

On the Way

Renewables are part of the strategy,



BY MELA BREEN AND DAVID GOOD

Once the majority of the structural framing is complete, we tackle the critical areas that affect its performance: air-sealing, insulation, and efficient mechanical systems. In a house that has a complicated air barrier like ours, some of the air-sealing and insulating happens during framing, so sequencing is key to not overlooking important air-sealing details. Once the performance of the building envelope is maximized and the mechanical systems are as efficient as possible, the amount of PV needed to take

an all-electric house net-zero is more attainable. The goal isn't to just put a lot of solar panels on a roof—it's to use as little energy as possible and then offset this energy use to create a zero-net-energy (ZNE) home that is also comfortable and healthy. As Dave always says, it makes sense to go after the low-hanging fruit of efficiency first!

Our attention to a building's comfort and efficiency always begins early in the design. Dave models our houses in the Passive House energy-modeling program WUFI to see the effects design decisions have on performance. The energy model—and our understanding of our microclimates—informs our decisions around insulation, windows,

and mechanical systems. While our projects, including our home, usually far exceed the Title 24 requirements, we are mindful of the decisions we make along the way. We want to meet our performance goals, but we also pay attention to rebate opportunities in the California Advanced Homes Program by meeting benchmarks that earn a Tier 3 rating (the ZNE tier) and lower the HERS score.

Minimize air infiltration

On our house, we're using plywood sheathing for the roof and walls because it's more robust and stands up to water better than the commodity OSB we see on many local builds.

to Net Zero

but conservation comes first



Mechanicals



Insulation

The Delta-Vent SA that we use as a water-resistant barrier (WRB) comes in 59-in.-tall rolls so that it covers the sheathing quickly like other building wraps, but this self-adhesive product tenaciously sticks to our plywood sheathing, creating an effective air-seal in one step. One of the things we really like about using this product is that it's part of a family of products; we don't have to worry about compatibility issues between flashing tapes and WRBs. And because it's a self-adhesive WRB, it simplifies window flashing by sealing directly to the rough opening without additional flashing tape.

The plywood roof deck is the air barrier at the top of the house, as we have an

FOLLOW THE BUILD IN THREE PARTS

- **Foundation & Framing**
(Aug/Sept issue)
- ▶ • **Envelope & Mechanicals**
- **Design & Reveal**
(Dec/Jan issue)

In this three-part series, we explore the design and construction of a new contemporary net-zero home in California. This installment recounts the efficiency measures and building-envelope details that will determine the size of the PV array needed to reach net-zero energy performance.

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TARGET AIR LEAKS AND THERMAL BRIDGES

Air-sealing is critical to our house's performance. Our practice is to place the air barrier at the exterior of the sheathing, for multiple reasons: We don't have to worry as much about lighting-fixture selections or how to air-seal fire sprinkler heads, and it's relatively easy for subcontractors to understand. Also, when it's on the sheathing, the air barrier is protected behind exterior insulation.

On past projects, we've achieved excellent blower-door results by taping the seams of all of our structural sheathing with flashing tape and then installing a water-resistive barrier (WRB) as a drainage plane. For our house, we're doing the air-sealing and WRB in one step with Dorken's Delta-Vent S and SA. It's important to us that our assemblies are able to dry to both the inside and outside so that moisture vapor doesn't get trapped. We use vapor-open WRBs/air barriers on the walls (the SA) and the roof (the S) so that they work with our mineral-wool insulation on the interior and exterior to allow drying in either direction.

THE FLAVORS OF MINERAL WOOL Available in batt and board forms, mineral wool comes in different densities tuned to the application. ComfortBatt is the interior batt insulation. While it's the least dense mineral-wool product used on this house, it's significantly denser than fiberglass batts. ComfortBatts are slightly wider than the cavities they fill and the compression holds them in place.

The exterior walls are covered with ComfortBoard 110—the denser of the two rigid-sheet products commonly available. The denser version was chosen to lessen the chances of oil-canning with the metal cladding mounted directly to the ComfortBoard without battens. The same material is also used as subslab insulation.

The roof sheathing is covered with TopRock DD. This dense sheet product is intended for low-slope roofs and provides thermal properties and will mute the sound of rain on the metal roof.



Gaps reduce bridging. Connecting the framing of unconditioned space (this breezeway) to conditioned space with Maine Deck Brackets creates a gap behind the ledger for continuous exterior insulation, limiting thermal bridging.



Interior batts



Exterior walls



Exterior roof

vented roof assembly. Here we taped all of the plywood seams with Delta Multi-Band as a belt-and-suspenders approach to ensure an airtight assembly. After the seams were taped we rolled out Delta-Vent S (not self-adhering) and underlayment, taped all seams, and taped the edges to the roof deck.

Select efficient windows

During the design phase, we consider which window manufacturer makes sense for the performance of the house, the budget, and

the aesthetic goals. We have installed Zola European Windows on several of our previous high-performance and Passive House projects and have found their price point to be better than comparable Passive House-certified windows. With a manufacturer like Zola, we are able to optimize the glass-to-frame ratio and design for large glazing units. The triple-pane glass is not only less expensive than the frame, its performance is also much higher. So in our house there are a relatively low number of window units, but

they have a large amount of glazing. The windows are tuned to allow for solar heat gain where needed, and we paired substantial fixed units with the operable tilt-turn units to get the most out of the overall window performance.

Insulation from rocks

With the air-sealing complete, we turned our attention to insulating the envelope. Our typical approach is to insulate on the interior and exterior and optimize the insulation



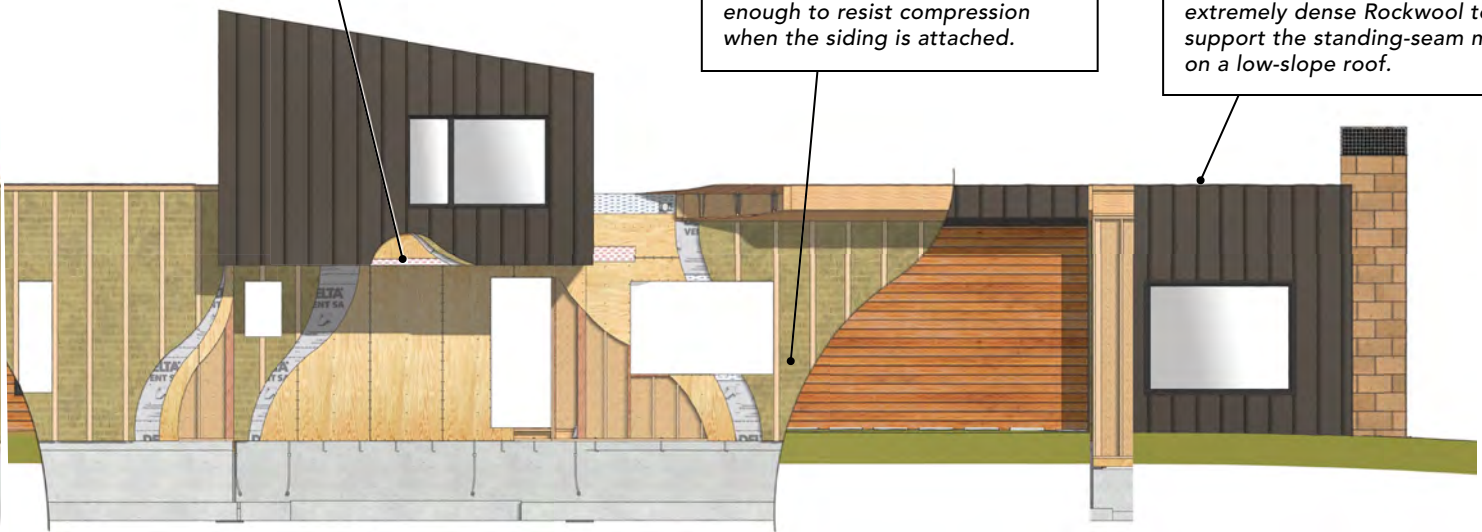
Exterior air barrier. The sheathing is air-sealed with Delta's self-adhesive, water-resistant air barrier. Wrapping the edges of the overhang first with Delta Multi-Band tape ensures a good seal.



A warm jacket. Exterior insulation acts like a down coat to reduce the ability of framing members to transmit cold through walls. ComfortBoard 110 is dense enough to resist compression when the siding is attached.

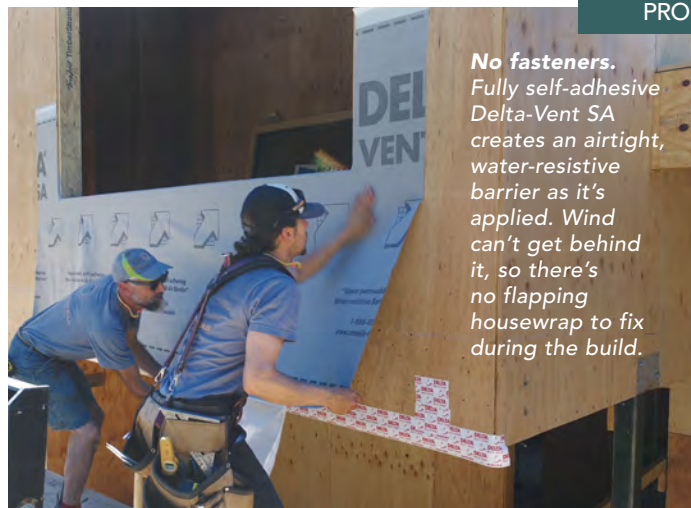


Moving the dew point. In this climate, 30% of the total insulation in an assembly should be on the exterior to prevent condensation on the sheathing. That's 5 in. of extremely dense Rockwool to support the standing-seam metal on a low-slope roof.



values for the climate. To prevent condensation on the sheathing, we balanced the total amount of exterior insulation to be at least 30% of the interior cavity insulation. A house with a simple form and less surface area requires less insulation than we are putting into our house. With our complex architectural form, we had to boost our insulation values to reach the Passive House level of performance that we're targeting.

We have an R-80 roof assembly, an R-39 wall assembly, and an R-60 elevated floor system. The cantilevered floor/porch ceiling at the front entry is treated as the mirror image of our roof assembly, with exterior insulation on the underside of the floor



No fasteners. Fully self-adhesive Delta-Vent SA creates an airtight, water-resistant barrier as it's applied. Wind can't get behind it, so there's no flapping housewrap to fix during the build.

PRODUCT KNOWLEDGE

- Delta-Vent SA is highly vapor-permeable to allow assemblies to dry to the outside.
- It fully adheres to concrete, masonry, OSB, and plywood sheathing without fasteners. A horizontal self-adhesive edge lap creates a watertight air barrier.
- Compatible Delta tapes and sealants are available for flashing penetrations.

EUROPEAN WINDOWS

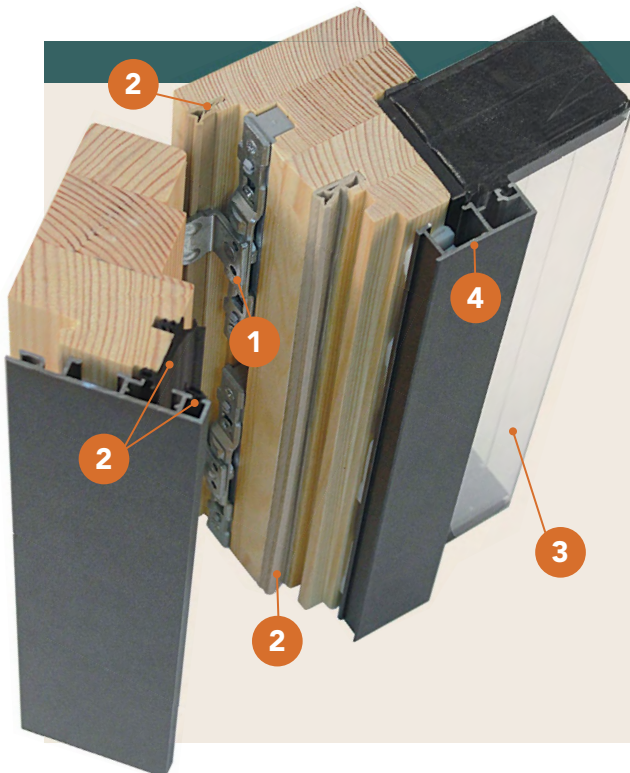
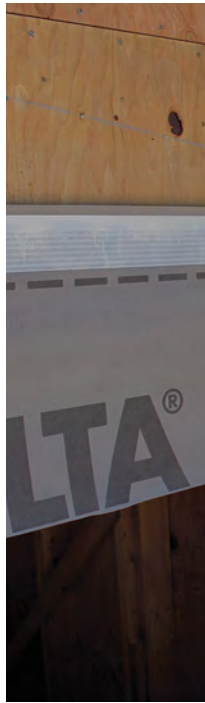
We expect the air barrier to get us below 1.0 ACH50, but we want our house to have Passive House-level performance, so we're aiming for 0.6 ACH50 or less. Past projects have taught us that once we've air-sealed the framing, the air leaks that we can't address are through the windows and doors. Finding truly airtight windows and especially doors that are manufactured in the United States and that offer the aesthetic quality we seek remains an ongoing challenge. We want doors and windows that provide performance to match the rest of our assembly and that are wood clad and beautifully crafted. This is most important for the doors, as they are the most frequently used component and often one of the leakiest. We chose Zola European Windows and settled on their Thermo Clad line, as the glass package is well-suited for our climate and offers four seals on the doors and operable windows for a very effective air-seal. The factory-finished interior is not only a higher quality than we can get with site finishing, but is less than the cost of having a painter finish raw wood.



Bevel the sill. Dave takes a grinder to the sill to provide positive drainage to the outside.



Start from the bottom. The peel-and-stick Delta-Vent SA wraps the opening. The self-adhesive WRB eliminates air leakage at the rough opening without additional tapes.



Passive House windows

Anybody who has ever designed or built a Passive House has wrestled with window selection. Passive House-certified windows are heavy, expensive, and typically end up being shipped from Europe. If you've ever wondered why they cost so much, here's a rundown of the window features on our house.

- 1. Tilt-and-turn.** The windows can swing inward to fully open or tilt in at the top for more limited ventilation. The multipoint locking system closes with a satisfying solid engagement.
- 2. Airtight seals.** The locking system pulls the windows tightly against four separate gaskets that run around the perimeter of each window for a complete seal.
- 3. Triple glazing.** Three Argon-filled glass layers reach R-11. The high glass performance allows the use of large windows without a drastic performance penalty.
- 4. Thermally broken frame.** The aluminum-clad wood frames are R-5 for a total window performance of R-7. By way of comparison to U.S.-manufactured windows with the NFRC rating, the U-factor of these windows is U-0.16 for fixed windows and U-0.17 for operable windows.



Shingle-flash the opening. With the head flashing in place, Delta flashing tape on the sill and corners ensures the integrity of the air and water barrier.



Securing the window. Zola windows are flangeless. Brackets are attached and the heavy window installed from the inside. 2x scraps tacked to the sheathing across each corner of the rough opening act as insurance against a dropped window. Screws through the brackets and the jambs secure the window.



Tape the edges. On the outside, the window head and jambs are sealed to the WRB with tape. After filling the cavity with insulation, the interior is taped on all four sides.

joists for a thermal-bridge-free floor that also reaches R-60.

We aren't dogmatic about avoiding all foam products (we use them when dictated by budget or remodeling constraints). Our preference, though, is to use as little rigid foam or spray foam as possible. Building redundancies into high-performance assemblies makes sense to us, so we particularly like using mineral wool as the exterior insulation, as it is vapor open and ensures that our assemblies will have the ability to dry toward the interior or exterior. Manufactured from basalt and slag from the steel and copper industries, mineral wool is fire resistant, doesn't off-gas, is bug resistant, and has no mold food source. On our house, we used Rockwool ComfortBatts to fill the 24-in.-o.c. framing bays, and they fit nice and tight into the wall framing on the interior. On the exterior, we used several different Rockwool board products. The board formulations are available in different densities, so we're able to use it as subslab insulation, beneath the metal roofing and metal cladding, and with the cedar

siding. The exterior insulation allows us to create a thermal break between the cladding and the framing. No good deed goes unpunished, though, and the trade-off of using exterior insulation is that trimming and detailing the cladding is trickier and more labor intensive.

Eliminate thermal breaks

To eliminate thermal bridges at porches, overhangs, and the balcony we used Maine Deck Brackets as standoffs between the framing and the element. At the south-facing second-floor master-bedroom balcony, these aluminum brackets act as a standoff for the ledger and we're able to run insulation behind the balcony ledger with just a thin metal fin between the balcony and wall framing. Working with our structural engineer during the design process, we devised a way to hang the balcony with threaded rods off the roof system, so the second story appears to be one volume projecting out beyond the first story (yet the balcony is thermally bro-

ken from the house). Similarly, we detailed the uninsulated roof areas of the overhang and the porch with ledgers mounted to Maine Deck Brackets to allow for near-continuous exterior insulation. The porch and eave ledgers are installed 5 in. above the roof deck so that the plywood of these uninsulated roof sections aligns with the exterior roof insulation, creating a seamless plane.

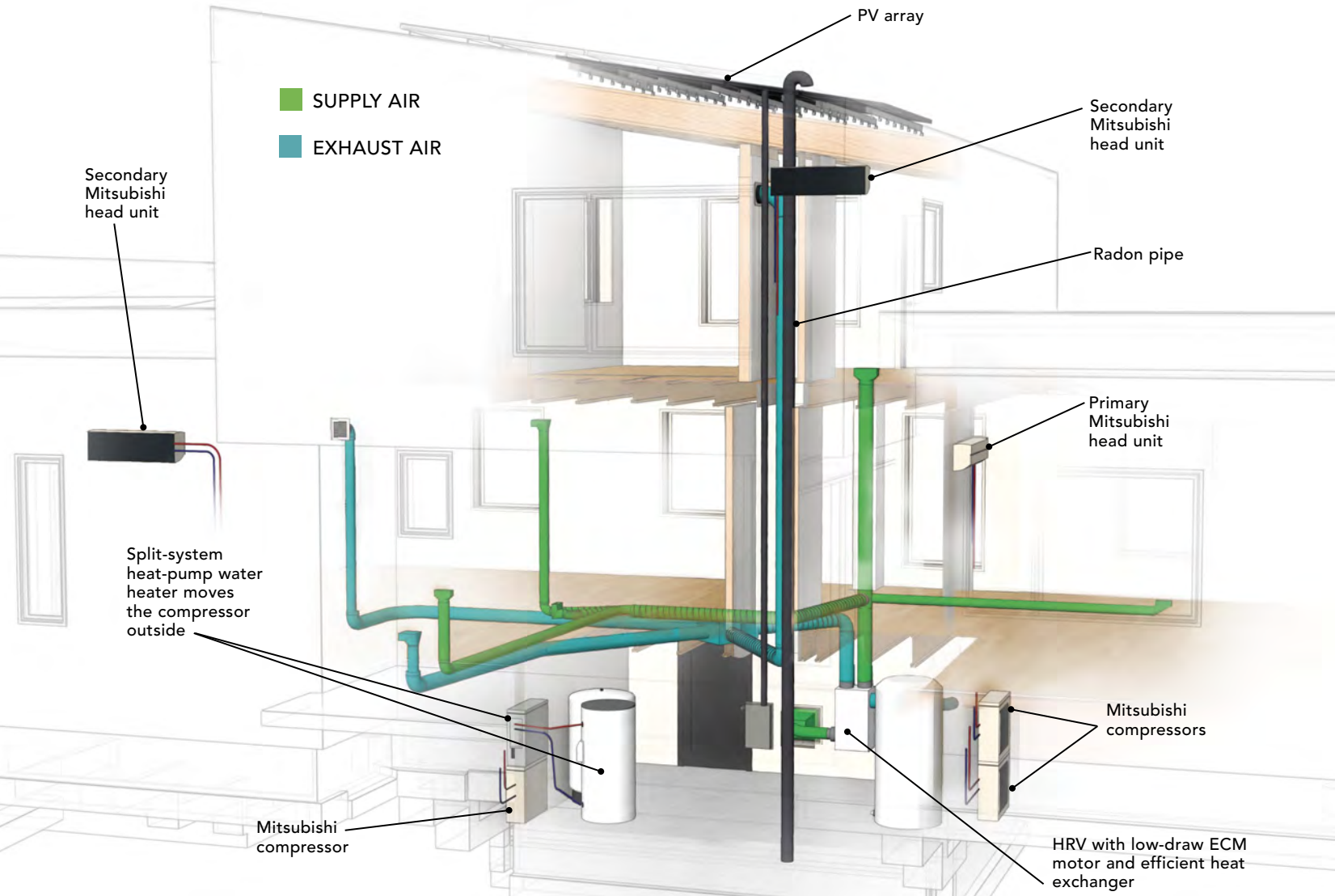
A small cooling system

Mitsubishi minisplits take care of the heating and cooling. We calculated heating and cooling loads for our home and found ourselves faced with an interesting challenge. The calculated loads for the home came to roughly 1 ton for the whole home. And while our house has low loads, it has some compartmentalization and is multiple stories. We wanted to be able to operate the home in two zones, upstairs and downstairs, and wanted to make sure that there wouldn't be much room-to-room variance in temperature. As Dan Perunko and Gavin Healy, our mechan-

MECHANICALS SHRINK THE PV ARRAY

Heat pumps, which extract heat from one place and move it to another, are efficient because they have a COP greater than one—in other words, for each unit of energy consumed in operation, it can put out more than one unit of heating or cooling.

Air-source heat pumps are the heart of the house's mechanical system—we use them for space heating and cooling and for domestic hot water. With Passive House-level airtightness, the house relies on an HRV for mechanical ventilation.



ical contractors at Balance Point Home Performance, say, “People often conflate efficiency and comfort, and while they intersect with each other, it’s important to figure out what expectations the occupants have for considerations like system responsiveness.”

Mela’s preference would have been to use a ducted unit for the obvious aesthetic reasons. However, ductless minisplits fit better into our budget, and we were able to meet the climate control goals with three ductless units. The downstairs load is 8000 Btu and the upstairs is 4000 Btu. The upstairs unit will likely be used more to meet cooling demand.

Because the first floor of our house is over 60 ft. long, it’s better suited to two wall heads to reduce hot and cold spots, but it’s unlikely that all three units will run at the same time. There may be times when just one of the smaller units is running (which allows for more adjustability, if, for instance, we want the bedrooms cooler for sleeping). Despite the high summer temperatures in our area, there should be long stretches when we let the air conditioners sit idle. With our tight, well-insulated house and a typical 30° temperature swing at night, we can flush the house with cool night air and close it up dur-



ing the day. However, the poor air quality that comes with more frequent forest fires and a longer fire season means this strategy isn't always feasible.

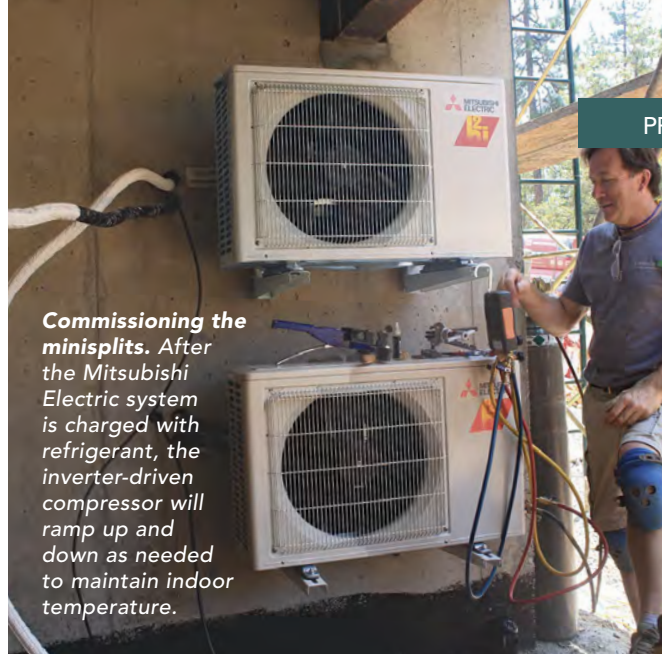
The capacity of Mitsubishi's smallest heads still exceeds the loads in our two smaller zones. However, by installing three completely separate minisplit units, our overall labeled efficiency is higher. And we expect that the separate pieces of equipment cycling independently from each other will minimize the potential inefficiencies that are driven by oversizing.

Low-load HRV

Residential indoor-air quality benefits greatly from mechanical ventilation and filtration and is a necessity in an essentially airtight house. Our mechanical contractors had in their inventory a European-manufactured HRV no longer sold in the U.S. and recommended it for our house. It checks all of the boxes we need in an HRV: It can be set up to automatically boost supply makeup air when the kitchen exhaust or laundry dryer is running, it has a low-draw ECM motor, and the heat exchanger is very efficient.

Heat pump with a twist

We've also chosen an air-source heat pump for hot water. The Sanden water heater is a unique product. The compressor is mounted outside with the minisplit compressors and it shares many of the same features: slimline construction, inverter motor, and ability to operate to -20°F. The outdoor compressor is able to heat water to 175°F. The compressor on more-conventional heat-pump water heaters is located with the tank and typically means cool air is dumped in the house during the heating season. With Sanden's split system there's no energy penalty in the win-



Commissioning the minisplits. After the Mitsubishi Electric system is charged with refrigerant, the inverter-driven compressor will ramp up and down as needed to maintain indoor temperature.

PRODUCT KNOWLEDGE

- The kumo cloud app allows homeowners to control settings and check filter status from a smartphone or tablet.
- Hyper-Heating means that the compressor works at 100% efficiency down to an outdoor temperature of 5°F and provides heat at temperatures as low as -13°F.
- An optical eye on the indoor unit scans the rooms and adjusts the temperature and airflow automatically to eliminate hot and cold spots.

ter. It doesn't have a (comparatively inefficient) electric-resistance backup element, so we installed the 115-gal. tank for a high first-hour rating. The large storage tank allows us to load shift electric use by shutting down the compressor during high time-of-use rates and rely on the stored hot water. Also, the larger tank will allow for better tank stratification, which improves the performance of all heat-pump water heaters.

It's important when selecting products to consider their life-cycle implications, not just their operating performance. That's why we really like the CO₂ refrigerant Sanden uses. It has a global-warming potential of 1, compared to the commonly used R138a with a global-warming potential of 1438.

Based upon our tight, well-insulated envelope and efficient all-electric mechanicals, we will easily be net-zero energy with the 6.5kw PV roof-mounted array. Often, we install smaller systems and then observe the occupant usage over a year to determine whether more panels are needed. But given that we are going after several rebates and incentives set to change in 2019, we opted for a PV system that will likely make our home net-positive and will keep us net-zero energy if we are able to get an electric vehicle at a later date. With the hard work of the performance details behind us, we're turning our attention to the aesthetic details in the next installment. □

Mela Breen and David Good are the founders of Atmosphere Design Build, a design/construction firm in Northern California. Photos by Kevin Nielsen, except where noted.

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COOLING & HEATING



PRODUCT KNOWLEDGE

Futureproof dryer vent. The DryerBox DB-480 can be installed to vent up or down. Either orientation accommodates a dryer on the floor or on a pedestal.

- The recess provides space for ductwork without pinching or crushing it, and the dryer sits tight to the wall.
- An extension rim acts as integral corner bead for quick drywall installation.
- Pairing with DryerWallVent helps maximize airflow efficiency.