies depending on the specifics of your project. The majority of time is upfront; the better you do at the beginning, the quicker the project goes.

There are three main steps:

Precertification (6 to 8 months): The length of this step depends on the project type, the experience of the project team, and the stage in the process the project team decides to certify, among other factors.

The project team typically receives the first-round review four to six weeks after submitting a project for PHIUS+ certification. Now, the team can reply to comments, upload requested documentation, update the energy model, and send back the completed documentation to PHIUS. Most projects require three rounds of review to achieve precertification.

On average, this process takes from six to eight months total, but can vary depending on the project schedule and turnaround time from the project team.

Project construction phase: Duration will vary by project.

Final quality-assurance protocol and on-site verification (~1 month): The PHIUS+ rater/verifier performs on-site quality-assurance/quality-control (QA/QC) protocols.

The typical PHIUS review turnaround time once final documentation is received is about one month.

Q **Tell me more about the HVAC system, please.**

A **OK. It looks more like this: hVac.**

The mechanical system is a critical component of all high-performance buildings. Design loads are drastically lower because of continuous insulation, extreme airtightness, and superefficient windows. In simple terms, the "H" and "AC" parts of HVAC are smaller, and the "V" is better, hence hVac.

Balanced ventilation that delivers fresh air and removes stale air from the living space is a primary design focus. Taller buildings have more ventilation challenges because of the stack effect, a pressure created by the buoyancy of warm air. It is also called the chimney effect because it is how chimneys work: Warm air rises and cool air rushes in to replace it. The stack effect becomes a dominant force in buildings over six stories, making heating and cooling tall buildings frustrating and complicated.

Katrin Klingenberg, the executive director of PHIUS, outlined "best" and "second best" systems for these scenarios. "Best-practice ventilation in airtight mid- and high-rise buildings is a dedicated balanced-ventilation system in each unit. This arrangement has many benefits. Best efficiency of the ventilation system (short distribution ducts, small pressure drop due to ductwork), best control of potential point loads, and best control from the user's perspective (increasing airflow when needed or shutting it off when going on vacation). It also delivers the best indoor-air quality."

Ducts are small and easy to maintain and replace if necessary over time. Each unit can be compartmentalized, so there is no stack effect, no cross-contamination of indoor pollutants, and lower fire risk from vertical-distribution penetrations.

Yes, it requires more maintenance and filter cleaning, but in most cases, projects use variable refrigerant flow (VRF) systems, and those air handlers also need filter maintenance on a regular basis.

Klingenberg's second-best practice is placing semi-decentralized balanced-ventilation units on each floor. This arrangement has many of the same benefits, (no stack effect to battle, ducts remain relatively small). They also do not require central air returns or fire dampers, and there is more zonal control than with centralized systems. This setup offers better building ventilation resiliency if one unit fails.

This solution has another benefit for densely populated buildings where cooling loads are high and indoor humidity could be an issue. Centralized dehumidification can be installed from the VRF system after the air has passed through the ventilator.

Q What risks are associated with passive building?

A Overdelivering.

OK, this was kind of a trick question. But the reality is that because quality assurance and quality control are built into the PHIUS+ certification process, and because the 3D energy- and moisture-modeling is so robust, the risk of moisture damage, comfort complaints, high energy bills, or construction cost overruns is minimal. We know how the building will perform before it is built, and we monitor the construction process to make sure that it lives up to expectations and its capabilities.

This is precisely why we worked with Fraunhofer Institute to tailor the WUFI Passive modeling tool to North America's many climate zones and weather data. Based on our experience building a few passive houses outside Germany's climate zone, we understood that if the standard wasn't improved, then comfort complaints, high energy bills, and moisture/mold damage could become synonymous with energy-efficient building and design, and we would not be able to achieve our mission, which is "to make structures that are durable, resilient, comfortable, healthy, and super energy efficient."

So if you build near passive-house standard or passive-house-inspired, the main risks are moisture problems and comfort complaints. Probably cost overruns and callbacks, too.

Really, the biggest risk in building is not building to PHIUS+, not modeling with WUFI Passive, and not going through the QA/QC-driven certification process. The modeling and the certification, the climate and cost optimization were all developed to make the risk question moot. The risk of passive building is not building to the PHIUS+ standard.

Q Are there affordable-housing discounts?

A Yes.

The discount for nonprofit developers and organizations seeking PHIUS certification for buildings is 25 percent off PHIUS's regular certification fee, not to exceed $1,000.

Affordable housing discount. Three foreclosed and vacant properties in Southeast DC were retrofitted into a 36-unit mixed income permanent supportive housing (PSH) community. Developed by Housing Up, it's the first multifamily passive-building project of its kind in Washington DC.

ABOUT PHIUS

Pushing the envelope of affordable excellence

Passive House Institute US Inc. (PHIUS) is a non-profit 501(c)(3) organization committed to making high-performance passive building the mainstream market standard.

Our mission is to develop and promote North American passive building standards, practices, and certifications for buildings, professionals, and products to create structures that are durable, resilient, comfortable, healthful, and super energy efficient.

The early groundwork

PHIUS was initially founded in 2003 as a nonprofit community-housing development organization that designed and built demonstration passive homes for the affordable-housing market. The organization shifted focus in 2007, becoming the leading passive-building standard-setting, research and information provider, and certification institute in North America. PHIUS supports and inspires the growing community of passive-building professionals and guides large-scale market transformation in the North American building industry.

In 2008, PHIUS established the Certified Passive House Consultant (CPHC®) credential to distinguish accomplished passive-house designers in the marketplace; the certification program for builders and onsite raters was first introduced in 2012. PHIUS is the leading passive building training provider in North America, and since 2003 has trained more than 2,000 architects, engineers, energy consultants, energy raters, and builders in the PHIUS+ Passive Building Standard.

Passive House Institute US

The PHIUS standard is born

PHIUS released the PHIUS+2015 Passive Building Standard in March 2015, the only passive-building standard on the market that is based on climate-specific comfort and performance criteria, and the only passive-building standard that requires onsite QA/QC for certification. Developed in cooperation with Building Science Corporation under a U.S. Department of Energy grant, the PHIUS+2015 standard targets the sweet spot between investment and payback to present an affordable solution to achieving the most comfortable and cost-effective building possible and the best path for achieving net-zero energy and carbon.

Hard work pays off

Buildings designed and built to this standard perform 60 percent to 85 percent better (depending on climate zone and building type) on an energy-consumption basis when compared to a code compliant building (International Energy Conservation Code IECC 2009).

PHIUS+ Certified and Pre-Certified projects now total more than 1 million square feet across 1,200 units nationwide. The cost-optimized PHIUS+2015 Standard is spurring new growth in passive buildings from coast to coast, with the most significant gains coming from the multifamily-housing sector.

Building up steam with respected partners

In addition to the Department of Energy and Building Science Corporation, PHIUS has established strategic relationships with key organizations including RESNET and the Home Innovation Research Labs, among others.

The organization has received funding from the Richard King Mellon Foundation and the John D. and Katherine T. MacArthur Foundation.

Through its Passive House Alliance US (PHAUS) program, a membership-based organization with more than 800 members across 18 local chapters and dozens of corporate sponsors, PHIUS is building a robust national network of passive-building communities across North America.

New research initiative launched

Most recently, we've launched the PHIUS High Performance Building Industry Advisory Council, or IAC for short. The IAC is a voluntary board of leading building scientists who set (through consensus) technical standards for project and building-component certification. The council does research, publishes the findings, and integrates the results into the PHIUS+ Standard during regular updates.

Learn more about the Passive House Institute US at www.phius.org

MacArthur Foundation

ROCKY MOUNTAIN INSTITUTE

PASSIVE HOUSE ALLIANCE UNITED STATES

ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY

RESNET® RESIDENTIAL ENERGY SERVICES NETWORK

bsc Building Science Corporation

CREDITS

Cover

p. 1 (top): Photo by Casey Braunger courtesy of Ankrom Moisan Architects
p. 1 (top left and bottom): Photos courtesy of Community Housing of Maine

Contents

p. 3 (top left): Photo courtesy of Hood Thomas Architects
p. 3 (center left): illustration courtesy of Ankrom Moisan Architects
p. 3 (bottom left): Photo courtesy of Community Housing of Maine
p. 3 (top right): Illustration courtesy of Zavos Architecture and Design
p. 3 (center right): Illustration courtesy of The Bluestone Organization
p. 3 (bottom right): Photo courtesy of Community Housing of Maine

Introduction

p. 4: Illustration courtesy of Ankrom Moisan Architects

Chapter 1: Passive Building Fundamentals

p. 5: Photo by Casey Braunger courtesy of Ankrom Moisan Architects
p. 5 (bottom): Illustration courtesy of Hammer and Hand
p. 6 (top): Photo by Mark Woods, courtesy of Hammer and Hand
p. 6 (bottom): illustration courtesy of Zavos Architecture and Design
p. 7 (top): Photo courtesy of Thoughtful Balance, Inc.

Chapter 2: Passive Building Benefits

p. 8: Photo by Carolyn L. Bates Photography, courtesy of Duncan Wisniewski Architecture
p. 9 (top right): Chart from Center for the Built Environment, University of California Berkeley via Wikimedia Commons
p. 9 (bottom): Photo by Carolyn L. Bates Photography, courtesy of Duncan Wisniewski Architecture
p. 10 (top): Photo courtesy of Hood Thomas Architects
p. 11 (top) Illustration courtesy of SolTerre Architects
p. 11 (bottom): Photo courtesy of Rodell Architects
p. 12 (top and bottom): Photos by Carolyn L. Bates Photography

Chapter 3: Passive Building Works for All Building Types

p. 13 (top): Illustration courtesy of The Bluestone Group
p. 13 (bottom): Photo courtesy of River Architects
p. 14 (top): Chart from PHIUS
p. 14 (bottom): Illustration courtesy of Sam Rodell Architects
p. 15: Photo courtesy of Housing Up
p. 16: Photo courtesy of Thoughtful Balance Inc.
p. 17 (top left): Map by PHIUS and Google Maps
p. 17 (top right): Map by U.S. Department of Energy
p, 17 (bottom): Photo courtesy of Thoughtful Balance, Inc.

Chapter 4: Three Examples of Passive Building

p. 18 (top left): Illustration by Zavos Architecture and Design
p. 18 right): Photo by Casey Braunger courtesy of Ankrom Moisan Architects
p. 18 (bottom): Photo by Ben Walter courtesy of CWS Architects
p. 19 (top): Photo courtesy of Housing Up
p. 19 (bottom): Illustration courtesy of ZA+D
p. 20 (top): Photo courtesy of Housing Up
p. 21: Photos by courtesy of Housing Up
p. 22 (left): Photo courtesy of Housing Up
p. 23 (left): Photo courtesy of Housing Up Illustration: ZA+D
p. 24: Photo courtesy of Housing Up
p. 25-29: Photo by Casey Braunger courtesy of Ankrom Moisan Architects, illustration courtesy of Ankrom Moisan Architects
p. 30–34: Illustrations and photos courtesy of Community Housing of Maine

Chapter 5: Breaking Down the Numbers

p. 35: Photo courtesy of Housing Up
p. 36: Illustration courtesy of Cascade Built
p. 38 (top right): Photo by iStock.com/Alxpin
p. 38 (bottom left): Photo courtesy of Cascade Built
p. 39: Photo by Vickey Rand, courtesy of Community Housing of Maine

Chapter 6: Six Steps to PHIUS+ Certification

p. 40: Graphic by Tinsley Morrison
p. 41: Book cover from PHIUS
p. 42 (top right): Illustration courtesy of Housing Up
p. 43 (left): Photo by Ben Bogie
p. 43 (right): Logo by PHIUS

Chapter 7: Frequently Asked Questions

p. 42: Photo courtesy of Community Housing of Maine
p. 46: Photo by by Carolyn L. Bates Photography, courtesy of Duncan Wisniewski Architecture
p. 47: Photo courtesy of The Bluestone Organization
p. 48: Photo courtesy of Thoughtful Balance, Inc.
p. 49: Photo courtesy of Housing Up

About PHIUS

p. 50: Logo by PHIUS