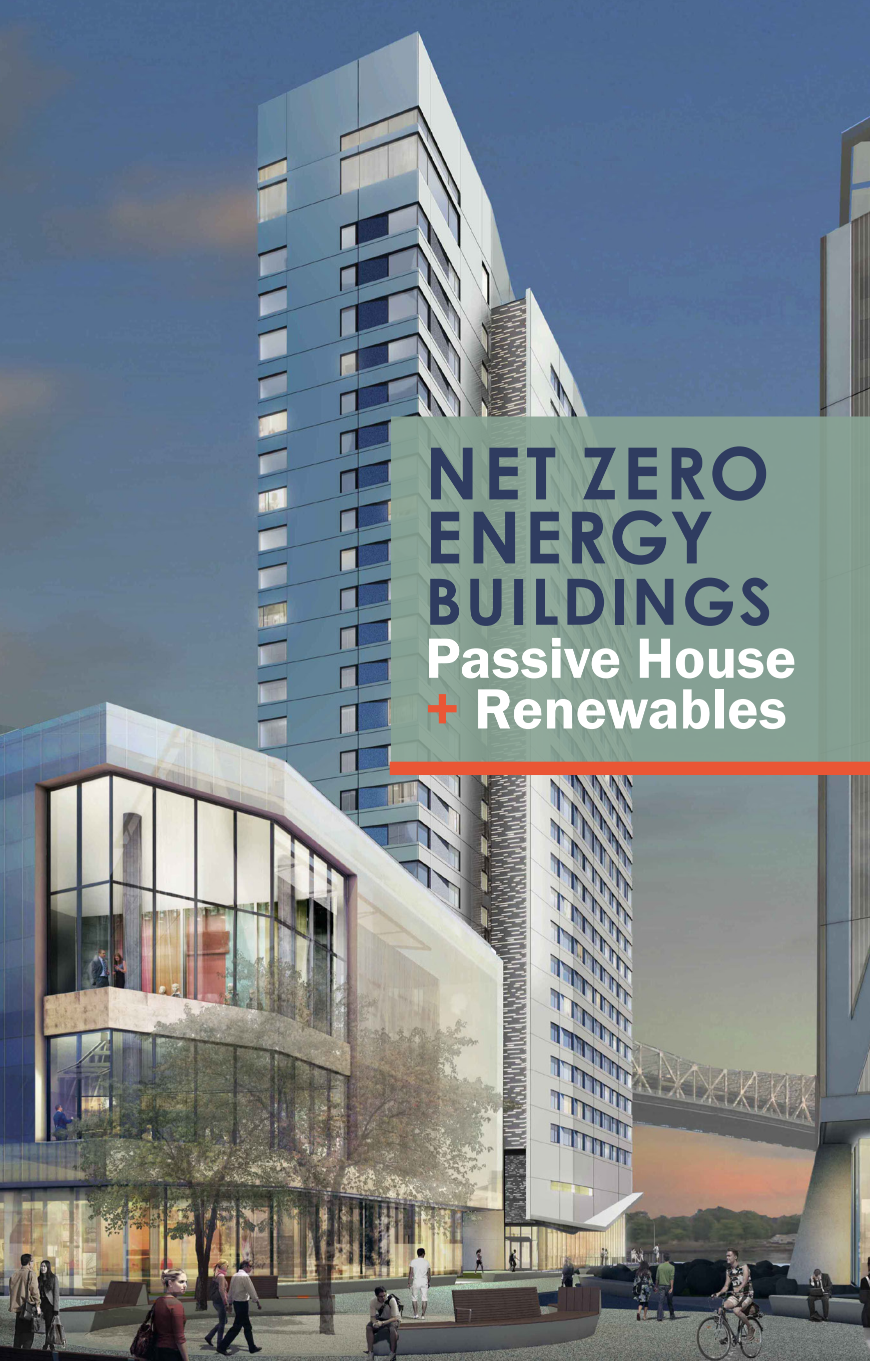
NET ZERO ENERGY BUILDINGS

Passive House + Renewables



NET ZERO ENERGY BUILDINGS

Passive House + Renewables

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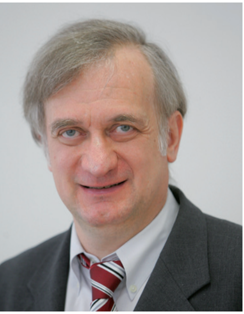
Foreword

The international Passive House Standard is steadily establishing itself as a solution for highly energy efficient construction—in all climates and for all building types. Complemented by renewables, as introduced in the certification classes Passive House Plus and Passive House Premium, the standard also represents a blueprint for increasingly stringent building regulations aimed at meeting energy and carbon reduction policy goals at all levels of government.

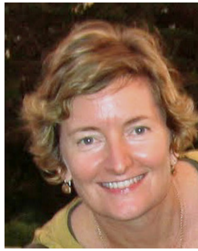


In North America, the combination of energy efficiency and on-site sustainable energy generation is becoming more common, as front-running cities and regions look to set the new norm of building: cost-effective and sustainable. The step is long overdue, as over a third of the total energy consumption in industrialized countries results from building operation – and up to 90 per cent of this energy can be saved with Passive House.

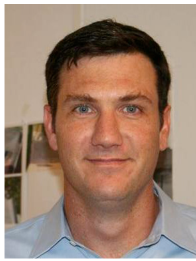
The time is now for local government leaders to match the commitment of these regions. Local officials have proven to be especially important in this regard. They can create a framework for energy-efficient construction with their innovative ideas, whether by means of financial incentives, pilot projects, or urban planning. This book highlights innovative examples in the hope that they will serve to motivate government leaders to cooperate at a global level and meet their shared responsibility to halt global warming.

Professor Dr. Wolfgang Feist
Director of the Passive House Institute

THE NORTH AMERICAN PASSIVE HOUSE NETWORK (NAPHN) *was created in 2013 to share resources and information among regional Passive House associations developing and operating across North America.*



Bronwyn Barry



Ken Levenson

We are pleased to present this book showcasing the successes of these associations and the individual architects, designers, and builders of Passive House buildings on this continent.

The implementation of the international Passive House Standard is dramatically altering the built environment, most notably in regions that have embraced measures to stop climate change. The projects within these pages embody the clear hallmark of the Passive House Standard: a strong framework of performance metrics. These metrics, accompanied by a set of reliable modeling tools, have allowed a wide variety of design and material options within the boundaries of optimized performance.

However, the performance of these buildings is not their only important feature. Most notably, the Passive House Standard is a standard defined by occupant comfort. It replaces the typical view of energy reduction from a punitive construct based on deprivation and compromise to one based instead on a vision of the possible: a life-affirming solution of comfort, durability, and health that just happens to deal squarely with the challenge of our century: carbon emissions reduction.

We hope these examples will inspire you, your city, and your region to action.

Ken Levenson & Bronwyn Barry
NAPHN Co-Presidents

1

PASSIVE HOUSE + RENEWABLES

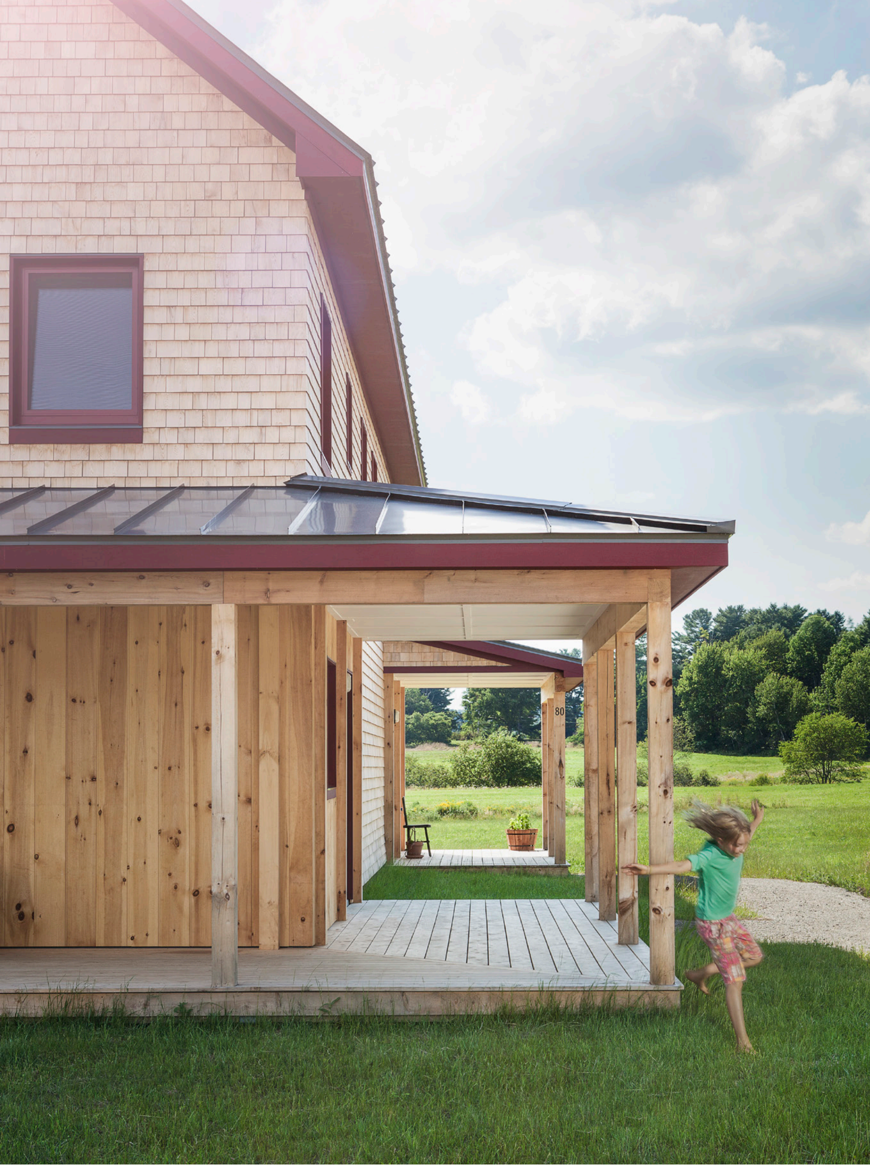
A NET ZERO ENERGY BUILDING, ACHIEVED USING THE INTERNATIONAL PASSIVE HOUSE STANDARD, *consumes very little energy on an annual basis and produces as much energy as it consumes. The building's small demand is met by renewable energy generated onsite or nearby.*

This definition prioritizes energy efficiency for a good reason. Energy from renewable sources is limited and is not available to the same extent in every locale and season. Although it is quite difficult for an inefficient building to be net zero without a massive renewable energy system, the situation looks quite different if you cut a building's energy consumption by 50-80%.

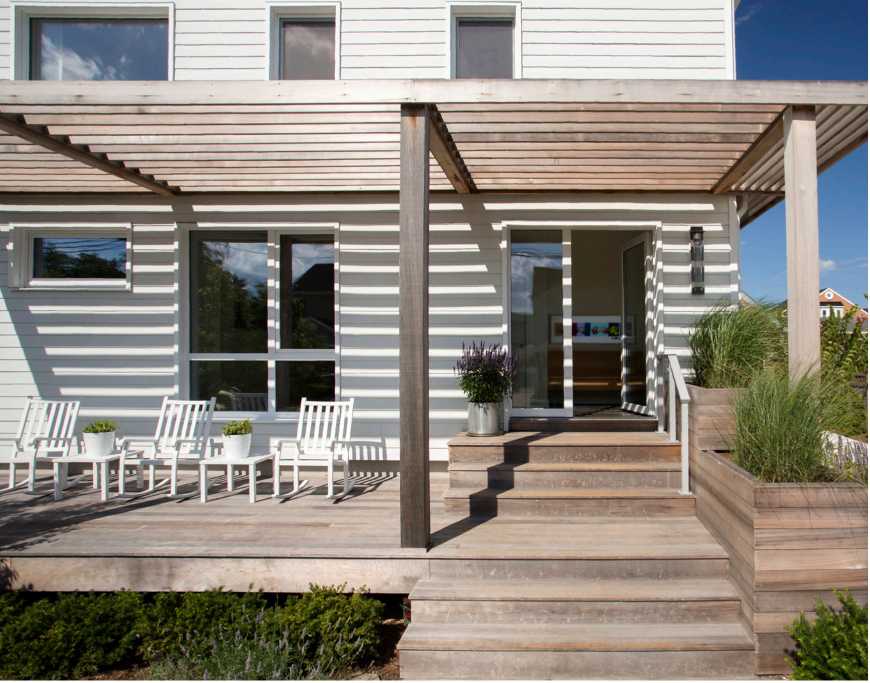
The Passive House Standard has proven successful in sharply reducing energy use in thousands of buildings over the last 25 years, making it an ideal basis for a Net Zero Energy Building. The Passive House Standard sets limits on a building's heating energy, cooling energy, and overall energy use. In addition, a building's air leakage must be tested and must not exceed 0.6 air changes per hour for new construction or 1.0 air change per hour for a retrofit.

Based on consistent compliance with these performance-related criteria, the Passive House approach has been used to create highly efficient houses, apartment buildings, schools, supermarkets, offices, laboratories, and a host of other building types. By slashing building energy demand, the Passive House Standard allows wind, solar, geothermal, and hydropower resources to meet 100% of a building's annual energy consumption.

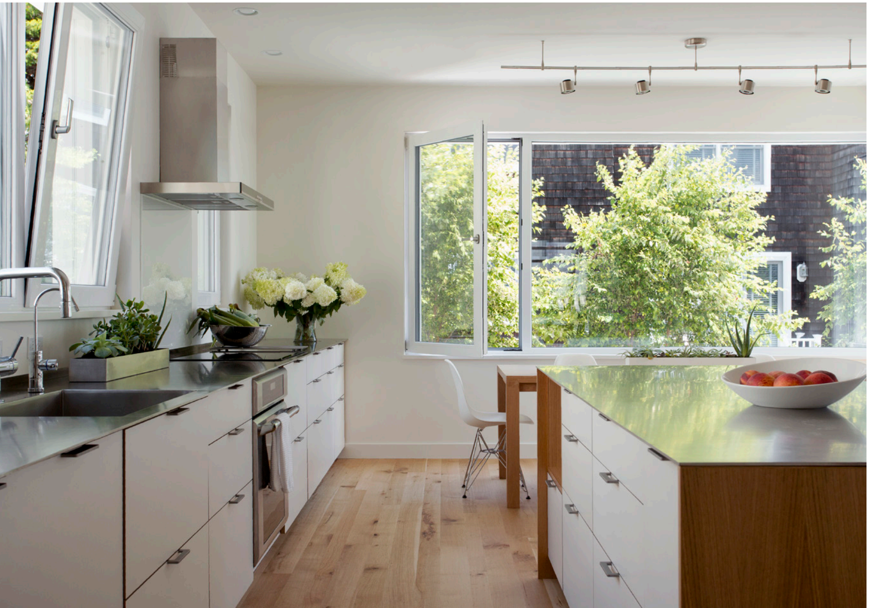
Heat that doesn't escape from a building in winter does not have to be actively supplied; similarly, in summer, the less heat that penetrates a building means the less cooling needed to keep the building and its occupants comfortable. This is the key principle of the Passive House Standard, which is mainly achieved by means of a well-insulated, airtight building envelope combined with appropriate mechanical ventilation. In this way, a Passive House dramatically cuts heating and cooling energy use. Thus, this standard makes a significant contribution to the energy revolution and climate protection.



Belfast Cohousing by GOLogic; Photo byTrent Bell



Margate by ZeroEnergy design; Photos by Eric Roth



The Passive House Standard is not limited to any specific construction design or materials. Any experienced architect can design a Passive House building in line with his or her own creativity. What matters is the quality of the details. With proper execution, the building owner will have an energy-efficient building that is both cost-effective and comfortable.

A Passive House is also an attractive investment for building owners: the small extra costs incurred in the construction phase are amortized within several years due to avoided energy costs. Because heating and cooling bills will then continue to be a fraction of what they are in conventional buildings, Passive Houses are more cost-effective than their conventional neighbors.

Passive House Fundamentals

Some of the very first modern, low energy houses—early Passive House prototypes—were built in the United States and Canada in the late 1970s, but continuing research was largely shelved in North America with the advent of lower oil prices. However, research continued in Europe, and the first pilot Passive House, designed by Dr. Wolfgang Feist and Dr. Bo Adamson, was built in 1990 in Darmstadt, Germany. Systematic measurement of this pilot building's energy use proved that the calculated energy savings were achieved in practice, and 25 years later the actual energy use still is consistent with the predicted use—clear evidence of a Passive House's long-term performance. Different types of Passive House buildings were then constructed, and their energy use was measured in further research projects, with similar results.

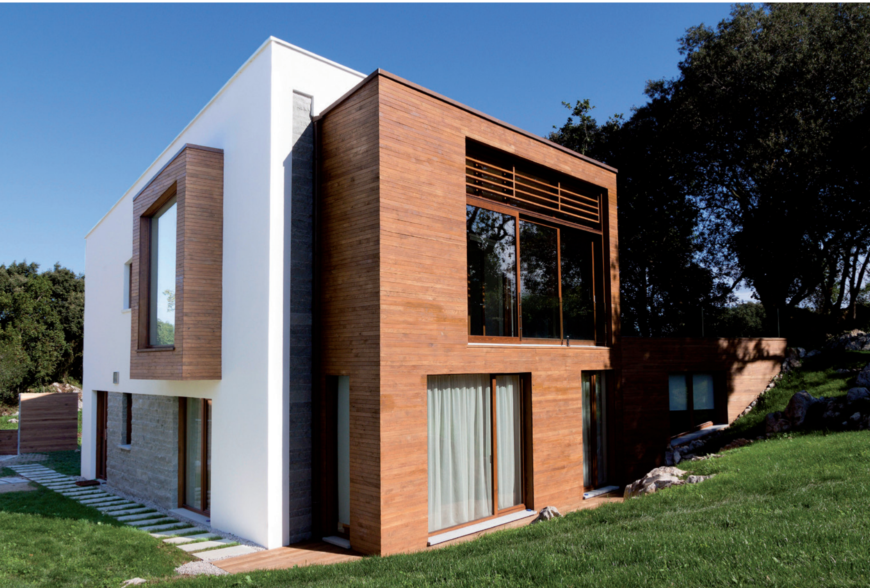
Over the next two decades this standard was successfully applied throughout Central Europe, and gradually to all other climate zones in the world. The general applicability of the Passive House Standard has led to a huge increase in its international adoption in recent years, with tens of thousands of Passive House buildings worldwide.

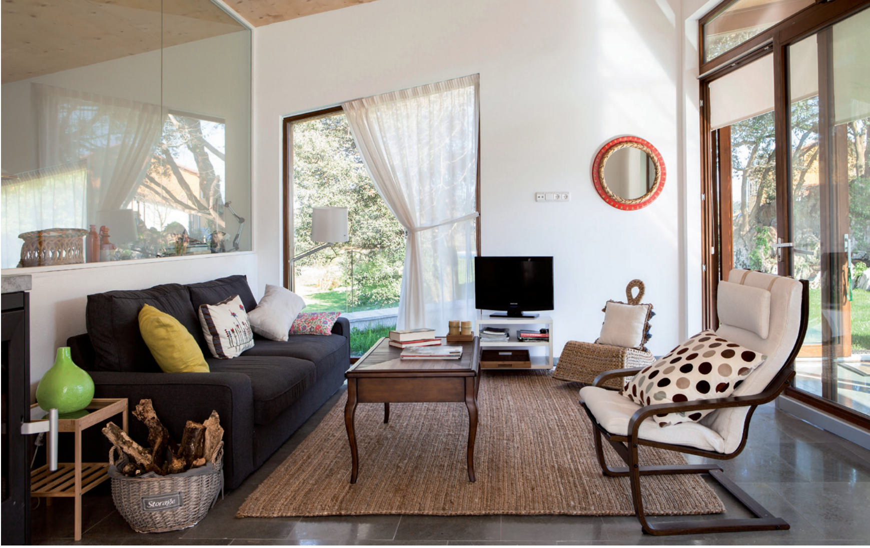
Of course, the exact implementation details depend greatly on the particulars of a project and its location. The technical challenges that must be mastered in the case of a supermarket with energy-intensive refrigeration systems are completely different to those of a conference building that is only used occasionally, but that is full of people when in use. A home constructed in Montreal, Quebec must be designed differently from a home in coastal California.

The fundamental principles of the standard, however, remain the same regardless of whether these are applied to new builds or to energy-efficient retrofits. The Passive House Standard for retrofits, EnerPHit, can be met either through meeting specific performance-related targets or by using Certified Passive House Components.

The five key factors for consideration in all cases are:

1. **An optimal level of thermal insulation.** Excellent thermal protection in the building envelope is essential for achieving high levels of energy efficiency, as most of the heat in conventional buildings is lost through the exterior walls, roof, and floor. This principle is reversed in the summer and in warmer climates: continuous insulation and external shading ensure that heat remains outside, keeping the inside pleasantly cool.





2. **Thermally insulated window frames with high quality glazing.** Such windows, typically with triple-glazing, trap the sun's heat during the cold winter months. South-facing windows in particular direct more solar energy into the house on an annual basis than the heat they lose through the glass to the outside. During the warmer months, the sun is positioned higher in the sky so that less heat is trapped. Still, external shading is important to prevent any overheating.
3. **Thermal bridge free construction.** Thermal bridges are weaknesses in the building envelope's thermal barrier that allow more heat to pass through than might be expected. Following the path of least resistance, heat travels from a warmer space toward a cooler one. Avoiding thermal bridges in building design is thus a great way to avoid unnecessary heat loss or heat entry into a building. Careful design and construction are essential, especially in connections between building components, intermediate ceilings, and foundations.

Photos: Casa EntreEncinas | DUQUEYZAMORA ARQUITECTOS
Villanueva de Pría | Spain

Photo: Office building | Stadtwerke Lemgo | h.s.d. architekten | Germany © Christian Eblenkamp

4. **An airtight building envelope.** An airtight envelope that encloses the whole interior space prevents energy loss, moisture-related structural damage, and drafts. To achieve this, Passive House buildings are designed with an uninterrupted and continuous airtight layer.

5. **Mechanical ventilation with heat recovery.** Mechanical ventilation with heat or energy recovery ensures a plentiful and consistent supply of fresh, clean, dust- and pollen-free air while reducing energy losses. In winter, up to 90% of the heat in the stale air being exhausted from the building can be recovered via heat exchange to warm the incoming cold, fresh air. In summer, up to 90% of the heat in the outdoor fresh air is transferred to the stale air exhausted from the home for "free cooling". These systems are usually very quiet and easy to operate.

Passive House is not just an energy-saving standard; a central component of the concept is the very high level of thermal comfort. Throughout the building, indoor temperatures remain even and comfortable year-round.

While the concept behind the Passive House Standard may be straightforward, great care must be taken during design and construction to achieve the desired results. Each Passive House project should be guided by an experienced expert right from the design phase.

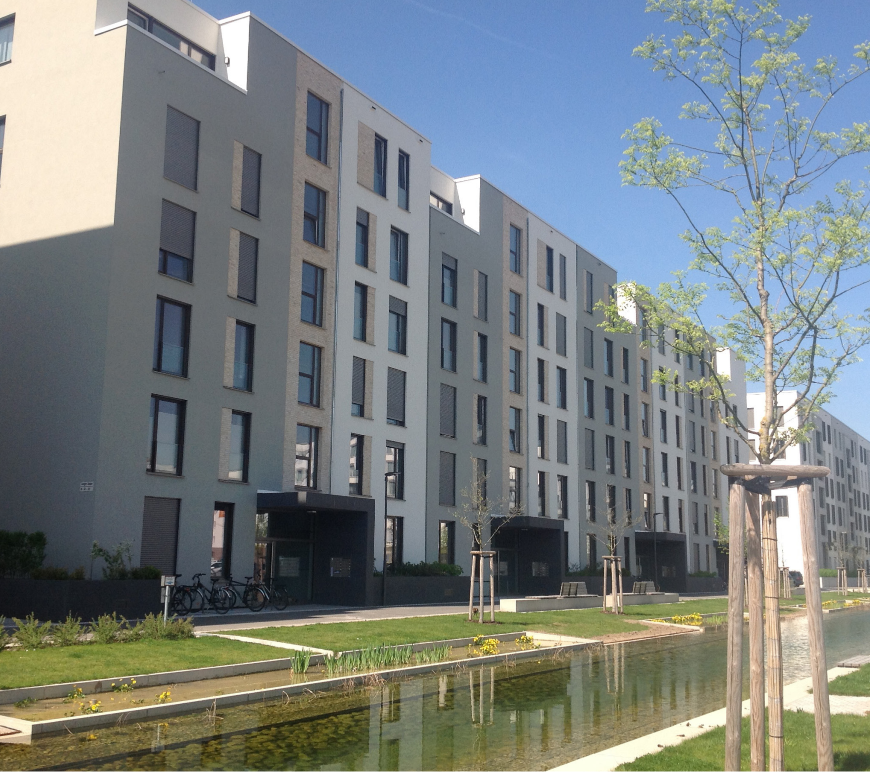
The Passive House Planning Package (PHPP) software, long internationally established as the premier design tool for Passive House and all other high-performance buildings, enables designers to accurately predict the effects of design changes on annual heating and cooling demand and other important values.

Passive House certification further ensures both high quality and that the designed energy performance will be delivered in practice. Certification is either carried out by the Passive House Institute itself or by an internationally accredited Building Certifier. Through certification you can be sure that the energy performance and quality will be as promised.

2

LEADING REGIONS

Some regions and municipalities are promoting the use of Passive House low energy principles and renewables and achieving these standards on a wide scale thanks to targeted policies, legislation, incentives, and support. Despite their very different social and political contexts, Heidelberg, Tyrol, Vancouver, New York, and the San Francisco Bay Area provide excellent examples.



(top) Bahnstadt Heidelberg, Germany; Photo by Mary James
(bottom) © City of Heidelberg; Photo by Kay Summer

HEIDELBERG, Germany

A striking example of forward-thinking planning is Heidelberg's new city district, the Bahnstadt. Established on the site of a former freight yard, the 280-acre redevelopment area will eventually provide housing for 5,500 people and office space for 7,000.

The City of Heidelberg made the Passive House Standard mandatory for the entire Bahnstadt development, making it one of the largest Passive House sites in the world. The district includes a student campus, offices, industry, retail, leisure, and housing, demonstrating the flexibility with which the standard can be applied.

A district heating system based on a combined heat and power plant fed by wood chips makes Bahnstadt net zero in terms of annual carbon emissions; 100% of its heating and electricity needs are supplied by renewable sources.

The development has been so well received that the second phase of construction was accelerated by two years. Public and private investment through 2022 has been estimated at €2 billion. City subsidies aid the ultra-low energy development; for example, the City provides €50 per square meter for residential Passive House buildings— up to a maximum of €5,000 per unit.

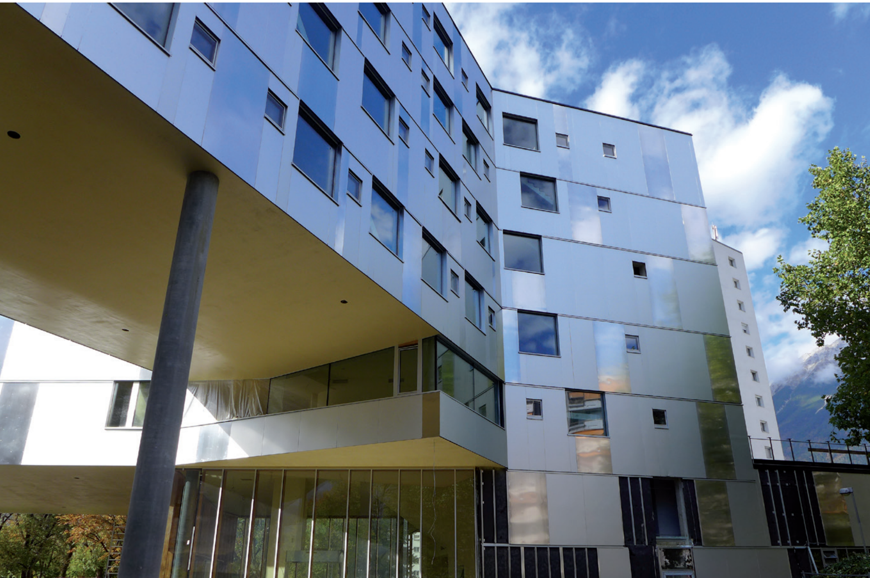
A recently completed monitoring study by the Passive House Institute confirms the accuracy of the PHPP, with the modeled energy demand closely matching the as-built energy demand in Bahnstadt, and highlights the potential of the Passive House Standard, even when applied at a district level, to significantly reduce energy consumption.

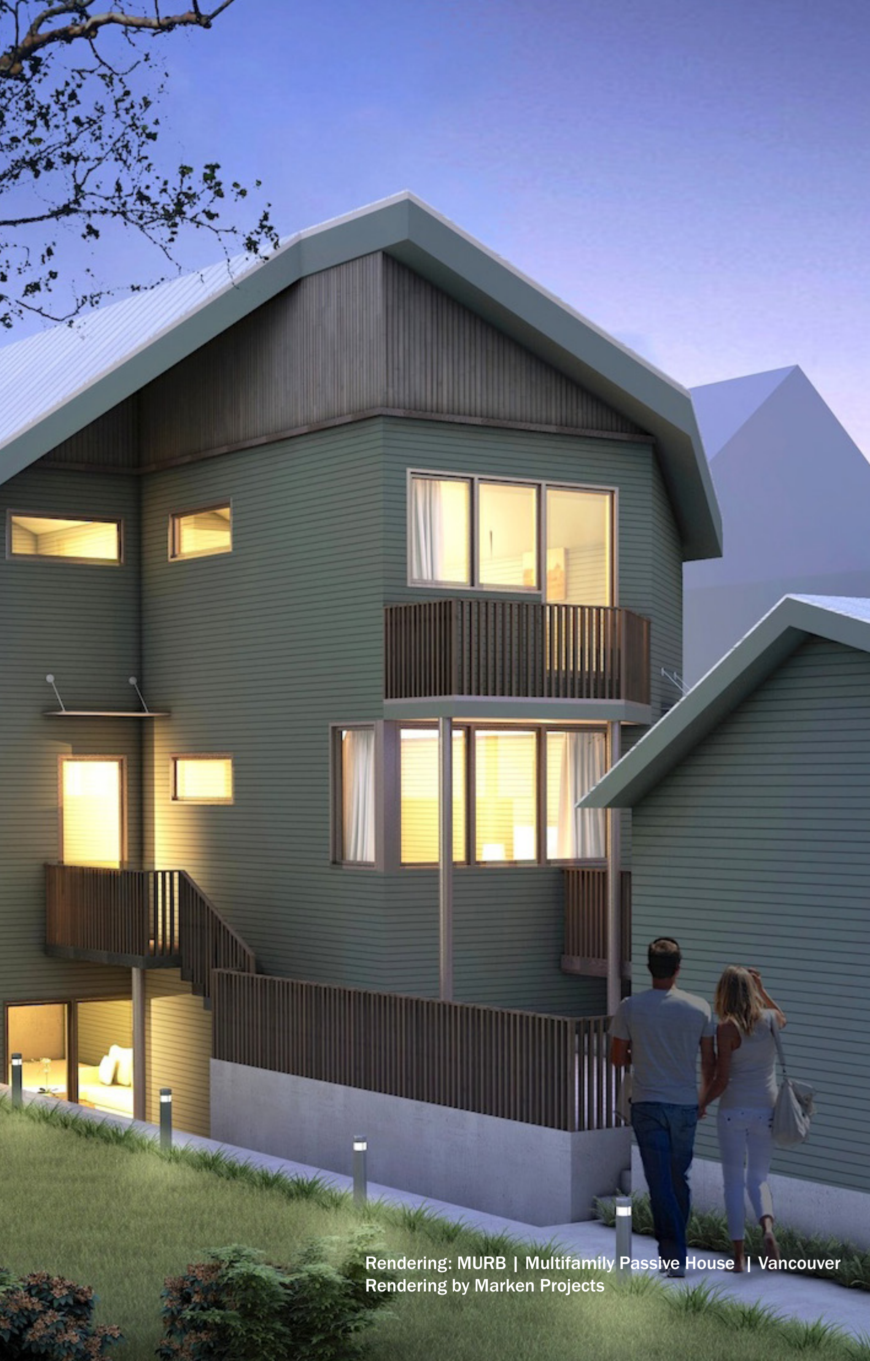
TYROL, Austria

Tyrol's success story began in 1999 when the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) launched a sustainable management research and technology program, "Building of tomorrow". Today the "Tyrolian Energy Strategy 2020" weaves Passive House and renewables into their strategy for climate protection via generous housing subsidies and Passive House promotion. In addition to energy efficiency in buildings, the policy also strengthens hydropower, solar energy, and energy from biomass in order to achieve energy autonomy for Tyrol within one generation.

Large-scale Passive House projects are playing a particularly important role. The Lodenareal in Innsbruck, for example, is a 354-unit apartment complex built to the Passive House Standard complemented with renewable energy from solar collectors and a wood pellet boiler. Energy performance monitoring and user surveys show how well the Passive House concepts works.

(Top) The Lodenareal in Innsbruck | architekturwerkstatt din a4, team k2 architekten | Austria © Passive House Institute
(bottom) Nursing home | retreat home | Tyrol | Artec Architekten | Passive House Consultant Herz&Lang GmbH | Austria © Herz&Lang GmbH





Rendering: MURB | Multifamily Passive House | Vancouver
Rendering by Marken Projects

VANCOUVER,
British Columbia

When the City of Vancouver in Canada's province of British Columbia announced its goal to become the Greenest City in the world by 2020, it set a target to reduce greenhouse gas emissions by 33%. Greening the local building stock has been at the forefront of sustainability changes, and Passive House has been identified as one tool that will make a big difference in reducing emissions.

Vancouver has introduced several new policies to encourage carbon-neutral buildings, including a rezoning policy recognizing Passive House and a wall thickness exemption policy for buildings with walls thicker than those required by code minimums. The City has also chosen to recognize the Passive House Planning Package (PHPP) as an alternative to the energy modeling software program, HOT2000, to demonstrate compliance with energy code requirements for single- and two-family homes. The Chief Building Official has issued a memorandum allowing the use of Passive House-compliant windows while the manufacturer is pursuing local certification.

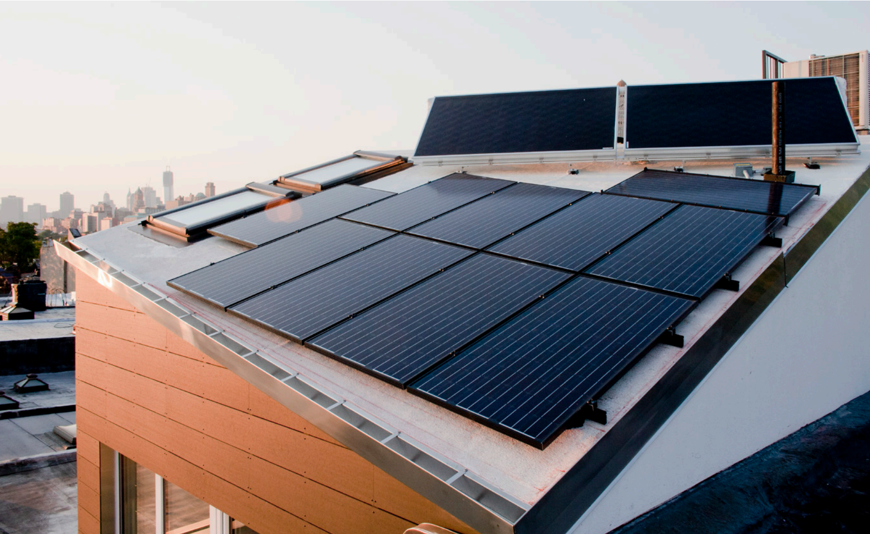
The City and the provincial government are simultaneously funding education initiatives, with the City holding staff training sessions to learn about Passive House features and supporting the production of the *Passive Design Toolkit*. British Columbia has contributed funding for Passive House trainings to CanPHI West, a regional Passive House education and advocacy organization and International Passive House Association affiliate.

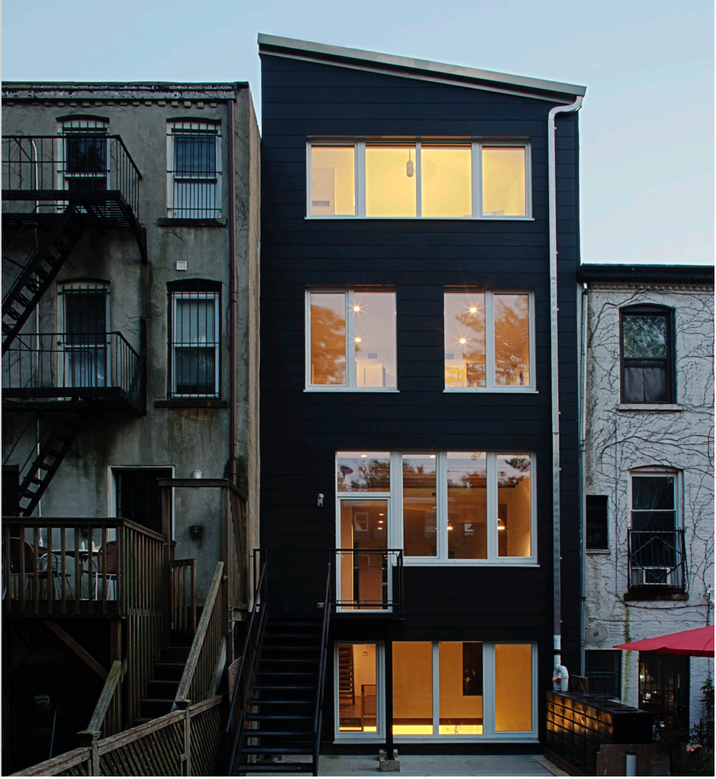
These new policies are bearing fruit. Several Passive House developments are underway—and, they're not all single-family, duplex, and row houses. A six-story rental apartment building received its rezoning and building permit to become a Passive House, and other multi-family projects are in the rezoning process.

NEW YORK, New York

New York City is aiming high in its rapid uptake of the Passive House Standard in the United States: In June 2015, Cornell Tech broke ground on the world's tallest Passive House building—and also the largest residential Passive House thus far. At the groundbreaking ceremony on Roosevelt Island, Mayor Bill de Blasio stated: "Passive House makes sense as a phrase, but I think it is an activist notion—a transformative notion….This is one example of how New York City can show the world a model that works in today's reality…"

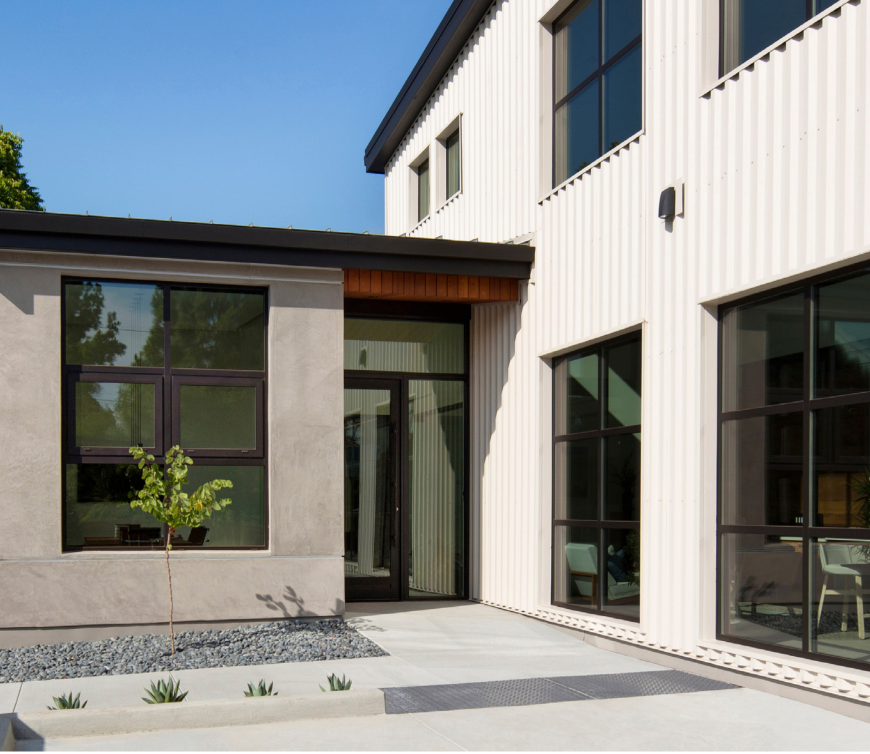
While grand, this high-rise is just one example of the roughly 50 Passive House projects across New York State. This proliferation could explain Mayor de Blasio's familiarity with Passive House, which he cited in his *One City: Built to Last* policy aimed at cutting greenhouse gas emissions by 80% by 2050, declaring New York City will look to "Passive House, carbon neutral, or `zero net energy' strategies to inform the [building performance] standards."



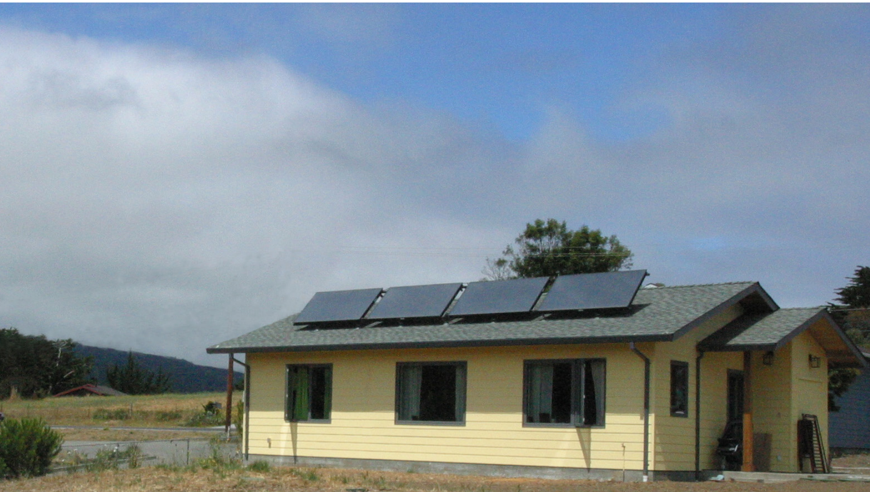


Passive House development requires expertise, and New York has it in spades. Based on an alliance with the International Passive House Association, New York Passive House (NYPH) began promoting Passive House buildings in 2010. Today, NYPH boasts 185 Passive House professionals who design, build, and certify Passive House buildings, the single largest concentration of Passive House trained professionals in the United States. The Association for Energy Affordability and the Passive House Academy have conducted ongoing Passive House trainings, recently with financial support from the New York State Energy Research and Development Authority (NYSERDA).

Row House by Julie Torres Moskovitz, FNA; Photos by Hai Zhang



(top) Clarum Homes Net Zero Office by Clarum Homes; Photo by Bernard Andre Photography
(bottom) CLAM House by ZIA Architecture; Photo by James Bill



California's SAN FRANCISCO BAY AREA

California's San Francisco Bay Area, and particularly the Silicon Valley region, is emerging as a Passive House development hotbed—due in no small measure to its technology–savvy population. Early adoption of Passive House is giving this region an edge when it comes to fulfilling California's goal of requiring all new residential construction to be Net Zero Energy Buildings by 2020 and all new commercial construction by 2030.

Starting in 2008, pioneering Bay Area Passive House projects spurred interest in the concept and created the catalyst for the formation of Passive House California (PHCA), a regional Passive House advocacy organization. PHCA estimates now that more than 50 Passive House projects have been completed in this region, with many more in design and construction phases of development. Approximately 25% of these projects are retrofits. Experienced California Passive House practitioners are evolving design adaptations that suit local microclimates, such as optimizing night-ventilation cooling to take full advantage of fog-influenced breezes.

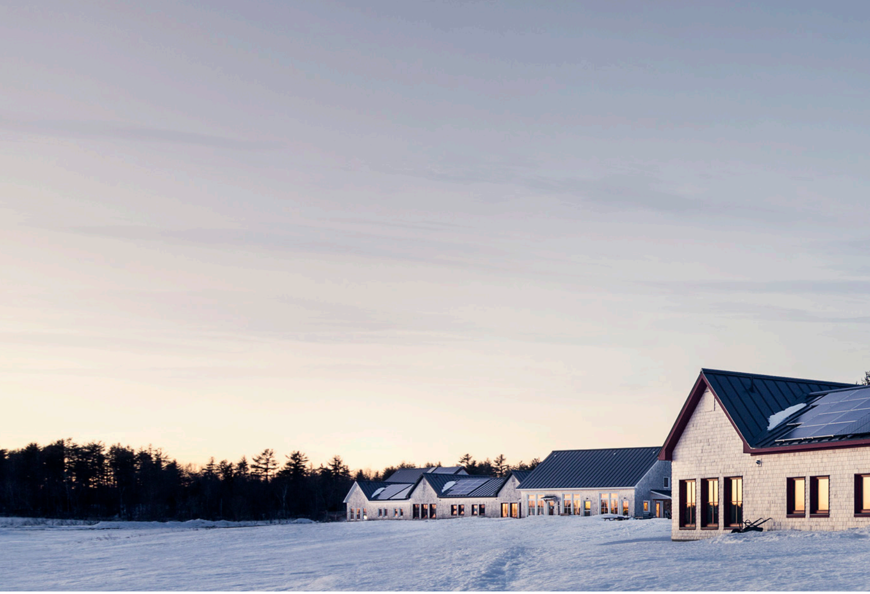
The City of Palo Alto hosts the largest cluster of Passive House projects, including an 8-bedroom residential community building and the first Passive House office building in California. The City is lending its support to a regional Passive House educational conference, entitled Building Carbon Zero. In previous years, the City of San Francisco, Marin County, and Santa Cruz County have hosted similar events. Laney College, with the support of Oakland Rotary and the City of Oakland, is supporting a Passive House retrofit of a single-family house as a training workshop for Laney College students.

3

BEACONS

Shining Examples

Innovative buildings show what can be practically achieved and offer encouragement. By combining Passive House principles with renewable energy sources, architects and builders are creating sustainable, resilient buildings that deliver superior comfort now and for many years to come. It is hoped that these examples will inspire widespread uptake of these approaches.

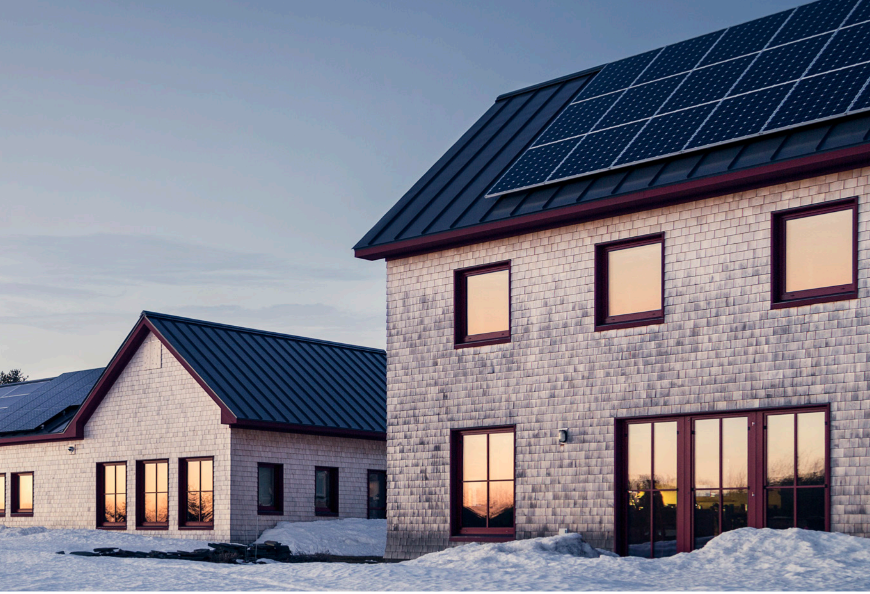


Belfast Cohousing and Ecovillage

Belfast, Maine

Belfast Cohousing and Ecovillage is a 36-unit Passive House development in rural Maine. The goal of the project was to preserve farmland while constructing a smart-growth, compact development of low-energy buildings—all built at costs comparable to standard residential construction. The 36 residences include 13 duplexes, two triplexes, and a quad, clustered to foster neighborhood interaction.

GO Logic, the designer and general contractor for the project, worked closely with the cohousing group to create a dense six-acre built footprint, with the remaining 36 acres of the property set aside for recreation and agricultural use. The buildings are sited on a south-facing, wooded knoll that permits unimpeded passive solar access.



The residences' super-insulated building shells make full use of wintertime passive solar gains to lower space-heating demands. The exterior walls are made up of 2 x 4 load-bearing stud walls insulated with blown-in dense-pack cellulose with 8-inch-thick structural insulated panels (SIPs)—a sandwich of oriented strand board and expanded polystyrene insulation—wrapping the exterior. The R-value of this assembly is about 50, with virtually no thermal bridging.

Belfast Cohousing and Ecovillage; Photo by Trent Bill

PASSIVE HOUSE METRICS

Heating energy	1.17 – 1.47 kWh/ft²/yr	12.6 – 15.8 kWh/m²/a
Cooling energy	1.17 – 1.47 kWh/ft²/yr	12.6 – 15.8 kWh/m²/a
Total source energy	13.77 kWh/ft²/yr	148 kWh/m²/a
Treated floor area	400 -1,250 ft²	37 – 116 m²
Air leakage	0.2 ACH_{50} – 0.4 ACH_{50}	

PROJECT TEAM

Design/Builder **GO LOGIC**

Friends School of Portland

Cumberland, Maine

The Friends School of Portland in Cumberland, Maine fully embraces the Quaker values that are taught there: simplicity, stewardship of the land, and sustainability. The school elected to set a goal of Net Zero Energy for their roughly 15,000-ft^2 building, achieving that by meeting the Passive House targets.

The exterior walls feature 2x6 wood-frame construction filled with cellulose with an additional 4 inches of exterior polyisocyanurate. The roof assembly has 32 inches of blown-in cellulose in the trussed attic above the classrooms. Careful air sealing led to an airtightness of 0.3 ACH_{50} at the first blower door test before the insulation was added. Energy-recovery ventilators (ERVs) bring in fresh air year-round, with CO_2 sensors to control adjustments for occupancy levels. Air source heat pumps provide supplemental heating and cooling.

The all-electric building will meet its annual energy needs with a 36.7-kW rooftop PV system. With this building, the Friends School has fulfilled its goal and created a model of sustainability for its community.

PASSIVE HOUSE METRICS

Heating energy	1.16 kWh/ft^2/yr	12.49 kWh/m^2/a
Cooling energy	0.30 kWh/ft^2/yr	3.22 kWh/m^2/a
Total source energy	9.19 kWh/ft^2/yr	98.93 kWh/m^2/a
Treated floor area	12,214 ft^2	1,135 m^2
Air leakage	0.3 ACH_{50} (preliminary)	

PROJECT TEAM

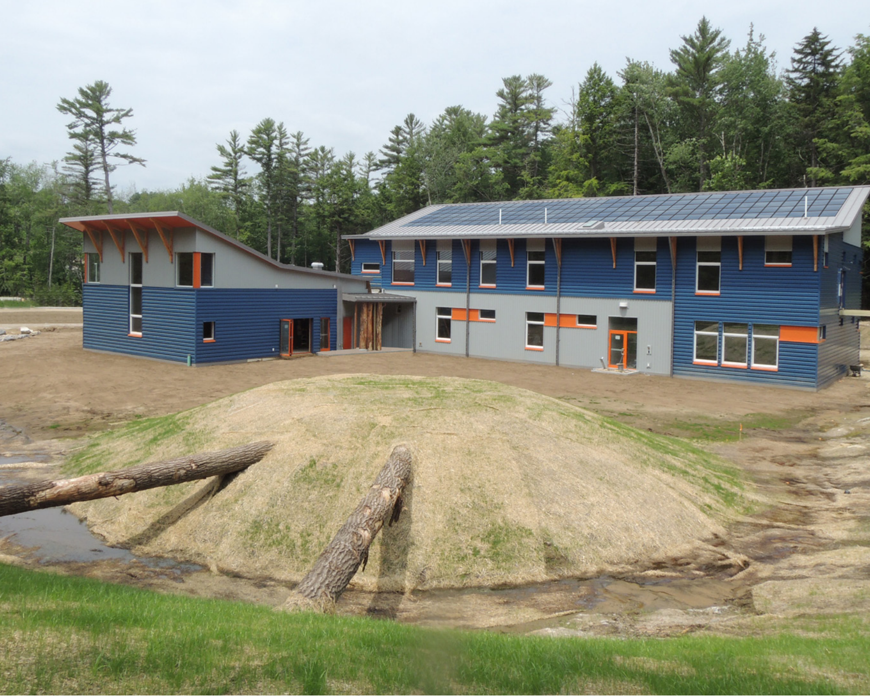
Architect Phil Kaplan, Richard Lo, Jesse Thompson
KAPLAN THOMPSON ARCHITECTS

Builder Peter Warren, **WARREN CONSTRUCTION GROUP**

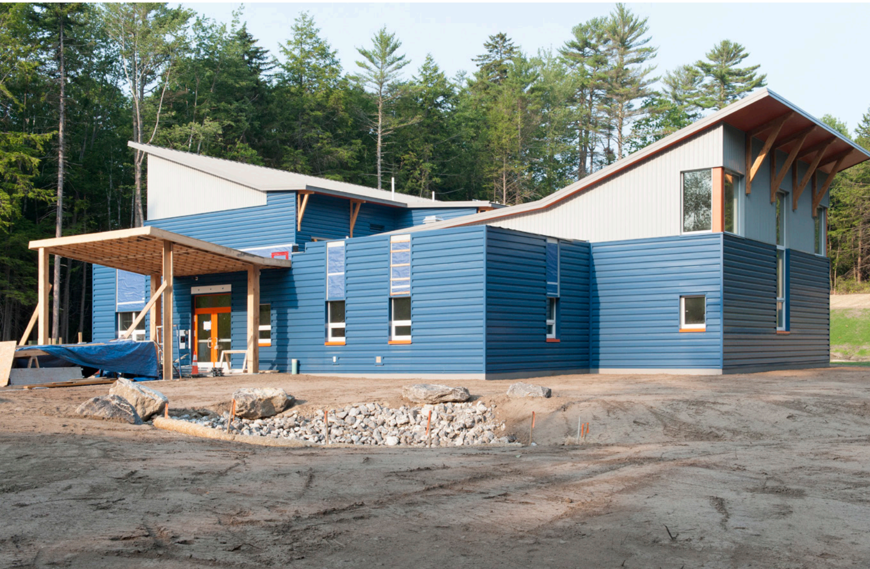
Landscape Architect **SOREN DENIORD DESIGN STUDIO**

Building Committee Chair **NAOMI C. O. BEAL**

Mechanical Engineering Ian McDonald, **ALLIED ENGINEERING**



Friends School of Portland; Photos by (top) KTA;
(bottom) Naomi C.O. Beal



Viridescent House

Falmouth, Maine

The Viridescent House is a net-positive Passive House in Falmouth, Maine. The owner, TideSmart Global, replaced an existing, crumbling house with an exemplary home and office designed as a showcase of sustainable building for its employees, clients, and other community leaders.

The home's construction started with an R-50 frost-protected slab—8 inches of concrete over 10 inches of expanded polystyrene (EPS) rigid insulation. The R-58 walls were built using vapor-open Larsen trusses, while the R-81 vapor-open roof also relied on a truss assembly. Aggressive air-sealing strategies ensured that the Passive House airtightness target would be met.

While the building uses solar heat gains for its primary heat source, the supplemental heating and cooling is provided by a pair of ductless mini-split heat pumps. An energy-recovery ventilator (ERV) that is 90-95% efficient delivers the fresh air.

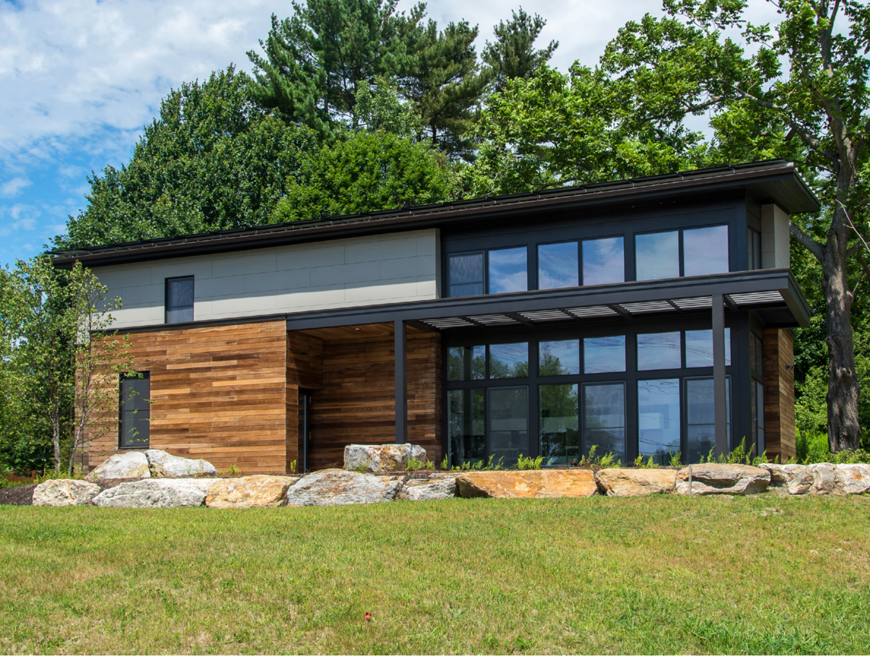
Viridescent House features a 19.4-kW photovoltaic array that generates twice the electricity the home would consume annually. The surplus energy goes to powering an on-site electric vehicle charging station and other structures on the TideSmart Campus.

PASSIVE HOUSE METRICS

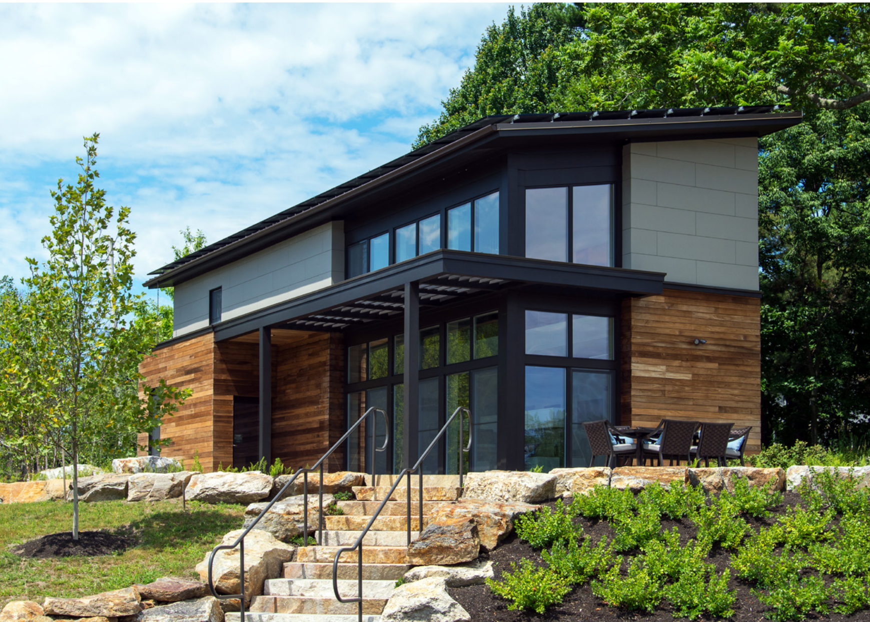
Heating energy	1.29 kWh/ft^2/yr	13.88 kWh/m^2/a
Cooling energy	0.29 kWh/ft^2/yr	3.15 kWh/m^2/a
Total source energy	9.7 kWh/ft^2/yr	104 kWh/m^2/a
Treated floor area	1,388 ft^2	129 m^2
Air leakage	0.54 ACH_{50}	

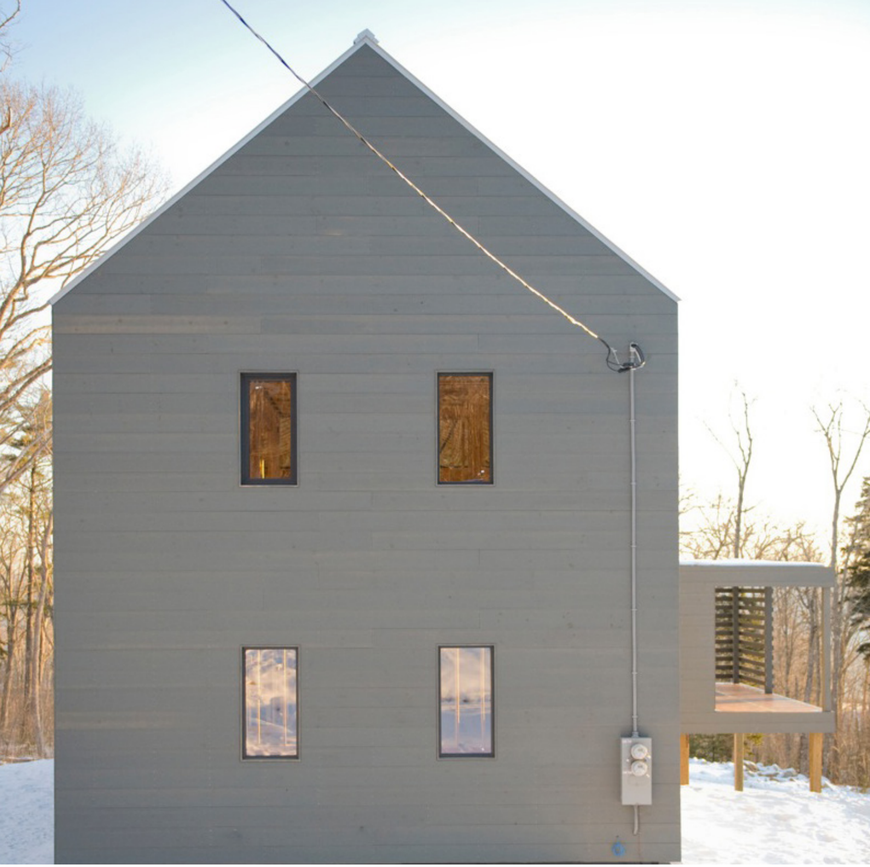
PROJECT TEAM

Owner TIDESMART GLOBAL **Landscape Architect** COWLES STUDIO **Architect** BRIBURN **CHPC** Edward Pais **Contractor** R&G Bilodeau **Solar** REVISION ENERGY

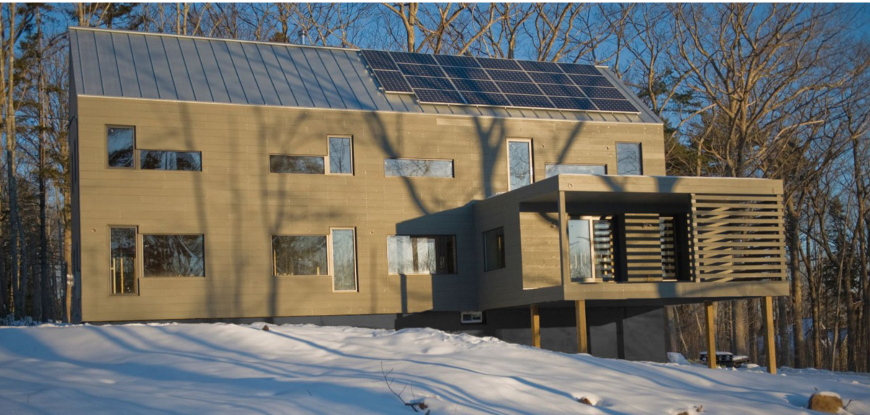


Viridescent House; Photos by Corey Templeton





Bayside; Photos by (top) Naomi C. O. Beal (bottom) Chris Corson, Ecocor



Bayside

Northport, Maine

The owners of this home started with the goal of creating a Net Zero Energy home that was as fossil-fuel free as possible and was constructed largely from locally sourced materials. Using Passive House as a foundation and adding a 6.3-kW rooftop photovoltaic system, this all-electric home achieves the Net Zero Energy over the course of the year.

This performance is all the more remarkable given the 7,500+ heating degree day (HDD) climate. They also met their other environmental goals, as all the materials used, including the siding and roofing material, were acquired from within a 200-mile radius.

Attaining their goals was facilitated by using a certified Passive House component wall and roof system from Ecocor. The superinsulated walls include 14 inches of cellulose and 3.5 inches of mineral wool insulation. The roof is insulated with a combination of loose fill and dense-pack cellulose. The walls and roof achieve R-values of 60+ and 136, respectively.

Even with an imperfect southern orientation, the owners stay comfortable all year long thanks to a combination of proper insulation, the sun, triple-glazed windows with high solar heat gain, a mini-split heat pump, and occasionally a wood stove. This home's typical utility costs for an entire year? Just $10 a month for the privilege of being connected to the grid.

PASSIVE HOUSE METRICS

Heating energy	1 kWh/ft²/yr	11 kWh/m²/a
Cooling energy	0.09 kWh/ft²/yr	1 kWh/m²/a
Total source energy	9.38 kWh/ft²/yr	102 kWh/m²/a
Treated floor area	2,454 ft²	228 m²
Air leakage	0.4 ACH_{50}	

PROJECT TEAM

Architect Sofia and Ian Weiss
Passive House Designer and Builder Chris Corson, **ECOCOR LLC**
Solar systems **REVISION ENERGY**

Salus Clementine

Ottawa, Ontario

The 42-unit Salus Clementine development in Ottawa exemplifies the highest quality in affordable housing, getting pre-certified as a Passive House and taking on the 2030 carbon neutral challenge. The project is funded by Ottawa Salus, the City of Ottawa, and the provincial and federal governments through the Investment in Affordable Housing for Ontario (IAH) Program to serve men and women living with serious mental illness. With its very high efficiency, this building's operational costs will be kept low, maximizing the funds that can be used for services.

The site's east-west orientation and poor soil conditions that require a light steel frame structure are adding to the challenge of meeting the Passive House targets. Twelve-inch thick structural insulated panels (SIPS) attached to the outside of the steel frame will help to deliver R-65 exterior walls. The R-75 roof assembly also incorporates 12-inch SIPS with integral wood I-joists.

The superinsulated and airtight structure is allowing the space heating demand to be met by the same system that is supplying the domestic hot water: a high efficiency gas boiler with a capacity of 120 gallons. Thanks to the strong commitment of all key players, the Salus Clementine project will deliver a comfortable environment to a deserving population.

Salus Clementine; Renderings by CSV Architects

PASSIVE HOUSE METRICS

Heating energy	1.11 kWh/ft²/yr	12 kWh/m²/a
Cooling energy	0.09 kWh/ft²/yr	1 kWh/m²/a
Total source energy	11.06 kWh/ft²/yr	119 kWh/m²/a
Treated floor area	22,421 ft²	2,083 m²
Air leakage	0.6 ACH_{50} (design)	

PROJECT TEAM

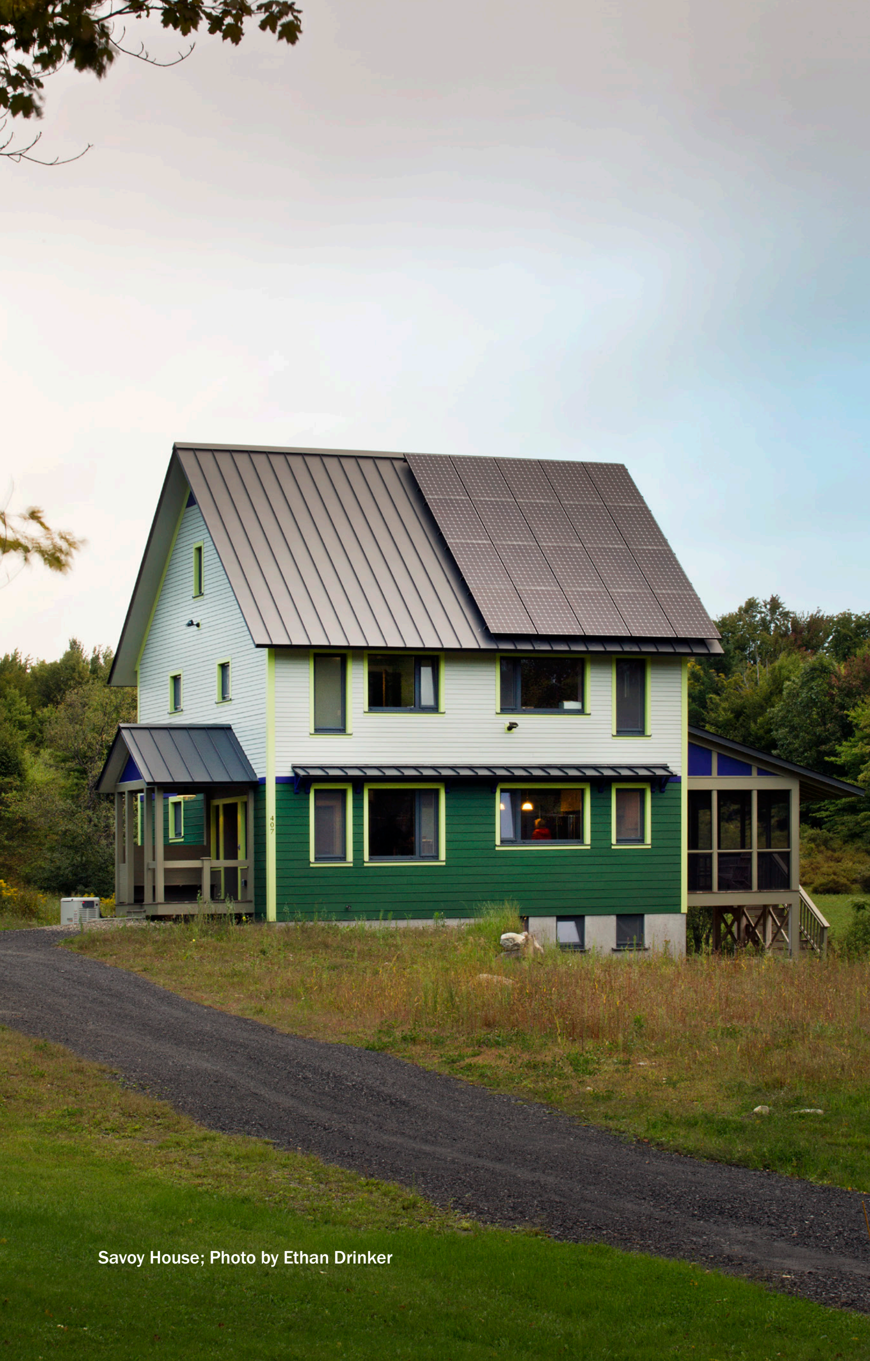
Owner/Operator **OTTAWA SALUS**

Architecture, Building Envelope & Passive House Design
Anthony Leaning & Sonia Zouari, **CSV ARCHITECTS**

Building Services Michael St Louis & Randa Khartabil
SMITH + ANDERSEN

Contractor **TAPLEN CONSTRUCTION**

Project Management Centretown Affordable Housing Development Corporation **(CAHDCO)**



Savoy House; Photo by Ethan Drinker

Savoy House

Savoy, Massachusetts

The Savoy House, an approximately 2,000-ft^2 single-family home with an integrated work space, was designed to meet the Passive House Standard and more. In its first year, the 6.5 kW rooftop photovoltaic system generated more energy than the occupants used for all heating, cooling, cooking, hot water, and plug loads—making the home truly a Net Positive Energy Building.

To minimize the heating load in this cold climate, the roof assembly consists of 16-inch trusses densely packed with cellulose, with another 6 inches of polyisocyanurate on the exterior. The 12-inch double-stud exterior walls are also dense-packed with cellulose and swathed in an additional blanket of 3.5 inches of polyisocyanurate. Thanks to this insulation, as well as the passive solar orientation and carefully detailed air sealing, the entire heating load is being handled by two ductless mini-splits, one per floor.

The clients emphasized their need for a healthy indoor environment, with exceptional indoor air quality and ultra-low VOC content, so all materials used were screened for potential chemical irritants. An exposed steel beam, rather than an engineered wood product, was used to achieve the large open span desired between the kitchen and living area.

PASSIVE HOUSE METRICS

Heating energy	1.51 kWh/ft^2/yr	16.3 kWh/m^2/a
Cooling energy	1.16 kWh/ft^2/yr	12.5 kWh/m^2/a
Total source energy	11.06 kWh/ft^2/yr	119 kWh/m^2/a
Treated floor area	1,866 ft^2	173 m^2
Air leakage	0.24 ACH_{50}	

PROJECT TEAM

Architect Jesse Selman, **COLDHAM AND HARTMAN ARCHITECTS**
Builder **KENT HICKS CONSTRUCTION**
CPHC and HERS Rater **MIKE DUCLOS**

R-951 Passive House

New York, New York

The R-951 Residence, a row house with three 1500-ft^2 duplex condos that was designed by Paul Castrucci Architect, is the first building in New York City to achieve both Passive House and the Net Zero Energy-capable certification set by the New York State Energy Research and Development Authority. Beautifully constructed, the building is clean, quiet, and comfortable in all seasons.

Designed for resiliency, the thermal bridge-free, high performance building envelope was constructed using an insulated concrete form (ICF) superstructure. Each all-electric apartment has its own energy-recovery ventilator (ERV) to bring in constant fresh air, a heat pump water heater for hot water, a mini-split heat pump for heating and cooling—and private outdoor space. The building has a 1,200-gallon rainwater collection system, adding to its sustainability.

A grid-tied 12.5-kW photovoltaic system tops the roof, yielding approximately 4 kW per apartment. Each apartment has its own inverter that can be switched to supply daytime backup power during a utility outage. This Passive House building has been estimated to reduce carbon emissions by 320,000 metric tons annually, compared to a conventionally built row house, directly addressing Mayor de Blasio's '80 by 2050' goals.

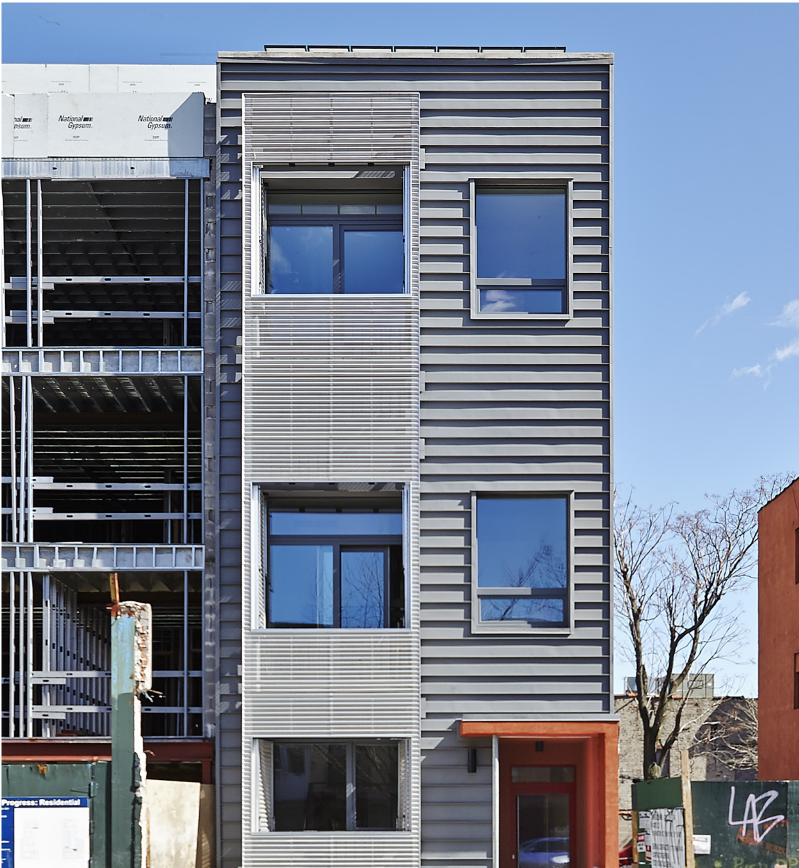
PASSIVE HOUSE METRICS

Heating energy	1.65 kWh/ft^2/yr	14.8 kWh/m^2/a
Cooling energy	1.16 kWh/ft^2/yr	12.5 kWh/m^2/a
Total source energy	10.13 kWh/ft^2/yr	109 kWh/m^2/a
Treated floor area	3,735 ft^2	347 m^2
Air leakage	0.6 ACH_{50}	

PROJECT TEAM

Architect PAUL CASTRUCCI
Passive House Consulting ZERO ENERGY DESIGN
Builder INTEGRAL BUILDING **Solar** AEON SOLAR

R-951 Passive House; Photos by Timothy Bell Photography



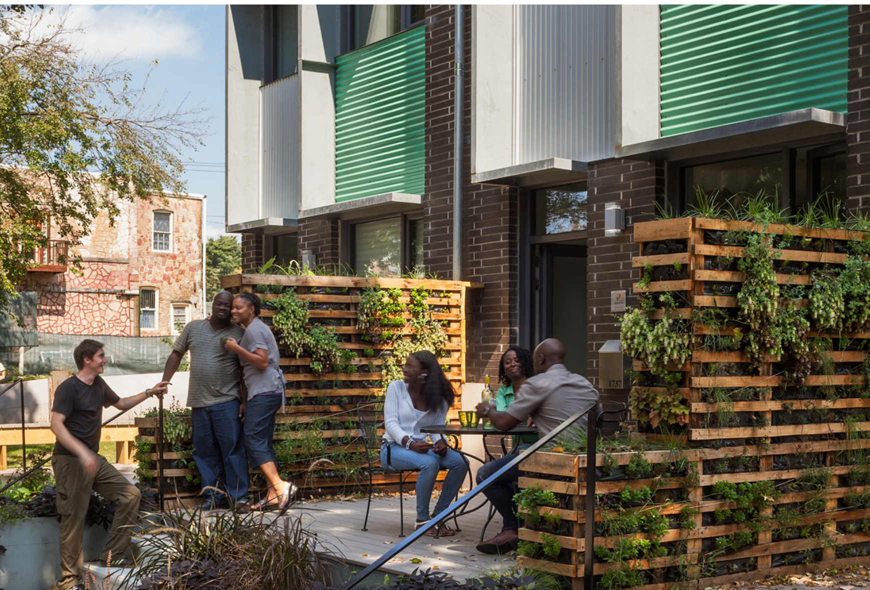
Belfield

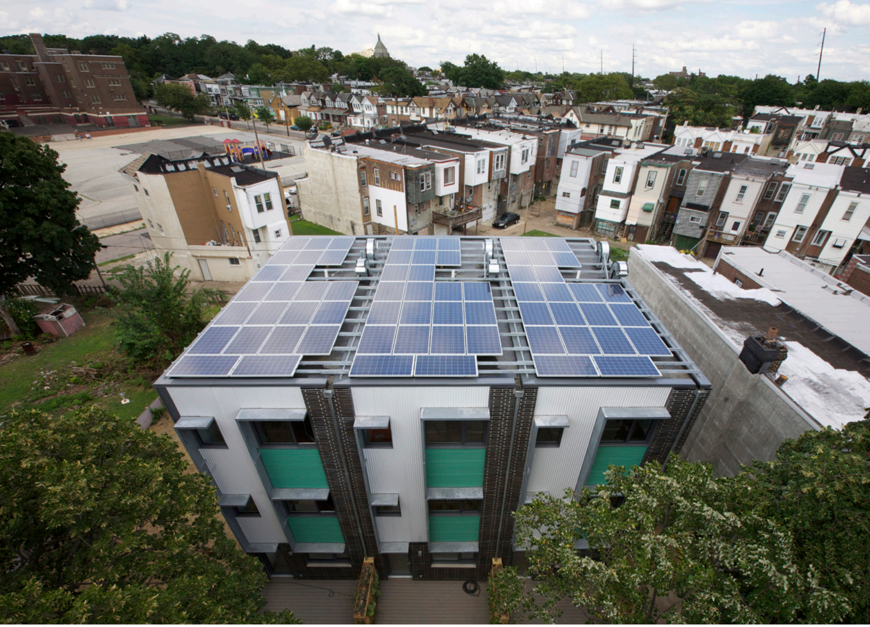
Philadelphia, Pennsylvania

Belfield Homes is a 3-unit townhouse development in North Philadelphia, constructed by Onion Flats in partnership with a non-profit community service organization. The project is a model for low-income urban infill development, providing sustainable low-energy homes for those who can least afford the rising cost of energy.

The three-story Belfield affordable-housing project was built from modules constructed in a factory. The R-34 exterior wall assemblies are built out of conventional 2x6 stud framing filled with dense-packed cellulose. Exterior to this framing is a proprietary ZIP sheathing and then two coats of foil-faced polyisocyanurate board insulation, staggered so that the junctions don't overlap.

The floor and roof assemblies are built with 2x12 joists, in order to house more cellulose insulation, but otherwise are constructed similarly. The R-values for the roof and floor are 52 and 58, respectively.





Each house comes with bamboo floors, an induction cooktop, a condensing dryer, and a 5.5-kW photovoltaic array on top. Even with these fine touches, as Tim McDonald, one of the principals of Onion Flats likes to say, he is building near-zero energy houses at a net-zero premium, so there should be zero debate about the standards that all new construction should have to meet.

Belfield Homes; Photos by (left) Sam Oberter (top) Tim McDonald

PASSIVE HOUSE METRICS

Heating energy	1.3 kWh/ft²/yr	14 kWh/m²/a
Cooling energy	1.11 kWh/ft²/yr	12 kWh/m²/a
Total source energy	10.5 kWh/ft²/yr	113 kWh/m²/a
Treated floor area	4,500 ft²	418 m²
Air leakage	0.4 ACH_{50}	

PROJECT TEAM

Architect PLUMBOB LLC | **Heating and Ventilation Engineering** DCM ARCHITECTURE AND ENGINEERING Robert Benson PE
Developer Raise of Hope and ONION FLATS | **Builder** JIG INC.
Energy monitoring Celantano Energy Services

Margate

Margate, New Jersey

This 2,600-ft^2 home was designed as the primary residence for a family of five in a coastal New Jersey town. Built on a tight infill lot within a traditional neighborhood, the home maximizes opportunities for light and space and offers a clean, healthy, modern interior.

To maximize solar gain on the south side, the home is positioned along the northern side of the lot. A wood trellis wraps the house to shade both the front porch and the south-facing windows on the first floor.

The R-44 walls incorporate dense-packed cellulose in 2x6 walls with 4 inches of rigid polyisocyanurate insulation on the exterior. The R-68 roof uses a similar assembly but with 12-inch TJIs dense-packed with cellulose. A 5-kW photovoltaic system graces the roof.

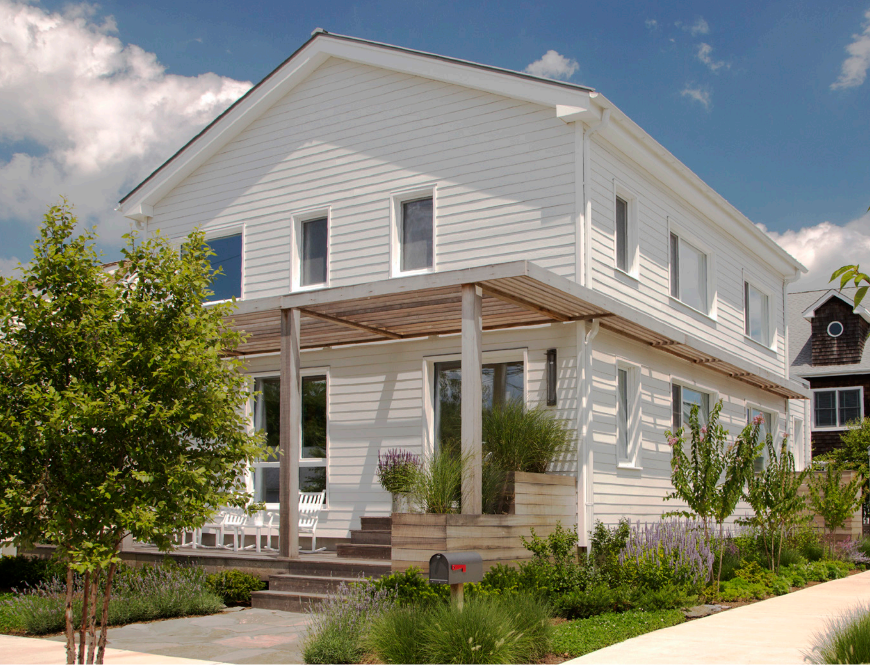
The home's design incorporates multiple resiliency strategies. The first level of the home is elevated four feet above grade to minimize the risk of flooding, while the front porch subtly mediates the change in elevation. The hurricane-resistant construction includes a shutter system, artfully incorporated into the window trim, that protects the triple-glazed windows from flying debris during a storm.

PASSIVE HOUSE METRICS

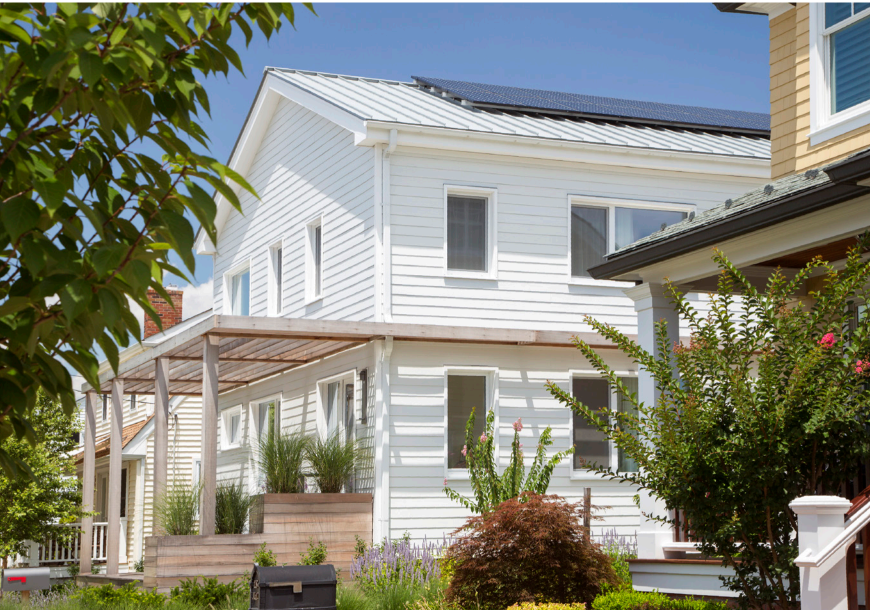
Heating energy	1.29 kWh/ft^2/yr	13.85 kWh/m^2/a
Cooling energy	1.53 kWh/ft^2/yr	16.5 kWh/m^2/a
Total source energy	7.06 kWh/ft^2/yr	76 kWh/m^2/a
Treated floor area	2,207 ft^2	205 m^2
Air leakage	0.47 ACH_{50}	

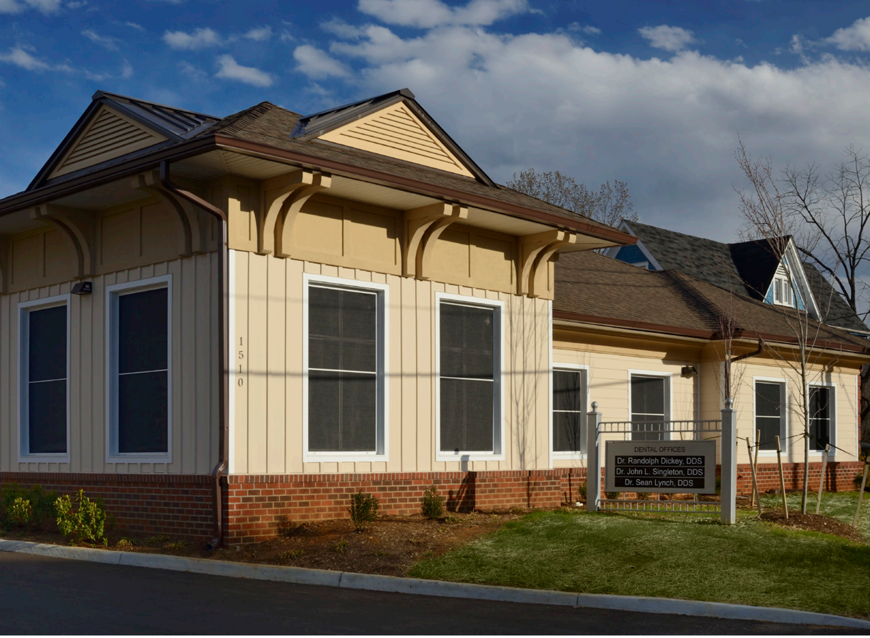
PROJECT TEAM

Architecture & Passive House Consulting ZERO ENERGY DESIGN
Construction C. ALEXANDER BUILDING

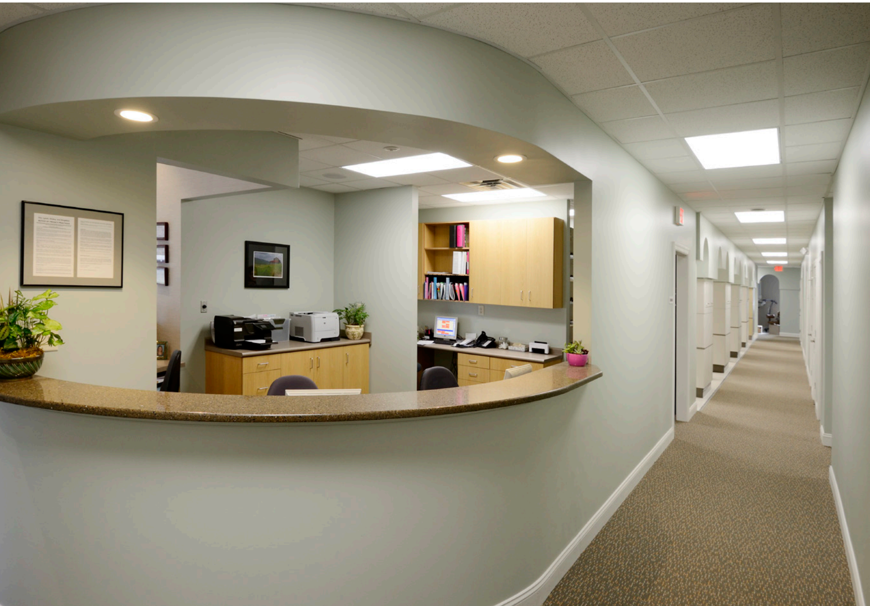


Margate; Photos by Eric Roth





Passive House Dental Clinic; Photos by Jim Stroup



Passive House Dental Clinic

Roanoke, Virginia

This 5,400-ft^2 dental clinic posed—and then answered—the question of whether Passive House principles could be used to create a very low energy building for a business with inherently high interior heat gains. After a year of monitoring, the building's energy use has been 2.5% less than was predicted by the Passive House Planning Package (PHPP) software.

Often in dental clinics doctors complain of being hot, while patients are cold. To overcome these comfort issues, BuildSmart installed a ventilation system that injects pre-conditioned fresh air along the ceiling of each operatory space at a very low velocity with a separate low-velocity, forced-air conditioning system directed behind the dental chair. By designing the ductwork and diffusers for low velocity, the conditioned air drops slowly enough to guarantee the patient's comfort.

They also installed 100-ft^2 passive radiant cooling loops in the floor around each dental chair. The radiative cooling takes heat from the dentist and assistant, while the chair acts as an insulated barrier for the patient.

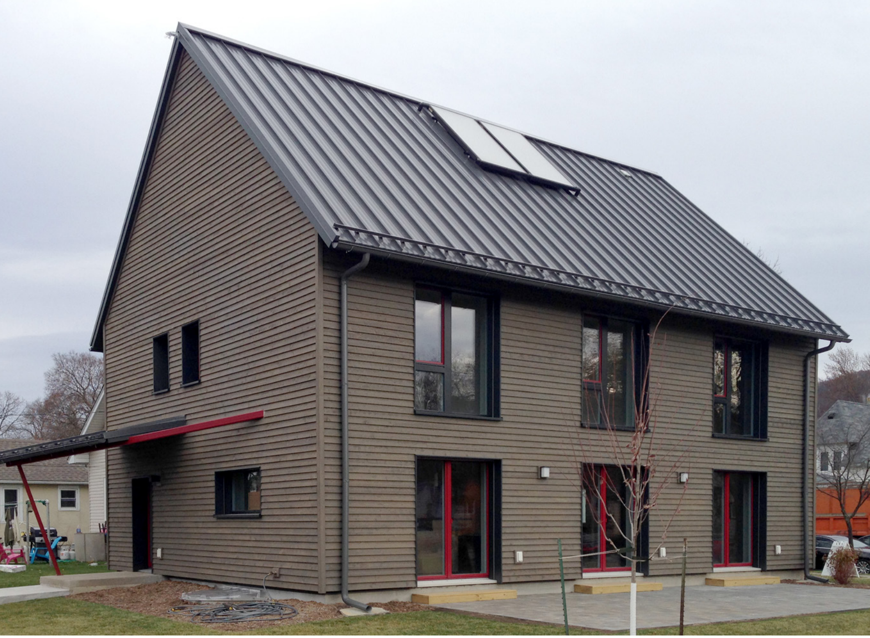
The doctors report that the operatory thermal comfort is exceptional. The patients frequently mention that the fresh air exchange has eliminated any dental clinic smell.

PASSIVE HOUSE METRICS

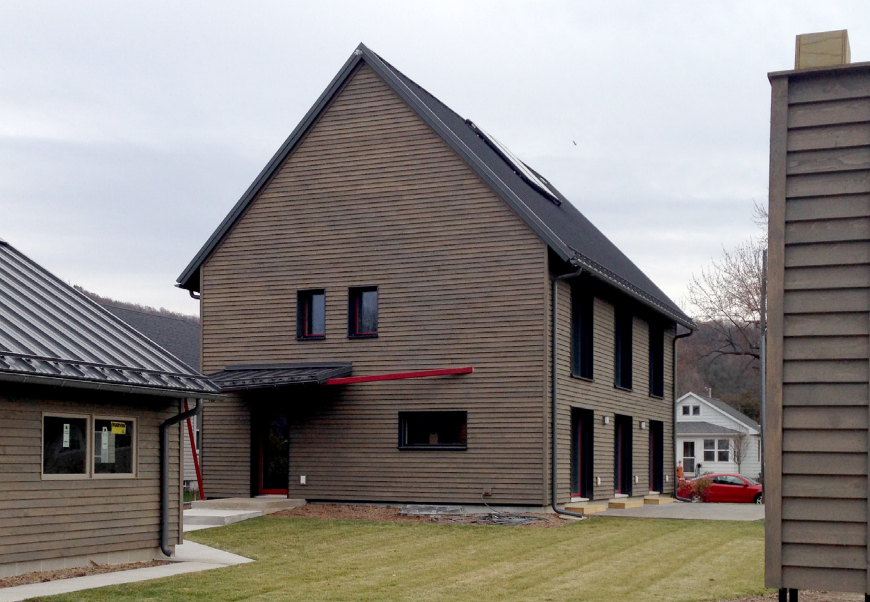
Heating energy	0.28 kWh/ft^2/yr	3 kWh/m^2/a
Cooling energy	2.6 kWh/ft^2/yr	28 kWh/m^2/a
Total source energy	19.7 kWh/ft^2/yr	212 kWh/m^2/a
Treated floor area	4,639 ft^2	431 m^2
Air leakage	0.27 ACH_{50}	

PROJECT TEAM

Architect and PH Consultant Adam Cohen, **BUILD SMART**
PASSIV SCIENCE
QUANTUM ARCHITECTS



24th Street Passive House; Photos by Intep



24th Street Passive House

LaCrosse, Wisconsin

This urban infill home on a brownfield site serves as a landmark for Western Technical College to demonstrate their leadership within the community. The college frequently develops homes to expose students in construction-related studies to hands-on practice in the field, but this one departed from typical construction methods to embrace the Passive House Standard.

Well insulated from bottom to top, the home's slab rests on 9 inches of expanded polystyrene (EPS) insulation, delivering an R-value of 38. The exposed concrete basement walls are also insulated to R-38 with an exterior insulation and finish system (EIFS). The above-grade walls consist of a mineral-wool-filled 2x6 structural framing cavity enveloped by 14-inch I-joist framing with dense-pack cellulose insulation, adding up to a total R-value of 65. German high-performance windows round out the envelope assemblies, which are capped by a cold roof assembly that delivers an R-83 insulating value with the help of loose-fill cellulose insulation.

To make the fullest use of this educational opportunity, TE Studio/Intep gave lectures and led workshops for both students and the community about the home and the methods used to attain the Passive House Standard.

PASSIVE HOUSE METRICS

Heating energy	1.3 kWh/ft²/yr	14 kWh/m²/a
Cooling energy	0.19 kWh/ft²/yr	2 kWh/m²/a
Total source energy	9.48 kWh/ft²/yr	102 kWh/m²/a
Treated floor area	2,600 ft²	242 m²
Air leakage	0.47 ACH_{50}	

PROJECT TEAM

Design Tim Eian, **TE STUDIO**, Stephan Tanner, **INTEP**
Construction **FOWLER & HAMMER**
Structural Eric Bunkers, **BUNKERS AND ASSOCIATES**

MinnePHit House

Minneapolis, Minnesota

The MinnePHit (Minneapolis EnerPHit) House, previously a fairly ordinary mid-30s Tudor home, was brought up to an outstanding level of performance, earning its certification as a Passive House retrofit, or EnerPHit.

In addition to significant architectural updates to maximize an efficient floor plan, the high-performance building envelope resulted in a reduced heat load of only 3.8 kW. To achieve this reduction, 9.5-inch I-joists were hung from an air-tightened sheathing layer on the outside of the existing stud walls and filled with dense-pack cellulose insulation. The R-78 roof is insulated with 22 inches of loose-fill cellulose.

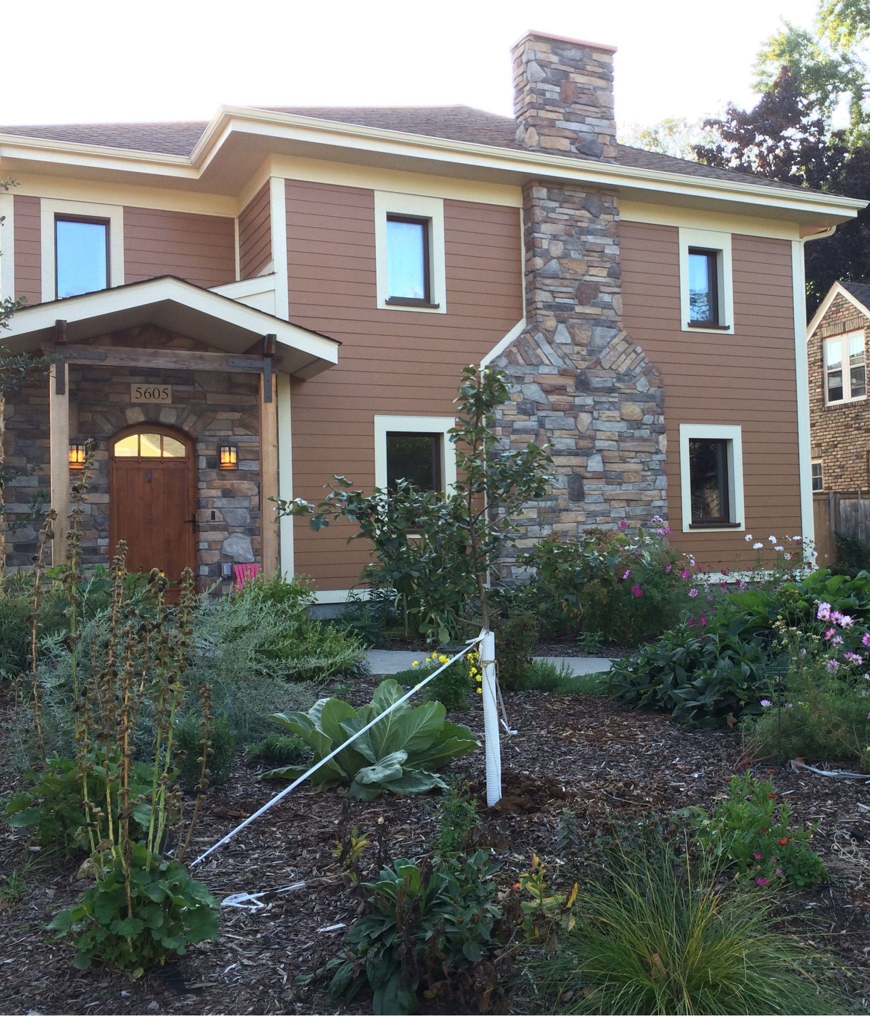
Diligent design and execution resulted in dramatic improvements in airtightness, allowing smaller mechanical systems to keep the home extremely comfortable year-round. A high-efficiency gas boiler supplies the hot water for the supplemental in-floor heating, while a mini-split air conditioner delivers cooling in summer.

PASSIVE HOUSE METRICS

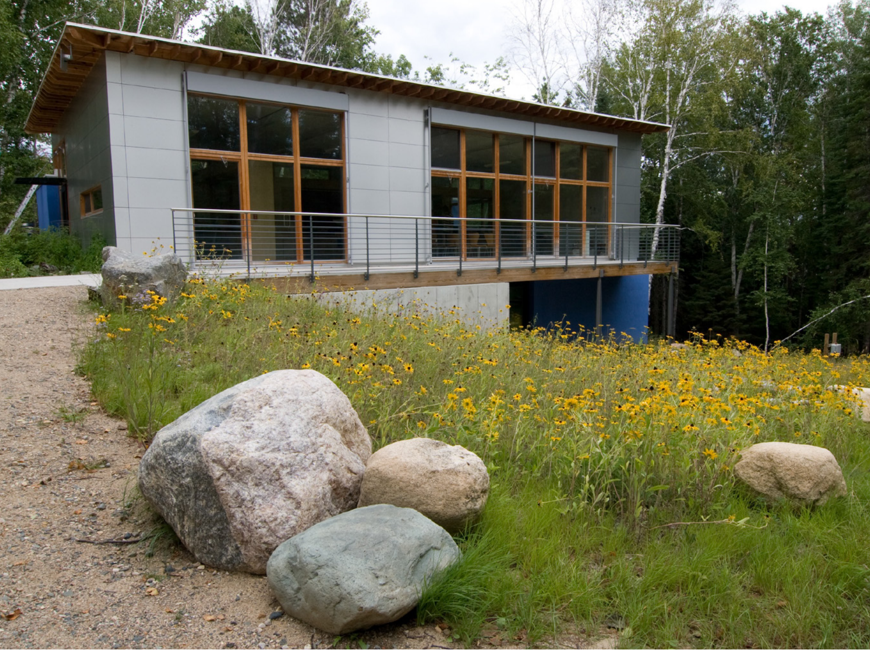
Heating energy	2.51 kWh/ft²/yr	27 kWh/m²/a
Cooling energy	0.19 kWh/ft²/yr	2 kWh/m²/a
Total source energy	11.15 kWh/ft²/yr	120 kWh/m²/a
Treated floor area	2,000 ft² (orig. 1,200 ft²)	186 m²
Air leakage	0.65 ACH_{50}	

PROJECT TEAM

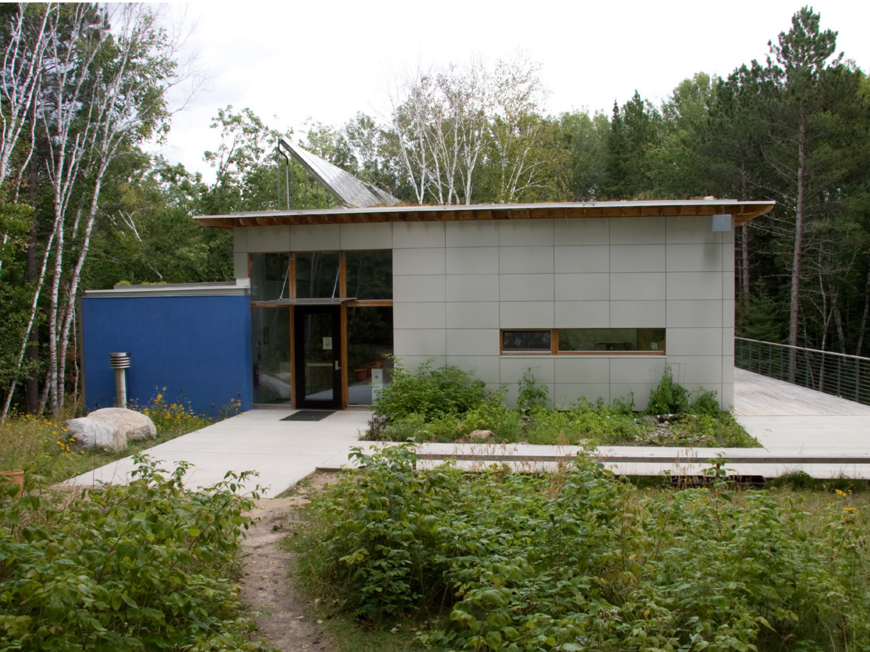
Design Tim Eian, **TE STUDIO**
Construction Owner **R.J. STEGORA INC.**
Structural Eric Bunkers, **BUNKERS AND ASSOCIATES**



MinnePHit House; Photo by Paul Brazelton



BioHaus; Photos by Cal Rice



BioHaus

Bemidji, Minnesota

BioHaus, an environmental living and learning center at Concordia Language Villages, was the first certified Passive House building in North America. The fortunate students who come here to be immersed in the German language, culture, and the study of sciences also get to experience the building's world-class comfort and sustainable design.

Minnesota's cold winters required an R-93 foundation assembly consisting of a concrete slab topping expanded polystyrene (EPS) insulation boards. The below-grade walls were built with insulated concrete blocks and an exterior insulation and finish system (EIFS) that together achieve an R-value of 55. The above-grade R-70 exterior walls used either standard stick frame construction with vacuum insulated panels or insulated concrete forms and EIFS.

The incoming fresh air passes first through a ground-to-air heat exchange system before arriving at the building's efficient heat-recovery ventilator. Passive solar gains and a ground source heat pump supply the residual heating needs. Visitors can monitor BioHaus' vital signs through the use of extensive sensors throughout the building and a mechanical room that showcases the building's technology.

PASSIVE HOUSE METRICS

Heating energy	1.3 kWh/ft^2/yr	14 kWh/m^2/a
Cooling energy	0.05 kWh/ft^2/yr	0.5 kWh/m^2/a
Total source energy	7.71 kWh/ft^2/yr	83 kWh/m^2/a
Treated floor area	5,000 ft^2	465 m^2
Air leakage	0.18 ACH_{50}	

PROJECT TEAM

Design Stephan Tanner, **INTEP**
Construction Zetha Construction
Structural David Morris

Bedford Road House

Nelson, British Columbia

Bedford Road House is the first multi-family dwelling to be certified as a Passive House in Canada. An exercise in compact design, the triplex includes two 600-ft^2 units and one 1,200-ft^2 unit.

Every effort was made to use locally familiar construction approaches that could be adapted to meet the Passive House Standard's targets. The R-59 walls encompass a triple-layer stud frame packed with cellulose, which incorporates a standard 6-mil polyethylene vapor barrier. The final airtightness rating came in at 0.2 ACH_{50}.

The R-120 roof was designed with the ideal slope for future photovoltaic and solar thermal panels, and the combined boiler and domestic hot water tank has a solar loop built in, to make the building net-zero capable. Other sustainable strategies include local materials, sustainably certified lumber, low toxicity and durable finishes, and low-flow water fixtures.

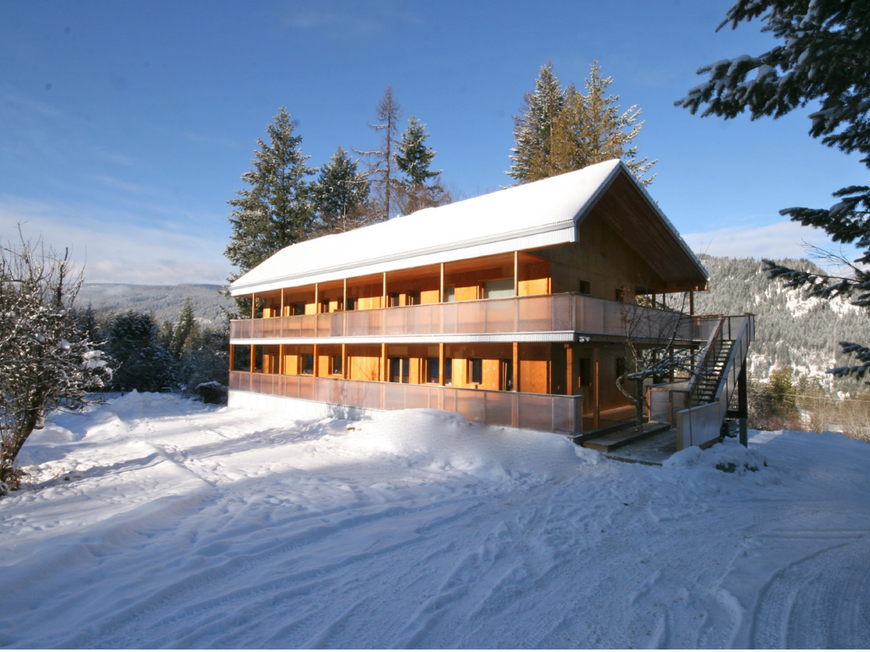
Costs were just under 10% more than standard construction—for a nearly Net Zero Energy Building.

PASSIVE HOUSE METRICS

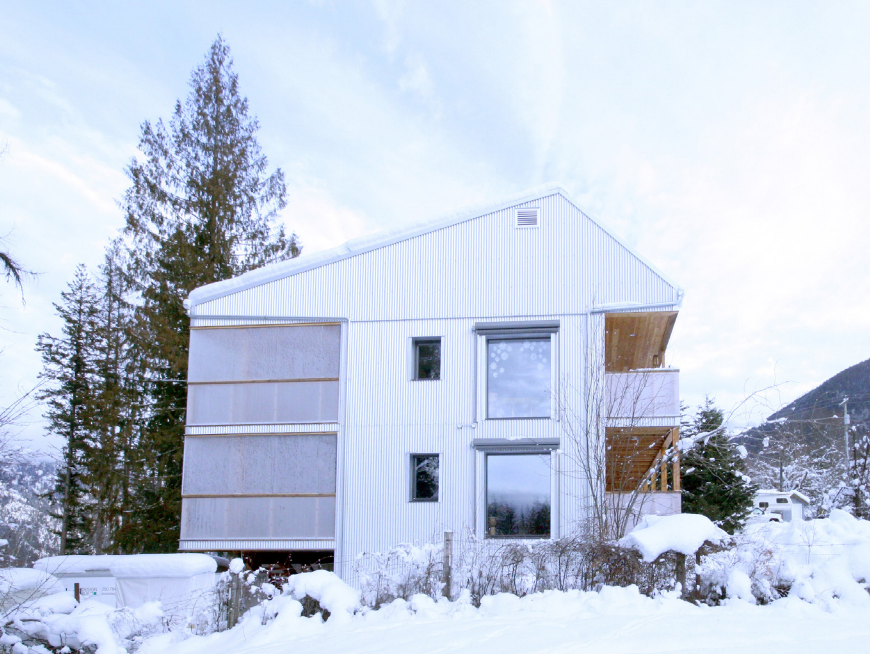
Heating energy	1.3 kWh/ft^2/yr	14 kWh/m^2/a
Cooling energy	0 kWh/ft^2/yr	0 kWh/m^2/a
Heating load	1.1 W/ft^2	12 W/m^2
Total source energy	11.06 kWh/ft^2/yr	119 kWh/m^2/a
Treated floor area	2,178 ft^2	202 m^2
Air leakage	0.2 ACH_{50}	

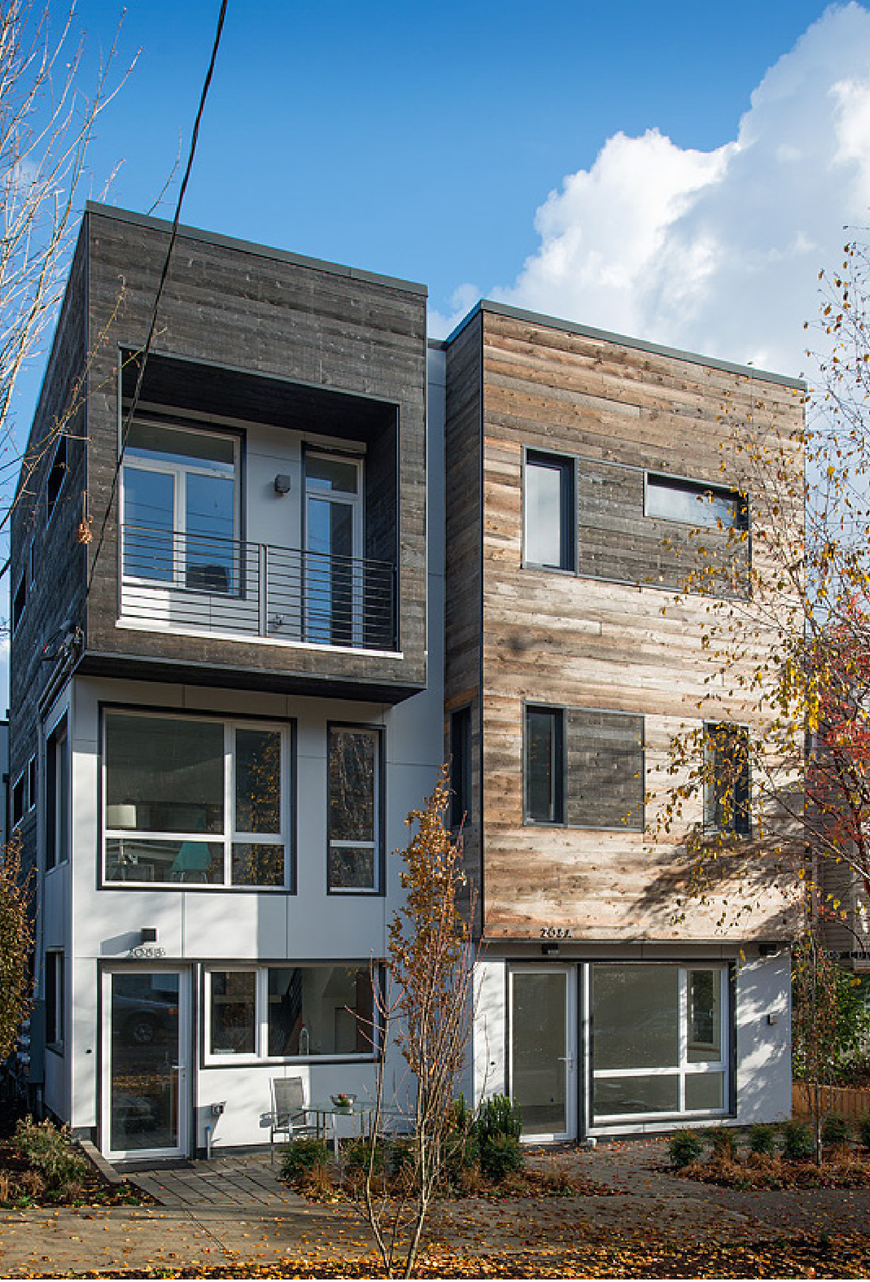
PROJECT TEAM

Architectural and Passive House Design
Lukas Armstrong, **COVER ARCHITECTURAL COLLABORATIVE INC**
Passive House Consulting
André Harrmann, **HARRMANN CONSULTING**
Construction Max Karpinski, **LOCAL DESIGN/BUILD**



Bedford Road House; Photos by Lukas Armstrong





View Haus 5

Seattle, Washington

View Haus 5 is Seattle's first Passive House-constructed townhome project, delivering healthy indoor air, thermal comfort, and quiet in the city's urban core. Its five individually designed, two-bedroom and three-bedroom townhomes, which range in size from 1,100 to 1,700 ft^2, share views of the Cascade Mountains.

The R-38 exterior walls were built using 2x6 studs insulated with dense-packed fiberglass and 4 inches of mineral wool screwed to OSB sheathing on the exterior. The R-61 roof incorporates almost 12 inches of dense-packed fiberglass between TJI rafters, which are topped by OSB roof sheathing and 2.5 inches of polyiso rigid foam. Careful sealing of the OSB layers led to a final airtightness result in one unit of 0.5 ACH_{50}.

Individual heat-recovery ventilators bring fresh air to each of the townhomes, which are all three stories with an open floor plan. Heating and cooling is provided by a ducted mini-split heat pump. An 8-inch in-line ducted fan promotes air circulation from the top to the bottom floors and ensures even temperatures throughout. With their reclaimed barn wood cladding, these homes blend a Seattle aesthetic with Passive House comfort and efficiency.

View Haus 5; Photo by Aaron Leitz

PASSIVE HOUSE METRICS

Heating energy	1.37 kWh/ft^2/yr	14.76 kWh/m^2/a
Cooling energy	0.61 kWh/ft^2/yr	6.56 kWh/m^2/a
Total source energy	9.91 kWh/ft^2/yr	107 kWh/m^2/a
Treated floor area	1,062 ft^2	99 m^2
Air leakage	0.5 ACH_{50}	

PROJECT TEAM

Architect and CPHC Joe Giampietro, **NICHOLSON KOVAL CHICK ARCHITECTS**
Builder Sloan Ritchie, **CASCADE BUILT**

North Park Passive House

Victoria, British Columbia

The North Park Passive House was developed as an urban in-fill project for the local market. With minimal marketing, the project sold out quickly and generated a list of prospective purchasers for future projects. Buyers were attracted to the quality, comfort, sustainability, and affordability of a Passive House building.

The design of the North Park Passive House combines neighbourhood context and Passive House features with a modern flare. The deep-set windows and doors, reflective of wall thickness, have a European feel. Contemporary detailing such as vertical slats on the sides of the balconies distinguishes the residences as modern.

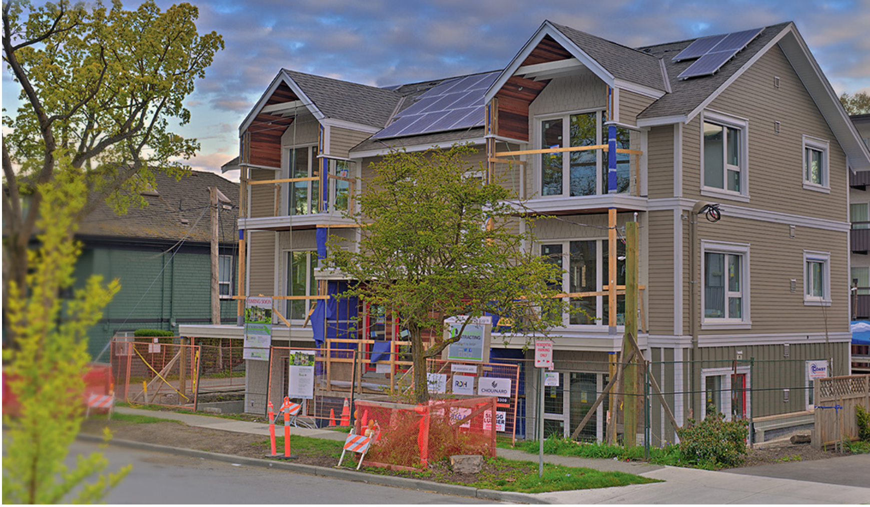
The walls consist of a 2x8 structural wall insulated with dense-pack cellulose and a 2x4 interior service cavity insulated with rock wool. Each unit is ventilated with its own heat-recovery ventilator (HRV), and the small, supplemental heat load is met with electric resistance heating. A photovoltaic array on the roof generates energy and an income stream through the local net metering program.

PASSIVE HOUSE METRICS

Heating energy	1.02 kWh/ft²/yr	11 kWh/m²/a
Cooling energy	0 kWh/ft²/yr	0 kWh/m²/a
Total source energy	10.96 kWh/ft²/yr	118 kWh/m²/a
Treated floor area	3,928 ft²	365 m²
Air leakage	0.5 ACH_{50}	

PROJECT TEAM

Developer BERNHARDT DEVELOPMENTS LTD.
Architect HUGHES CONDON MARLER ARCHTECTS (HCMA)
General Contractor & Passive House Consultant
Bernhardt Contracting Ltd.



North Park Passive House; (top) Photo by Ryan Hamilton; (bottom) Rendering by HCMA

Orchards at Orenco

Hillsboro, Oregon

The Orchards at Orenco is a 57-unit affordable housing development that will deliver comfort and low energy bills for decades to come. The owner, REACH CDC, made Passive House a project goal from the start, after touring many Passive House social housing developments in Europe. Establishing this goal from the outset was critical in allowing the project team to collaborate on cost-effectively meeting the insulation, airtightness, and mechanical design challenges.

The three-story, L-shaped building frames a prominent street corner in the highly walkable Orenco Station neighborhood. The project includes a fully insulated, thickened-edge slab. The walls were built using 2x10 studs with blown-in fiberglass cavity insulation and 1.5 inches of mineral wool insulation on the exterior. On the roof 12 inches of polyisocyanurate foam sit atop an open web truss.

The mechanical system, which is housed in three insulated rooftop pods, consists of three energy-recovery ventilators (ERVs), each of which is coupled to a single heat pump for primary heating and summer tempering. Back-up heating through electric radiant cove heaters in each unit facilitates tenant control of their environment.

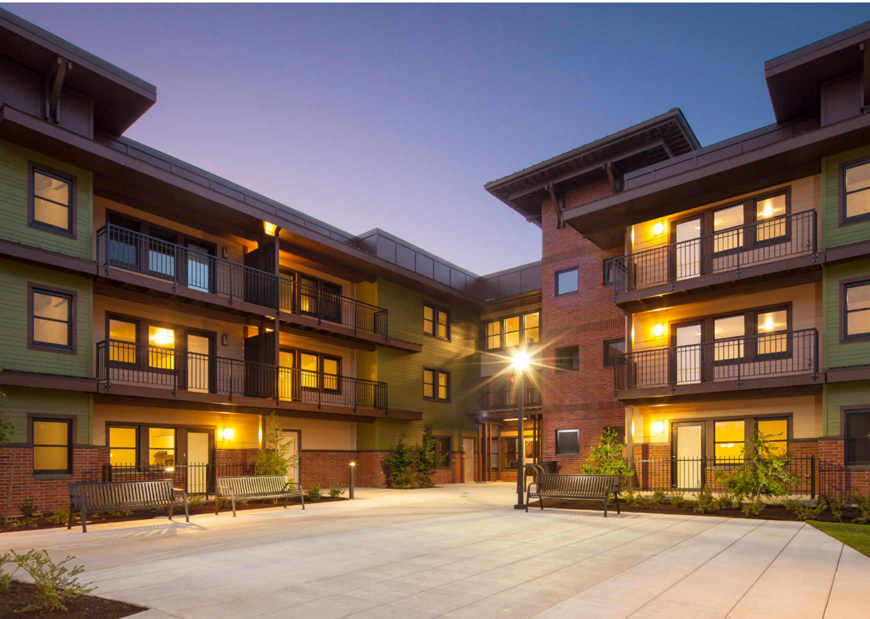
PASSIVE HOUSE METRICS

Heating energy	1.61 kWh/ft^2/yr	17.35 kWh/m^2/
Cooling energy	0.038 kWh/ft^2/yr	0.41 kWh/m^2/a
Heating load	0.693 W/ft^2	7.47 W/m^2
Cooling load	0.644 W/ft^2	6.94 W/m^2
Total source energy	10.9 kWh/ft^2/yr	117.35 kWh/m^2/a
Treated floor area	42,584 ft^2	3,956 m^2
Air leakage	0.13 ACH_{50}	

PROJECT TEAM

Architect Michael Bonn, **ANKROM MOISAN ARCHITECTS, INC.**
Certified Passive House Consultant Dylan Lamar, **GREEN HAMMER**
Builder Mike Steffen, **WALSH CONSTRUCTION CO.**

Orchards at Orenco; Photos by Casey Braunger



Ankeny Row
Portland, Oregon

The Ankeny Row cohousing community grew out of a desire to create an environmentally friendly, socially engaging living space. Its five townhouses, one loft apartment, and community hall surround a central courtyard, whose gardens have become a warm gathering place for the residents. By using the Passive House Planning Package to sharply reduce each building's demand, the cohousing community is on track to achieve its goal of being Net Zero Energy, with only a 25-kW photovoltaic system on the back building's south-facing roof.

The community's three buildings were sited so the courtyard could get the most sun penetration, and great consideration was also given to maximizing the building's solar heat gains in winter while preventing overheating in summer. Deep overhangs shade the large, south-facing windows on the topmost floor, while awnings protect the lower and ground-floor windows. For supplemental heating and the small amount of cooling needed, all units come equipped with mini-split heat pumps.

To minimize the environmental impact of the building materials, roughly 90% of the buildings' components are made from wood or cellulose. The R-50 wall assemblies include I-joists that are 9.5 inches deep filled with cellulose. The monosloped wood trusses in the roof assembly are 28 inches deep and are filled with cellulose insulation. All of the lumber and most of the finished wood is Forest Stewardship Council (FSC)-certified.

Ankeny Row; Photos by Dylan Lamar

PASSIVE HOUSE METRICS

Heating energy	1.37 – 2.09 kWh/ft²/yr	14.76 – 22.46 kWh/m²/a
Cooling energy	0.07 – 0.21 kWh/ft²/yr	0.73 – 2.27 kWh/m²/a
Total source energy	12.07 – 14.83 kWh/ft²/yr	130 - 160 kWh/m²/a
Treated floor area	1,312 - 3,965 ft²	122 - 368 m²
Air leakage	0.5 – 1.0 ACH_{50}	

PROJECT TEAM

Design/Builder **GREEN HAMMER**

Cottle House

San Jose, California

Designed and built as a luxury home, the Cottle House meets all the requirements for a Passive House and even goes beyond to be a true Net Zero Energy Building. The roof houses a 6.2-kW photovoltaic system with a total annual capacity of 11,100 kWh of production, supplying all the energy needs of a family of five—including charging their electric vehicle. Monitored for the last two years, the home's measured energy use closely tallies with the Passive House Planning Package's predicted energy use.

Cooling is the challenge in this locale. Solar-controlled exterior shades cover the west-facing windows, helping to keep this home cool even during heat-storms. Supplemental cooling and heating for this large, two-story home is handled by a heat pump. A NightBreeze, a ventilation cooling system integrated with the heat pump, further reduces cooling demand by drawing in the naturally cooler evening air, allowing the building to dump any excess heat built up during the day.

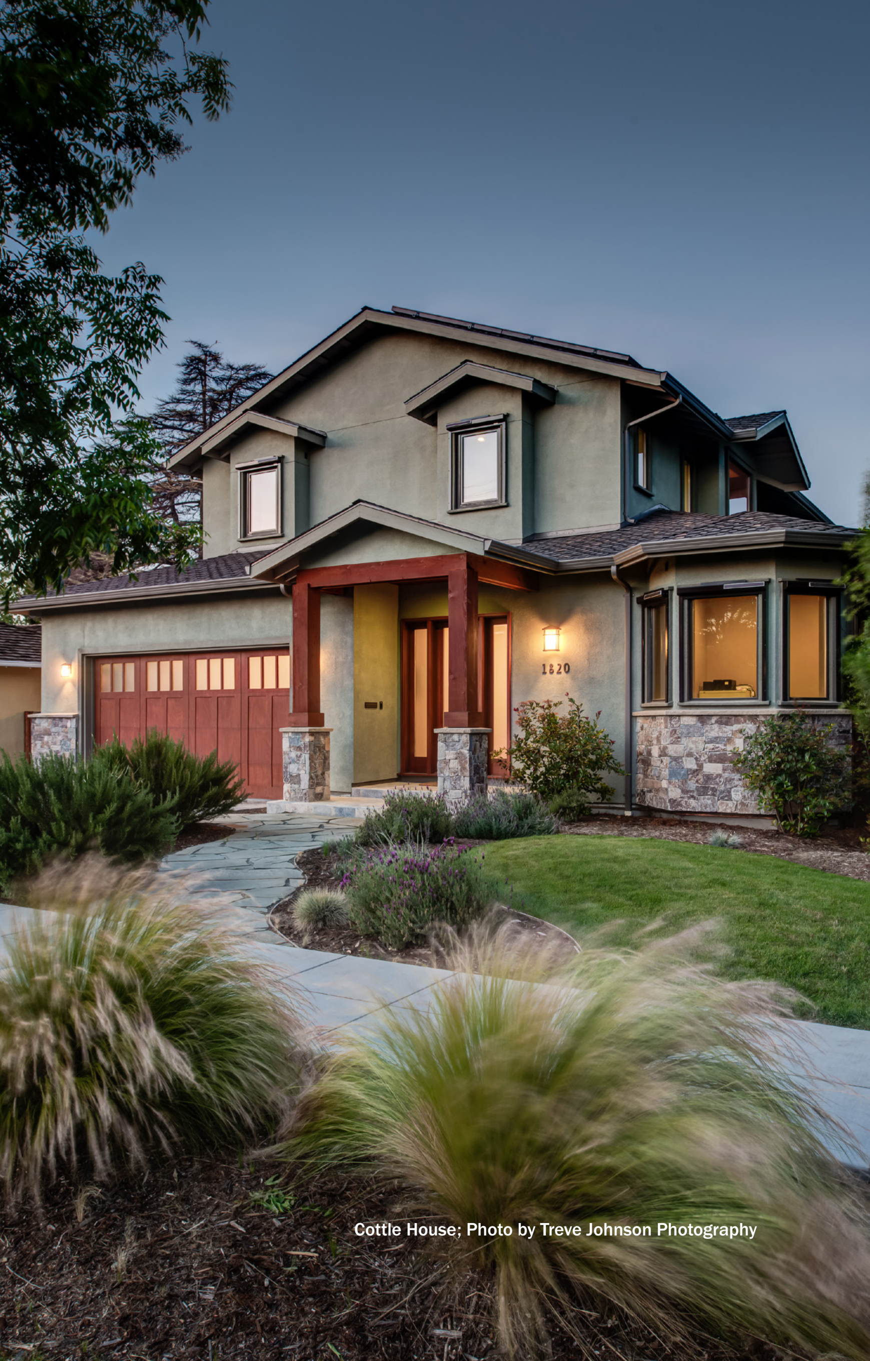
Outside, this house boasts a grey-water collection tank that is used to irrigate the xeriscaped, indigenous plants and wild grasses. At the front door, old beams reclaimed from San Jose's historic fruit-packing warehouse support the covered entry. They carry a century of history and now hold up the entry to a building designed for the future.

PASSIVE HOUSE METRICS

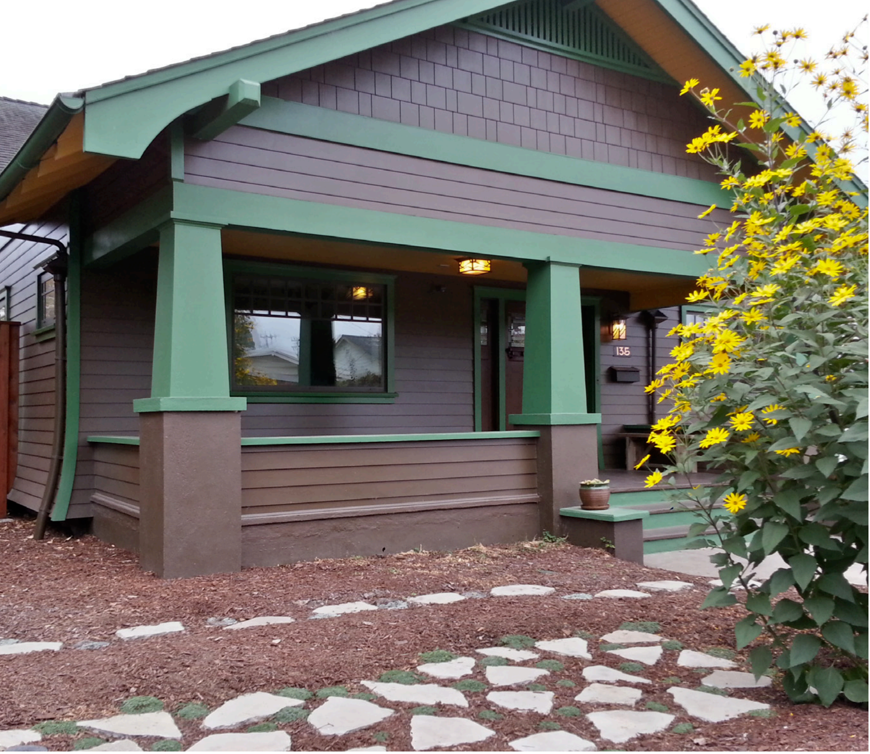
Heating energy	1.07 kWh/ft²/yr	11.51 kWh/m²/a
Cooling energy	0.07 kWh/ft²/yr	0.73 kWh/m²/a
Total source energy	7.43 kWh/ft²/yr	80.44 kWh/m²/a
Treated floor area	2,776 ft²	258 m²
Air leakage	0.6 ACH_{50}	

PROJECT TEAM

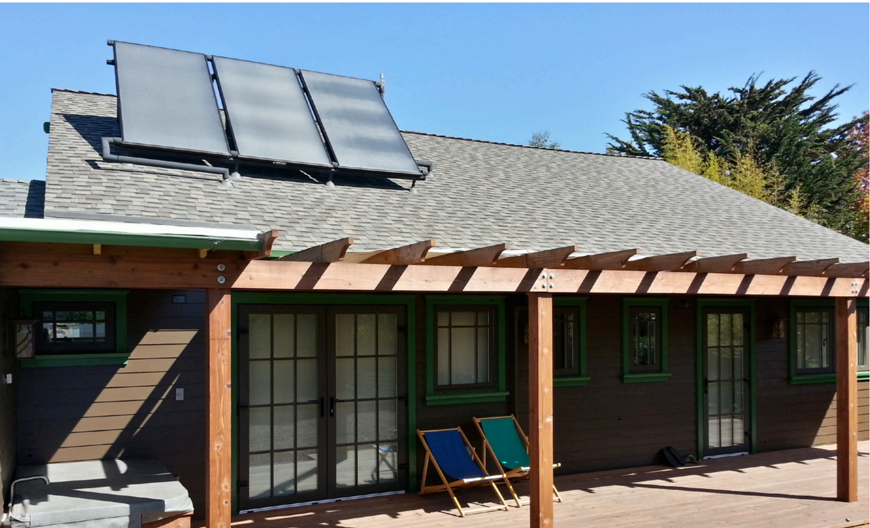
Designer and Builder Allen Gilliland, **ONE SKY HOMES**



Cottle House; Photo by Treve Johnson Photography



Midori Haus; Photos by Kurt Hurley



Midori Haus

Santa Cruz, California

Certified by the Passive House Institute in Germany, Midori Haus carries the distinction of being the millionth square meter of certified Passive House in the world. This 3-bedroom, 2-bathroom California bungalow, originally built in 1922, retained its Arts and Crafts style while achieving the performance of Passive House.

Post-retrofit utility bills document an 80% drop in energy consumption, but not at the expense of comfort. During a 4-day summer heat wave, when exterior temperatures reached 100 °F (38 ºC), the home's efficient shell and the strategic use of shading and night flushing kept inside temperatures in the mid-70s °F (~24 ºC). In winter, the interior temperature stays at a consistent 71 ºF (22 ºC) using a hydronic coil in the ventilation air stream coupled with the solar thermal system.

Concerned about California's persistent drought, the homeowners installed a 5,000-gallon rainwater harvesting storage tank. They are using the rainwater to flush the toilets and for cold water laundry—saving 6,000 to 8,500 gallons per year. The house is wired to be "renewable ready," with plans for a future rooftop photovoltaic system.

PASSIVE HOUSE METRICS

Heating load	0.93 W/ft²	10 W/m²
Cooling energy	0 W/ft²	0 W/m²
Total source energy	8.92 kWh/ft²/yr	96 kWh/m²/a
Treated floor area	1,421 ft²	132 m²
Air leakage	0.59 ACH_{50}	

PROJECT TEAM

Architecture and Building Physics Graham Irwin, **ESSENTIAL HABITAT**
Solar Thermal Design Patrick Splitt, **APP-TECH**
Builder Taylor Darling, **SANTA CRUZ GREEN BUILDERS**

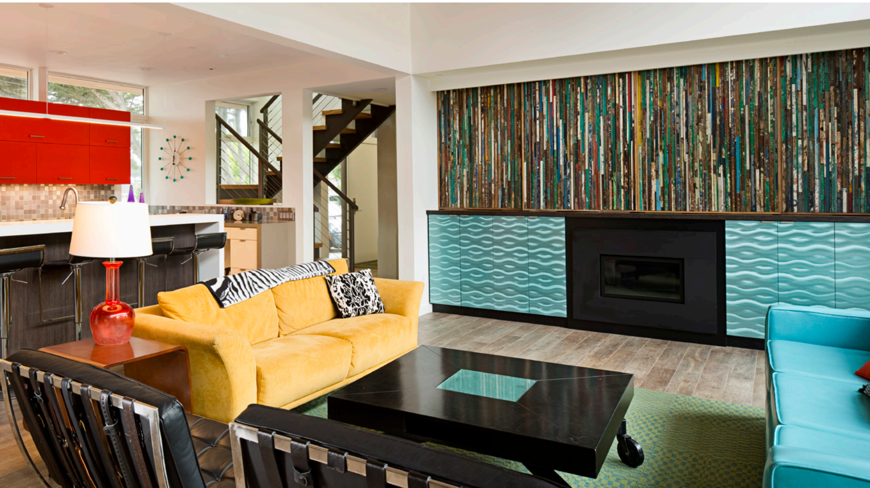
Pacific Grove Passive House

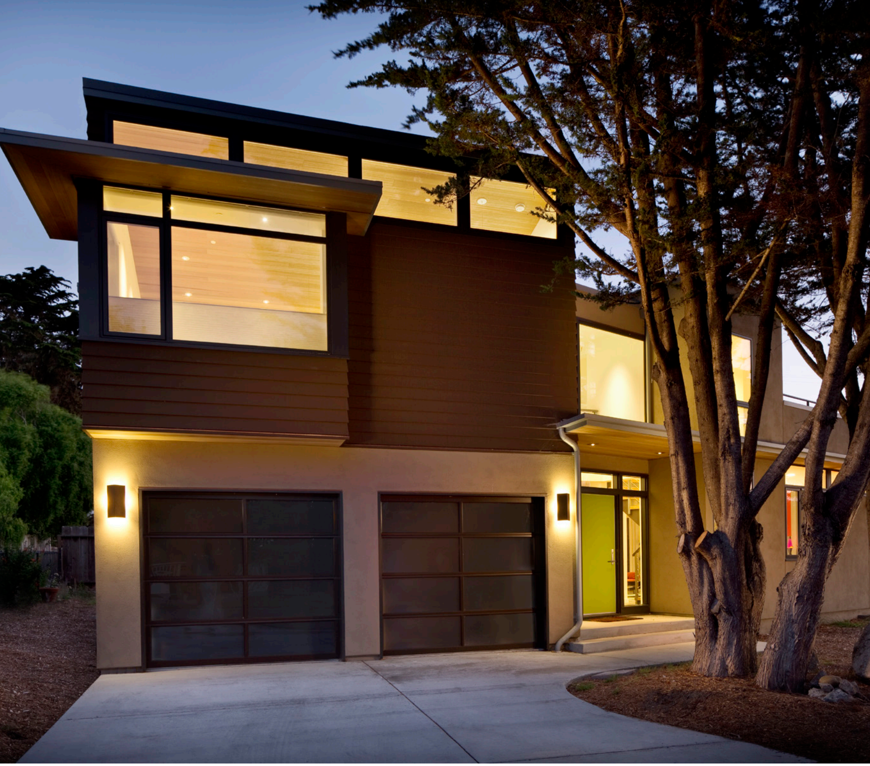
Pacific Grove, California

This 2,400-ft² ultra-environmentally friendly, contemporary home started life as a 950-ft² ranch home before being transformed to take advantage of ocean views and meet the Passive House Standard. The newish home uses about 70% less energy than a typical new home, and its 2.45-kW photovoltaic system offsets much more energy than its half-time occupant currently uses.

Even with the home's often foggy location, its passive features—shaded higher solar gain glass on the south, thermal mass, and phase change materials—have proven effective in minimizing the home's heating demands. A whole-house heat recovery ventilation system, a high-efficiency condensing gas fireplace for the lower main space, a single-zone mini-split heat pump in the upper bedroom and office suite, and electric towel bar warmers in the bathrooms together suffice to meet the minimal heating needs.

The owner reports that the comfort is amazing. "For brief periods in the early morning I've used the fireplace and heat pump to take the chill off but otherwise never use the heating," he says.





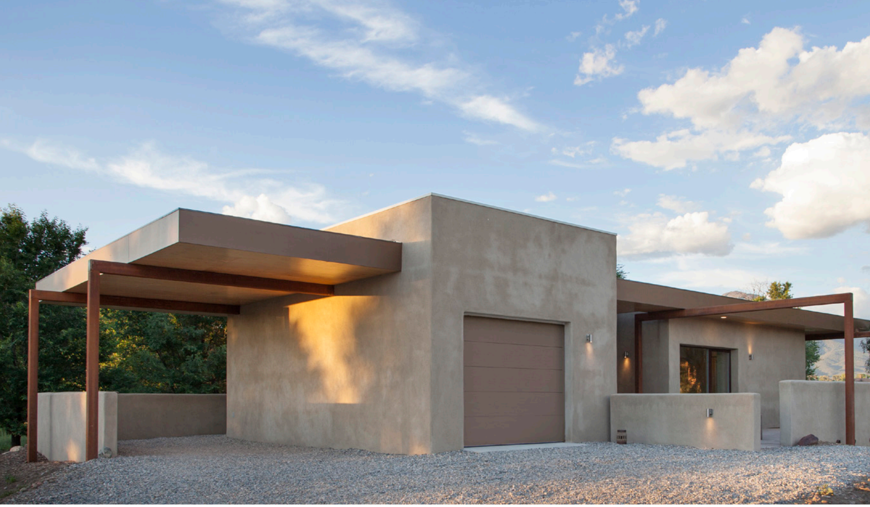
Pacific Grove Passive House; Photos by Rick Pharaoh Photography

PASSIVE HOUSE METRICS

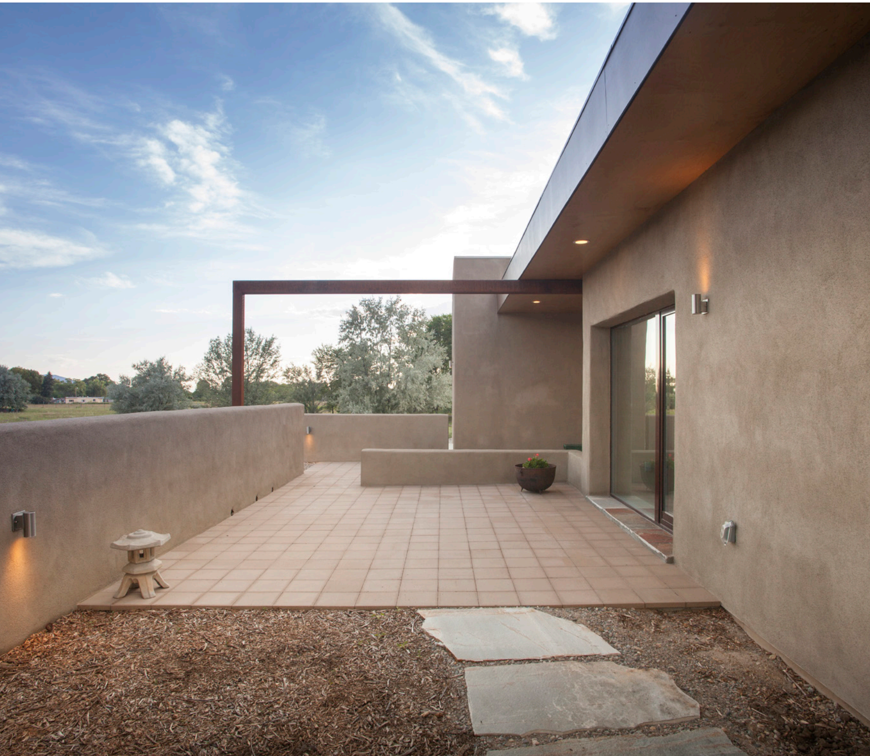
Heating energy	1.38 kWh/ft^2/yr	14.86 kWh/m^2/a
Cooling energy	0.38 kWh/ft^2/yr	4.1 kWh/m^2/a
Total source energy	9.14 kWh/ft^2/yr	98.42 kWh/m^2/a
Treated floor area	1,816 ft^2	169 m^2
Air leakage	0.57 ACH_{50}	

PROJECT TEAM

Architect Bill Foster, **WILLIAM E. FOSTER ARCHITECTURE**
Builder Rob Nicely, **CARMEL BUILDING & DESIGN**
Passive House & LEED Homes Consultants
Katy Hollbacher and Lizzie Adams, **BEYOND EFFICIENCY**
HERS Rater Steven Jungerberg, **RETRO GREEN**



TAOsHouse; Photos by Leitner Photography



TAOsHouse

Taos, New Mexico

The TAOsHouse, a contemporary, prairie-style Passive House and Net Zero Energy Building, exemplifies a model of sustainable living. This three-bedroom, two-bath house is situated within an adult cohousing community that is just a 15-minute walk from Taos's historic plaza.

The home's open-concept floor plan and large expanses of glass allow the homeowners to fully appreciate the nearby Taos Mountain, while its aging-in-place design features extend its usability through all life stages. The R-58 wood-frame walls are insulated with expanded polystyrene (EPS) and coated in earth-pigmented plaster on the interior. Taking full advantage of the local solar resources, both photovoltaic and solar thermal panels top the R-96 roof.

Stained concrete floors add thermal mass to the home, modulating the large daily temperature swings in this desert climate. An energy-recovery ventilator and in-floor hydronic radiant heat keep the home comfortable throughout the year. Actual primary energy use, after accounting for renewables, amounts to 3,013 kWh annually or 2.35 kWh/ft^2/yr.

PASSIVE HOUSE METRICS

Heating energy	1 kWh/ft^2/yr	11 kWh/m^2/a
Cooling energy	0 kWh/ft^2/yr	0 kWh/m^2/a
Total source energy	7 kWh/ft^2/yr	75 kWh/m^2/a
Treated floor area	1,282 ft^2	119 m^2
Air leakage	0.42 ACH_{50}	

PROJECT TEAM

Architect Jonah Stanford, **NEEDBASED**

4

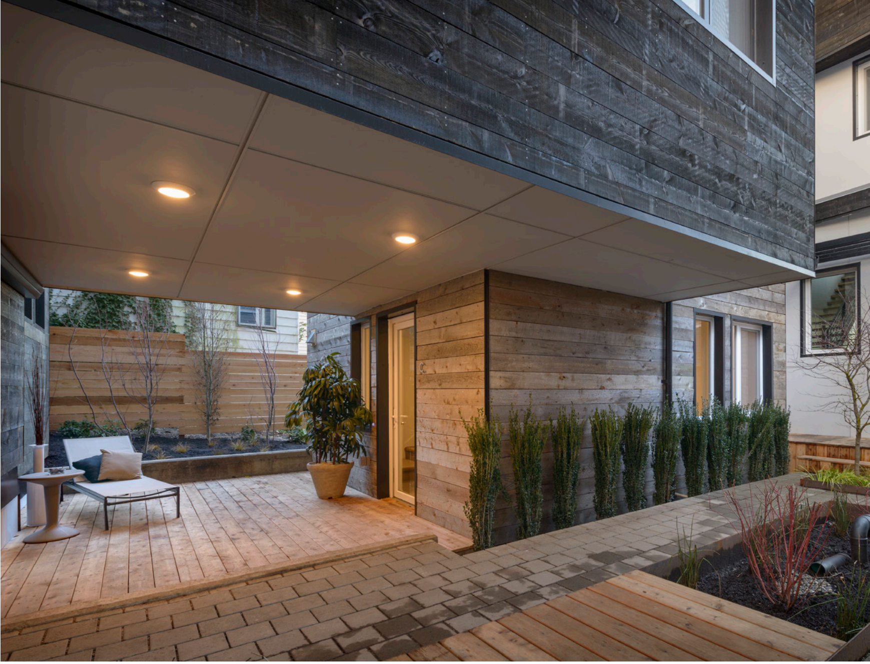
PASSIVE HOUSE

The Foundation for Net Zero Energy Buildings

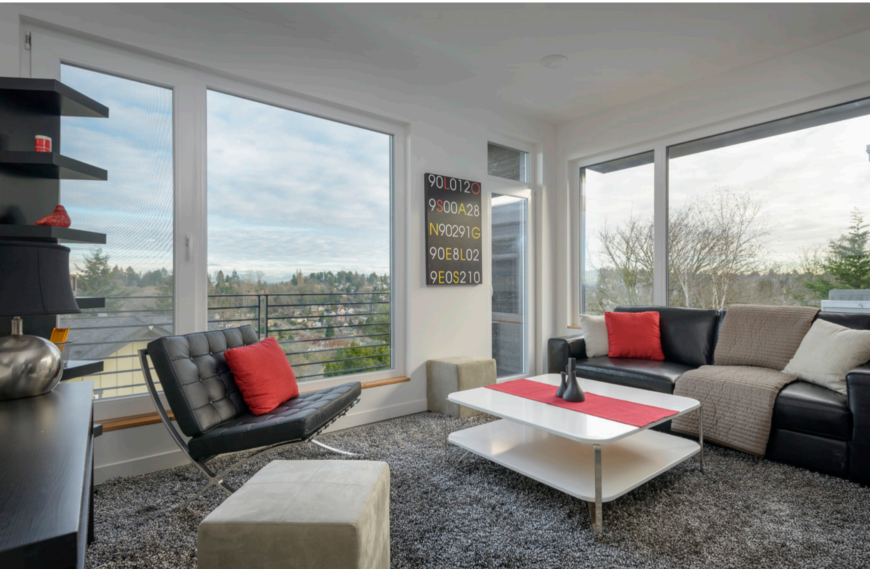
***NET ZERO ENERGY BUILDINGS** are characterized by extremely high energy efficiency as well as the use of renewable energy sources.*

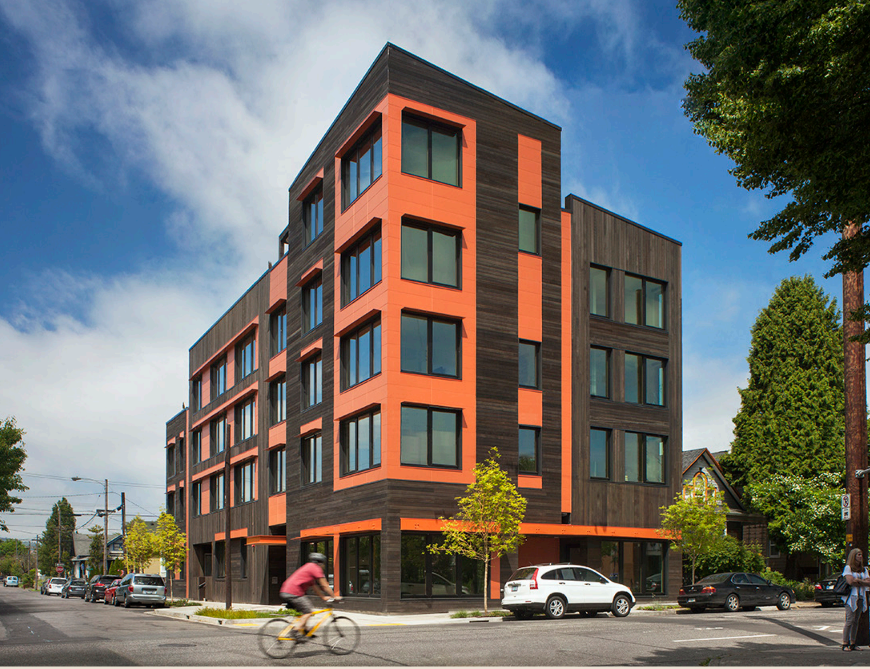
10 Reasons why the Passive House Standard is the Ideal Foundation for Net Zero Energy Buildings

1. The use of the Passive House approach reliably succeeds in delivering highly energy-efficient buildings. The low remaining energy demand can be met by using renewable energy sources on a long-term basis.
2. The Passive House Standard is an advanced concept that treats a building comprehensively. Compliance with the Passive House Standard is assured easily and reliably by means of the Passive House Planning Package (PHPP) energy-modeling software and can be verified by a certifying body.
3. The Passive House concept is suitable for new buildings as well as for deep energy retrofits. It has proven successful in many thousands of buildings for more than 25 years.
4. The Passive House Standard is available to everyone; it is a quality assurance and energy efficiency standard, not a protected brand.
5. The Passive House Standard can be combined with any architectural style and does not require a particular construction method. All types of buildings can be constructed to the Passive House Standard. Whether single-family houses, apartment buildings, schools, offices, kindergartens, hospitals, production facilities, recreational and sports facilities, or even high-rise towers—the Passive House Standard is universally applicable.



View Haus 5 by Nicholson Koval Chick Architects; Photos by Aaron Leitz





(top) Kiln Apartments in Portland, Oregon; Photo by Pete Eckert used by permission of GBD Architects Incorporated (bottom) Stellar Apartments in Eugene, Oregon; Photo by Bergsund DeLaney Architecture & Planning

6. It is the meticulous execution of Passive House details and use of high-quality components that together guarantee an optimal level of energy efficiency. Accredited certifiers can verify the quality of these components and that of the entire building. Thanks to the certification process, accurate performance data for a large number of very efficient building components and construction systems are available.

7. Using the Passive House approach, design errors are avoided right from the start, reducing construction costs. In the long term, the overall costs of Passive Houses, due to their low operating energy costs, are lower than those of buildings that just meet standard building codes.

8. Ongoing research supports the continual advancement of the Passive House Standard, and this research is published regularly in the scientific literature. In addition, educational institutions throughout the world are dedicated to the training of Passive House architects, engineers, builders, and tradespeople.

9. All renewable energy sources—from solar panels to geothermal energy—can be successfully integrated into a Passive House.

10. With Passive House as a basis for all Net Zero Energy Buildings—and energy-plus buildings—the energy revolution is possible, and we can avoid catastrophic climate change!

Passive House Resources

NORTH AMERICAN PASSIVE HOUSE NETWORK (NAPHN): A cooperative of North American regional Passive House organizations sharing the common mission of promoting the international Passive House Standard to the general public and building industries of North America. The Network fosters a vibrant and open Passive House community. We share resources, information, financial benefits, and responsibilities.

PASSIVE HOUSE INSTITUTE: An independent research institute that has played an especially crucial role in the development of the Passive House concept – the only internationally recognized, performance-based energy standard in construction.

INTERNATIONAL PASSIVE HOUSE ASSOCIATION (IPHA): A global network for Passive House knowledge working to promote the Passive House Standard and connect international stakeholders.

PASSIPEDIA: The ever-expanding knowledge database on energy efficient building and Passive House, comprising over two decades of research. This site includes links to other useful information, methods, and tools for various stakeholder groups from regions that have already successfully implemented Passive House.

Sponsors

Passive House Institute

International PASSIVE HOUSE Association iPHA

CanPHI West Canadian Passive House Institute West

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NAPHN gratefully acknowledges the many generous contributions of the PHI and iPHA, particularly their permission to reuse and adapt the underlying, preexisting work without compensation and their patient technical assistance. Without them, this project would not be possible.

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*“***PASSIVE HOUSE** *makes sense as a phrase, but I think* **IT IS AN ACTIVIST NOTION—A TRANSFORMATIVE NOTION…***This is one example of how New York City can show the world a model that works in today’s reality…”*

—Mayor Bill de Blasio

The Passive House Standard has proven successful in sharply reducing energy use in thousands of buildings over the last 25 years, making it an ideal basis for a Net Zero Energy Building. The Passive House approach has been used to create highly efficient houses, apartment buildings, schools, supermarkets, offices, laboratories, and a host of other building types.

By slashing building energy demand, the Passive House Standard allows wind, solar, geothermal, and hydropower resources to meet 100% of a building’s annual energy consumption. Thus, this standard makes a significant contribution to the energy revolution and climate protection.

Passive House Institute

naphn
North American Passive House Network