Building Ω: Mechanical Systems

Small heat pumps, balanced ventilation, solar power, battery storage, and exceptional airtightness helped turn an ambitious owner-builder project into a net-zero reality

By Amber Westerman , Clay Yapp | September 17, 2026



Over the past few years, as a designer and construction coach, I've had the privilege of helping homeowners navigate the complex path to net-zero. In an introductory article, we met Clay and Danielle in rural Wauzeka, Wisconsin (climate zone 5A), and discussed the design of their two-story, 1536-sq.-ft. home. In a second article, we followed them from framing through insulation. In this final article, we'll cover the mechanical systems that made net-zero possible, and the blower-door test that proved their air-control strategies worked to create a practical, affordable, resilient, and healthy home.

Right-sizing the heat pump

Because high-performance, airtight homes have very low heating and cooling demands, off-the-shelf mechanical systems are often oversized. Having never engineered a mechanical system before, Clay completed a room-by-room Manual J calculation to determine the exact heating and cooling demands of the home. Based on the data and by referencing NEEP's Cold Climate Air Source Heat Pump List, he selected a 9,000-Btu/hour ductless air-source heat pump (ASHP) for the main floor and a 6,000 Btu/hour unit for the second story. These small minisplits were intentionally slightly undersized, to minimize energy-wasting short-cycling while maximizing interior dehumidification during the summer.



> *Considering our climate, where the shoulder seasons make up most of the year (not to mention some mild winters that I'm sure aren't ominous), I'd rather have something smaller that needs a little help a couple nights of the year than a big hoss who inflates my electric bill the rest of the time.* —Clay Yapp

Designing the ventilation system

To ensure a constant flow of fresh air (whenever windows are closed), the couple installed a fully ducted energy-recovery ventilator (ERV). The system extracts stale, humid air from the bathrooms and kitchen, runs it through a high-efficiency core to capture sensible and latent heat energy, and transfers that energy to filtered, incoming fresh outdoor air delivered straight to the bedrooms and great room.



Danielle calculated the specific duct and grille sizes required for each space, cutting and fabricating all the components herself, including custom decorative grille covers. She also installed jump ducts on the great room's tall wall to passively distribute convective heat upstairs, while the open central stairwell allows cool air to sink naturally back to the main level.

Heating with masonry mass

The primary source of heat for the home is a masonry mass heater. After years of cutting, splitting, stacking, and loading cordwood into a conventional stove, Clay wanted a more efficient solution. A masonry heater burns just one armload of wood per day. The fire burns rapidly and cleanly at extremely high temperatures, maximizing combustion while routing the exhaust gases through an internal maze of firebrick channels.



The masonry absorbs the thermal energy and slowly radiates it into the living spaces over the course of the day. The resulting exhaust trailing from the chimney is nearly free of creosote and polluting particulate matter, and nothing but a small pile of fine ash is left in the firebox. To master this complex installation, Clay attended a hands-on three-day workshop before ordering the necessary steel components and flue system from a regional supplier.

Domestic hot water

Beyond the inclusion of high-efficiency, low-flow fixtures, the plumbing system follows a straightforward, conventional approach. However, rather than opting for a costly electric

heat-pump water heater (HPWH), Clay selected a Rheem Marathon electric-resistance water heater.



Constructed from high-strength plastic inside and out, the tank simply can't rust out and is wrapped in 2.5 in. of continuous foam to minimize standby thermal losses. Clay wired the water heater to a timer, programming it to operate exclusively during daylight hours. This simple hack allows the home's solar array to power the heater, for virtually free hot water. Given their conservative two-person lifestyle, the extended payback period for a

HPWH would likely never net a return on investment compared to the super-insulated Marathon.

Solar and battery storage
To achieve net-zero performance, a subcontractor was hired to install a 7.2-kW photovoltaic (PV) solar array directly onto the south-facing great room roof, sized to offset the home's projected annual electrical demand.



Clay then stepped back into his owner-builder role to tackle the energy-storage system himself. He integrated two Enphase batteries providing 10 kWh of backup capacity for use at night or during grid outages. While professional installation quotes for the storage system hovered around $22,000, Clay sidestepped the markup by sourcing the equipment and executing the installation himself, dropping his total out-of-pocket cost to just $9,000.

The blower-door test

Testing the house for airtightness during construction was very important to Clay and Danielle. They were determined to catch and remediate any stray leaks while the framing cavities were still exposed and easily accessible, long before insulation or drywall went up. High-performance best practice typically recommends three blower-door tests: first before insulation, second after drywall, and a final test prior to occupancy.

However, securing a certified rater willing to travel to their rural location was a real struggle. The rater they finally booked agreed to make the nearly four-hour roundtrip just once—for the critical preinsulation test. Upon arrival, a hitch arose—the rater didn't have a full set of reduction rings for his blower-door fan. Armed with only Ring A and Ring B but lacking the crucial Ring C typically required to measure highly airtight homes, the rater fired up his equipment.



As the house depressurized, friendly wagers were placed on the final number. The rater bet 500 CFM, Danielle guessed 450 CFM, and Clay optimistically hoped for 400 CFM. For a house of this volume, 400 CFM would translate to an exceptional performance score of 1.0 ACH50. Because the rater primarily tested production housing, he had literally never required a Ring C in the field. Cheers erupted when the gauge dropped, stabilized, and finally bottomed out at an astonishing 330 CFM—surpassing their goal and landing at a very impressive 0.81 ACH50.

Clay had the final blower-door test performed recently (Ring C in use) with the final numbers coming in at a very respectable 0.70ACH50.

Lessons from an owner-builder

The pursuit of rural self-sufficiency has been undertaken by generations of Americans, each in their own way. While modern home ownership can often feel financially out of reach, Clay and Danielle proved that innovative problem-solving and an unyielding DIY work ethic can still bridge the gap. Today they are fully settled into a cozy, resilient, net-zero home. Their efforts have earned them a well-provisioned lifestyle: a stocked pantry, two year's worth of neatly stacked cordwood, a freezer full of venison, and enough battery storage to comfortably ride out several days of cloudy skies.

> *The past year has been the hardest year of my life, and it's not really even close. This says as much about the life I lucked into as it does about my year, but the point stands. It was a toughie. We passed all our inspections, aced our blower-door test, and the appraisal came through for well over what we needed. We did almost all the work ourselves and, I'm proud to say, never had to rip anything out or do anything over. The mistakes, though inevitable, were minor, and the list of things I wish I could get back is small enough to be a rounding error. The home is solid, cozy, and absolutely gorgeous, which I can say because I didn't design it. I just had to make it look like the pretty pictures.* —Clay Yapp

They've made new friendships within their community. Looking forward, Clay is leveraging his firsthand building-science education to train as a certified RESNET Home Energy Rater. Equipped with unique hands-on insight, he hopes to act as a crucial liaison between owners and builders, filling the knowledge gaps that so often lead to construction errors.

The modern DIY ethos has never been more viable or widely accepted. Rather than casting doubt, friends and family are increasingly eager to rally behind owner-builders through the toughest phases of a project. High-quality building science and home-design information are more democratized than ever before. Educational resources abound, including builder conferences, online classes and videos, owner-builder blogs and forums, and industry publications like *Green Building Advisor, Fine Homebuilding*, and *Journal of Light Construction*. For those looking to gain initial confidence, volunteering for a local build with organizations like Habitat for Humanity remains an unmatched training ground.

Every owner-builder will ultimately draw their own line regarding what to build themselves and what to delegate to specialized trades. Some will draft their own architectural plans, while others will partner with professional designers. Some will limit their hands-on efforts to material ordering and logistics, while others will tackle more technical details. While nothing can fully replace years of raw field experience, cultivating a rigorous research mindset, staying organized, and choosing the right guidance will carry an ambitious homeowner a remarkably long way.

> *If I can help it, this house will never be finished. I can't call it home if there's not a project in it somewhere.* —Clay Yapp