
Passive House Buildings
California's
ENERGY
FUTURE

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CALIFORNIA'S ENERGY FUTURE

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Introduction

Lizzie Adams

California's Passive House journey began where so many of our State's progressive and innovative movements have begun: in Berkeley. Architect Nabih Tahan and his wife, Margarita, returned there from Austria in 2008 so their daughters could attend high school in the United States. They brought with them the latest European building techniques and methodologies and applied them to the renovation of the 1904 bungalow they owned on Grant Street.

Subsequent presentations and open houses hosted by Nabih Tahan and his builder, Christopher Polk, sparked a nascent Californian Passive House movement and resulted in the formation of Passive House California (PHCA). Since 2008, a steady stream of open houses, site visits, networking events, and technical trainings have resulted in the projects you'll enjoy in this book, plus many more. As we researched projects for this book, we were excited to discover that more than 100 projects have utilized the Passive House tools and methodology in buildings across California.

Bronwyn Barry

The people featured in this book represent many early adopters who've spent countless hours figuring out how to design and construct buildings that are not only highly energy efficient but also comfortable and healthy for their occupants. These early adopters have shifted the baseline for "high performance", and we are pleased to recognize their efforts here. We encourage you to connect with them directly to learn more about their journeys. These pioneers—architects, designers, and builders of actual hardware (buildings)—continue our State's tradition of innovation and exploration. We anticipate their hardware will be useful for many more years to come as we transition into a new climate reality. We're optimistic these buildings will be both useful and highly comfortable for the next hundred years—like the renovated 1904 bungalow in Berkeley that inspired our local movement.

On behalf of Passive House California, we'd like to thank all those who have contributed to this book and to the growth of our movement and organization. We look forward to continuing to support this community and watch it not only grow, but thrive.

As we look to the future, be sure to keep up with our evolution and integration of renewable energy sources. We're hosting the **2017 NORTH AMERICAN PASSIVE HOUSE NETWORK CONFERENCE & EXPO** in Oakland from October 4-7. The event will feature "Passive House + Renewables" to showcase the new Passive House Plus and Premium standards. Join us!

Lizzie Adams, CPHC
Bronwyn Barry, CPHD
2016 PHCA Co-Presidents

PASSIVE HOUSE FOR ALL OF CALIFORNIA

Finding What Matters

The development of Passive House in California is accelerating, from one completed project in 2007 to numerous single-family, some multifamily, and even one commercial building as of 2016. With high levels of satisfaction being reported by owners and occupants, California's building industry is beginning to take notice.

Air leakage reduction, from the code assumption of 5 ACH_{50} to the Passive House maximum of 0.6 ACH_{50}, was the most effective first measure in every climate.

Widespread adoption of Passive House offers great potential benefits for California. In the state's more extreme climates, large performance improvements can be realized on a project-by-project basis. In the milder climates of southern California where the majority of the state's population resides, smaller performance improvements in numerous buildings could yield a large cumulative benefit.

Continued on p. 120

Our All-Renewable Energy Future

PASSIVE HOUSE PLUS AND PASSIVE HOUSE PREMIUM

If you've been puzzled by the proliferation of 'net,' 'nearly,' and 'almost ready' Zero Energy definitions and standards and have wondered just how *net* or *nearly* they truly are, take heart. The Passive House Institute (PHI) has introduced an equitable assessment of energy use to help guide us toward the 100% renewable energy future our State—and planet—must rapidly achieve.

Inspired in part by the impressive leaps in the efficiencies of renewable energy generation, coupled with the urgency of meeting global climate change goals, PHI initiated a review of non-renewable energy use in buildings in 2013. They recognized that their previous calculations for Primary Energy needed updating, especially as they favored the use of natural gas over electricity. (Primary Energy accounts for all the source energy used by a building, including the amount of energy it takes to generate and transmit power to the building site.) PHI recognized that non-renewable forms of energy use by buildings needed to be rapidly phased out, so they devised a method to incentivize the use of renewable forms of energy in buildings. Their research resulted in the overhaul of the existing Passive House 'Classic' standard and the introduction of two new standards: Passive House Plus and Passive House Premium.

Primary Energy Renewable 'Factors' and How They Work

All of the new Passive House standards now calculate Primary Energy using Primary Energy Renewable (PER) factors. These are designed to encourage the use of renewable energy sources and create either incentives, or disincentives, for installing various types of mechanical equipment in Passive House buildings. For example, in San Francisco, using a heat pump water heater to produce hot water will result in lower Primary Energy requirement numbers than using a gas tank water heater would, making it easier to meet the certification target. (A heat pump water heater has a PER factor of 1.25 versus the 1.75 factor for a gas-fired water heater.)

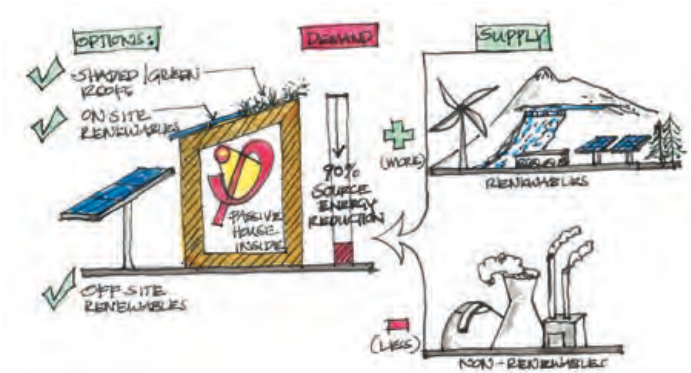


Figure 1. Integrating Renewable Energy Options in Classic, Plus and Premium Passive House Buildings

PER factor calculations are based not only on fuel source, but also on site-specific load profiles calculated on an hourly basis. In this way, variations in regional utility grid source energy and typical time-of-day use profiles, which impact the availability of renewable energy to meet a utility's load, for the local climate and region are factored into these calculations. As a result, the PER factors can vary from city to city in California. For example, the electricity PER factor for heating demand via heat pumps is 1.80 in Sacramento. This relatively high PER factor incentivizes reducing heating demand in winter, when renewable energy supplies are low. In San Diego the comparable PER factor is set at 1.30, where the climate is milder and cooling is typically a greater peak load issue.

Crediting Renewable Energy Equitably

Conventionally, calculations of net zero depend on the difference between a building's annual energy demand and annual on-site renewable energy production. These calculations penalize tall buildings with small roof areas, buildings with no solar access, or buildings that opt to use their roof area for green space or as active living spaces. PHI took a major deviation from such traditional methods for crediting renewable energy supply to buildings, recognizing that all sites are not created equal in this regard. PHI's approach uses the following principles:

Renewable offsets are calculated as a function of Projected Building Footprint (PBF) rather than total floor area. PBF is more proportional to available roof area than total floor area, which means multi-story buildings may achieve the Plus and Premium standards.

- Buildings with no solar access on site may purchase off-site renewable energy facilities to achieve Plus or Premium certification.
- PH 'Classic' Buildings with no on-site or off-site renewable energy supply are still optimized for efficiency first and a future grid supply of all renewable energy.
- While biofuels are considered a renewable energy source, they carry a penalty for replacing food production. Their burning also generates particulate matter that is both unhealthy and emits carbon. For these reasons, the use of biofuels is allowed, but has been capped to limit its use.

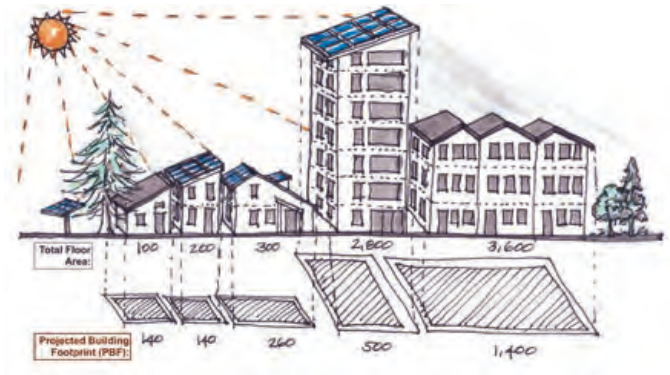


Figure 2. An Equitable Calculation for Renewable Energy Generation

WHY SITE 'ZERO' IS NOT SOURCE 'NET ZERO'

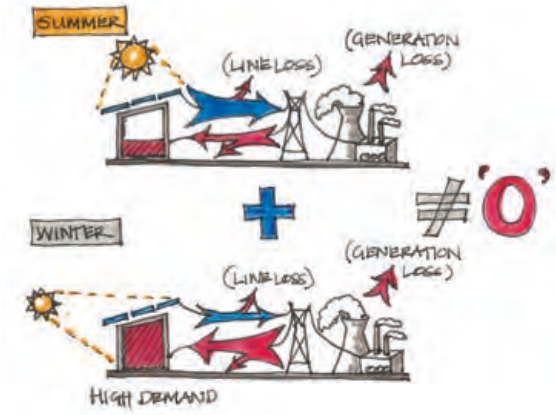


Figure 3. Source energy accounts for generation and transmission losses, but site energy does not.

The most intriguing areas of innovation with regards to manifesting the 100% renewable energy future currently look to be in developing our capacity to store renewable energy. We're excited by the contributions being made right here in California to develop technologies that are contributing to our new energy future. Existing storage capacity from hydroelectric schemes is now being joined by a growing array of affordable short- and long-term battery storage options. Converting renewable energy into methane gas is another rapidly developing technology that could increase the viability of renewable energy by allowing us to store it for longer.

Remarkably, these options *are all currently supported by the Primary Energy Renewable calculations embedded in the Plus, Premium, and Passive House Classic standards*. Indeed, the 'Classic' standard at the heart of all of them remains the foundation that most equitably supports an all-renewable energy future. The Classic standard ensures that these buildings are optimized to become batteries themselves: they've been proven to retain an unprecedented level of thermal comfort while eliminating peak loads. This optimization ensures that even without the addition of 'active' power, their passive capacity is what is literally doing the heavy lifting. These buildings enable occupants to survive in adequate comfort for very lengthy periods of time *without any active energy inputs*. This quality offers economic benefits to both the utilities and microgrid designs of renewable energy storage systems that extend well beyond comfort. Just imagine what we could do with renewable energy if we didn't need so much of it to simply operate buildings? The possibilities are boundless.

Bronwyn Barry
One Sky Homes

References
PASSIPEDIA.ORG/CERTIFICATION/PASSIVE_HOUSE_CATEGORIES/PER#THE_PER_SUSTAINABILITY_ASSESSMENT

Casa Aguila; Photo by KNB Associates

ALLIANCE Green Builders

Alliance Green Builders (AGB) was formed in late 2013 by Jeff Adams, president and owner of Wave Crest Enterprises, and Rich Williams, vice president, to bring the most advanced building techniques to the San Diego County area.

Adams and Williams had previously been on parallel paths within the green building industry, Adams as a builder and Williams as a real estate developer and green building consultant. Together, they bring more than 50 years of experience to the alliance. And, to ensure that their firm can deliver on every aspect of green building, they have added a full-service, 10-person "Green Team" to their roster, with experts in energy efficiency, renewable energy, water storage and reuse, and more.

Within months of teaming up, first Williams and then Adams took the Passive House builders training. "Passive House was a natural progression in our high-performance building path," says Williams. They were sufficiently fired up by the whole approach that they helped to start a local Passive House Alliance chapter in San Diego. Williams now serves as president of that chapter.

AGB is also proud to be a participant in the 2030 Challenge to reduce greenhouse gas emissions and achieve carbon neutral building construction by 2030. Consistent with the New American Dwelling principles espoused by architect Tom Bassett-Dilley, the firm strives to create beautiful, healthy, efficient homes that benefit both the owners and the environment. Although AGB primarily builds custom homes, they also branch out into working on gut renovations and multifamily and hotel developments.

The timing of the founding of Alliance Green Builders proved to be ideal. In previous years, regional demand for green building services had been limited, and the recession further reduced that demand. With increasing awareness of the benefits of solar energy and the growing concern for mitigating climate change and other environmental problems, there was an enormous shift in public perception of the benefits of green building. Coupled with the recovery of the housing market and construction industry, AGB found themselves with sufficient demand to rapidly grow their business.

Because green building requires a greater level of craftsmanship to provide a higher standard of quality, AGB limits their workload to three to four major projects at any one time in order to assure they can provide the attention required to maintain that higher standard of quality. Says Williams, "High performance homebuilding requires more attention by the general contractor than business-as-usual construction." On their first couple of AGB projects, they invested a lot of time into learning about new technologies that they wanted to incorporate into their work—innovations that they had not encountered or used in their previous LEED for Homes projects. "Continuously striving to raise the bar on what is possible takes great effort, but now that we have hit our stride, we intend on growing our workload at a healthy pace. I can project that by this time next year we could be working on six to eight major projects at any one time," Williams adds.

Casa Águila

RAMONA

TEAM

Architect
ANDREW WILT DESIGNS

CPHC
JORDAN WYATT

Builder
ALLIANCE GREEN BUILDERS (AGB)

Casa Águila, named for the golden eagles that frequent the area, is achieving many firsts for a residence in the region. It is the first home in San Diego County to receive a permit for on-site wastewater treatment, the first home in the area to use collected rainwater for all indoor water use, and it will be San Diego's first certified Passive House. The 3,129-ft^2 home's energy goals are equally as lofty, striving for grid disconnection after a trial period of using the on-site battery power, PV, and wind turbine.

The site's location on the wildland-urban interface, just next door to the Cleveland National Forest, is a big driver behind the owners' lofty goals for this house. Fires and drought are ever-present concerns in this area. The previous house on the site burned down in 2007, as did many of its neighbors. The area also experiences somewhat regular power outages, because the utility cuts the power to the neighborhood's

Casa Aguila; Photos by KNB Associates

lines whenever the winds are particularly high to reduce the risk of another wildfire.

The home features a wide array of advanced building products including high-performance doors and windows, a liquid-applied membrane for consistent air sealing, a phase-change material in the exterior and interior walls and in the ceiling for thermal energy storage, and heat-recovery ventilation. The triple-glazed doors and windows are shielded with an outer layer of glass that is essentially bullet-proof so they will not shatter if fire-driven winds project rocks or debris into them. The home also incorporates highly energy-efficient appliances, including an induction cooktop and a ventless heat-pump clothes dryer.

Although San Diego County generally has a mild climate, Ramona has a very different climate than the coastal regions. It can snow here in winter, and temperatures can top 100 °F for days at a time in summer. For year-round thermal comfort, the home's double-stud walls are filled with approximately 16 inches of blown-in cellulose. To reduce the cooling load, the standing seam metal roof has a solar reflectance index that is 79% more effective than the minimum value required for LEED for Homes. External shading was not included in the original design as the home has generous overhangs, but there are plans to add shading systems should performance data show the home would benefit greatly from the strategy. The roof assembly consists of structural insulated panels made with polyurethane foam, which has a higher melting point than EPS.

The owners really wanted radiant hydronic floors for wintertime warmth, which the builders coupled with hydronic fan coils for cooling. A very large—900 gallons—solar thermal system supplies the hot water,

Casa Aguila; Photos by KNB Associates

with a backup heat pump that also can provide chilled water in summer. Excess heat from the solar thermal system gets dumped into the pool and spa. A ducted mini-split system operates as a further space-conditioning backup, allowing the home to adapt to a changing climate for the next century or more.

Drought is a regional reality, so Casa Águila incorporates 50,000 gallons of rainwater storage, 40,000 gallons of stormwater storage, and a grey water and black water reclamation system. The filtered and aerated reused water will provide subsurface irrigation to a permaculture-based "Food Forest". The Food Forest mimics a woodland ecosystem by incorporating edible trees, shrubs, perennials and annuals. Fruit and nut trees make up the upper level, while berry shrubs, edible perennials, and annuals make up the lower levels.

In an effort to produce more energy than this highly energy-efficient home would use in a year, Casa Águila features elements such as light-finding dual-axis solar trackers that stretch the 22-kW PV system's production time to 7 to 9 hours per day. A 17-foot vertical axis wind turbine, mounted on a 45-foot tower, is expected to reliably produce power from 10 am to 10 pm. The owners have ordered and are waiting for a commercial-sized battery storage system so that they will only have to rely on the grid as a backup energy source. A sophisticated energy monitoring and control system will help them manage their production and demand, including shedding non-essential loads, such as the pool pumps, when required. They plan to become grid independent after a year's trial period of their energy systems.

The builders salute the homeowners, Amy McQuillan and Pete Beauregard, for being passionate about building a house that is a forward-looking example of what's possible for the Southern California region in green building. Going into the project, the owners knew this building would be both a demonstration project and case study. It is also their dream home that they look forward to enjoying for many years to come.

PRODUCTS

Windows & Doors
UNILUX

Air/Moisture Control
PROSOCO R-GUARD

Ventilation
ZEHNDER AMERICA

Insulation
GREENFIBER

Heating & Cooling
FUJITSU

Casa Aguila; Photos by KNB Associates

PASSIVE HOUSE METRICS

Heating energy	4.6 kBtu/ft²/yr	1.3 kWh/ft²/yr	14.4 kWh/m²a
Cooling energy	0.3	0.1	0.9
Total source energy	36	10.6	114
Air leakage	0.6 ACH_{50}		

Mild-Climate Retrofit
LOS ANGELES

TEAM

Architect
EVE REYNOLDS
and Host Architects

Certified Passive House Consultant
XAVIER GAUCHER

Passive House retrofits are always tricky, more complicated than new builds and often more expensive as well. Passive House consultant Xavier Gaucher embarked on a retrofit of his 1906 house in downtown Los Angeles with a particularly challenging goal: figuring out a cost-effective model for a mild-climate, Passive House retrofit that could be replicated in thousands of homes across Southern California.

The first Passive House pillar to be rethought was ventilation. Yes, constant fresh air—and, even better, filtered fresh air—would be needed but not heat recovery, given that winter barely happens. Gaucher, who used to work in the HVAC industry, devised a solution that delivers filtered fresh air through the ductwork required for the split-system heat pump that will be supplying the minimal cooling and heating needed. The fresh-air system includes an intake fan with a MERV13 in-line filter and a separate exhaust fan, both operated by the same efficient variable-speed controller. The ductwork's symmetrical layout will ensure proper fresh air distribution whether the heat pump is operating or not.

A high-performance window is another Passive House pillar being given a new twist. In this climate high performance means double panes. Gaucher was happy, after much research, to find a reasonably priced double-pane wooden window with a Passive House–quality frame that has been rated by the National Fenestration Rating Council (NFRC)—a requirement for permitting in some jurisdictions and for qualifying for certain rebates.

Fiberglass batts will be used to insulate the existing walls and under the floor, a material chosen both for its cost-effectiveness and familiarity to construction crews. The walls will have 3.5 inches of fiberglass between the studs, an airtight barrier membrane, and then a 2.5-inch insulated cavity for wiring and plumbing.

In terms of the cost of materials Gaucher anticipates there won't be much of a price difference between his house and other retrofits. There will be additional costs for the airtight barrier, but the downsized HVAC system will be cheaper. The additional labor needed to guarantee the quality of the construction is the unpredictable factor.

Mild-Cliimate Retrofit; Rendering by Jordan Wyatt / Y8 studio, Inc

PRODUCTS

Windows
ZOLA

Air/Moisture Control
CERTAINTEED MEMBRAIN

Insulation
CERTAINTEED HIGH PERFORMANCE BATTS
CERTAINTEED NOISEREDUCER BATTS

Heating & Cooling
MITSUBISHI ELECTRIC US

Solar Energy Systems
PICK MY SOLAR

PASSIVE HOUSE METRICS

Heating energy	2.9 kBtu/ft²/yr	0.8 kWh/ft²/yr	9 kWh/m²a
Cooling energy	3.2	0.9	10
Total source energy	23	6.7	71
Air leakage	0.6 ACH_{50}		

Passive House Los Angeles (PHLA+)

CULVER CITY

TEAM

Architect/Builder
Christian Kienapfel
PARAVANT ARCHITECTS

Certified Passive House Consultant
Sylvia Wallis

Builder
Guillermo Delgadillo

Located in Culver City, a suburb of Los Angeles, this new single-family residence that is being built to the Passive House standard is at the back of a duplex property behind an existing house. This infill development, which is currently under construction, will have 1,750 square feet of living space and a large roof deck above the carport. The contemporary, two-story home's rectangular geometry was engineered to withstand significant seismic loads, an important concern throughout California.

Having been educated and worked in Germany, the founders of PARAVANT Architects were excited to bring Passive House concepts and practices to their clients in Los Angeles. One of PARAVANT Architects' founders, Christian Kienapfel, is building this family home as the first newly constructed Passive House in Los Angeles to showcase how comfortable, efficient, and sustainable a Passive House can be while maintaining an affordable budget. Additionally, the home is meeting California's more stringent new construction efficiency standards targeting Zero Net Energy (ZNE) Homes by 2020, ahead of the official schedule.

Large windows provide sufficient natural light and a connection between indoor and outdoor living even with this home's limited footprint. As the neighborhood is located in the Los Angeles International Airport's flight path, the triple-glazed windows were selected to optimize both building and acoustical sound performance, largely alleviating noise pollution. Exterior venetian blinds will reduce UV, heat, and glare, effectively keeping the house cooler and comfortable.

The goal of healthy indoor air quality will be met by using a highly efficient heat-recovery ventilator (HRV). Additionally, a motion-activated hot water delivery system will be utilized to improve water conservation.

A 4-kW photovoltaic system, in combination with a solar water heater, will make this home net zero—or possibly plus—energy, reducing the utility bills for a lifetime. PARAVANT Architects is looking forward to routinely monitoring and verifying the building's daily performance as further proof of the Passive House concept.

Passive House Los Angeles; Renderings by PARAVANT Architects

PRODUCTS

Windows
ZOLA

Insulation
ROXUL

Heating &Cooling
MITSUBISHI ELECTRIC US

PASSIVE HOUSE METRICS

Heating energy	0.6 kBtu/ft²/yr	0.2 kWh/ft²/yr	2 kWh/m²a
Cooling energy	1.3	0.4	4.2
Total source energy	34	10	108
Air leakage	0.6 ACH_{50} (design)		

SYLVIA WALLIS

Harley Ellis Devereaux

Architect Sylvia Wallis uses her Passive House expertise on educational, institutional, and multi-family projects as an associate with Harley Ellis Devereaux (HED), a firm with more than 300 employees spread across 5 offices.

West Berkeley Branch Library; Photos by David Wakely

HED has been designing high-performance and LEED Platinum institutional and commercial buildings for years. The firm is currently sponsoring Wallis to participate on a joint AIA and ASHRAE committee tasked with developing an advanced energy design guide (AEDG) for zero net energy kindergarten through 12th-grade school buildings. Wallis will lead an effort in evaluating and quantifying the cost effectiveness of Passive House strategies to reach the zero net energy targets.

HED's long history of energy-efficient design was used to advantage in their project for the West Berkeley Branch of the Berkeley City Library, which won the 2016 AIA COTE Top Ten award. Its integrated design of skylights, natural ventilation, wind chimney, and radiant heating has allowed the comfortable and light-filled library to be successful in achieving net positive energy on an annual basis.

With experience designing automotive facilities, HED was recently selected as master architect for a new campus for the Southern California branch of the Air Resources Board (ARB) on an 18-acre site. The campus will include smog testing facilities and chemistry labs, which means high process loads—and high HVAC loads. The design requirements include not just net zero for the entire campus on an annual basis, but also reducing ARB's energy bills by managing peak energy use. The resulting facility is intended to establish a roadmap for compliance with California's ambitious AB32 policy for reducing greenhouse gas emissions.

Although the campus facilities are not being designed to meet the Passive House standard, Wallis' expertise with Passive House strategies will inform the performance criteria for the buildings. Such strategies as optimizing the buildings' solar orientation, minimizing thermal bridges, ensuring rigorous airtightness, and using balanced heat-recovery ventilation will work to shrink ARB's energy use and help ensure successfully meeting their net zero goal for the campus.

Shift House
LOS ANGELES

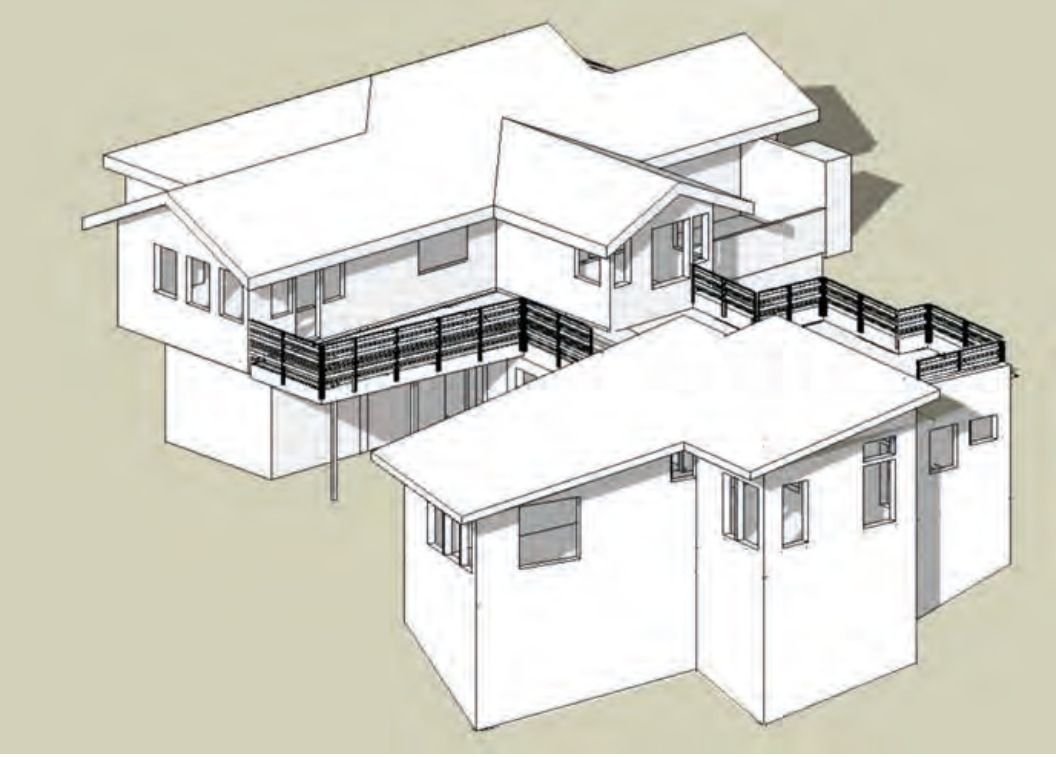
TEAM

Architect
SYLVIA WALLIS

Certified Passive House Consultant
Sylvia Wallis

Located in an older neighborhood of northeast Los Angeles, this single-family house retrofit and addition demonstrate energy efficiency and sustainability on an infill property within a limited budget. The design upgrades and expands a 1909 cottage to meet the Passive House standard. The project pioneered the concept of Passive House in Southern California with construction beginning in 2010. Building components include Passive House heat-recovery ventilation (HRV), tilt-turn windows, tight air sealing, a cool roof, photovoltaic panels, energy monitoring, rainwater harvesting, FSC wood, and native landscaping.

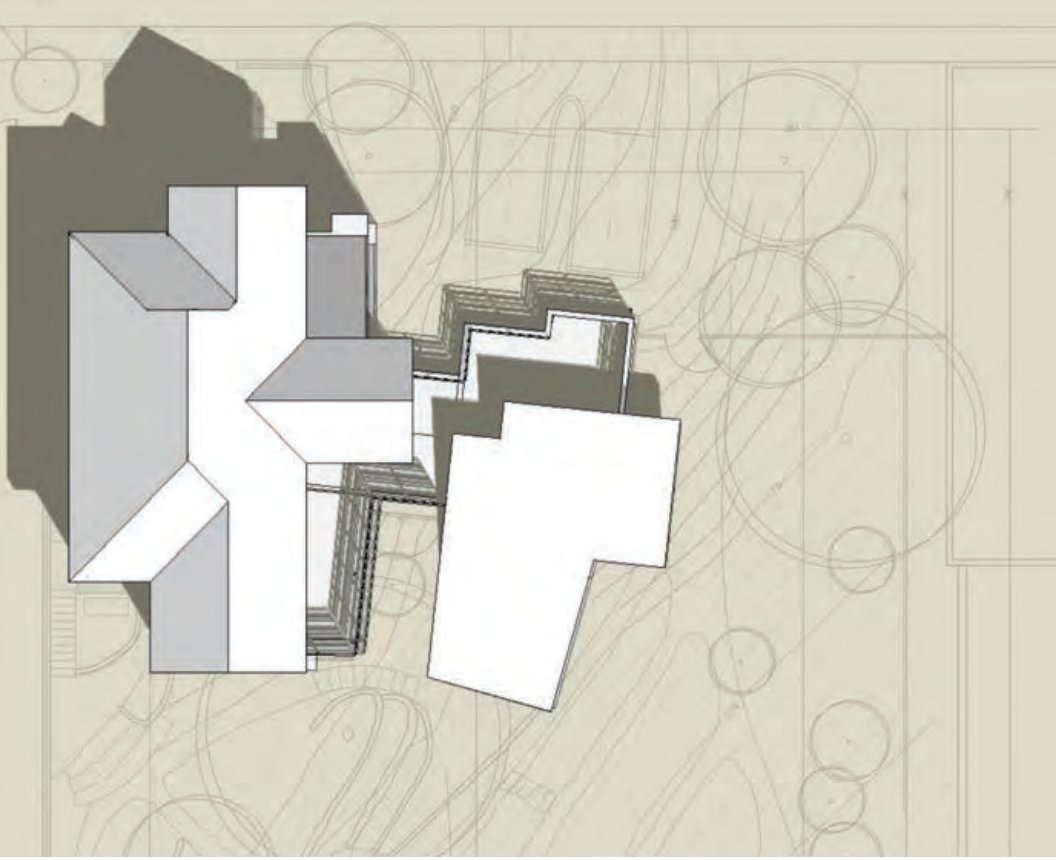
The existing cottage had no wall or floor insulation, some poorly installed ceiling insulation, and single-pane windows. The initial pressurization test result—29 ACH_{50}—would be laughable if not for being so typical a result for this older housing stock. After the addition was already permitted for construction, and just as details were being finalized for the mechanical systems, an article about the Passive House approach appeared in *The New York Times*. Impressed by the integrated strategies of Passive House, but without the option of starting over, the family chose to adapt the plans to meet the Passive House standard.



Shift House; Photo and rendering by Sylvia Wallis

Though the needed modifications were fairly straightforward for the 1,200-ft^2 addition, the retrofit of the roughly 1,200-ft^2 existing house was not included in the original budget. At the time, modeling of a step-by-step phased EnerPHit project, which is available using the current version of the PHPP energy model, PHPP9, was not yet an option. So, the owners embarked on their own path to integrate Passive House retrofit components into the project as budget and incentives allowed.

An apparent solution to making the Passive House goal feasible was offered up in the form of the Energy Upgrade California program, which lowered the costs of some of the energy efficiency improvements. However, taking advantage of the incentives brought various limitations. On the positive side, the existing house received air sealing and enhanced insulation that were not otherwise in the project budget. But the mechanical system design did not take full advantage of the reduced loads of the Passive House approach. And, the air sealing work was considered successful once 12.5 ACH_{50} had been reached for the existing house.



An upgraded mechanical system with an HRV was part of the scope; however, the Energy Upgrade energy modeling software, as with most energy software packages, could not recognize the highly efficient performance of the Passive House air sealing and balanced ventilation components. The Energy Upgrade design replaced the two ducted mini-splits of the initial design with a zoned heat pump and a huge central air handler. (The zoning responds to the difference in conditions between the upper retrofit level of the house and the lower new level.) An HRV system was installed separately by another contractor. The system has worked well; however, a greater understanding of Passive House strategies and performance by the Energy Upgrade team might have facilitated a simpler, more cost-effective system.

Further challenges to completing the Passive House project were the local business-as-usual construction practices. On at least one wall of the existing house, the drill-and-fill insulation used for the Energy Upgrade filled only half of the wall cavities. This led to a third-party infra-red (IR) assessment of all the walls, followed by additional drill-and-fill, far exceeding the standard level of practice. Getting and keeping insulation in smaller areas blocked off by framing or mechanical ducts is still a recurring problem for local contractors, requiring constant vigilance and on-going training.

Similarly the installation of high performance tilt-turn windows presents challenges for local contractors. At the time this project was specified, the most appropriate windows for the project were German windows. The small number of subcontractors willing and able to install the windows led to a significant upcharge in their installation cost.

Another concern typical of California projects is the need to reconcile seismic issues with Passive House insulation requirements. In seismic zones, the geotech engineers stress the importance of maintaining contact between the footings and friction piles and the supporting subgrade and bedrock, potentially limiting the ability to insulate under the concrete. The geology of the hillside site necessitated 5 piles extending 18 feet deep, connected by grade beams. To minimize these potential thermal bridges, the thermal envelope was established at the raised floor above the crawl space rather than at the grade, for both existing house and addition. This required more complex air sealing at the floor plate and its intersection with the walls.

The addition is almost completed, as of presstime, and, with the installation of new windows and final air sealing, the existing house will soon follow. Replacement of aging appliances will occur over time to reach the primary energy targets. The really great news is that by applying Passive House principles—and sticking with them—the owner has doubled the size of the house, and the modeled total energy is penciling out at lower than the original house's energy use. And, the whole family appreciates the increased thermal comfort, improved acoustics, superior indoor air quality, and long-term resilience afforded by taking the Passive House approach.

Shift House; Rendering by Sylvia Wallis

PRODUCTS

Windows & Doors
UNILUX

Air/Moisture Control
STUDOR/IPS
SIGA

Ventilation
ZEHNDER AMERICA

PASSIVE HOUSE METRICS

Heating energy	4.1 kBtu/ft²/yr	1.2 kWh/ft²/yr	13 kWh/m²a
Cooling energy	2.3	0.7	7.3
Total source energy	38	11.1	120
Air leakage	1.0 ACH_{50} (design)		

Canon Perdida Affordable Housing

SANTA BARBARA

TEAM

Architect
DEVICENTE MILLS HOLLIDAY ASSOCIATES ARCHITECTURE (DMHA)

Certified Passive House Consultant
STEVE MANN

General Contractor
HABITAT FOR HUMANITY SSBC/ALLEN CONSTRUCTION

Engineer
ASHLEY & VANCE

Developed by Habitat for Humanity for Southern Santa Barbara County (SSBC), these 12 California Craftsman-style townhomes are beautiful, comfortable, healthy, sustainable, affordable, and mostly maintenance-free, thanks in large part to the volunteer efforts of the first-time homeowners who moved into the units and more than 800 other community volunteers. Led by a traditional building team that included the general contractor and trade contractors, every new owner and their family provided 250 hours of sweat equity toward the construction of their homes. Many of the trade contractors also donated portions of their time or materials to the project.

Habitat for Humanity SSBC had set a goal for this affordable housing project to be as green as possible, including achieving near zero energy usage and Passive House Institute US certification for one of the buildings that has 3 of the 12 units. Thanks to the hundreds of volunteers who taped, sealed, and caulked gaps around every piece of drywall, window, door, wall penetration, and siding, air leakage was kept to a minimum. Together, they helped the project achieve Passive House certification, the first multi-family development in Southern California to do so.

The project's low-energy design incorporated such features as advanced framing to maximize the amount of insulation in the walls. Exterior to the sheathing a layer of 1 inch of rigid foam insulation adds a continuous thermal blanket to the homes. Individual heat-recovery ventilators (HRVs) provide continuous, filtered fresh air to each unit. Strategically placed windows enable nighttime flushing, helping to completely eliminate the need for a cooling system. The minimal heating demand is met through supplemental wall heaters.

With the housing's sharply reduced energy demand and its on-site 30-kW photovoltaic and solar thermal hybrid systems, the project has been able to achieve the developer's goal of near zero energy use. Low-maintenance landscaping and permeable paving combine to also reduce the housing's water use.

Canon Perdida Affordable Housing; Photos by Jim Bartsch

PRODUCTS

Ventilation
ZEHNDER AMERICA

PASSIVE HOUSE METRICS

Heating energy	4.8 kBtu/ft²/yr	1.4 kWh/ft²/yr	15 kWh/m²a
Cooling energy	0		
Total source energy	33	9.5	103
Air leakage	0.6 ACH_{50}		

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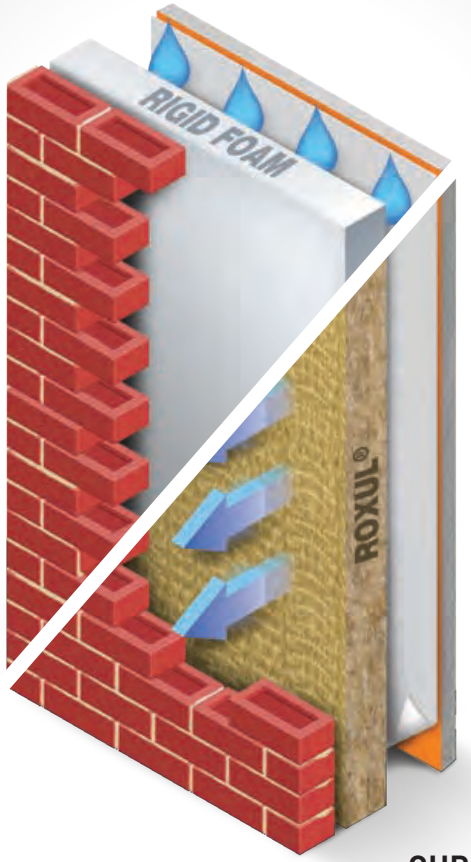

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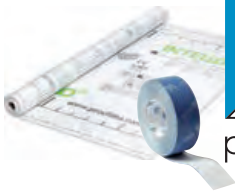

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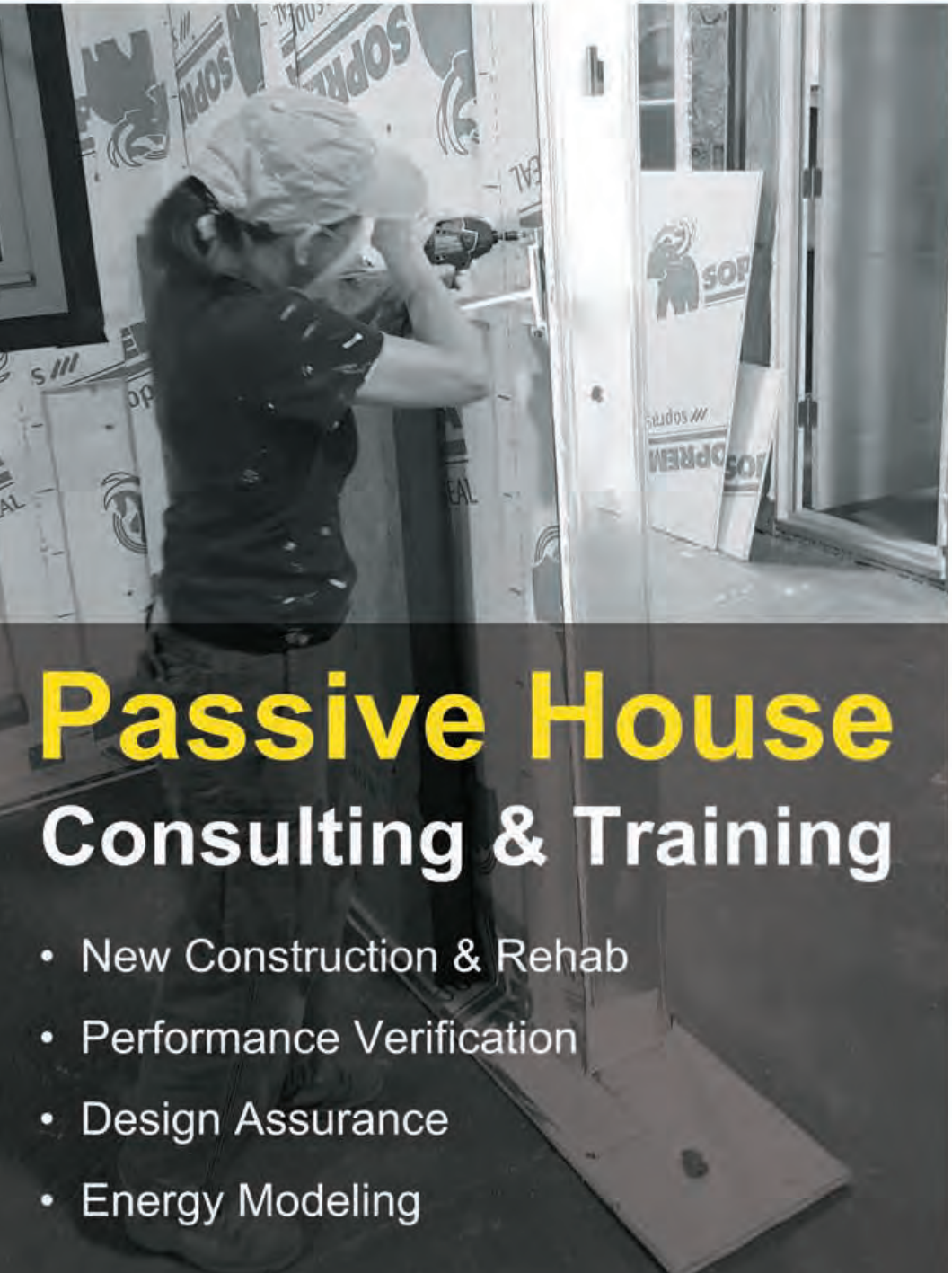

Passive House
Consulting & Training

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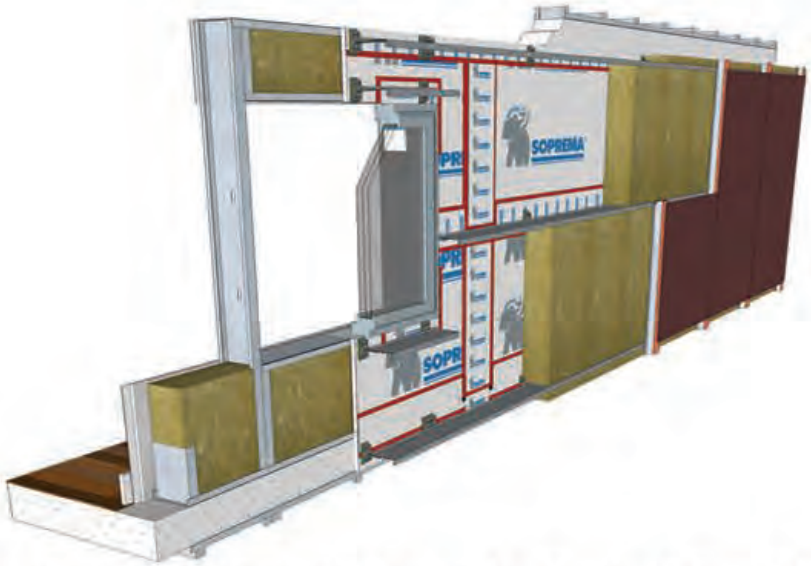

The Association for Energy Affordability has worked for over 23 years to make multifamily buildings more energy efficient. AEA's knowledge and experience in Passive House consulting, design assurance, construction verification, air sealing, and airtightness testing reduces the learning curve for Passive House projects. Our multifamily expertise and commitment to energy affordability for low-income households position AEA as a leader driving the widespread adoption of Passive House in California and across the country. AEA also works with Passive House Academy to deliver the internationally-recognized Certified Passive House Consultant & Designer training.

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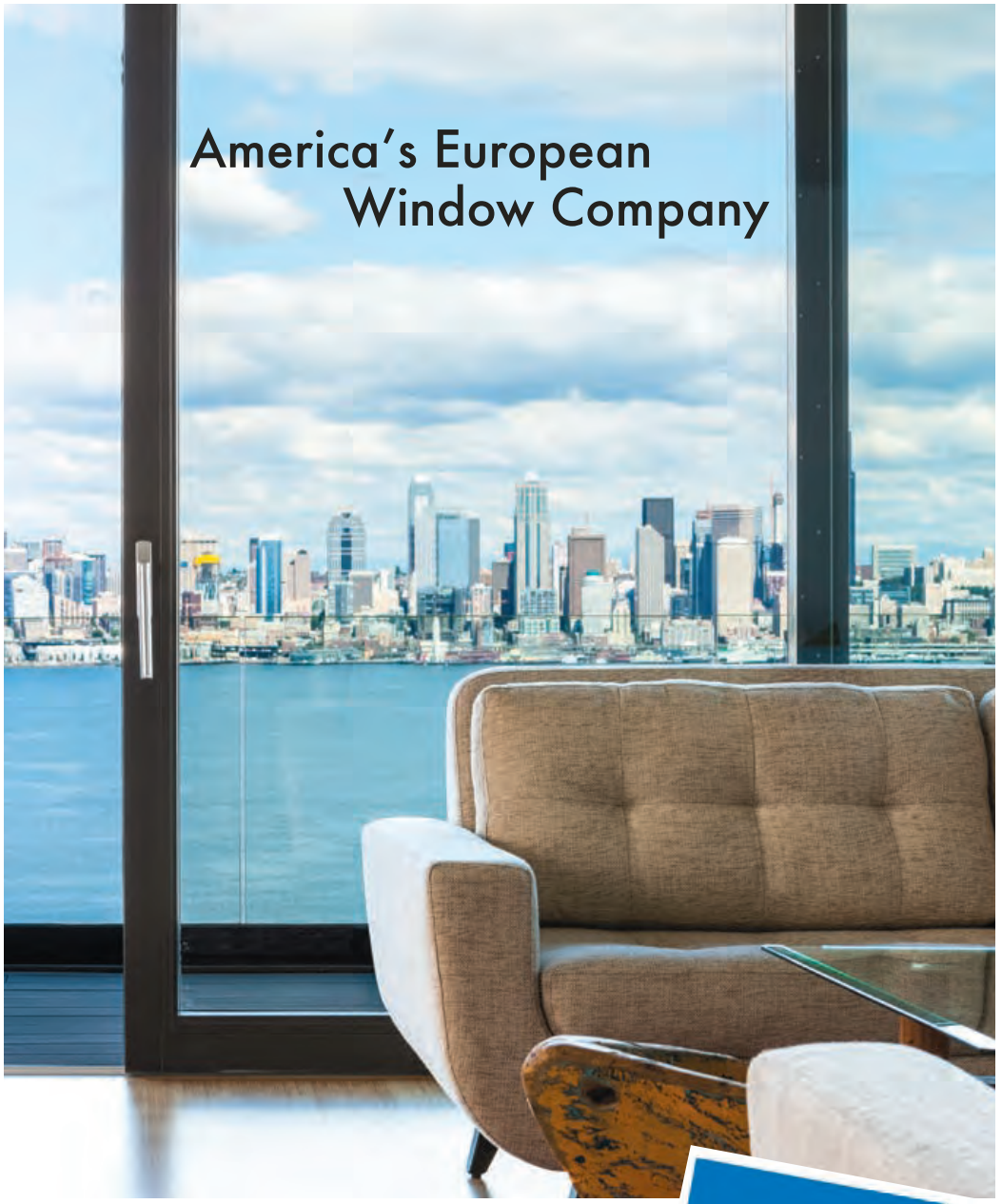

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Carmel Passive House; Photo by Rick Pharaoh Photography

CARMEL
Building & Design

Rob Nicely, principal of Carmel Building & Design, got his start in the building industry more than 25 years ago.

His construction methods shifted permanently when he learned about Passive House in 2005. As he says, "Once you know how to build smartly, it's hard to go back."

Nicely's focus on building high-performance homes has led to significant growth for his company that now employs 24 people. In the Monterey Peninsula area where his business is located and focused, his firm is recognized as a leader in advanced green building techniques. Many clients seek him out specifically for this expertise. While not every client wants a *certified* Passive House, they are all interested in having a high-quality house. For Nicely, high quality and Passive House are closely linked. "My goal is to build or remodel each house using Passive House principles whether or not we're pursing certification. It's simply the way I build."

His passion for Passive House is rooted in an understanding of how buildings work, including air and moisture movement and the impact on a home's comfort, indoor air quality, and durability. His firm also stresses the use of healthy building materials. This passion is also rooted in a broader understanding of his industry's impact on the environment. Nicely says, "The things that we've learned to do to make buildings better for the planet are also a better way to meet the needs of my clients—like the need for healthy indoor air quality, quiet, durability, and energy and water conservation."

He views Passive House as a powerful tool not only for buildings, but also for municipalities to employ to meet climate action plan goals. Toward that end, he is talking to as many local policymakers as he can reach, advocating for the broad adoption of demand reduction strategies, including Passive House. "The building industry has a tremendous impact on reducing harmful carbon emissions through the homes, buildings, and communities we design and build," Nicely says.

His firm has long embraced energy-efficiency strategies in every house they build, remodel, or retrofit. Given California's persistent drought and the limited water resources on the Monterey Peninsula, Nicely now incorporates innovative ways to reduce water usage as well. Techniques like structured plumbing, on-demand hot water recirculating pumps, and well-insulated pipes can bring hot water to faucets within as little as 3 to 5 seconds using about one cup of water.

Summing up what he sees as a growing acceptance of environmental responsibility, Nicely says, "The reasons we decide to adopt a more planet friendly, sustainable lifestyle don't matter as much as the decision itself. One person might want healthier indoor air quality because there's asthma or allergies in the family. Another might be looking to build or remodel a home that is more durable and has a better resale value. Another could be most concerned with lowering their carbon footprint, while yet another might focus more on energy and water conservation and reducing related costs."

Although his firm primarily builds single-family homes, his newest project is a bit outside the box. This client is aiming to create a high-performance, resource-efficient, mixed-use building, with retail on the ground floor and office and residential space above. It's a challenge Carmel Building & Design is primed to tackle.

Carmel Passive House
CARMEL

TEAM

Architect
JUSTIN PAULY ARCHITECTS

Certified Passive House Consultant
BEYOND EFFICIENCY

Builder
CARMEL BUILDING & DESIGN

The owners of Carmel's only certified Passive House knew from the beginning that they wanted a very energy-efficient home. That's why they chose Carmel Building & Design, which has a reputation as a leader in crafting high-performance homes that also achieve the owners' vision for design and function. With the firm's encouragement, they opted to pursue Passive House certification—resulting in a home that exceeds their expectations in every way. This Passive House not only surpassed the aesthetic expectations of its neighbors and the local planning commission, it was named Best New Home in *Fine Homebuilding* magazine's 2013 Houses Awards issue; architect Justin Pauly, AIA, took top honors in the Monterey Bay Chapter of the American Institute of Architects' 2013 Awards Program for Design Excellence for his work on this home.

Carmel Passive House; Photos by Rick Pharaoh Photography

A twist on a traditional farmhouse design, the 1,568-ft² home incorporates rustic elements and natural lighting that shows off the building's open floor plan. To meet Passive House requirements, the builder incorporated advanced framing techniques, using 24-inch stud spacing and appropriately sized, insulated headers. Rather than insulating at a single point during construction as is typical, he insulated every step along the way to make sure no areas were omitted. The walls are filled with open-cell spray foam and covered with 2 inches of continuous exterior insulation. Phase-change materials (PCM) are installed in the wall and dropped ceilings to soak up the sun's heat from large south-facing windows and release it for passive heating when temperatures cool.

The air-sealed structure uses a heat-recovery ventilation system to provide continuous fresh air, heated by a hydronic coil when needed. Rob Nicely, the firm's owner, also developed a custom venting system for the professional-quality stove the homeowner and avid cook wanted in her kitchen. In all, the home uses about 70% less energy than a traditionally built house. Additional

measures, including reclaimed 110-year-old oak flooring, low- and no-VOC finishes, ENERGY STAR appliances, WaterSense fixtures, LED lighting, drought-tolerant landscaping, and a rainwater catchment system contribute to the home's outstanding environmental performance.

According to the happy homeowners, the Passive House also provides benefits they hadn't anticipated. "In the three years since we moved in, we haven't had to dust once, there are no bugs, and it's amazingly quiet. The air filtration system works beautifully whether the windows and doors are open or closed. We absolutely love this house."

Carmel Passive House; Photos by Rick Pharaoh Photography

PRODUCTS

Air/Moisture Control
PROSOCO R-GUARD
SIGA
Ventilation
ZEHNDER AMERICA

PASSIVE HOUSE METRICS

Heating energy	2.6 Btu/hr/ft²	0.8 Watts/ft²	8.2 Watts/m²
Cooling energy	1.5	0.4	4.7
Total source energy	36 kBtu/ft²/yr	10.6 kWh/ft²/yr	114 kWh/m²a
Air leakage	0.5 ACH_{50}		

Pacific Grove Passive House

PACIFIC GROVE

TEAM

Architect
WILLIAM E. FOSTER ARCHITECTURE

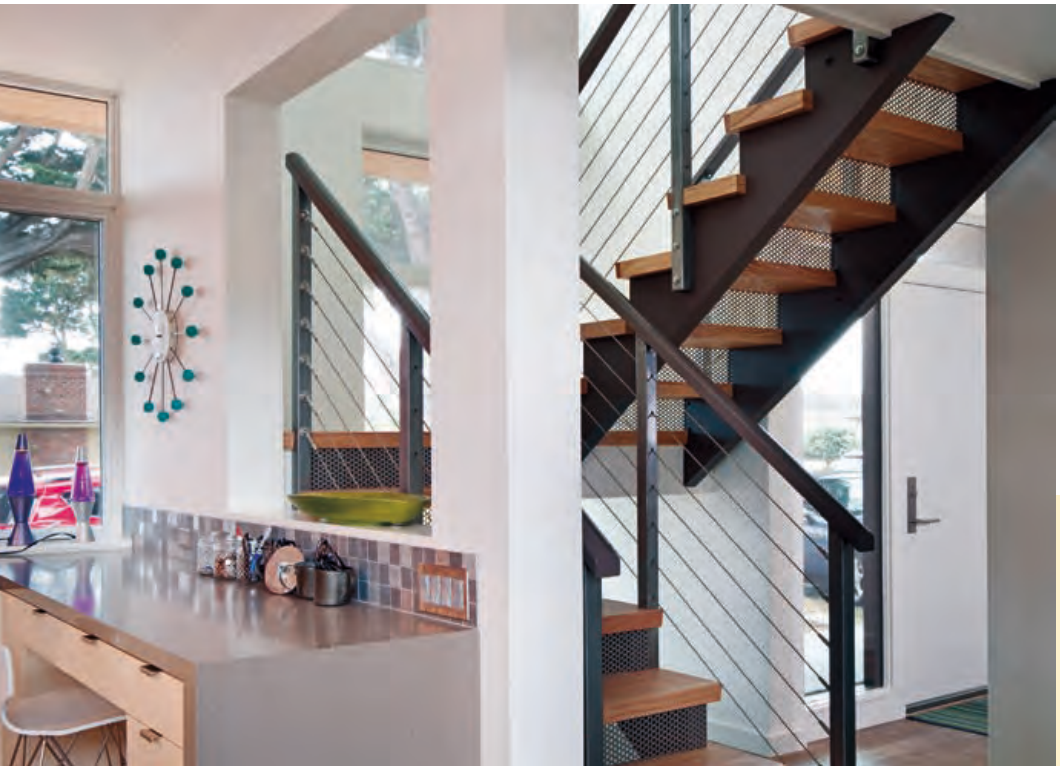
Builder
CARMEL BUILDING & DESIGN

Passive House & LEED Homes Consultants
BEYOND EFFICIENCY

HERS Rater
Steven Jungerberg
Retro Green
GORETROGREEN.COM

This 2,400-ft² ultra-environmentally friendly, contemporary home started life as a 950-ft² ranch-style house before being transformed to meet the Passive House standard. A second floor that includes a bedroom, bathroom, and office, as well as an outdoor terrace, was added to take advantage of ocean views. The home now uses about 70% less energy than a conventionally built structure, and its 2.45-kW photovoltaic system offsets significantly more energy than its occupant currently uses.

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



The California Advanced Homes Program (CAHP) selected this home as Project of the Quarter for the first quarter of 2015. Based on PG&E data, the home's energy efficiency exceeded the standards of 2008 Title 24 by 64.6%, the highest percentage of any residence in the state.

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

PRODUCTS

Windows
ALPEN HPP

Air/Moisture Control
SIGA
ZIP SYSTEM SHEATHING & TAPE

Ventilation
ZEHNDER AMERICA

Heating &Cooling
MITSUBISHI ELECTRIC US

PASSIVE HOUSE METRICS

Heating energy	4.7 kBtu/ft²/yr	1.4 kWh/ft²/yr	14. 9 kWh/m²a
Cooling energy	1.3	0.4	4.1
Total source energy	31.2	9.2	98
Air leakage	0.6 ACH_{50}		

The Eco Cottage

SANTA CRUZ

TEAM

Architect
ZERO IMPACT ARCHITECTURE

Certified Passive House Consultant
SKYLAR SWINFORD

What started as a simple bathroom remodel progressively evolved into a whole-house Passive House retrofit of a roughly 1,300-ft² beachside cottage. The stepwise creep in scope complicated some of the Passive House measures, especially the airtightness approach. And, there were permit-related hurdles to incorporating the low-embodied-energy materials that the client wanted to use. In the end, though, this 1940s-era cottage was transformed into a lovely, extremely energy-efficient home that will be comfortable for decades to come.

With the goal of reducing both operating energy use and embodied energy use, the exterior insulation and siding is cork, a sustainable, carbon-negative material that delivers an R-value of 3.7 per inch. Although there are many cork-sided buildings in Europe, it's among the first in the United States. Interior to the cork is a vapor-open water-resistant barrier. Additional insulation is provided by 3.5 inches of cellulose in the stud cavity.

The insulation levels and airtightness of the revamped cottage, combined with the area's mild climate, allowed for a fairly dramatic simplification of the heating system. Two radiant electric-resistant heaters can supply heat to the modestly sized great room, when needed, while an electric post-heater installed in-line with the heat-recovery ventilator (HRV) can distribute warmed air to the bedrooms. The HRV has a nighttime cooling feature that obviates the need for air conditioning.

With drought as an ever-present concern, structured plumbing was used to minimize plumbing runs and reduce water waste. The grey water and black water waste lines were separately plumbed to ease future reuse of the grey water in the toilets or for irrigation. All of the cold water lines were also separated, so that the two showers, the two toilets, and the three sinks were plumbed together. Three cold water lines enter the house and end at the water distribution area in separate manifolds. One is for city water, and the other two are for future filtered grey water and rain water sources. As these sources are activated, the appropriate cold water line can be moved from the city water manifold to this manifold. Although budgetary concerns prevented further development of this system, pre-plumbing for it when the plumbing is easily accessible is just as critical as installing insulation when an exterior wall is exposed. In both cases, trying to do the job later would not be economical.

The Eco Cottage; Photos by Joel Bernstein Photography

PRODUCTS

Windows
EUROLINE WINDOWS INC.

Air/Moisture Control
SIGA
PRO CLIMA

Ventilation
ZEHNDER AMERICA

Insulation
THERMACORK

Water Heater
SANDEN

Lighting
ILLUMINEE

PASSIVE HOUSE METRICS

Heating energy	5.1 kBtu/ft²/yr	1.5 kWh/ft²/yr	16 kWh/m²a
Cooling energy	0		
Total source energy	37	11	117
Air leakage	1.0 ACH_{50} (design)		

San Anselmo Passive

SAN ANSELMO

TEAM

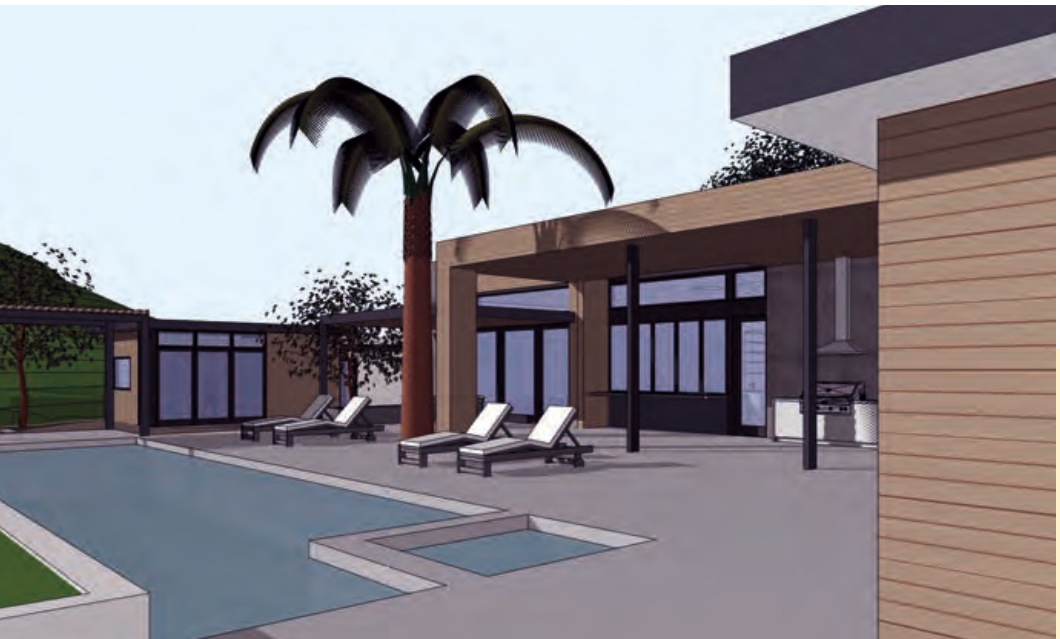
Architect
POLSKY PERLSTEIN ARCHITECTS

Certified Passive House Consultant
ZERO IMPACT ARCHITECTURE

Polsky Perlstein Architects opened its doors 35 years ago with a philosophy of creating residential designs that are carefully considered responses to the site, the neighborhood context, and the owner's wishes. Given that history, it's not surprising that the firm has had many repeat clients over the years.

In this case, the clients' family had lived happily in a hillside home that Polsky Perlstein had remodeled 25 years ago. But as empty nesters, their dreams had changed. Their old home is high in the Marin hills at the end of a winding road; this time they were fortunate to find a level site in the same town, though in a more accessible and less fire-prone area. Accessibility is generally one of the new 4,000-ft² home's features; its single story will minimize wear on aging joints. A detached 1,000-ft² studio and guest house, a pool, and a separate two-car garage—all enhanced by a low-water-use landscape design—complete the project.

The clients always intended their home to be efficient and environmentally friendly, so another goal was added to the project wish list: having the home meet Passive House specifications. One of the owners has been deeply involved in climate advocacy for several years, and through this work met James Bill, Passive House consultant and principal of Zero Impact Architecture. Richard Perlstein, one of the firm's principals, was familiar with the Passive House movement and was thrilled to have a consultant added to the team who could help with reducing the home's operational and embodied energy.



"The ideal for any project would be to start with Passive House as a goal," says Perlstein. However, Bill joined the team just after the design review process was completed—not exactly ideal timing. Fortunately, Polsky Perlstein's design already incorporated many Passive House strategies. The owners desired a modern aesthetic with large expanses of glass. Because the best views are to the east, the L-shaped home's major glazed areas look to the east and south, capturing maximal solar heat in winter. A covered patio off the east façade will shade those windows in summer. A stand of trees on the western side will screen out heat gains on summertime afternoons.

Bill is helping to bring in other Passive House design elements that will minimize thermal bridging and aim to create an airtight structure. The clients are excitedly looking forward to their comfortable, modern, very efficient home.

Renderings by Polsky Perlstein Architects

PASSIVE HOUSE METRICS

Heating energy	4.7 kBtu/ft²/yr	1.4 kWh/ft²/yr	14.8 kWh/m²a
Cooling energy	0.6	0.2	1.9
Total source energy	16.5	4.8	52
Air leakage	0.6 ACH_{50} (design)		

Clarum Homes Office; Photos by Bernard Andre Photography

BEYOND EFFICIENCY

Beyond Efficiency is a consulting firm that provides building science and green building services, empowering clients to create enduring human-centered buildings.

Small enough to be nimble and personalized yet large enough to deliver comprehensive value, their services range from energy modeling to building enclosure optimization to mechanical systems engineering to low-water plumbing design. Their expertise extends to commercial, educational, multifamily, and single-family residential projects. They can help ensure their clients' buildings realize the goals and promises of building codes and green building programs, including LEED, Living Building Challenge, and Passive House.

Katy Hollbacher, principal of Beyond Efficiency, started the firm in 2009, coincidentally the same year she took the Passive House training. The training's emphasis on building science and, specifically, optimizing the building envelope to control energy flows was a game-changer for Hollbacher. "Passive House is an incredibly valuable standard," says Hollbacher, although she would never call herself a "Passive House or bust" consultant. "Envelope efficiency is critical to long-term performance and comfort—and that's where design should start," she says, noting that she brings her Passive House expertise to every project. Depending on the client or type of building, though, there may also be other issues, such as server rooms and plug loads, that dominate a building's energy use.

In addition to their pre-construction services, Beyond Efficiency also offers energy monitoring and post-construction commissioning, a particular benefit for their commercial building clients. The energy use in these buildings can be strongly affected by small changes in the controls set-up or tweaks to equipment schedules, and only commissioning can catch these missteps. For clients who are aiming for net zero energy use annually in a building—whether residential or commercial—monitoring actual energy use can be critical for reaching that goal.

Whatever the ambition or goal, Beyond Efficiency helps clients achieve it, starting from a deep familiarity with how buildings really work. They know how to fully leverage the capabilities of modeling and optimization studies while also understanding the limitations of applying them to the real-world complexity of buildings. As Hollbacher says, "Building science isn't quite rocket science, but high-performance building development is complex. Our practical experience and pragmatic approach to solving design and engineering challenges set us apart from the rest."

Clarum Homes Office

PALO ALTO

TEAM

Architect
EID ARCHITECTS

Certified Passive House Consultant
BEYOND EFFICIENCY

Builder
CLARUM HOMES

When Clarum Homes decided it needed new office space, the design-build firm—a green building leader since its founding 20 years ago—naturally set a goal of creating the first commercial Passive House project in California. They bought what had been a warehouse for heating, ventilating, and air conditioning equipment and completed a gut renovation of the building, transforming it into a 5,800-ft² office space. The large, triple-pane fiberglass windows provide a modern look and excellent thermal performance while flooding the offices in daylight.

While the daylighting design may be quintessential California, the heating and cooling system is much more European. As it's an office building with numerous computers and other electronic loads, the primary concern is the cooling load, not the heating. An air-to-water heat pump system supplies either chilled or heated water to radiant ceiling panels. In this office about 60% of the ceiling drywall panels are the radiant panels, and the rest are regular drywall panels with no visible difference between the two areas. A cool ceiling has no furnishings or floor coverings to impact performance and creates an extremely comfortable workplace with practically no stratification.

The HVAC system includes a heat-recovery ventilator (HRV) that can operate at an airflow rate of 1,000 CFM. The higher speed can help to flush the building whenever the outdoor temperatures drop below 67 °F and there's a demand for cooling.

Subslab insulation, R-24 wood-frame walls with continuous exterior insulation, an R-40 roof, and highly airtight envelope have all contributed to creating a workplace where the occupants rave about comfort. Electricity production from the 20-kW PV system, along with careful review of post-occupancy electricity monitoring data, enabled the 100% electric building to achieve net positive energy in its first year of occupancy.

Clarum Homes Office; Photos by Bernard Andre Photography

PRODUCTS

Windows
CASCADIA FIBERGLASS WINDOWS & DOORS

Air/Moisture Control
SIGA

Heating & Cooling
MESSANA RADIANT COOLING

PASSIVE HOUSE METRICS

Heating energy	4.4 kBtu/ft²/yr	1.3 kWh/ft²/yr	13.7 kWh/m²a
Cooling energy	3.5	1.0	10.9
Total source energy	37.6	11	119
Air leakage	0.2 ACH_{50}		

Russian Hill
Multifamily
SAN FRANCISCO

TEAM

Architect
Daniel Hruby
VISUALIZE IT BUILT

Certified Passive House Consultant
BEYOND EFFICIENCY

Developer and Builder
EVOLVE DEVELOPMENT

On a desirable and challenging site in the heart of one of San Francisco's tonier neighborhoods a 6,250-ft², three-unit Passive House multifamily is rising. Seen from the street, the building appears to be four stories tall, but two lower floors hug the steep slope behind the garage. The garage has its own extraordinary features that aren't immediately apparent: it includes car lifts so it can fit one car for each unit and bike parking, and more futuristically, it shelters a compact lithium-ion battery system. That and the 8.8-kW PV system on the roof will cut the building's overall load and provide functionality during power outages.

The development was a quasi-retrofit given that 95% of the aging structure had to be taken down, including the brick foundation—highly inadequate in earthquake country. The only original feature remaining is the front façade.

As the new building's first three levels were required to be fire-resistive, non-combustible (Type 1A) construction, concrete provides the structure for the airtight barrier. This concrete is protected to the exterior with a waterproof membrane and rigid EPS insulation. The foundation rests on several inches of high-density EPS—a new concept for the engineer, but it won approval after an analysis of the friction between the insulation and the ground. As the developer says, every time you try a new approach you can expect some pushback, but the global climate crisis has made optimizing building efficiency a critical task.

The above-grade wood-framed walls are insulated with polyiso on the exterior and sprayed fiberglass in the cavities. A fluid-applied coating ensures an airtight barrier, while also providing premium protection against rain. Each unit has its own heat-recovery ventilator (HRV) to bring in fresh air. The heating loads throughout the building are expected to be low enough that they can be met with small sections of in-floor hydronic heating.

The upper unit, which occupies the top two floors, has abundant west-facing glazing and an unobstructed view of the Golden Gate Bridge. To manage solar heat gains, these windows will have electrically controlled exterior blinds or dynamic solar-control glazing. Because temperatures are rising even in relatively cool San Francisco, the top unit also features a mini-split for backup cooling.

Larkin Street Residences; Renderings by Visualize It Built

PASSIVE HOUSE METRICS

Heating energy	1.5 kBtu/ft²/yr	0.5 kWh/ft²/yr	4.8 kWh/m²a
Cooling energy	0.5	0.2	1.6
Total source energy	25	7.4	80
Air leakage	0.6 ACH_{50} (design)		

Soquel Passive House

SOQUEL

TEAM

Architect
Danielle Grenier
TALMADGE CONSTRUCTION

Builder
Talmadge Construction

Certified Passive House Consultant
BEYOND EFFICIENCY

Engineer
ANDREW RADOVAN

The owners of this 7-acre parcel came to Talmadge Construction because they wanted to work with a firm that had an in-house architect and could deliver a beautiful, energy-efficient home to enjoy for years to come. They had heard a little bit about the Passive House approach and, with more information, became enthusiastic about setting that as their goal. They also wanted an accessible home suited for aging in place, so they could, if need be, roll from the garage through the home and even into the pool.

Looking at the home, with its hip roof and multiple pop-outs and tie-ins, you wouldn't discern the airtight box at its core. The 2x6 exterior walls forming the box are filled with blown-in cellulose, and the exterior sheathing is air sealed with a fluid-applied membrane. One inch of polyiso serves as the exterior insulation. Specialized tapes were applied to all the penetrations and seams in the crawlspace and roof assemblies, which were insulated with spray foam. The 36-inch deep overhangs that shade every façade were added on afterwards.

As the home is located in a wildland-urban interface area, extra attention was given to fire protection measures. The soffit vents in the overhangs have screens to prevent embers entering, as do the foundation vents. The only wood on the outside of the structure is the fascia around the roof. All of the other exterior elements are either stucco or stone.

Large sliding glass doors on the south-facing façade allow for easy access to the outdoors and bring in needed warmth in winter. To prevent overheating in summer, Talmadge Construction designed a custom fixed arbor from aluminum.

Two heat-recovery ventilators bring in constant fresh air to this roughly 3,500-ft² home. The owners wanted the ambiance of a gas-burning fireplace, so two of those are the main heat sources, likely overkill if used together, but picturesque. The builders installed a mini-split heat pump in the bedroom, mostly as a back-up cooling device, given the forecasts for rising temperatures.

PRODUCTS

Air/Moisture Control
SIGA
PROSOCO R-GUARD

Ventilation
ZEHNDER AMERICA

Soquel Passive House; Photos by John Anderson, Talmadge Construction

PASSIVE HOUSE METRICS

Heating energy	3. 5 kBtu/ft²/yr	1 kWh/ft²/yr	11 kWh/m²a
Cooling energy	2.5	0.7	8
Total source energy	32	9.3	100
Air leakage	0.6 ACH_{50}		

Location provided by Cooper Cary – The Center for Connective Architecture

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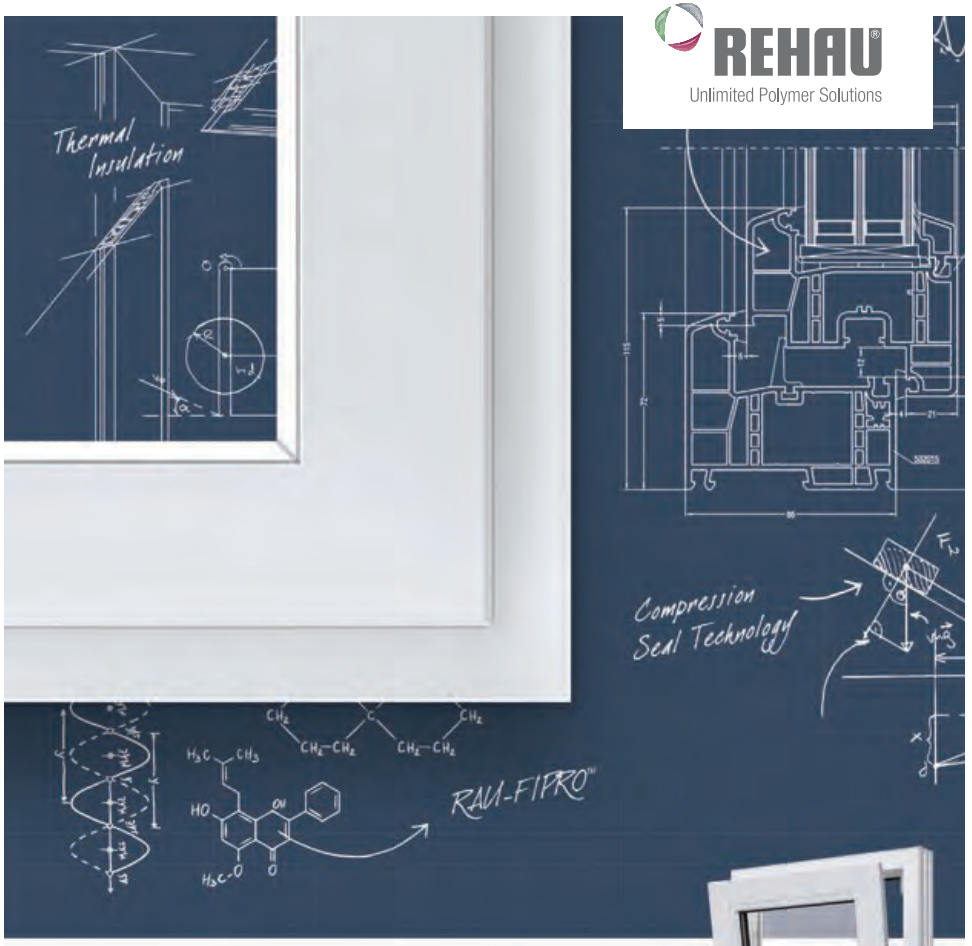

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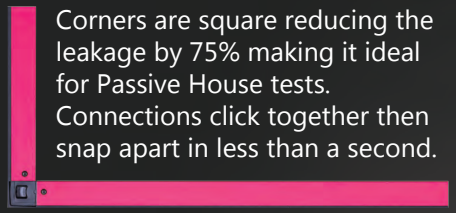

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Sunnyvale EnerPHit; Photo by Treve Johnson Photography

ONE SKY Homes

One Sky Homes is an integrated design-build firm that combines building science with good design, followed by performance monitoring for constant evaluation.

This process has honed the skills of the two principals, Allen Gilliland and Bronwyn Barry, allowing them to predictably deliver Passive Houses—frequently also Net-Zero Energy (NZE) homes—at a cost parity with typical custom building. As Barry says, "Our experience has earned us a hard-won comfort level with consistently delivering Passive House buildings."

For Gilliland, the integrated design-build process is key to the value engineering they bring to every project. He brings his builder's cap to the collaborative design process he shares with Barry, who hones in on the details from the get go. Allen designs the building assemblies and mechanical systems while Barry optimizes form, function, and daylighting. They bring complementary skills to the process, and their clients are the happy beneficiaries.

Key to the guaranteed performance they deliver is their commitment to Passive House. While clients might be seeking NZE homes, One Sky Homes projects are always "Passive House inside," says Barry. Their NZE homes simply have renewables added.

Their confidence in their homes' performance can be traced to the detailed energy monitoring they have been doing for the last five years of every home they've built, starting with the Cottle House, an award-winning new-construction NZE house in San Jose. That monitoring was paid for by the U.S. Department of Energy, and they've been hooked on monitoring's benefits ever since. "It serves so many purposes," says Gilliland. "Clients can track their home's performance on their smart phones." So can One Sky Homes, allowing them to evaluate a system's performance or detect when equipment may be malfunctioning.

In one larger residence the occupants kept turning off the air conditioning system, thinking they would be saving energy. Monitoring data proved the opposite was true: cooling the house after the system was temporarily shut down took more energy than simply leaving the superefficient conditioning system on.

Their most recent project is a new build in Alamo that has been occupied for a few months. Looking at the monitoring data, Gilliland says: "The performance is unbelievable. There will be surplus renewable energy even after charging an electric vehicle used daily for commuting." Their wall assemblies at this point are pretty much standardized, but there is always a new tweak or system to evaluate, such as the LED lighting in this home. "We are both highly engaged and challenged by Passive House," says Barry happily. "It's still a high bar to meet." Clearly, meeting that challenge is their kind of fun.

Sunnyvale
EnerPHit
SUNNYVALE

TEAM

Designer, Builder and Certified Passive House Consultant
ONE SKY HOMES

This 1957 ranch redux was a classic chainsaw retrofit, stripped back to its bones. The tree-shaded 1,650-ft² home had been uncomfortable and dark, and most of its components were failing. Today, the home's reconfigured layout optimizes how the spaces serve the family. All new triple-pane windows usher in sorely needed daylight. And, a smartly designed, integrated heating, cooling, and ventilation system delivers Passive House comfort using less energy annually than what the family uses for clothes washing and drying.

Preserving the exposed tongue-and-groove ceiling, One Sky Homes framed a simple plywood enclosure that started at the foundation and continued up and over the roof rafters. A liquid-applied sealant on all the exterior surfaces of that box serves as the air barrier.

Two inches of exterior insulation pads the plywood sheathing layer, adding an extra R-12 to the interior wall insulation. Polyisocyanurate (polyiso) insulation was selected for its high R-per-inch value as the open-frame ceiling has no attic cavity to hold insulation. Six inches of polyiso tops the roof sheathing.

The existing raised floor, with its numerous penetrations, complicated the insulation and air sealing at that level. Four-inch polyiso sheets were snugly fitted between the floor girders, but the subfloor proved difficult to air seal. The final blower door test result was 1.47 ACH_{50}. In this relatively mild climate, One Sky Homes calculated that the marginal return for getting any tighter was too small to justify the expense. Energy monitoring bears up that calculation, with overall energy use meeting the Passive House targets.

The customized mechanical system was designed to deliver heating, cooling, and ventilation within tight space and budget constraints. An unusually tall client ruled out using soffits to hide ductwork. Instead, the heat-recovery ventilator (HRV) and the wall-mounted mini-split heat pump both supply to the open plan kitchen, living, and dining area. A small, wall-mounted fan continuously pulls 110 CFM of air to the rear bedrooms. Monitoring has shown that the system succeeds in delivering fresh, conditioned air throughout the home. Most of the year—8 or 9 months—all the rooms in the building are within 1 degree of each other. Only in the winter is the northeast-facing master bedroom a few degrees colder than the great room. The clients were warned about this possibility and happily traded capital cost savings for a slightly cooler bedroom.

PRODUCTS

Windows
ALPEN HPP

Air/Moisture Control
PROSOCO R-GUARD

Ventilation
ZEHNDER AMERICA

Insulation
CERTAINTEED OPTIMA
BLOW-IN

Heating & Cooling
FUJITSU

Sunnyvale; Photo by Treve Johnson Photography

PASSIVE HOUSE METRICS

Heating energy	3 Btu/hr/ft²	0.9 Watts/ft²	9.5 Watts/ m²
Cooling energy	2	0.6	6.3
Total source energy	34 kBtu/ft²/yr	10 kWh/ft²/yr	107 kWh/m²a
Air leakage	1.47 ACH_{50}		

Cottle House
SAN JOSE

TEAM

Designer and Builder
ONE SKY HOMES

Designed and built as a luxury home, the award-winning Cottle House received a special recognition from the California Energy Commission for being the first certified Net Zero Energy (NZE) home in California. In 2014 it also won the U.S. Department of Energy's (DOE's) Housing Innovation Award in the custom homebuilder category. The attention to detail in creating this spec NZE home was evident from the beginning, as even the lot was chosen with an eye to its solar access.

Passive House supplied the method and the tool, the Passive House Planning Package (PHPP), for reducing the home's energy demand. A rooftop 6.4-kW PV system produces enough electricity annually to meet the needs of the family of five who lives here—including charging their electric vehicle. A solar thermal system preheats the water for a gas-fired condensing water heater that rarely is needed. Monitored for two years by DOE, the home's measured energy use closely tallies with the PHPP's predicted energy use.

Cooling is the challenge in this locale. Solar-controlled exterior shades cover the west-facing windows, helping to keep this two-story

home cool even during heat-storms. A NightBreeze, a ventilation cooling system integrated with the heat pump that provides supplemental cooling and heating, 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 primarily 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.

Cottle House; Photos by Treve Johnson Photography (opposite) One Sky Homes (above)

PRODUCTS

Windows
ALPEN HPP

Air/Moisture Control
PROSOCO R-GUARD

Ventilation
ZEHNDER AMERICA

PASSIVE HOUSE METRICS

Heating energy	3.7 kBtu/ft²/yr	1.1 kWh/ft²/yr	11.5 kWh/m²a
Cooling energy	0.2	0.1	0.7
Total source energy	25	7.3	79
Air leakage	0.5 ACH_{50}		

Alamo Passive House

ALAMO

TEAM

Designer, Builder, and Certified Passive House Consultant
ONE SKY HOMES

Topping the wish list for this family's dream house was attaining Net Zero Energy, complete with electric vehicle charging, and an East Coast-style colonial look. As this look doesn't optimize solar control, One Sky Homes designed a modified two-story colonial Passive House, with the front, north-facing façade boasting classic boxed eaves and shutters. On the south side, they extended the eaves and integrated lower awnings to shade the exposed windows and deck, reducing the home's cooling load while capturing the views and abundant light. The south- and north-facing windows provide most of the day-lighting, allowing for fewer windows on the other facades. Exterior, solar-powered, vertical shade screens limit the glare and heat gain through the west-facing windows and glass door.

Site limitations—a very tight buildable space on a lot with a steep drop-off—meant careful design to fit in some outdoor deck areas between the home and the detached garage. Inside, the aesthetic leans toward modern with some traditional references.

Subtract the awnings, siding, and roof details and what remains is essentially a two-story plywood box, wrapped in a continuous vapor-open, airtight peel-and-stick membrane. Two inches of stone wool insulation coat the exterior of the walls, and dense-pack cellulose fills the 2x6 cavity.

A 2-ton, variable-speed, split-system heat pump supplies the heating and cooling to this roughly 3,000-ft² home. In an innovative and cost-effective approach, the 120 CFM of continuous ventilation provided by the heat-recovery ventilator (HRV) is ducted into the return side of the air handler and delivered through the space-conditioning ductwork, which was sized for the heating and cooling loads. The system design defies conventional logic, but it not only works, it actually optimizes the efficiency of the ventilation system by decreasing the static pressures in the ducts. Occupied since late 2015, the residents are happily impressed; they never hear any noises from the ducts and haven't experienced any drafts or cold spots.

Water heating is supplied by another heat pump, which is housed in an attached outdoor shed. The family of three has been using just under 4 kWh/day for water heating, adding up to only 1,500 kWh annually. Energy monitoring shows that the home's overall energy efficiency is as stellar as the modeling predicted. With a 7.5-kW PV system on the roof, the clients are living their Net Zero Energy dream, powered by 'Passive House inside.'

Alamo Passive House; Photo by Treve Johnson Photography

PRODUCTS

Windows
INTUS

Ventilation
ZEHNDER AMERICA

Insulation
ROXUL
CERTAINTEED OPTIMA BLOW-IN

Lighting
CERNO

PASSIVE HOUSE METRICS

Heating energy	3.8 kBtu/ft²/yr	1.1 kWh/ft²/yr	12 kWh/m²a
Cooling energy	2.2	0.6	7
Total source energy	23	6.7	73
Air leakage	0.3 ACH_{50}		

ESSENTIAL HABITAT Architecture

When Graham Irwin, principal of Remodel Guidance, a green residential design business, learned of Passive House in 2008, he was immediately inspired.

"Passive House offered the holistic and technically complete approach I'd been seeking," he says. He completed the first consultant's training in the United States that year and transformed his business, rebranded as Essential Habitat, to focus on Passive House. In 2015 Irwin became a licensed architect, and Essential Habitat became Essential Habitat Architecture. Passive House remains the major focus of his work.

Optimizing Passive House building envelopes for California climates was difficult in 2008, as there weren't precedents to follow. "I developed optimization tools to differentiate what was necessary from what was excessive," says Irwin. He is committed to value engineering every project, which is partly why he finds Passive House methods so valuable. "Passive House is practical idealism," Irwin says. "It applies physics and engineering to the challenges of climate change and sustainability." He worked on the first certified Passive House in California, which is also the first certified retrofit in the United States, and the first certified multi-unit Passive House in the United States.

His extensive experience has made him an expert on questions about trickier Passive House projects, such as retrofits. Early on, when a client would consult with him about remodeling to the Passive House standard, he would spend days exploring various fairly complicated strategies designed to preserve, for example, the exterior siding or other major building components. After nearly two dozen projects, no longer. "Now I say, you will be re-skinning the building and replacing the windows and doors," he says. "If someone wants to preserve the exterior, they can, but it will be a lot more difficult."

Difficult is not a quality Irwin shies away from however, and he isn't saying that every Passive House retrofit has to be accomplished immediately. Indeed, his recently purchased "new" home is a prime example (www.weboughtaruin.com). It needs major work, but a total rehab is not practical now, so he is applying his knowledge to make the eventual transformation to Passive House smooth.

"There's a huge lost opportunity when people do a major remodel but don't do Passive House," he says. "It often doesn't take much more than what is being done in a remodel anyway. With new construction, it's even easier." What it does take is what Irwin has—deep experience with Passive House design.

Anchor Bay House
GUALALA

The Anchor Bay House, the first Passive House in Mendocino County, is an elegant and unassuming cube clad in black corrugated metal and set in a sloping meadow among pine and redwood stands. Its interior is an open and light-filled, double-height loft space with one bedroom and one-and-a-half baths. Windows are sized and placed to establish a strong relationship between the minimalist interior and the rough nature of the surrounding coastal landscape.

Anchor Bay; Photo by Matthias Oppliger

TEAM

Architect and Certified Passive House Consultant
MATTHIAS OPPLIGER ARCHITECT

Builder
JOHN SCHMIDT CONSTRUCTION INC.

Certified Passive House Consultant
ESSENTIAL HABITAT ARCHITECTURE

PRODUCTS

Windows
CASCADIA FIBERGLASS WINDOWS & DOORS

Air/Moisture Control
PRO CLIMA

Insulation
ROXUL
CERTAINTEED OPTIMA BLOW-IN

PASSIVE HOUSE METRICS

Heating energy	2.9 kBtu/ft²/yr	0.9 kWh/ft²/yr	9.2 kWh/m²a
Cooling energy	1	0.3	3.2
Total source energy	34	10	107
Air leakage	0.5 ACH_{50}		

Noe Valley Passive House

SAN FRANCISCO

Intent on creating an urban living space with seamless access to the outdoors, the owners retrofitted a 1960s fixer-upper hidden by a detached front garage that had outdoor access on three sides. They achieved their goals with a sleek, modern design, open floor plan, plenty of glass, and an ultra-energy-efficient building envelope. Their hands-on role in design and construction, together with a patient, DIY-friendly project team, helped make the project fit the budget.

Noe Valley Passive House; Photo by Jonathan Kaplan

TEAM

Architect and Certified Passive House Consultant
Graham Irwin
ESSENTIAL HABITAT ARCHITECTURE
with Jonathan Kaplan, Andrew Dunbar and Zoee Astrakhan, Interstice Architects

Builder
JOHN SCHMIDT CONSTRUCTION INC.

Interior Design
Sarah Malarkey

PRODUCTS

Windows and Exterior Doors
KLEARWALL

PASSIVE HOUSE METRICS

Heating energy	3.8 kBtu/ft²/yr	1.1 kWh/ft²/yr	12 kWh/m²a
Cooling energy	0.3	0.1	0.9
Total source energy	14	4.1	44
Total renewable source energy	5.4	1.6	17
Air leakage	0.6 ACH_{50}		

Midori Haus

SANTA CRUZ

This retrofitted 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, and the homeowners attest to outstanding levels of comfort. Certified by the Passivhaus Institut in Germany, Midori Haus carries the distinction of being the millionth square meter of certified Passive House in the world.

TEAM

Architect and Certified Passive House Consultant
ESSENTIAL HABITAT ARCHITECTURE

Builder
SANTA CRUZ GREEN BUILDERS

Mechanical/ Solar Thermal Design
Pat Splitt
APP-TECH INC.

PRODUCTS

Windows
CASCADIA FIBERGLASS WINDOWS & DOORS

Air/Moisture Control
SIGA

Insulation
ROXUL

Midori Haus; Photo by Kurt Hurley

PASSIVE HOUSE METRICS

Heating energy	3.3 Btu/hr/ft²	0.9 Watts/ft²	10.4 Watts m²
Cooling energy	0.1 Btu/hr/ft²	0 Watts/ft²	0.4 Watts/m²
Total source energy	28 kBtu/ft²/yr	8.9 kWh/ft²/yr	89 kWh/m²a
Air leakage	0.6 ACH_{50}		

Sol Lux Alpha

SAN FRANCISCO

Sol Lux Alpha is designed to be the first "Nanogrid" carbon-neutral living and transportation system on the residential market in the United States. One of the project's main goals is demonstrating that it is possible to build sustainable luxury that is in harmony with the Earth.

Six years of research and development by Off the Grid Design made possible this synergy of technologies that will allow this six-story residential structure to achieve carbon neutrality, using only the solar energy generated within its small urban footprint. A raised building-integrated photovoltaic (BIPV) canopy over the rooftop's outdoor deck and garden spaces will be the energy supplier. This state of the art bi-facial PV trellis will also serve as a rainwater catchment system for the roof gardens and vertical gardens in the west-facing light well. The roof deck also includes kitchen and lounge spaces for residents. Integrated ambient LED lighting is designed into the system to create "Energy as Art".

Energy will be stored on site with a 104-kWh advanced energy storage and management system. If the grid goes down, the building will remain almost fully functional, including energy for transportation. Building-integrated electric vehicle (BIEV) infrastructure is provided for each of the building's four luxury units.

Passive House methodology and passive solar design are being utilized to achieve the lowest energy use possible for space heating and cooling and are the main "building blocks" for achieving the net positive energy goal. Many innovative strategies and technologies are being employed to reduce building energy use, such as CO_2 heat pump water heaters and ultrasonic motion detectors to reduce "vampire loads" from receptacles.

The advanced wood-frame walls were prefabricated and shipped to the site in order to increase efficiency and reduce waste. The wall panels were site assembled using a neoprene gasketing system and a new liquid interior sealant. They were finished with liquid waterproofing products, applied both in the factory and in the field. Its design and density allowed the building to be modeled to Passive House levels with conventional 2x6 wood-frame construction, dense-pack fiberglass fill insulation, and very tight dual-glazed windows and doors.

Sol Lux Alpha received a permit through the alternate path of compliance to the S.F. Green Building Code by certifying through PHIUS+, DOE Zero Energy Ready Home, Energy Star, and EPA WaterSense. The design team used a comparative matrix showing how the combined certifications not only meet but exceed LEED and other green building rating standards.

TEAM

Design Concept, R&D, and Construction Supervision
OFF THE GRID DESIGN, LLC

Architect
RG-ARCHITECTURE INC.

Certified Passive House Consultant
ESSENTIAL HABITAT ARCHITECTURE

PRODUCTS

Windows
KLEARWALL

Water Heater
SANDEN

Air/Moisture Control
STO CORP.
SIGA

Sol Lux Alpha; Photo by Off the Grid Design

PASSIVE HOUSE METRICS

Heating energy	3.6 kBtu/ft²/yr	1.1 kWh/ft²/yr	11.4 kWh/m²a
Cooling energy	0.7	0.2	2.2
Total source energy	37.4	11	118
Air leakage	0.6 ACH_{50}		

Equilibrium House
SAN FRANCISCO

On a Friday afternoon, Ewen Utting, the eventual builder of the Equilibrium House, was reluctantly dragged to a talk by Graham Irwin on the benefits and challenges of building a Passive House. Utting was so inspired that he declared his next house would be a Passive House. The Equilibrium House, a 1918 Victorian that was retrofitted to become a certified Passive House, became the first Passive House built to spec in San Francisco. The house was such a success that it sold before it was even completed!

Equilibrium House; Photo by Open Homes Photography

TEAM

Architect
HOOD THOMAS ARCHITECTS

Certified Passive House Consultant
ESSENTIAL HABITAT ARCHITECTURE

Builder
ENU CONSTRUCTION

PRODUCTS

Windows
KLEARWALL

Air/Moisture Control
PRO CLIMA
PROSOCO R-GUARD

Insulation
CERTAINTEED OPTIMA
BLOW-IN

PASSIVE HOUSE METRICS

Heating energy	5.1 kBtu/ft²/yr	1.5 kWh/ft²/yr	16.1 kWh/m²a
Cooling energy	0.7	0.2	2.2
Total source energy	29	8.5	92
Air leakage	0.3 ACH_{50}		

Roberts Residence
SAN FRANCISCO

Scott Roberts was touring homes built by various contractors to select a builder for his upcoming home remodel when he visited the unfinished Equilibrium House—a Passive House in the making. After the tour and multiple discussions with the builder, he told his architect that Passive House was his retrofit goal. His home became not only an excellent Passive House example but also went on to be a featured home in the 2015 AIA Home Tour.

Roberts Residence; Photo by Eric Rorer Photography

TEAM

Architect
ANDY ROGERS DESIGN STUDIO

Certified Passive House Consultant
ESSENTIAL HABITAT ARCHITECTURE

Builder
ENU CONSTRUCTION

PRODUCTS

Windows
KLEARWALL

Air/Moisture Control
PROSOCO R-GUARD
PRO CLIMA

Insulation
ROXUL
CERTAINTEED OPTIMA
BLOW-IN

PASSIVE HOUSE METRICS

Heating energy	3.5 kBtu/ft²/yr	1 kWh/ft²/yr	11 kWh/m²a
Cooling energy	0.8	0.2	2.5
Total source energy	22	6.5	69
Air leakage	0.3 ACH_{50}		

FERGUS GARBER YOUNG Architects

Fergus Garber Young (FGY) Architects is a full-service architectural firm providing a high level of attention, management, and environmental stewardship to clients, both residential and commercial, that have a long-term interest in their properties. The varied architectural styles of the firm's projects reflect its emphasis on embracing their clients' interests and desires.

Spanish Colonial Passive House; Photo by Tom Rossiter

FGY matches their clients' goals to the essential qualities of good architecture: strong plans, good proportions, and a high attention to detail to make functional and beautiful buildings.

FGY, which is based in Palo Alto, has been a leader in environmental stewardship since its inception 29 years ago in Chicago. For the first 23 years the firm worked exclusively on residential projects. Six years ago FGY added commercial projects as a design offering, and these projects now constitute roughly 50% of its annual work.

FGY's focus on green design has helped its clients receive Passive House and LEED Platinum certifications, among others. Although many in the firm's staff of 21 have expertise in the sustainability area, their commitment to a strong environmental practice was strengthened nine years ago by the addition of a sustainability manager, who is involved in nearly all of the firm's projects.

Over the years, using its portfolio of houses as a laboratory, FGY has undertaken research to understand how these houses have performed and to benchmark different design solutions. In 2010, FGY gave a presentation at Greenbuild on the embodied environmental footprint of a portion of the firm's residential portfolio. More recently, information from a study of the actual energy and water consumption of the firm's residential portfolio was presented to the local AIA chapter.

In both studies, FGY came to conclusions that differed from standard green building guidance. For example, in the embodied carbon footprint study, the size of the house didn't necessarily correlate with the size of the footprint. One of the smallest projects had among the highest footprints due to its heavy use of concrete stucco. This small project had a higher footprint than another house more than twice its size, which was built with more traditional light-frame wood construction. Similarly, in the more recent study, the firm found no correlation between the size of a house and its energy use, nor the landscape area and its water use. The actual performance was tied more closely to the provision and judicious use of energy services within the home and water-saving irrigation systems outside.

Given that most of FGY's clients live in their homes for 20 to 30 years, FGY's research has inspired the firm to spend much more time in the very initial stages of their interactions with their clients on gaining a clear understanding of how their clients will use their houses and gauging how actively they will or will not manage them. "Their actions after they move in have the largest impact on the long-term sustainability of FGY's designs," says Dan Garber, one of FGY's principals. "Energy use and environmental impacts are concerns of all of our clients, whether or not they are interested in pursuing a given certification." For these reasons, he adds, "We are going to design with Passive House principles in mind, because that will reduce energy bills going forward and leads to a better use of our natural resources."

Spanish Colonial Passive House; Photo by Tom Rossiter

SPANISH COLONIAL PASSIVE
Palo Alto

The owners' mission for this house was to create an extremely energy efficient and healthy house—with no aesthetic compromises. Although they wanted the house to have an iconic design, they also wanted it to fit well within their Old Palo Alto neighborhood. The

TEAM

Design Architect
FERGUS GARBER YOUNG ARCHITECTS

Architect of Record
EID ARCHITECTS

Builder
SMITH HYDER

Certified Passive House Consultant
Integral Impact

Spanish Colonial style was chosen not only for its historic antecedents but because of its success in mitigating the impacts of this climate on its occupants. The style's typically deep-set windows and doors and protected courtyards help to shelter the occupants from too much solar heat.

The merger of Passive House and Spanish Colonial resulted in an exemplary and stunning home. With its 12.6-kW PV system, the home, with its two electric car chargers, is operating at net positive energy annually. In addition to this high level of performance, the house demonstrates that sustainable building does not need to come at a cost premium and can be built faster—completed in 10 months—than a comparable custom home.

The project did have some challenges, mostly rooted in its site constraints. The site is in the existing grid of Old Palo Alto, so the home's orientation was effectively fixed to non-optimal rotations, with the main axis of the house 46 degrees off due south. Southwest-facing direct solar gain, which could have contributed to overheating problems, is seasonally

Spanish Colonial Passive House; Photos by Tom Rossiter

controlled with a steel veranda for climbing wisteria on the first floor and deep inset windows on the second floor.

To streamline project completion, the above-grade building was constructed with structural insulated panels, rather than wood framing, with added exterior continuous insulation. The home's mechanical systems and appliances were minimized as much as possible, without compromising performance or functionality, to reduce ongoing maintenance. A custom home typically would include a furnace or boiler, an air conditioner, and a water heater. One heat pump water heater substituted for these three appliances, with distribution of heated or chilled water to radiant panels instead of to tubing in the floor or ducted registers.

The grey water system was similarly simplified, using a gravity-fed system that irrigates the landscaping, rather than one with a surge tank, pump, sand filter, and pressurized irrigation lines. Remote controls for various electronic systems were eliminated in favor of a pared-down system of stand-alone devices. Particular attention was paid in the simplification process to dramatically reducing, and in some cases eliminating, the vampire loads of these systems.

The house, in addition to serving extended family and friends, is a place where the owners host educational events and gatherings. In the last two years the owners have hosted events, many with up to 100 guests, for several environmental organizations, the local AIA chapter, academic institutions, and others. This beautiful venue has helped to focus attention on global warming, the environment, and the importance of sustainable building.

Spanish Colonial Passive House; Photo by Tom Rossiter

PRODUCTS

Air/Moisture Control
SIGA

Ventilation
ZEHNDER AMERICA

Heating & Cooling
MESSANA RADIANT COOLING

PASSIVE HOUSE METRICS

Heating load	2.5 Btu/hr/ft²	0.7 Watts/ft²	8 Watts/ m²
Total source energy	34	10	107
Air leakage	0.6 ACH_{50}		

Poe Street House

PALO ALTO

TEAM

Architect
FERGUS GARBER YOUNG ARCHITECTS

Builder
PETE MOFFAT CONSTRUCTION

Certified Passive House Consultant
PEARL RENAKER

The owners came to Fergus Garber Young (FGY) asking them to design a Passive House in the Craftsman style to suit their eclectic and active lifestyle. The owners, who had previously lived in Europe, were already familiar with Passive House and so were set on that objective. The style of the house also was a firm requirement, both because it was personally meaningful for the owners and it's the neighborhood's predominate style.

Blending Passive House and Craftsman was fairly seamless, according to FGY. Yes, the house was built with triple-glazed windows and doors—

Poe Street House; Photos by Tom Rossiter (below) and Conroy + Tanzer Photographic (right)

not exactly typical of California craftsman—but the long overhangs that help keep too much sun from entering the windows and doors in summer and warming the interior of the house are in keeping with the style.

The exterior wall is composed of 2x6 stud construction with 1 inch of exterior XPS insulation. The foam insulation continues down to cover the entire height of the basement wall below grade. The exterior foam also extends over the top of the roof decking, allowing for the underside to be insulated with 14 inches of netted loose-fill fiberglass insulation. The exterior shear had been carefully taped to meet the air-sealing target before the insulation was installed. Finishing the exterior wall assembly is a wood shingle and horizontal siding rain screen assembly. The exterior bricks were reclaimed from another project that had been demolished on Stanford University's campus.

The house includes radiant ceiling and wall panels, fed by a heat pump water heater unit, to provide both heating and cooling. An HRV regulates and distributes the ventilation air throughout the house. Photovoltaic (PV) panels are arrayed on the roof and generate 17.6 kW a year. An 80-kWh deep-cycle lead-acid battery system with islanded inverters allows the house to run off-grid indefinitely.

Rainwater is captured, when it falls, and is stored in a 5,000-gallon tank in the back yard for distribution to the yard, garden, toilets, and washing machine. Grey water from the house is captured and piped to non-edible plants in the landscape.

All the house's appliances are electric, and all the lights are LEDs. When the weather outside doesn't allow for line drying of clothes in the back yard, the laundry room has interior hanging and, if necessary, a ventless electric dryer. Motion sensors turn off lights and water heating in unoccupied spaces.

Poe Street House; Photos by Conroy + Tanzer Photographic

PRODUCTS

Exterior Doors
NANAWALL

Air/Moisture Control
SIGA

Ventilation
ZEHNDER AMERICA

Heating & Cooling
MESSANA RADIANT COOLING

PASSIVE HOUSE METRICS

Heating energy	4.1 kBtu/ft²/yr	1.2 kWh/ft²/yr	12.9 kWh/m²a
Cooling energy	0.2	0.1	0.6
Total source energy	38	11.1	120
Air leakage	0.6 ACH_{50}		

MightyHouse

MENLO PARK

TEAM

Architect, Builder and Certified Passive House Consultant
DIMENSIONSTYLE

It's a tiny house. It's a Passive House? Actually, it's a novel hybrid: a high-performance micro dwelling unit on wheels. This might be the next affordable housing prototype. The fact that the MightyHouse is mobile is almost a minor subplot. The ability to pull up and plug into any home with a garden hose and an electric vehicle charger is fun and broadens its utility. Still, the general design and approach can be applied to any type of residential housing: micro, accessory dwelling unit, backyard cottage, or small cabin.

Beyond its looks, what is really stunning about the MightyHouse is its budget. Built exclusively from the least-toxic materials the architects could find—no foams, no formaldehyde products, no VOC paints, glues, or finishes—their total cost is targeted at $35,000 for a home that needs little-to-no heating or cooling year-round. Measuring 8.5-ft wide by 24-ft long, the 250-ft² MightyHouse explores the balance of economy with performance and how a home can be constructed with high quality design, materials, and assemblies at a smaller scale.

Aside from the size, the house is no different from most Passive House projects. The wood-frame construction features superinsulated walls with mineral fiber batt and continuous exterior fiber board, high-performance windows, air infiltration and moisture barriers to keep things dry and tight, a ductless heat-recovery ventilation system that provides superior indoor air quality, and carefully detailed connections to the trailer that reduce thermal bridging.

The MightyHouse is currently under construction in Menlo Park, designed and built to achieve Passive House requirements in this temperate climate. However, its mobility is challenging site-specific design, and it could be a case study exploring where a mobile home may perform as a Passive House in a range of locales.

Brian Rubin and Siena Shaw created the MightyHouse as a direct response to the inflated cost of housing in the San Francisco Bay Area, in addition to their love for small, efficient, well-detailed spaces. "It is not about points, statistics or certifications," they say. "It is about comfort, health, and building the right way." Downsizing to tiny-house living may not be for everyone, but the lessons from this high-performance, 'Small is Beautiful' design are broadly applicable.

PRODUCTS

Windows
ALPEN HPP

Air/Moisture Control
SIGA

Ventilation
LUNOS

Insulation
ROXUL

MightyHouse; Rendering by dimensionStyle; photo by Krista Watzel

PASSIVE HOUSE METRICS

Heating energy	5.1 kBtu/ft²/yr	1.5 kWh/ft²/yr	16 kWh/m²a
Cooling energy	2.9	0.9	9.3
Total source energy	45	13.2	142
Air leakage	1.1 ACH_{50}		

Project Green Home

PALO ALTO

A simple, iconic house on a typical city lot, Project Green Home is far from ordinary. Certified as a Passive House and as 'Beyond-LEED-Platinum', this Net-Zero Energy family home pushes the technological boundaries of energy- and water-efficient design.

The 2,500-ft² house is traditional, but also uncompromisingly modern from its open floor plan to its well-sealed envelope and advanced, high-efficiency heating system. In addition to four bedrooms plus a ground-floor senior suite, the simple, two-story gabled form allows for extra attic space and two interconnected play lofts above the kids' bedrooms.

The most significant innovation is in the building envelope. Starting with 2x8 framing insulated with sprayed-on cellulose and R-5 triple-pane windows, the walls' outstanding thermal performance was further improved by the addition of an exterior wrap of 1 inch of rigid insulation. The slab floors that provide thermal mass are well insulated with 4 inches of rigid EPS, wrapping to 2 inches at the stem walls. While generally the temperate weather allows windows to be open, a heat-recovery ventilator (HRV) provides fresh air when temperatures outside stray from moderate.

TEAM

Architect
ARKIN TILT ARCHITECTS

Certified Passive House Consultant
Integral Impact Inc.

Builder
JOSH MOORE

Structural Engineer
KEVIN DONAHUE

To minimize the use of non-renewable fuels such as natural gas, this house features an air-to-water heat pump that feeds a hydronic heating system, as well as an induction range—replacing the two most common consumers of natural gas in California homes with electric appliances. A PV system generates enough electricity to power these appliances and meet all of the family's other electricity needs on an annual basis.

The radiant heating was a bit of a conundrum; thermal modeling showed that the added heat needed to keep the house comfortable would be so limited that the floors wouldn't feel warm if the tubing was evenly distributed. Instead, the small amount of required tubing was allotted to circulation spaces, bringing the temperature of the floors up to a level that feels warm and cozy.

Project Green Home; Photos by Ed Caldwell

PRODUCTS

Air/Moisture Control
SIGA

Drain Water Heat Recovery
RENEWABILITY ENERGY INC.

PASSIVE HOUSE METRICS

Heating energy	3.9 kBtu/ft²/yr	1.2 kWh/ft²/yr	12.4 kWh/m²a
Cooling energy	0		
Total source energy	27	7.9	85
Air leakage	0.6 ACH_{50}		

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When Cedar Street Builders teamed up with Delv Design to produce Indiana's first passive house, the builders planned to achieve the required R-52 walls using SIPs construction but were confronted with a few hurdles.

The SIPs insulation was not as perfectly continuous as they had hoped, leaving thermal bridges in certain areas such as around windows. The walls also needed a separate rainscreen solution to prevent trapped moisture. At 12 inches thick, R-52 SIPs represented a significant investment that didn't fully solve their problems.

Fortunately in the midst of their research, they discovered they could dramatically cut costs and fulfill requirements by **combining a 10" SIP wall with 2½" InSoFast panels**. This reduced costs because they could complete the continuous insulation requirement with a more affordable SIPs profile, effortlessly integrate a rainscreen, and still have an attachment layer for the various finishes.

InSoFast

InSoFast's Continuous Insulation Panels offer several unique benefits over traditional insulation. Each panel is an easy-to-handle 4' x 2' engineered section of rigid EPS that interlocks seamlessly at every edge with tongue-and-groove connections.

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Panels optimized for exterior applications include fully integrated rainscreen and moisture management surfaces that meet the requirements of ORSC, Sec. 703.1.1 and beyond, allowing builders to bypass complex construction processes in the field.

Learn more at **insofast.com/passive**

THE COMFORT OF RADIANT HEATING AND COOLING IS ALSO FOR PASSIVE HOUSE.

As buildings meet higher standards, especially in terms of air tightness, ventilation becomes far more important than ever before for a healthy and comfortable environment.

Alessandro Arnulfo (left) and Francesco Marchesi (right), co-founders and owners of Messana Inc. (Messana Radiant Cooling).

At the same time, as buildings are better insulated, they obviously need less heating and cooling.

As a result, it becomes more effective to separate the ventilation from the heating and cooling system. These two systems have different functions and different requirements.

Combining them typically leads to overheating, under-cooling, under-ventilating, and/or over-ventilating. This is true even if the heating and cooling loads are significantly reduced in Passive House buildings.

Ray Magic® ceiling gypsum panels for radiant cooling and heating solutions. (US Patent 9285126).

While HRVs have become standard practice in Passive House construction, there is a promising innovation for heating and cooling: hydronic radiant gypsum panels.

A Perfect Partner with Passive House Buildings.

Radiant floor is problematic due to sluggish reaction time and is most likely to cause overheating as well as not being a viable option for cooling.

However, for the lovers of radiant, there is a better solution:

Messana Radiant Cooling Ray Magic® radiant gypsum panels installed on the ceiling or walls.

There are a multitude of benefits of a ceiling gypsum panel delivery system: very quick response time, is essentially invisible, no air handler or mini-split hanging on the wall, and is silent.
Perhaps the most talked about benefit by owners of the system, it is its unmatchable uniform comfort.

Spanish Colonial Passive House, Paolo Alto CA. Installation of Ray Magic radiant gypsum panels on a rounded ceiling. The piping layout is laser engraved on the paper surface of the panel for easy installation without puncturing pipes.

With their incredibly high efficiency, a few radiant gypsum panels can meet low heating and cooling loads typical of Passive House constructions. As little as 30-40% of ceiling area is sufficient.

The Poe Street House, Spanish Colonial and Clarum Home's Office building already enjoy superior Messana radiant heating and cooling.

Poe Street Passive House, Paolo Alto CA. One and a half Ray Magic panels installed on the wall seen through infrared camera in cooling.

Comprehensive controls.

The Messana system also includes sophisticated controls that optimize heat pump performance, manage zoning and modulate the supply water temperature to prevent condensation issues, and meet the actual loads in the most efficient way.

"With our system we can remotely monitor our clients' homes and measure the real heating and cooling loads", said Alessandro Arnulfo, Messana co/founder and CEO. And he added: *"over years of evaluation, the surprise is that the system is delivering much more energy in both cooling and heating than we expected. Most important is the incredible comfort level and efficiency that our clients talk about and enjoy"*.

PRODUCT PROFILE

Radiant panel	Messana Ray Magic: EPS with pex piping in aluminum transfer plates, laminated with 1/2" drywall
Performance	up to 35Btu/h/sf in cooling and up to 65Btu/h/sf in heating
More information	info@radiantcooling.com radiantcooling.com

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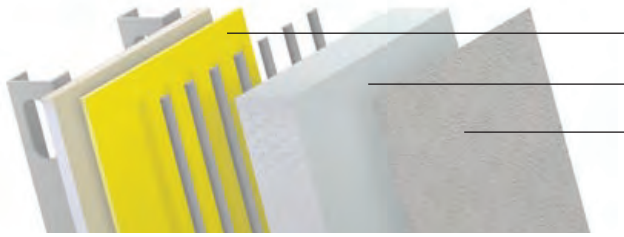


sto

Building with conscience.

Zero Cottage; Photo by Matthew Millman

DAVID BAKER Architects (DBA)

David Baker Architects (DBA) opened its doors 34 years ago and has been changing the urban landscape ever since.

Although multifamily housing—both market rate and affordable—is the firm's mainstay business, its projects range from housing to mixed use to commercial developments, and even to planning entire neighborhoods. The firm's numbers speak to their successful implementation of their design ethos—creating thoughtful places that allow communities to thrive. The firm employs 35 people. They have built more than 10,000 housing units that range from micro-units to single-family detached housing, and in the process they have earned more than 250 local and national design awards.

One of those recent awards was for the redevelopment of a 7.5-acre public housing site in Oakland. The Tassafaronga Village has knit the neighborhood together with diverse housing types and a Village Square public plaza that encourages community. Baker submitted this project to the American Institute of Architecture's Committee on the Environment (AIA COTE) Top Ten Projects competition, which they won, and also signed his firm on to the AIA's 2030 Commitment. That commitment requires tracking and reporting the performance of each architecture firm's overall portfolio against Architecture 2030's established benchmarks in the 2030 Challenge, which is intended to achieve a carbon-neutral built environment by the year 2030.

With their firm's mix of multifamily and mixed-use buildings, tracking the portfolio's energy use intensity is particularly challenging, because of the lack of data and the split between residential and other uses, says Katie Ackerly, the firm's sustainability lead. Still, sustainability has been one of the firm's core values for a long time.

Indeed, to say that David Baker, the firm's founder, had an early focus on sustainability would be an understatement. He was born in a passive solar, high-mass, rammed earth house that had big overhangs. Rather than a showcase of advanced technologies, the home's comfort depended on its passive features. Initially the home didn't have any heating, although eventually radiant floor heating was added. That early exposure to passive principles primed him for a receptivity to the Passive House method. As he says, "The active technologies can get so complex."

Baker's first Passive House building was his Zero Cottage in his own San Francisco backyard. The combination of the almost silent heat-recovery ventilation system and the triple-pane windows screening out urban noise brought a sense of tranquility to the interior that was inspiring.

DBA is now working on a design for their new office in Oakland, DBA-OAK, and achieving Passive House certification is one of the firm's goals for this building. Situated between a freeway and a Greyhound bus station, the site is ripe with urban attributes—both the positive ones, such as easy accessibility, and the not so pleasant ones, like noise and particulates in the air. Passive House, which requires an airtight envelope, high-performance windows and doors, and mechanical ventilation bringing in filtered fresh air, will help to address the unwanted attributes. The office will also enjoy the other more well-known Passive House advantages, such as comfort and reduced energy use. Plus, there's the thrill of not having to dust as often.

While not all of DBA's clients have jumped on the Passive House bandwagon, minimizing a client's building energy loads and increasing its comfort is always an attractive package to offer. Looking at the Passive House Planning Package energy model is always useful, says Baker, even if certification isn't a goal.

Zero Cottage

SAN FRANCISCO

TEAM

Architect
DAVID BAKER ARCHITECTURE

Certified Passive House Consultant
Integral Impact

Builder
FALCON FIVE

When David Baker decided in 2011 to build Zero Cottage—a 712-ft², two-level home above a ground-floor workshop—on a San Francisco infill lot, he took on three challenges. He wanted the project to be certified as Passive House, LEED for Homes Platinum, and as a Net Zero residence by the Living Building Institute in 2014. Approaching the project as a chance to experiment with a wide variety of sustainability initiatives—including energy consumption, construction impacts, materials, technologies, and recycling—he succeeded at all three.

After multiple iterations, the Passive House modeling called for R-29 walls consisting of 2x6 framing filled with compressed cellulose plus two inches of exterior XPS. The R-41 roof assembly has

Zero Cottage; Photos by Matthew Millman

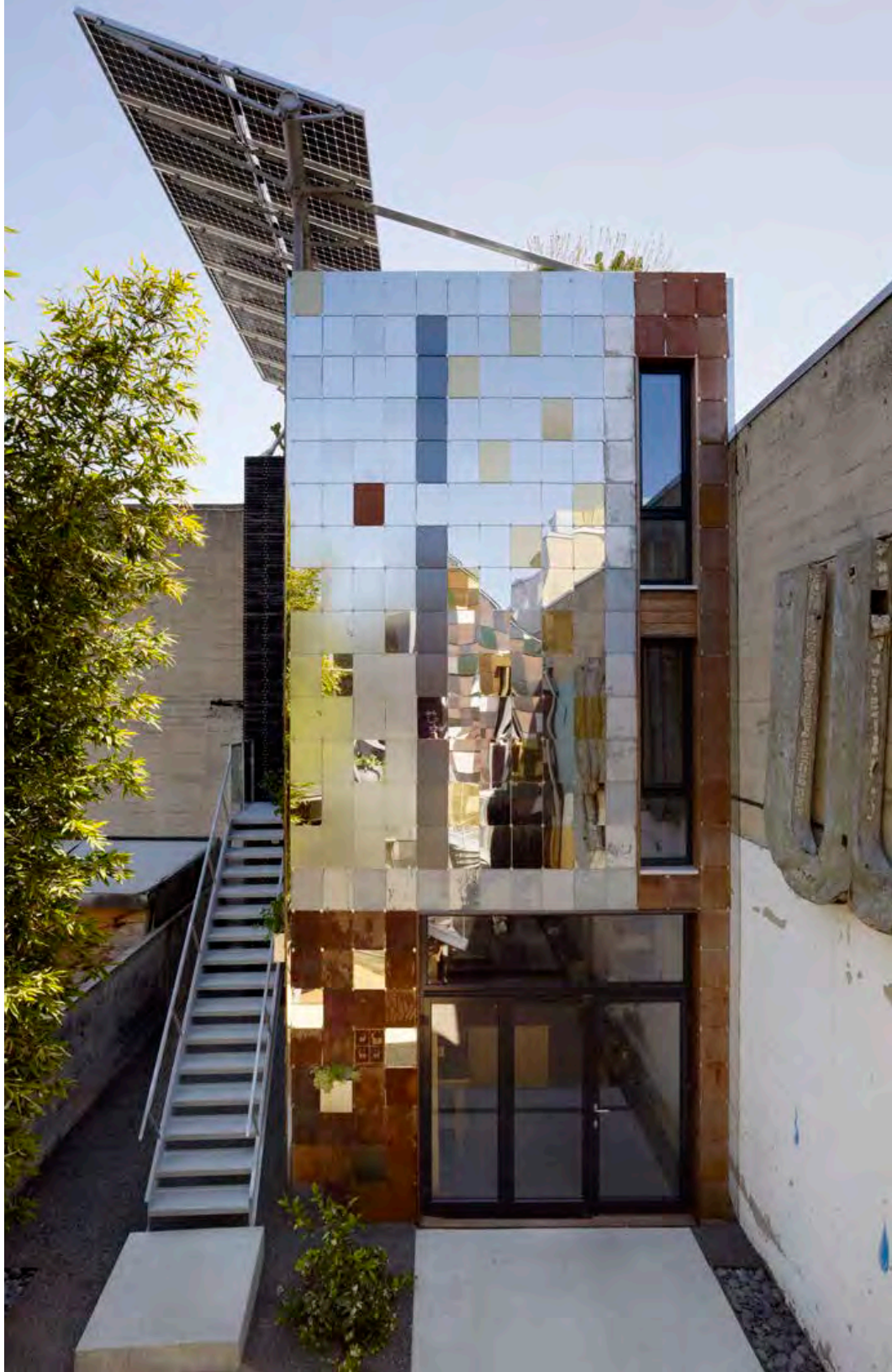
cellulose-filled 2x12 FSC-certified framing topped with six inches of XPS. Sitting on top of a ground-floor workshop, the floor of the cottage's conditioned living space is made of FSC-certified engineered joists filled with R-51 of cellulose.

Typical of a high-density urban environment, two of the exterior walls are butted up against a neighboring building. This presented some challenges during construction. Those walls had to be built as a combined L-shaped assembly, detailed for airtightness, then dropped into place on anchor bolts. The air barrier consists of plywood and a self-sealing waterproofing membrane. Coupled with triple-pane, argon-filled windows that have a solar heat gain coefficient (SHGC) of 0.49, the final blower door test came in at 0.43 ACH_{50}.

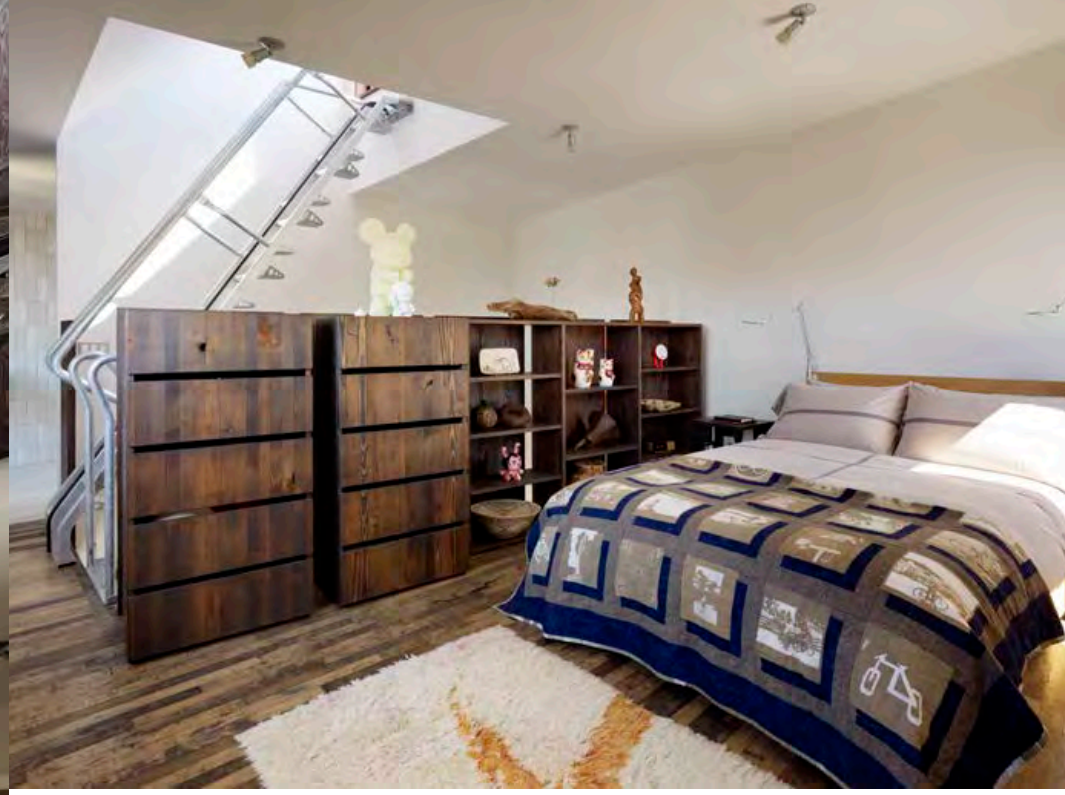
The all-electric house is optimized to use as little electricity as possible. A passive solar thermal collector with integral storage provides the bulk of the hot water, preheating a supplemental electric tankless water heater. While the heat-recovery ventilator (HRV) provides most of the heat required for the home to stay comfortable, there are radiant electric panels in the lower floor of the loft and the upper level bathroom. The kitchen's compact appliances include under-counter refrigerator and freezer drawers, a combination washer/dryer, and a two-burner induction cooktop. The dimmable fixtures—all LEDs—supplement the natural light provided by careful window placement.

Designed to be Net Zero, the PV system was carefully sized to exceed the building's electricity demand by 860 kWh/yr. Because of the site's small size, the proximity of the neighbors, and the desire to include a roof garden, the PV modules are mounted to a custom steel frame suspended over the exterior staircase. Oriented for optimal solar production, the 3-kW system produces on average 22% more electricity than projected, more than satisfying the electricity loads for both the cottage and the workshop on which it sits.

Baker spent quite a bit of time thinking about imaginative ways to use recycled materials. Much of the building's exterior siding consists of metal panels made of recycled steel and other scrap ornamental metals. The panels are mounted with a custom system that allows for removing and replacing individual panels, including small planter boxes. Additional siding and the interior hardwood floors are salvaged from a deconstructed warehouse. The extensive succulent roof garden is growing in repurposed tires. The bathroom tiles are factory seconds.



Zero Cottage; Photo by Matthew Millman



The cottage offers all the benefits of a Passive House: excellent indoor air quality (aided by no-VOC indoor finishes); low energy consumption; and near-constant comfortable temperatures. Once used to opening windows for fresh air, Baker is very pleased with the quiet ventilation provided by the HRV. He and his partner, Yosh Asato, now keep the windows closed to shut out city noises. Although they have another apartment in the front of the property, they tend to spend most of their time in the cottage. Not surprisingly, their cats like the cottage too.

Zero Cottage; Photos by Matthew Millman

PRODUCTS

Ventilation
ZEHNDER AMERICA

PASSIVE HOUSE METRICS

Heating energy	3.9 kBtu/ft²/yr	1.1 kWh/ft²/yr	12.2 kWh/m²a
Cooling energy	0		
Total source energy	27	7.9	85
Air leakage	0.4 ACH_{50}		

Sonoma House; Photo by Judit Lange

450 Architects

David Bushnell and Richard Parker, principals of 450 Architects, met while studying for their Bachelor of Architecture degrees at Cornell University, and they have remained close friends ever since.

Their post-college collaboration gave birth to an ecologically intelligent architecture firm, rooted in the belief that architecture can make the world a better place. Before the term "sustainability" became mainstream, 450 Architects promoted the benefits of earth-preserving practices through advocacy and action.

450 Architects' approach is collaborative and hands-on, balancing conceptual innovation with thoughtful craftsmanship to shape soulful spaces and structures. Having been in business now for 20 years, their expertise has fashioned a diverse variety of projects, both large and small: residential, commercial, renewable, educational, and open and public space. While they have a passionate interest in creating beautiful dwellings, they are particularly driven toward civic work, with a deeply engaged consideration of how a building can impact a wider public and accommodate people in a nourishing, uplifting, and lasting way.

Their firm's focus has shifted slightly from sustainability, which they characterize as treading water, toward a regenerative design approach, one that heals and improves a site and the surrounding community. They have one Passive House consultant among their staff of eight, and they try to infuse all of their projects with the fundamentals of Passive House.

Roughly a third of their work is residential, a third is educational, and the remaining third is an eclectic mix of the rest. Within the eclectic category are public open spaces, social justice and non-profit work, and small civic projects. Falling into this eclectic and impactful bin is the work they do with SolarCity, designing and managing permitting for their solar installations on more than 50 school sites across California.

Indeed, all of the projects they take on can be characterized as impactful—and hopeful. "We see ourselves as a small, scrappy firm that is advocating for a better future," Bushnell says. Asked how they manage to manage as many projects as they do, Bushnell laughs and replies, "We work really hard, and we have amazing people."

Bernal Heights Retrofit

SAN FRANCISCO

TEAM

Architect and Certified Passive House Consultant
450 ARCHITECTS

Builder
KEVIN STAMM CONSTRUCTION

This 1960s-era house seriously needed renovating, and one of the owners, an artist, needed more workspace. The other owner is a meticulous builder with a strong environmental ethic, so these combined skills and needs created the perfect opportunity for a Passive House retrofit and addition. The in-progress home and artist's studio sits atop one of San Francisco's hills and has long views toward the west and east.

Adding a third floor for studio space meant the two lower floors needed structural upgrades. The house was taken apart from the inside and outside, preserving the framing for the most part while fully replacing the building systems. New sheathing was installed, which was air sealed with a liquid-applied sealant and then covered with a weather-resistant barrier. An exterior insulation and finishing system (EIFS) provides the continuous exterior blanket.

Solar panels will cover the roof, exceeding the anticipated energy loads to provide power back to the grid. The roof assembly consists of TGI framing, with an overlay of rigid insulation that tapers down from 6 inches at its greatest depth to 1 inch.

A heat-recovery ventilator (HRV) will bring in fresh air and may also be the vehicle for distributing heat in the house, although the heating strategy has not been finalized yet. Either there will be an electric resistance heater in line with the HRV or small areas of electric resistance mats in the floor. Exterior shading on the south- and west-facing windows will be used to control solar heat gain and minimize the chances of overheating, precluding the need for active cooling.

Bernal Heights Retrofit; Rendering by 450 Architects; Photo by Thea Schrack

PRODUCTS

Air/Moisture Control
SIGA
PRO CLIMA

Ventilation
ZEHNDER AMERICA

Insulation
ROXUL

Shading
HELLA by PEAK BUILDING PRODUCTS

PASSIVE HOUSE METRICS

Heating energy	2 .1 kBtu/ft²/yr	0.6 kWh/ft²/yr	6.7 kWh/m²a
Cooling energy	2.6	0.8	8.3
Total source energy	5	1.5	15.8
Air leakage	0.6 ACH_{50}		

Hillside Residence

SAN FRANCISCO

TEAM

Architect
450 ARCHITECTS

Certified Passive House Consultant
BEYOND EFFICIENCY

Builder
RINALDI CONSTRUCTION

This 2,245-ft² home was designed to provide a flexible, future-proofed layout for a growing family anticipating changing needs. Within the envelope is a 245-ft² secondary studio unit that is independent but communicates with the roughly 2,000-ft² main house. Both of the owners are engineers, and from the start they wanted their new home to meet the Passive House standard and push the envelope of exceptional sustainability. The existing 1950s-era house needed major reworking just to meet current structural code in an earthquake-prone area, so the owners decided to add attaining LEED Platinum certification and meeting the Living Building Challenge guidelines to their renovation work.

Meeting the Passive House standard called for continuous exterior insulation on the walls—a problem for a property line to property line house. So, the framing had to be moved inboard of the property line to create space for adding on a mineral wool board blanket. To complete the thermal envelope, rigid glass insulation was installed underneath the new foundation where square footage had been added to the house.

A self-adhered air and water barrier membrane wraps the conditioned area of the house, leaving the unconditioned garage level outside the barrier. A heat-recovery ventilator (HRV) will bring continuous fresh air to the primary residence, with a separate, small ductless HRV system for the studio.

The heating load for the home is expected to be low enough that it can be met with electric resistance heating—not the most efficient means but the most environmentally benign for small loads. Water heating will be accomplished with a heat pump water heater that uses CO_2 as a refrigerant—a technology that fully satisfies the owners' environmental goals.

PRODUCTS

Windows
ZOLA

Ventilation
LUNOS
ZEHNDER AMERICA

Insulation
ROXUL

Water Heater
SANDEN

Hillside Residence; Renderings by 450 Architects

PASSIVE HOUSE METRICS

Heating energy	4.7 kBtu/ft²/yr	1.4 kWh/ft²/yr	14.8 kWh/m²a
Cooling energy	0		
Total renewable source energy	17.4	5.1	55
Air leakage	0.6 ACH_{50} (design)		

Small and Sustainable

BERKELEY

This 235-ft² dwelling sips kWh and boasts ample renewables—a 1.85-kW PV system and solar thermal—to get to Net Zero annually. The windows' placement optimizes cross-ventilation, providing passive cooling and eliminating the need for air conditioning. Sufficient insulation allows for the simplest heating system: two 24 x 24, wall-mounted electric resistance panels.

Small and Sustainable; Photo by Steve Mann

TEAM

Designer and Certified Passive House Consultant
STEVE MANN

PRODUCTS

Windows
ALPEN HPP

Air/Moisture Control
PRO CLIMA
PROSOCO R-GUARD

Ventilation
LUNOS

Insulation
ROXUL

PASSIVE HOUSE METRICS

Heating energy	1.2 kBtu/ft²/yr	0.4 kWh/ft²/yr	3.9 kWh/m²a
Cooling energy	0.9	0.3	3.1
Total source energy	NA		
Air leakage	1.1 ACH_{50}		

Beausoleil

PACIFICA

This project, originally planned as a large, multi-generation house, evolved through multiple budget-driven iterations into a lean, green machine for living, a high-performance house on a budget. Every detail was scrutinized to minimize excess material and construction labor, while maintaining energy performance and a bit of architectural pizzazz. A flexible floor plan, plumbing for grey water reuse, rainwater harvesting, cork outsulation and siding, and recycled tile mosaics are just a few of its many outstanding features.

Beausoleil; Rendering by Beausoleil Architects

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BEAUSOLEIL ARCHITECTS

Certified Passive House Consultant
BEYOND EFFICIENCY

Engineer
BRUCE KING

PRODUCTS

Air/Moisture Control
SIGA

Insulation
ROXUL

Heating & Cooling
FUJITSU

Water Heater
SANDEN

PASSIVE HOUSE METRICS

Heating energy	3.1 kBtu/ft²/yr	0.9 kWh/ft²/yr	9.7 kWh/m²a
Cooling energy	0		
Total source energy	38	11.2	120
Air leakage	0.6 ACH_{50} (design)		

Laney College Passive House

OAKLAND

Laney College in Oakland has a very active Carpentry Department, led by Cynthia Correia, that regularly builds and renovates houses as a way to teach carpentry skills to students. In 2012, with encouragement and volunteer participation by Passive House California, they decided their next project would be a Passive House renovation. The City of Oakland sold them a lot, including a burnt-out house, for a minimal fee. The Oakland Rotary Club, which had partnered with Laney on past projects, financed the project as part of their mission to provide low-income housing in the community.

Laney College hadn't built a Passive House yet, but Carpentry Instructor Karl Seelbach, who had trained as both a Passive House consultant and Passive House tradesperson, was ready for the challenge, and he became the project lead. The project was built with overall coordination and project management from contractor Christopher Polk, a founding member of Passive House California. Volunteers from the Passive House community also provided architectural drawings, PHPP modeling, and testing. Between November 2013 and May 2016, various classes rotated through the structure. Hands-on classroom tasks included demolition, framing, air sealing, and insulating. The result is a comfortable, extremely efficient 1,040-ft², three-bedroom, two-bathroom house.

The house framing is typical of California bungalows in this climate zone: 2x4 walls, 2x8 floor joists, and 2x8 rafters in an intersecting double gable configuration. The living room has a vaulted ceiling, while the rest of the house has 8-foot ceilings with a semi-conditioned attic above. Batt insulation was used throughout, as it's easiest for unskilled volunteers to work with. In addition to completely filling all framing cavities, 2 inches of polyisocyanurate rigid insulation were layered outside of the OSB air barrier, followed by a weather-resistant barrier (WRB), furring strips, and cementitious siding. Two-and-one-half inches of polyisocyanurate were also layered on the roof, plus a WRB and flat-framed 2x4s for a ventilated roof and overhangs.

The project had multiple challenges. Construction scheduling was often difficult because of the combination of classroom timing, volunteer trade participation, and the uncontrollable arrival of donated materials. For instance, the subfloor had to be installed because of the approaching winter. In the extremely tight crawl space, the insulation was installed first, even though plumbing and electrical rough-in were not finished. Subsequently, the plumbers and electricians disturbed the insulation, requiring an insulation touch-up in tight quarters.

An even more significant challenge was air sealing. The hardest-to-seal connection was the joint between the exterior bottom plates, the subfloor, and the exterior OSB air barrier.

According to Seelbach, it was a great learning experience, particularly figuring out "how much time and money should be spent to get a few CFM lower". The house sold in late spring of 2016. No doubt the new owners will be pleased with the air quality, comfort, and lower utility costs of their new Laney College Passive House.

Laney College Passive House; Photo by Larry Chang architect

TEAM

Designer
Chuck Campanella Design

Certified Passive House Consultant
BRONWYN BARRY

Builder
LANEY COLLEGE CARPENTRY DEPARTMENT led by Cynthia Correia, Karl Seelbach, and John Shurtz

Funding
OAKLAND ROTARY & CITY OF OAKLAND

Project Management
Christopher Polk

PRODUCTS

Windows
ALPEN HPP

Ventilation
ZEHNDER AMERICA

Insulation
ROXUL

Heating & Cooling
MITSUBISHI ELECTRIC US

PASSIVE HOUSE METRICS

Heating load	3.2 Btu/hr/ft²	0.9 Watts/ft²	10 Watts/m²
Cooling load	1.3	0.4	4
Total source energy	38 kBtu/ft²/yr	11.2 kWh/ft²/yr	120 kWh/m²a
Air leakage	1.5 ACH_{50}		

Grant Street
EnerPHit
BERKELEY

TEAM

Architect and Certified Passive House Consultant
NABIH TAHAN

Builder
CHRIS POLK

After living in Austria for several years and learning about the Passive House standard, the owners, one of whom is an architect, returned to Berkeley in 2006 to remodel their aging bungalow. At the time, the Passive House standard was unknown to Californians. It was a challenge to promote such a foreign concept, especially its emphasis on airtightness, to a building industry that believed airtight buildings caused condensation and mold. Another big challenge was that Passive House products were not yet available in the United States.

The Grant Street retrofit was revolutionary. It introduced the Passive House approach to California as a common-sense method of making a building energy efficient. It demonstrated how to think holistically about and harmonize the elements of the building envelope—the framing, insulation, openings, and airtightness—and also introduced heat-recovery ventilation to the local residential construction market. The project was also the first in California to use the Passive House Planning Package (PHPP), which had been proven in Europe to accurately predict a building's energy performance during the design stages. However, the emphasis of this demonstration project was necessarily more on the strategies than on the metrics, given the dearth of appropriate products and training.

Due to the mild Berkeley climate, the PHPP indicated that 2 x 6 stud walls with cellulose insulation and 2 inches of exterior rigid insulation would be enough to meet the Passive House standard. The heat-recovery ventilator made a significant difference. The biggest challenge, especially then, was to convince the construction team of the importance of air sealing. After implementing several techniques, the final blower door test measured 1.1 ACH_{50}.

After completing the project the owner presented the Passive House concept at several local venues. People were curious to learn more, which led to a series of meetings being held in the Grant Street house in 2007. These meetings led to the birth of Passive House California (PHCA) in 2008. PHCA was then instrumental in creating the North American Passive House Network (NAPHN), connecting Passive House enthusiasts throughout North America.

The Passive House philosophy should be implemented on all projects, even if the first attempt is overwhelming. Now, 10 years later, plans have been submitted for a third-story addition on Grant Street. It will be an opportunity to fine-tune the house based on the lessons learned. With many of the hurdles to implementing the Passive House approach diminished, this second phase should be much easier.

PRODUCTS

Ventilation
ULTIMATEAIR

Grant Street EnerPHIt; Photo by Nabih Tahan

PASSIVE HOUSE METRICS (Actual average energy use)

Heating energy	4.4 kBtu/ft²/yr	1.3 kWh/ft²/yr	14 kWh/m²a
Cooling energy	0		
Total source energy	45	13.2	142
Air leakage	1.1 ACH_{50}		

"Passive House for All of California: Finding What Matters," Continued from page 6

To gain a better sense of how Passive House would perform throughout the state, I undertook a study comparing a code-compliant and a Passive House-compliant building in all 16 California climate zones, using a California Energy Commission (CEC) prototype 2,100-ft², single-story, single-family home. The building was initially configured as code-compliant, then systematically upgraded to meet Passive House standards. The upgrades were chosen in order of efficacy and cost-effectiveness.

The intention of this study was twofold: 1) to examine and compare the requirements and benefits of Passive House throughout the state, and 2), to evaluate the difference between Passive House and the 2013 state energy code.

The optimization process is illustrated in Figure 1. The vertical axis shows demand for heating and cooling energy in kBTU per year. For each climate zone (CZ1-CZ16), a line traces the optimization process from left to right, code-compliant to Passive House. The horizontal axis shows each optimization step (the first four are specific to the energy code, converting "standard" to "baseline" design.) If a particular upgrade was used in a climate zone, a dot appears above it on the line in question. The dashed horizontal lines show the Passive House limits, one for climate zone 15 (Palm Springs), which has an adjusted cooling limit due to high summer temperatures, and the other for the remaining climate zones.

Figure 1. The Optimization Process

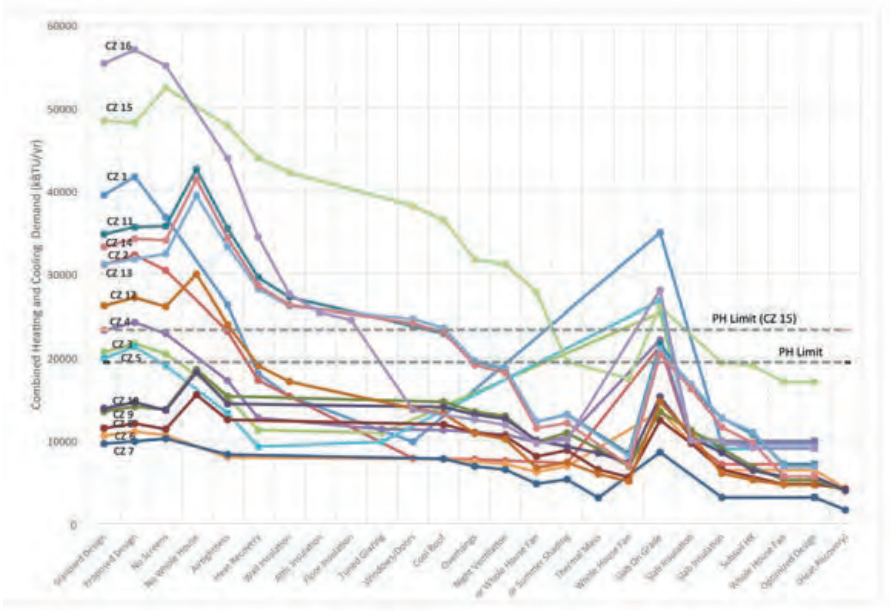
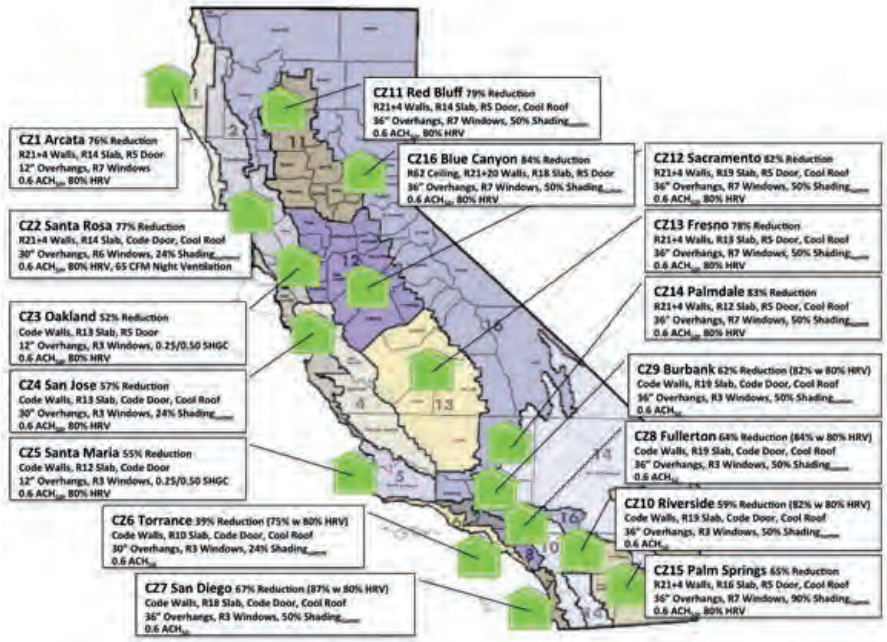


Figure 2. The Optimized Buildings



The jump in demand above "slab on grade" occurred because the building was switched from a code-compliant insulated raised floor to a code-compliant uninsulated slab-on-grade. The building performance was then restored with slab insulation, first to meet Passive House standards, then to match the performance of the previous raised-floor building, if it exceeded the standard. Several climates did not require heat-recovery ventilation; it was added as an optional step at the end for the sake of comparison. The code-required whole house fan was switched in and out to test its efficacy versus other measures, because large fans use a lot of energy and they face diminishing returns. At some point, a small air conditioner is more efficient than a large fan.

Some interesting patterns were found. While there were differences in the specific requirements for each climate zone, and not all upgrades were used every time, the upgrade order was consistent.

Because the energy code is based on prescriptive building shell measures that don't vary much with climate zone, the performance of the code-compliant building varied widely, with the largest energy demand in the coldest (CZ 16, Blue Canyon) and hottest (CZ15, Palm Springs) climate zones, and the lowest energy demand in the five milder climates of southern California (CZ6, Torrance through CZ10, Riverside.) By contrast, because Passive House is a performance-based approach with energy limits based on building area, the optimized buildings were far more consistent in their performance, though the cooling demand for CZ15 (Palm Springs) remained quite high, since passive measures are of limited efficacy when the outdoor air is very hot throughout the day. The energy savings from upgrading to Passive House are shown in Figure 2.

Heating demand was more easily dealt with than cooling, even in the coldest climate zones. Because buildings have internal heat gains from their occupancy and operation, reducing heating needs through passive measures is easier than reducing cooling needs, unless nighttime temperatures drop low enough.

Air leakage reduction, from the code assumption of 5 ACH_{50} to the Passive House maximum of 0.6 ACH_{50}, was the most effective first measure in every climate. Another extremely effective upgrade, universally, was insulating the slab. In some cases, the improvement from slab insulation exceeded that of air tightness. Beyond these measures, adjusting the building for its orientation with "tuned" glazing (high solar gain glass on the South and low gain glass elsewhere, along with seasonal shading via window screens, exterior blinds, or both) was helpful for both heating and cooling. This is another profound difference from code, which is intended to be "orientation agnostic." Code standard 12-inch overhangs were generally insufficient; 30 inches to 36 inches were typically the optimal depth.

Even though heat-recovery ventilation was not required for climates 6 through 10, in climate zone 7 (San Diego) it reduced heating and cooling demand by 50%.

Interestingly, there was a relatively small difference between code and Passive House requirements, once air-tightness, slab insulation, orientation, and overhangs had been addressed. In climate zones CZ03 (Oakland) through CZ10 (Riverside), code-minimum insulation requirements, except for the slab, were adequate. Code-minimum windows were also adequate in those locations. Slab insulation requirements in these climates ranged from R10 to R19. In the more extreme climates, code-minimum wall insulation (R15 in the cavity plus R4 exterior) was increased to R21 in the cavity, with R4 exterior, except in CZ16 (Blue Canyon) where the exterior insulation was also increased to R20. Code-minimum R19 raised-floor insulation was adequate everywhere but CZ16, where it was increased to R23.

Passive House offers significant performance improvements across the state of California with relatively straightforward, but fundamental, changes from current building code. Although the 2016 energy code has not yet gone into effect, the expectation is that the difference in requirements for Passive House relative to the energy code will be smaller, yet still very significant in impact.

Graham Irwin, AIA
Principal, Essential Habitat Architecture

The Future of California's Energy Grid

The price of electricity for consumers in California is relatively steady, but the cost of supplying it varies widely by the hour and the season, with summer peak costs as much as thirty-four times the minimum. The biggest driver of this cost is generation equipment that must be kept idle, but ready, to meet peak loads, which occur for less than one percent of the year, currently during summer afternoons and evenings.

Renewables (particularly solar) are exacerbating this problem, because much of the load is not synchronized with renewable energy supply. The shift to renewables is creating a new value proposition for Passive House buildings, which flatten peak loads—a value that may even exceed savings from lower overall energy consumption.

Passive House Buildings Reduce Daily Peak Loads

Passive House buildings use less energy overall, but are also valuable for reducing peak loads. Passive House buildings have long "thermal time constants," which means they don't really notice daily temperature swings. In winter, they glide through cold nights without cooling down much. In summer, they glide through hot days without warming up much. Passive House buildings use far less energy to keep comfortable, minimizing or even eliminating the need for mechanical heating or cooling at times when conventional buildings are straining the grid.

Dampening the Duck Curve

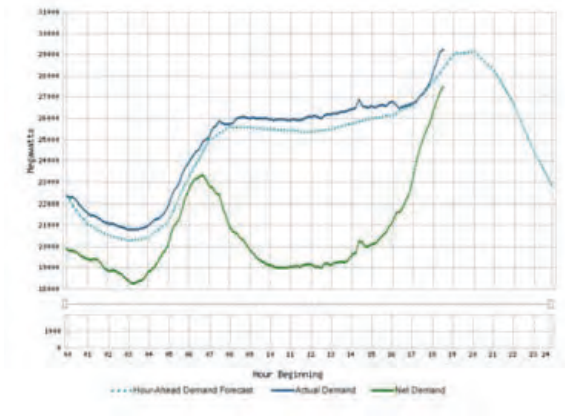
Figure 1, which shows the California grid load on March 9, 2016, demonstrates the daily challenge utilities face to integrate solar energy with the electrical grid (the so-called "Duck Curve"). Solar energy reduces the grid's load most at midday, when solar output peaks. Solar output tapers off in the afternoon, before the late afternoon and evening peak load occurs as people return home from work, use appliances, watch TV, and cool or heat their homes.

Solar hollows out the load in the middle of the day (duck's "belly"), but the peak load is not reduced. The result is an aggravated load ramp (duck's "neck") in the late afternoon and evening, caused by simultaneous tapering solar output and increasing grid load.

Daily swings in both solar energy production and consumer demand for power make the most expensive aspect of grid operation—stabilization—more difficult. The grid's base load is significantly reduced for much of the day, further idling generation equipment that must be kept in reserve and quickly brought on line as the load on the grid from millions of households begins to peak.

As renewable energy replaces fossil fuels and nuclear, the Duck Curve will worsen unless grid loads are reduced and/or shifted. Rather than requiring large energy storage systems to run heating and cooling equipment, Passive Houses themselves ARE the storage. Any necessary space conditioning can be scheduled away from peak load to times of available renewable supply, flattening out the daily load and reducing the stabilization challenge. Passive House buildings can be heated or cooled on a convenient and cost-effective schedule instead of when outdoor temperatures are most severe and power is expensive. Passive House buildings can help dampen the peak and reduce the ramp.

Keeping Californians Warm in Winter



Balancing daily loads and renewable energy production is challenging, but it is easy compared to managing seasonal imbalances. Seasonal variation in solar output, along with electrification of space heating (even via heat pumps), could shift the peak load in California from summer to winter. A 100% renewable grid with a large amount of solar will require costly long-term storage to make surplus summer power available in winter.

Because the need for space heating is largely caused by a lack of solar power, heating is the biggest challenge for a renewable grid. Fortunately, vastly reduced heating needs are a well-known hallmark of Passive House buildings. Passive House was conceived to reduce space heating with the lowest cost solutions. Insulation, air-tightness, heat-recovery ventilation, and direct solar gains are long-lasting, reliable, and cost-effective means of reducing both winter energy demand and peak loads.

While phenomena such as the "Duck Curve" and its variants are fundamentally changing the economics of the grid, they make Passive House buildings a significant value proposition for both daily and seasonal peak load reduction. Passive House buildings reduce the disparity between grid loads and renewable energy supply. In the future, the annual energy cost savings from Passive House buildings may be dwarfed by the economic value of peak load reduction, both for building owners and California grid managers.

Graham Irwin, AIA
Principal, Essential Habitat Architecture

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Santa Cruz Millwork, Santa Cruz


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PASSIVE HOUSE HAS SET A BASELINE FOR HIGH PERFORMANCE BUILDINGS IN CALIFORNIA.

We applaud the pioneers—architects, designers, consultants, engineers, and builders—who have not only created beautiful Passive House buildings but also are helping to combat climate change.

What these pioneers are doing is farsighted. The beauty of Passive House is that the expertise, techniques, and materials needed to reduce carbon emissions are available now—as evidenced by the many Passive House projects found from Southern to Northern California.

PHCA

PASSIVE HOUSE CALIFORNIA