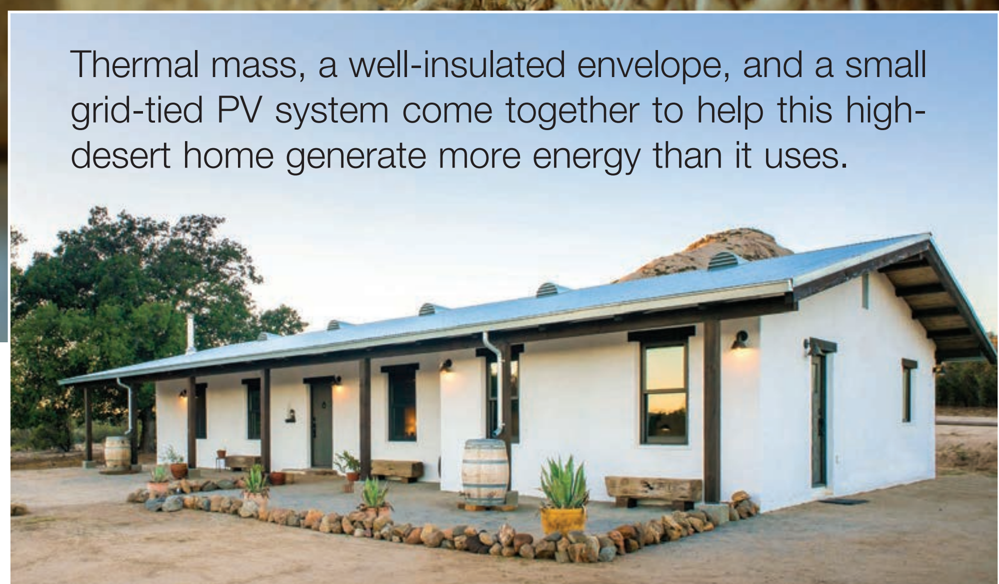
Net Zero, Naturally

The Fallgren Strawbale Home

Thermal mass, a well-insulated envelope, and a small grid-tied PV system come together to help this high-desert home generate more energy than it uses.



by Rebecca Tasker

All photos courtesy Simple Construct

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Home Design

Brian and Sue Fallgrens' home, 60 miles east of San Diego, was inspired by traditional adobe ranchos. It uses time-tested natural materials—straw, clay, and wood—to create a well-insulated, high-performance envelope. Thoughtful design by Simple Construct, a design-build company specializing in strawbale homes, included incorporating passive solar orientation to maximize cooling; shading on the south face; and a compact size in a relatively simple footprint. Coupled with careful construction—well-detailed strawbale walls, ensuring an even distribution of mass, and attention to mitigating air infiltration—these strategies help this home maintain comfortable temperatures year-round, while using little supplemental energy for heating or cooling. A 4.1 kW batteryless grid-tied PV system provides almost twice as much electricity as this home uses each year, even though every system in the home is electric—there are no fossil-fuel-powered appliances. The only combustion that takes place is in the small woodstove that uses brush collected for wildfire prevention.

The shared ethic of simplicity between the homeowners and builders led the home's design—to try the lowest-tech solution; the most affordable off-the shelf choice; the refurbished/reclaimed option; and the passive technology first. It started by making the home as small as possible—a smaller building translates into fewer materials and less energy used.

The owners' desire to tread lightly on the land guided many of the design decisions, as did the commitment to achieving high performance by using natural, nontoxic, low-embodied-energy materials. Opportunities to design with salvaged and repurposed furniture and to use reclaimed materials were identified, such as refurbishing an old buffet for the bathroom vanity, using wood from collapsed sheds on the property for trim, and constructing the kitchen countertops from reclaimed vintage oak planks. Human

solutions—such as opening windows for ventilation rather than relying on fans—took priority over mechanical options whenever possible.

The 1,600-square-foot interior (1,900 sq. ft. exterior footprint), two-bedroom, one-bath home was completed in the spring of 2016. It is one of only 27 to have achieved the International Living Future Institute's (ILFI) Net Zero Energy Building (NZEB) certification. ILFI, a nonprofit organization promoting ecological design, coordinates the Living Building Challenge, a rigorous green-building standard from which the certification draws (see "NZEB Certification" sidebar for more information).

Material Selection & Use

What distinguishes this house from most zero-energy homes is the use of natural, local, low-embodied-energy, carbon-sequestering materials, which consume less energy and emit less carbon pollution in their manufacture and transport.

The Fallgrens had planned to build an adobe home, but were disappointed to learn that obtaining a permit for adobe construction in this seismic zone is difficult. That's when they began examining strawbale building. What began as a compromise became an exciting opportunity as they learned about the benefits—good insulation, high fire resistance, humidity buffering, and sound isolation.

The three-string bales are an agricultural byproduct of wheat production in the Imperial Valley, about 50 miles from the project site. Laid flat and tightly chinked, these walls have an insulation value of about R-30. The clay for the plaster finish came from a mine about 125 miles away. Much of the wood used in the project traveled feet rather than miles: most of the nonstructural lumber was salvaged from old buildings at the job site. The oak countertops were fabricated from vintage timber purchased from a wood salvage company.

The adobe blocks were made on-site from the same clay, sand, and straw used to make the plaster finish for the walls. Nonstructural elements, such as the central bookcase, the dividing wall at the entry, and a bench in the great room, were constructed with the blocks, which provide additional thermal mass.

Energy-Efficiency Strategies

To meet the NZEB requirements, the Fallgren home relies on several energy-conservation and efficiency strategies:

- A well-insulated, well-sealed envelope
- Well-placed thermal mass for storing heat and "coolth" for reliance on passive heating and cooling
- Appropriate building orientation, plus ample overhangs and careful window placement for avoiding solar gain during the hot summer months and shoulder seasons (spring and fall)
- Energy Star appliances—Dishwasher, refrigerator, induction stove, chest freezer, clothes washer, and clothes dryer
- Fujitsu Slim Duct minisplit—12,000 Btu heat pump for cooling and heating; model ARU12RLF; SEER: 14.7; EER: 11.7
- GE Geospring 50-gallon hybrid heat-pump water heater
- All-LED lighting
- Passive ventilation through well-placed, operable windows

The NZEB certification verifies, through a third-party audit of performance data over a year of occupancy, that the building operates as claimed, harvesting energy from the sun, wind, and earth to exceed net annual demand.

- Annual energy use: 3,813 kWh
- Annual electricity generated: 7,023 kWh
- Total surplus: 3,210 kWh

Thermal Performance

The Fallgren home's most important energy strategy—thermal mass and ample insulation—requires no electricity. The 4-inch-thick concrete slab, the clay-plastered walls, and the adobe block pony walls provide well-distributed thermal mass, acting like a thermal battery—storing heat and then reradiating it. The R-30 strawbale walls and R-40 blown-in cellulose in the attic reduce envelope heat loss, and the influence of the mass—known as the thermal flywheel effect—minimize interior temperature swings for good comfort.

After a warm fall heated the mass—and before the minisplit heat pump or insulation in the attic had been installed—the unfinished home was able to maintain 62°F, even though the outside temperature fluctuated between 60°F during the day and 35°F at night. Even after the temperature dropped into the 20s for a week, the home's interior temperature dropped only one degree—to 61°F.

Summer performance was even more dramatic. During interior plastering, the doors and windows were opened to ventilate the space and disperse excess moisture. Within an hour, the interior temperature had risen from 75°F to 95°F. Once the windows and doors were shut, the ambient temperature returned to 75°F within an hour. The house had effectively cooled itself, with the thermal mass acting as a sink for the heat.

"Last winter," says Brian, "the house stayed about 70°F without turning on the minisplit. And this is in a climate with average lows of 33°F in December. Last summer, the house stayed about 74°F without running the air conditioning. Our average summer high is 94°F."

NZEB Certification

The Net Zero Energy Building (NZEB) certification was a program operated by the International Living Future Institute (ILFI) using the structure of the Living Building Challenge (LBC), a rigorous green-building program.

The Fallgren home was the 27th and final project to be certified under the NZEB program, which was retired at the end of 2017. Other projects are now being certified under the ILFI's Zero Energy (ZE) program, which simplifies and streamlines the certification of zero-energy buildings to create broader market adoption, codification, and standardization of ZE technologies in everyday buildings. ZE certification still requires a year of energy monitoring to verify that the building performs as designed, but does not require compliance with any other LBC imperatives.

NZEB was one of three certification paths under the LBC. Projects that met the requirements rely on exceptional energy conservation and on-site renewable energy systems to meet all of their heating, cooling, and electricity needs. The NZEB certification verified, through a third-party audit of performance data, that the building is truly operating as claimed, harnessing energy from the sun, wind, or earth to exceed the home's annual energy demand. In addition to requiring that 100% of the home's annual energy needs be met by on-site renewable energy, the NZEB certification differs from most net-zero certifications (and ILFI's current ZE certification) in that the project also had to meet three LBC imperatives:

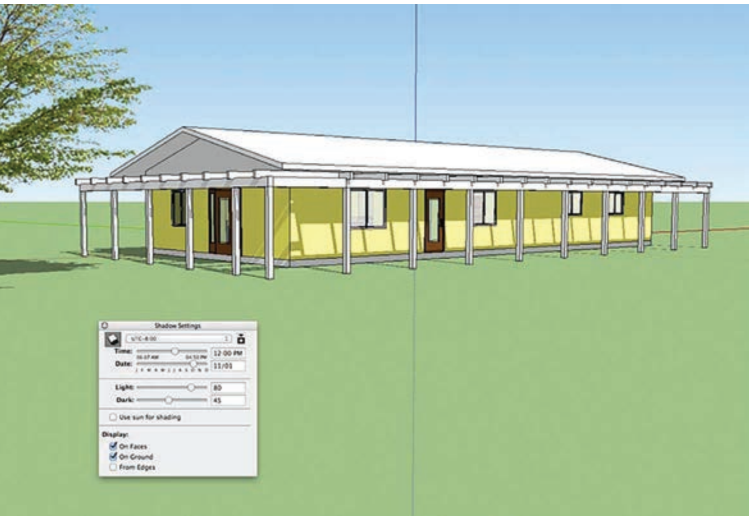
- **Limits to Growth** addresses sprawl and encourages sensitive land development. As a former dumping ground, surrounded by development on three sides, this was a fitting site for an environmentally sensitive home and landscape restoration.
- **Beauty + Spirit** explores the less-tangible goals of designing structures to create delight and foster well being. Beauty in this project centered on authenticity of design and materials as they relate to this location, which dovetails Simple Construct's focus on achieving a high-performance envelope with natural, local, carbon-sequestering materials.

  The project's aesthetic was grounded in the land and its rich history, native plants, and subtle color palette. Exploring the shapes and variations of local adobe buildings opened up dialogue about what looked and felt right. Themes emerged: being low and integrated with the landscape; simple lines; interplay of strong light and shadow; and a color palette of bright white, silver gray, and deep brown. Incorporating reclaimed wood from the site as trim further celebrated what was already there. A few scraps of brightly painted wood from Camp Lockett, a local abandoned WWII army base, were saved until their place in the home revealed itself.
- **Inspiration + Education** covers efforts to reach out to the public to share information about the project. The home was part of the U.S. Green Building Council's Green Homes Tour in 2016 and will be a featured home on its 2018 tour. It also received an Excellence in Energy Leadership award from San Diego Gas & Electric, who produced a promotional video about the project (see youtube.com/watch?v=JgsWMgs7TMs).

Nichos—shapes carved into the walls—are a tradition in both strawbale and adobe building, as pictured below in a historic rancho. Though they can serve specific functions, they often host objects of beauty.

Above: Besides providing good insulation, the two-foot-thick strawbale walls lend themselves to sculptural interpretation, especially around window openings. The flared window shapes in this home echo the window shapes at local historic ranchos (left) and missions (right). This technique minimizes glare by creating a light gradient—from the bright outdoors to the more subdued indoors.

Nichos throughout the home reference a traditional aesthetic and draw attention to objects of beauty and function.



A ground-mounted 4.125 kW batteryless PV array—15 SolarWorld 275 W modules and 15 Enphase M250 microinverters—provides the home's energy generation. This array was sized to meet the anticipated needs of this all-electric home but has proven to be larger than needed. An electric car could easily be charged with the surplus electricity. Once energy-storage prices drop, a battery bank would be an asset to this remote rural home when the grid goes down.

Solar orientation is another important energy strategy for this home. Given the sunny location and very hot summers, the home is oriented with its longer face to the southeast (165° off north). A deep porch shades the home's south face to reduce solar gain and facilitate summer passive cooling. The porch depth and window height were designed so that almost no direct sunlight enters the windows at any time of year, yet views are maintained. A small amount of unshaded east-facing glass allows for solar heat gain in the mornings, which are generally cool.

In this climate, there is too much hot sun year-round. In the summer, the ambient sun and air temperature slowly heat the mass; night-time ventilation keeps the interior temperature comfortable. Well-insulated high-thermal-mass buildings are easy to overheat and, once overheated, require quite a bit of energy to shift the temperature back to the ideal comfort range, so controlling heat buildup from solar gain is a priority. The majority of heating and cooling for this home relies on the mass to maintain a steady temperature. Once the house is at a comfortable temperature, it is a matter of fine adjustments—a little bit of supplemental heating or cooling.

The Cost of "Green"

This home cost approximately $350,000 to build (which includes the cost of the appliances, but not the PV system). Keeping the building's shape and the systems simple allowed for more intricate finishes. The homeowners were very involved with the design and with certain parts of the construction, such as staining the wood for the porch ceiling and antiquing the tin wainscoting around the bathtub. The homeowners also shopped for their appliances and fixtures, finding some good deals.

A custom strawbale home can cost the same to build as a custom conventional home if it is well-designed and the builders have a good understanding of strawbale details. In general, the materials for a strawbale building cost less but more labor is required. It is important to compare apples to apples: Any well-insulated wall system will cost more than one that only has code-minimum insulation.

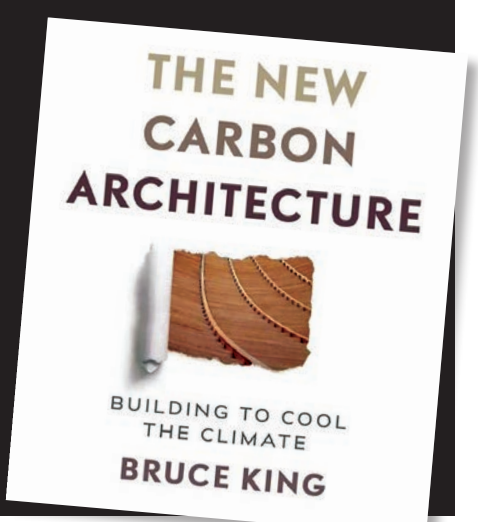
A truth window is a small opening in the wall that reveals the substrate behind the plaster—straw-clay (above) and straw bales (below). A tradition in strawbale houses, truth windows are a source of surprise and delight as guests get a peek inside.

Beyond Net Zero: Embodied Energy & Carbon Sequestration

It wasn't long ago that few people understood what "net zero" meant in relationship to building design, and though there's still some dispute about exactly how to define it, it's broadly understood that a net-zero building generates as much energy as it uses on an annual basis. A net-positive building generates more energy than it uses over a year's time.

The energy a building uses—its operational energy—has been the focus of the green building industry. We now know how to dramatically decrease a building's operational energy use through building techniques (better and more insulation, building orientation, and more airtight building envelopes). But we can push the boundaries of sustainable building further, saving even more energy, by considering the energy that goes into making and transporting the building's materials. Known as embodied energy or embodied carbon, this is often referred to as the building's "carbon footprint."

If we're truly serious about saving energy and resources, embodied energy matters. And if we can build with materials that act as a carbon sink—a place to store compounds that contain carbon, thereby sequestering carbon dioxide from being released into the atmosphere— we make an even bigger, immediate difference. For an in-depth discussion of embodied energy in construction and why it matters, *The New Carbon Architecture* by Bruce King is an excellent resource.



The owners prefer to be smart operators of a passive home rather than passive owners of a smart home, so they open and close windows and doors to provide ventilation as needed for fresh make-up air and night-air flushing. Mechanical ventilation, required by code, is provided by a NuTone 742RBNT, 70 cfm exhaust fan in the bathroom and a Zephyr Tornado Mini AK8400AS exhaust fan in the kitchen. Unconditioned air exchanges like this have little effect on the interior temperature due to the home's high thermal mass. A Fujitsu minisplit, located in the attic above the central hallway and ducted to the master bedroom, provides supplemental heating and cooling.

web extras

"Straw Bales & Solar Energy—A Natural Partnership" by Rebecca Tasker in *HP175* • **homepower.com/175.46**

California Straw Building Association and conference • **strawbuilding.org**

Embodied carbon in the built environment • Carbon Leadership Forum • **clf.be.washington.edu**

Living Building Challenge • **living-future.org/lbc/**