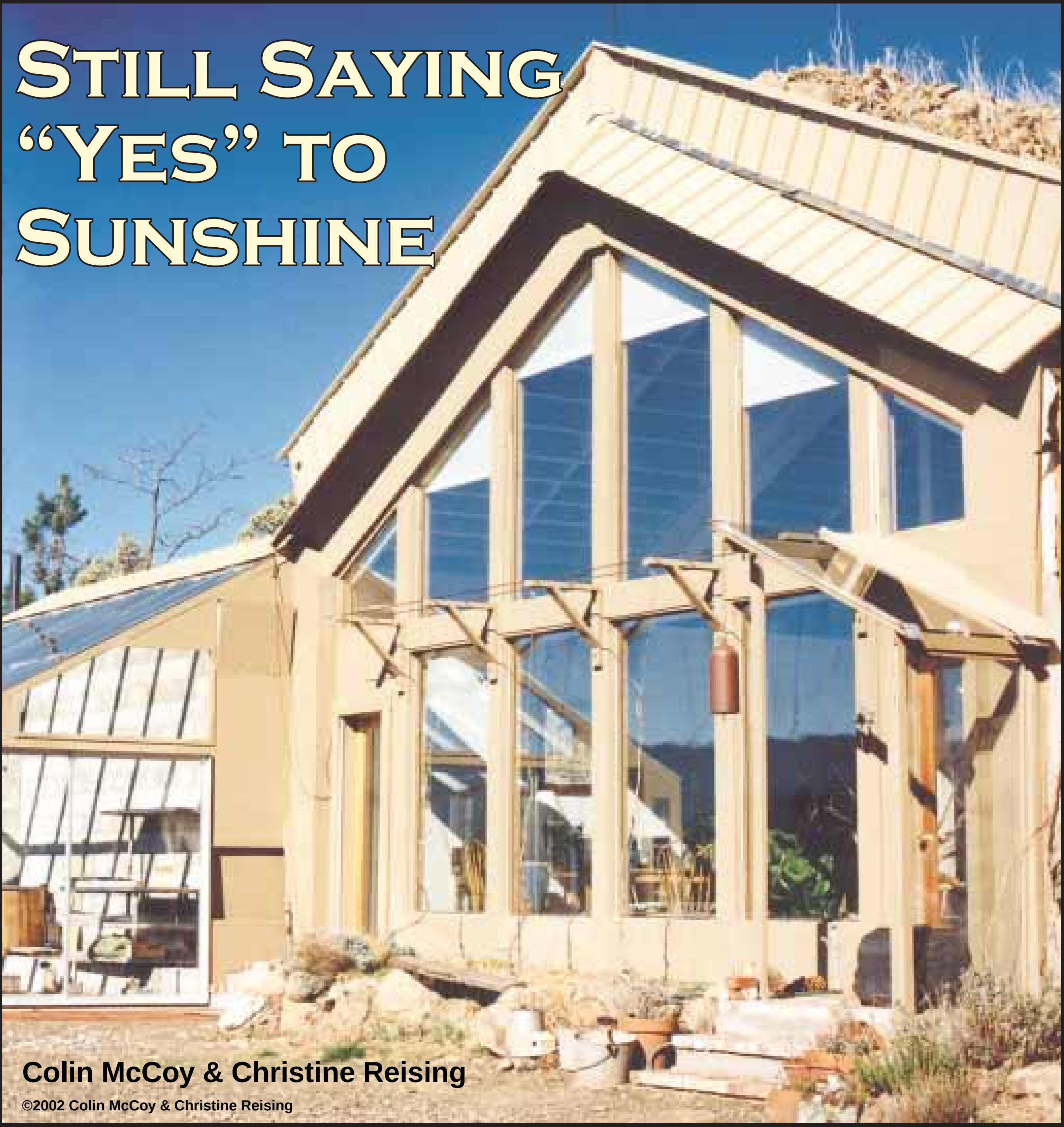
Still Saying "Yes" to Sunshine

Colin McCoy & Christine Reising



Colin McCoy and Christine Reising's earth-sheltered and passive solar home in sunny southern Oregon stays cool in the summer and warm in the winter.

We opted to build an underground, passive solar house, due to the success of this building method for our previous homes. Surrounding a house with earth tempers the fluctuations of temperature within. The site we chose for the house was the crown of a small, rocky hill with excellent southern exposure. This enabled us to receive the maximum amount of sunshine during the short days of winter. The rocky site would be difficult to excavate, but would provide excellent stability and sturdiness of construction.

A Whisper H900 wind genny with 600 watts of PV meet the family's power needs.

Earth-Sheltered Past

With my seven-year-old daughter, I moved from the suburbs of Medford, Oregon, into the mountains of southern Oregon in the fall of 1973. At first we lived in a cabin, and then moved into a house I built, using wood for heating and cooking, and kerosene lamps for light. We were joined by Christine in 1976, and we built our first earth-sheltered, passive solar home in 1980. We used our own sawmill to saw most of the lumber for the new house.

In 1981, we purchased photovoltaic panels to power electric lights and a refrigerator. We sold this house and property in 1986, and moved to 80 acres near Jacksonville, Oregon. In 1989, we built our second earth-sheltered, passive solar house. (See *HP24.*) Due to the encroachment of suburbia, we sold this house and acreage in 1994, and moved into a barn on 320 acres near Lake Creek, Oregon. In 1998, we finally were able to grind our way through the Jackson County permit process and started our present home.

Approval & Excavation

Before moving, we had a road built into our homesite. This gave us access to our barn. After making part of it into a living space, we moved. We planned on living in the barn (all 528 square feet of it) for a year. But the permit process took longer than we expected, and we ended up living there for five years.

The county, pleading ignorance about earth-sheltered structures, was hesitant to approve our building plans. I was prepared with research from the University of Minnesota, magazine articles, and *The Underground House Book*. The county's viewpoint was that this just wasn't Minnesota. County planners tend to favor building methods with which they are familiar, and this would prove to be a lengthy learning experience for all of us. With the help of an engineer, we were finally able to proceed.

We realized right away that hiring all of the excavation work we planned to do would cost a fortune. So we purchased a used John Deere 310 backhoe for US$12,500, and used it to excavate for our house. It also came in handy to dig water lines, drainfield lines, water sumps, ponds, holes for tree planting, drainage ditches along the road, and several other jobs. After four years of use, we sold the backhoe for US$10,500.

The site for the house hole was solid rock. We went as far as we could with the backhoe, but eventually we had to have the rock drilled and blasted, using a total of 150 pounds (68 kg) of ammonium nitrate and 25 sticks of dynamite. The total size of the hole was about 40 feet (12.2 m) wide, 46 feet (14 m) long, and 12 feet (3.6 m) deep at the sides. Most of the excavated rock was pushed to the front of the house area to provide some flat space.

Concrete Forever

We dug the trenches for the footings, but hired out the concrete work. Since the house was to be buried, it needed to be strong. The footings for the walls are 5 feet (1.5 m) wide, and 18 inches (45 cm) deep; the walls are

After the excavation produced a home-sized hole, construction began on the concrete walls.

McCoy/Reising Home Construction Costs

Item	*Cost (US$)*
Concrete	$ 36,247
Lumber	9,965
Septic system	9,414
Misc. hardware, paint, doors	9,051
Structural steel and installation	7,615
Insulation	3,981
Glass	3,475
EPDM rubber for roof	1,815
Window shades	1,419
Fixtures and plumbing	1,368
Stove and chimney, est.	1,200
Electrical wiring, boxes, switches, etc.	950
Total	$ 86,500

16 inches (40 cm) thick and 10 feet (3 m) tall. Several tons of rebar went into the concrete.

The back wall is two stories tall, with the second story walls 12 inches (30 cm) thick. An 8 foot (2.4 m) wide by 12 foot (3.6 m) long by 8 foot high room at the second floor level provides a rear exit. Total concrete in the house came to 130 cubic yards (98.4 m^3).

After the walls were poured, they were waterproofed on the outside with Thoroseal, a cement sealing mixture, and insulated to R-16 with 4 inches (10 cm) of closed cell foam. The ambient earth temperature here is 55°F (13°C). Four mil plastic sheeting was placed against the insulation, and held in place by $^3/_8$ inch (10 mm) reject particle board.

A 4 inch drain pipe was placed at the base of the walls on the outside, and covered with drain rock. This French drain ensures that water going down the outside wall is directed away from the building to prevent seepage and hydrostatic problems. Soil fabric was placed over the drain rock. This fabric is permeable to water, but keeps soil from clogging the drain pipe. The drain pipe is placed around the perimeter of the walls below the footing, and diverts the water away from the walls to where the pipe emerges in the daylight on either side. The ends of the pipe are covered with screen to keep rodents out.

The walls were then backfilled with the dirt and rock from the house excavation. Huge, junk, earthmover tires, filled with rock, act as riprap to hold the west wall's backfill. On the east end, we stacked huge boulders to create a retaining wall to hold the backfill in place. For an amateur backhoe operator, this was a bit tricky.

Roof Construction

The peaked roof is held up with four, huge, steel I-beams, with three center posts in the house and five steel uprights across the front. The span across the front of the house is 30 feet (9.1 m). The span from front to rear is 40 feet (12.2 m). Our engineer, Phillip B. McCulloch of Medford, Oregon, specified the placement of the beams after calculating the roof loads. He assumed 25 pounds per square foot for snow load, and a saturated earth load of 140 pounds per cubic foot.

The ends of the I-beams were welded to steel plates embedded in the tops of the walls. Bolted to the top of the I-beams are 2 by 12 (5 cm x 30 cm) Versa-Lam purlins (made from fingerjointed, laminated Douglas-fir veneers). Next, we glued and nailed $1^1/_8$ (2.9 cm) inch tongue and groove plywood to the purlins as roof sheathing. Then came 30 pound felt and 12 inches (30 cm) of closed cell foam insulation (R-36), glued in place. The 12 inches of insulation was necessary

The steel I-beams arrived by truck, and were hoisted into place by a crane.

Roof layers—shown are the roof felt and closed cell foam over tongue and groove plywood.

because, according to the building department, "Dirt has no insulating quality."

This was confirmed by Ralph Smoot, a builder of earth-sheltered homes in Austin, Texas. Basically, the benefit of an earth-sheltered home is that the earth moderates the temperature swing by storing heat. So, he recommends that you first find out what your yearly average daytime temperature is, and use the following guidelines:

The finished roof in full bloom—with weather vane and chimney.

- 3 feet (0.9 m) of dirt covering will yield a plus or minus 9°F (5°C) variation from the average;
- 9 feet (2.7 m) of dirt covering will yield plus or minus 5°F (3°C) variation; and
- 27 feet (8.2 m) of dirt covering will keep the temperature constant.

Ralph says that if your area gets frost, the structure needs to be insulated (high density foam) and waterproofed, again! Adding insulation helps prevent stored heat from escaping. (For an article about earth-sheltered homes, see *HP29,* page 22.)

After the insulation, two, 50 by 20 foot (15 m x 6 m) sheets of EPDM rubber roofing came next. Each sheet weighed 450 pounds (204 kg), and was very difficult for two people to handle. The EPDM was placed on both slopes and overlapped by two feet at the center. Contact cement was used to glue the overlaps. A sudden rainstorm while we were gluing proved that contact cement really won't hold when wet. Tempers got short, and cooling off, drying out, and regluing were in order.

Two layers of horse fencing (road wire) were laid down on top of the EPDM to act as reinforcement, and 3 inches (8 cm) of concrete was poured on the roof. We hired a concrete crew that specialized in sidewalks to complete this stage. Working on the steep pitch of a roof proved to be a challenge for these guys, and provided a bit of comic relief.

The house's open interior, looking toward the north exit.

We placed $^{3}/_{8}$ (10 mm) inch reject particle board on the concrete to act as a cushion, and to protect it from damage during backfilling. About 3 feet (1 m) of dirt was then placed on the roof. A 3 foot parapet across the front and back of the roof keep the dirt from spilling over the ends. This spring, wildflowers were in full bloom up there.

Interior

The floor of the house is a 4 inch (10 cm) concrete slab, covered with 14 inch square (35 cm) floor tiles. We chose a tile that varies from light color to a medium dark. This gives good heat absorption from sunlight without making the house seem dark

The loft's view—the passive solar design includes a window-to-floor ratio of about one to eight.

The kitchen, Russian masonry heater, and wood cookstove that doubles as a hot water heater.

inside. We did not insulate under the slab because we were afraid that the house would overheat.

The walls inside have a thin coat of plaster, floated to a sand finish. The back wall of the bedroom loft is covered with cedar we milled ourselves.

The layout of the interior is open, with the bedroom loft overlooking the great room. Under the loft, is our library, with a bathroom off the side. Also under the loft is a pantry, opening off the kitchen area. Upstairs, at the rear of the loft, a closet-lined hallway serves as the second-story egress. Additional storage space is located under the eaves.

Dominating the great room is a Russian masonry heater and its chimney. We had lost the plans we had gotten from a friend for this heater, but since it was the same as the one in our last house, we were able to build it from memory. The heater is seldom used because of the solar gain we get in the house. If the heater is needed, a couple of armfuls of wood, burned at a high temperature, heat the stove's five tons of mass. The outside of the stove never gets too hot to touch, and will stay warm for two to three days.

The front of the house is all windows, which provide lots of light, as well as solar heating. The windows are regular, double pane glass. Pleated shades are used to keep excess summer and fall heat out and winter nighttime warmth in. We use an antique wood cookstove for fall, winter, and spring meals. This also adds heat to the house, so in the summer, we use solar ovens and a small, two-burner, propane stove.

The total area of the house is about 1,800 square feet (167 m^2). If a passive solar house is too large, it will usually not maintain an even temperature, and if too small, will likely overheat. We have a very good ratio of window area to thermal mass to house volume. The temperature year-round is 68° to 74° F (20–23°C). The ratio of window to our floor area is about one to eight.

Water System

When we decided on our domestic water system, we went with one that had proven adequate for our needs in our last two houses. Collection of rainwater in storage tanks provides all of our domestic water. Our rainwater has no minerals, while some local wells have arsenic and heavy concentrations of other minerals.

The collection system consists of a galvanized shed roof over two, 1,300 gallon (5,000 l) drinking-water-grade, black tanks. The rainwater is collected from the shed roof and channeled through a screen and into the tanks. Once a year, during a heavy rain, we put $^1/_4$ teaspoon or so of chlorine bleach into the intake. The heavy water input mixes with the bleach, which prevents any bacterial or algae buildup.

The water tanks are located about 150 feet (46 m) higher than the house, so we have plenty of water

Rainwater, collected in these tanks, provides all of Colin and Christine's domestic water.

The underside of the PV rack showing its homemade mounts.

McCoy/Reising System Loads

Load	Watts	Hrs./Wk.	Avg. WH/Day
VestFrost fridge, 12 cu. ft.	64	140.0	1,280.0
Radio/stereo	38	50.0	271.4
Lights, 12 VDC	15	112.0	240.0
Computer	138	3.0	59.1
Hot tub filter	22	7.0	22.0
Circular saw	1,500	0.1	21.4
Sewing machine	100	1.0	14.3
Electric drill	700	0.1	10.0
Blender	400	0.1	5.7
Ceiling fan, 12 VDC	8	5.0	5.7
Lights, 120 VAC	13	2.0	3.7
		Total	1,933.4

pressure. Water exerts 1 pound per square inch (psi) of pressure for every 2.3 feet of elevation gain. So our operating water pressure is about 60 psi at the house. Inside, we have a shower, toilet, and bathroom and kitchen sinks, with a low-flow shower head and flow restrictors throughout. With careful use of water we have enough for our needs. Our laundry is done at a laundromat and our dishes are washed by hand. We choose to have neither a washing machine nor a dishwasher—the two biggest water users in the average house.

Our hot water is heated by a custom-fabricated water jacket, installed in our wood cookstove. Hot water is stored in a super-insulated, standard hot water tank, and is circulated through the stove by thermal convection. One or two meals a day cooked on the stove provide plenty of hot water during fall, winter, and spring. During the summer, when we are not using the wood cookstove, we use solar showers. Careful layout of kitchen and bathroom plumbing eliminated long runs of hot water piping. The use of rainwater eliminates any buildup of minerals in the hot water jacket.

RE System Evolution

While we were living in the barn, we had minimal room. We had a Wind Baron Neo Plus 750 watt wind genny and six Siemens SP75 PV modules. Their output was stored in twelve Interstate L-16 batteries. A Trace 2512 inverter provided AC power for our VestFrost refrigerator/freezer. We chose the VestFrost because it does not use ozone-destroying CFCs. Lights were all 12 volts DC. The size of this system was overkill.

The loft's north exit leads outside to these electrical compartments. Also pictured are the wind genny's tower base and the PVs.

The barn living quarters have since been converted to a shop that is powered by the Wind Baron and an old Arco M75 salvaged from our first use of solar-electric panels in the mid-1980s. Energy is stored in six, ancient T-105 batteries. The Trace 2512 serves a few 120 volt power tools, a concession to the fact that I am not as young as I was when I started my off-grid lifestyle 29 years ago.

McCoy/Reising PV/Wind System Costs

Item	*Cost (US$)*
Trace SW2512 inverter	$2,600
6 Siemens SP75 modules, 75 W	2,530
12 Interstate batteries, L-16	1,548
Whisper H900 wind genny & controls	1,500
Tower and installation	1,500
2 AstroPower AP7105 modules, 75 W	790
2 Breaker panels, 12 VDC & 120 VAC	450
Disconnect switch, 12 V, 400 A	300
Ananda PV60 charge controller	250
Misc. wiring and parts	225
DeSulfator, DS-1000	144
Total	$11,837

For our new house, we have eight PV panels—the six Siemens SP75s and two, 75 watt Astropower modules for a total of 600 rated watts. These are controlled by an Ananda Power Manager PV60 charge controller. The panels are mounted over the rear exit on two I-beams set in concrete. A 2 inch galvanized pipe is bolted to the I-beams, and the PV rack is U-bolted to the pipe. Adjustable braces from the rack to the I-beams keep the whole thing stable, and allow for winter and summer orientation.

We used #4 (21 mm^2) wire for the 20 foot (6 m) distance from the PVs to the charge controller. I used a chart to find the correct wire size, then chose the next size larger.

Another Wind Generator

We also have a Whisper H900 wind generator. Our Whisper is mounted on a four-section, army surplus crane boom. Total height is 56 feet (17 m), which gets the genny adequately above surrounding trees. The wire run from the genny to the controller is 65 feet (20 m), using #00 (67 mm^2). The Whisper produces 60 amps peak output when winds are 28 mph.

We are still using the twelve Interstate L-16 batteries to store energy in our system. The 6 volt, 375 amp-hour batteries are wired in series and parallel for a rated 2,250 amp-hours at 12 VDC. I made my battery cables out of welding cable from a defunct portable welder.

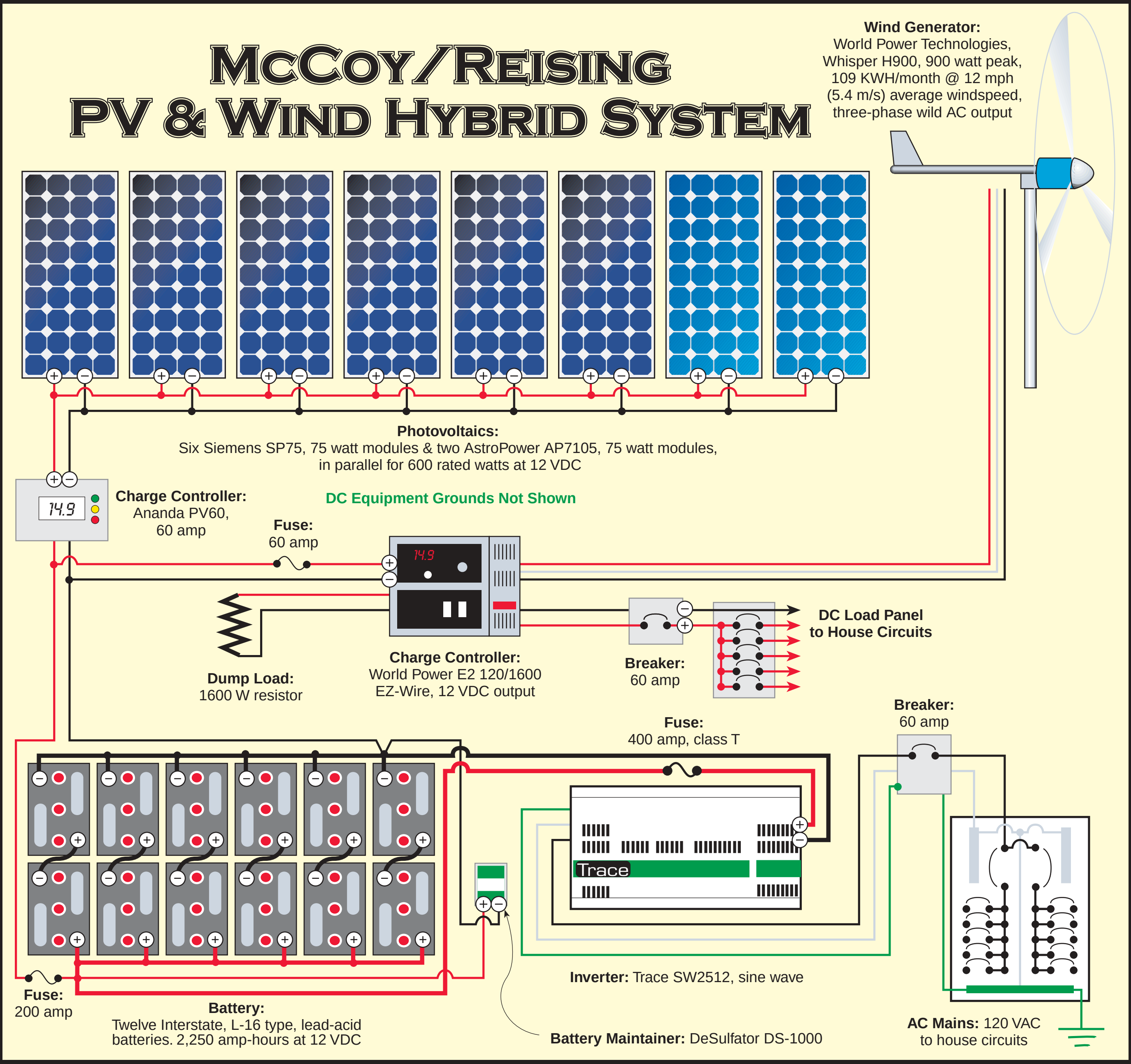
Since we are on a hilltop, we get plenty of wind. The hilltop is not large, so putting up the tower was not easy—no room for a tilt-up! We hired a crane with a 130 foot (40 m) boom. The crane operator set up out front and reached over the top of the house to set the tower in place. The tower only cost US$500 delivered, but the cost of the crane was nearly US$1,000. The tower is extremely sturdy and is guyed to three points. It is easy to climb and feels solid. It stands on a footing that is 5 by 5 foot by $1^1/_2$ feet (1.5 x 1.5 x 0.5 m) deep. The guy wires are fastened to poured concrete footings.

We did have problems with the Whisper control unit. The circuitry that monitors the battery voltage failed. So once the batteries were fully charged, instead of shunting the wind generator output to the diversion load, the wind generator continued to charge the batteries. The unit got so hot during the failure that the solder was melted off the wire terminal connections.

We thought that two returns to the factory for repairs had fixed the problems. A third failure, while we were on vacation, proved too much for our batteries. After ten days of high winds with the diversion controller and dump load not working, our twelve storage batteries are now operating at about half their rated capacity. The factory finally sent us a new control unit, and it seems to be working properly. However, we do feel compelled to keep a constant watch on its operation.

The RE components are safely outside the house in insulated compartments, with the batteries in their own vented space.

The house's 120 VAC and 12 VDC wiring allows Colin and Christine to use either AC or DC loads.



Dual Wiring

Our electrical controls, master switches, metering, and inverter are housed in an insulated compartment that is attached to the north side of the house. Batteries are in a separate space below the other electrical equipment. The battery space is insulated with 4 inches of foam insulation on all sides. EPDM rubber sheets line the battery area. A 4 inch plastic pipe vents to the outside. A positive ventilation fan is in the future. Both spaces are well vented to prevent buildup of heat or gasses.

Originally, our AC power was from a Trace 2512 modified square wave inverter. We decided to upgrade to a sine wave inverter. Since we run some 12 VDC appliances, we wanted to keep our nominal system voltage at 12 VDC. Energy Outfitters found us a 12 VDC Trace SW2512 sine wave inverter, and we were good to go. Input from the batteries is through a 400 amp, fused disconnect.

The house is double wired for both 120 VAC and 12 VDC. The DC wiring is #12 (3 mm^2), and the AC wiring is #14 (2 mm^2). Most of our lights are 12 VDC. The circuits are wired through separate breaker panels. Both voltages are available in each receptacle box. Different plug patterns eliminate the possibility of plugging AC into DC, or vice versa.

As of now, we have no plans to increase our electrical generating capacity. We have never had to have any generator other than PVs and wind power. We have always lived within our energy generating capacity. Our motto is, “Keep it simple.” Complexity only adds more things to possibly fail.

Greenhouse Add-On

We decided to live in our underground solar house for a year or two before we built our attached greenhouse. Then, if we needed extra heat, we could vent it into the house. After a couple of cozy winters, we knew that the passive solar design features of the house were adequate, and no backup was needed. So we focused the design of our greenhouse primarily on the plants' needs, not ours.

We used the retaining wall at the west end of our house as the back wall of our 24 by 12 foot (7.3 x 3.6 m) greenhouse. Since this wall is concrete block, insulated away from the dirt, it also serves as a heat sink. We used 3 inch (7.6 cm) square aluminum for the framework since, in past greenhouses, we found that untreated wood tends to deteriorate over time. We garden organically, and did not want to use treated wood.

We used recycled 34 by 76 inch (86 x 193 cm) single pane, tempered glass for the south facing front and the single slope roof. The glass is held in place with glazing tape and 3 inch aluminum strips, screwed to the framework. An 8 foot (2.4 m) sliding glass door—also recycled—finishes the east end, while the west wall has three large windows. Both the east and the west ends have vents with automatic, heat-operated openers. Total cost was less than US$2,300.

Besides vegetables, citrus trees, and the seeds we start for our garden, the greenhouse also houses a hot tub. The tub is actually a 5 foot (1.5 m) oval, rubber-type stock tank. We plumbed the tub to a small stove that sits outside the greenhouse. Made to our specifications by a local shop, the steel stove is shaped like an inverted U, and has double walls that serve as a "water jacket." Water from the tub enters the stove at the bottom, and through natural convection, exits at the top.

It takes an arm load of wood and a few hours to get the tub to about 100°F (38°C)—about 10°F (5.6°C) per hour. We use a Magnum 350 aquarium pump and filter system, plus Baqua Spa products to keep the water clean. We opted for this water treatment system because it is both bromine and chlorine free, and doesn't take a lot of fussing.

During the summer months, we move most plants outdoors. A shade cloth covers the south side and roof to prevent overheating. Future plans call for a solar water heating system to provide hot water for an "outdoor" shower, as well as to heat the spa on sunny days.

McCoy/Reising Greenhouse Costs

Item	*Cost (US$)*
12 Aluminum box beams, 21 ft., 3 x 3 in.	$1,800
16 Aluminum straps, 16 ft., 3 x 1/4 in.	200
Sliding glass door, 8 ft. single pane, used	75
Tempered glass sheet, 5 x 2 ft.	60
Metal roofing	60
Concrete footings	50
Misc. bolts and screws	40
27 Tempered glass sheets, 34 x 76 in.	0
Total	$2,285

Just Say Yes

We were able to build this house using mostly our own labor. The cost, including septic system and our off-grid electrical system, was less than US$50 per square foot. We have learned through our various homes exactly what our needs are, and we were able to comfortably and easily accommodate them in this home.

We were saying yes to sunshine ten years ago (*HP24*), and we still are saying yes today. We have a large organic vegetable garden and extensive plantings of fruit and nut trees, berries, and grapes. Our garden and orchard, along with our natural house and new greenhouse, fit our desire to be self-sufficient and to live as lightly on the planet as we can.

This stove and its water jacket make the greenhouse's tub hot!

Proud owner/builders Colin and Christine in front of their home. It's the third earth-sheltered, passive solar, RE powered house that they've built.

Access

Colin McCoy and Christine Reising, 7401 South Fork Little Butte Creek Rd., Eagle Point, OR 97524

Energy Outfitters, 543 Northeast E St., Grants Pass, OR 97526 • 800-467-6527 or 541-476-4200 Fax: 888-597-5357 • sales@energyoutfitters.com www.energyoutfitters.com • Inverter

Gaiam Real Goods, 13771 S. Hwy. 101, Hopland, CA 95449 • 800-919-2400 • Fax: 303-222-8702 techs@realgoods.com • www.realgoods.com PVs, wind generators, Ananda Power Center

Interstate Batteries, 12770 Merit Drive, Suite 400, Dallas, TX 75251 • Consumer Customer Service: 888-772-3600 • Fax: 972-392-1453 CustomerService@interstatebatteries.com www.interstatebatteries.com • Batteries

Resource Conservation Technology, Inc. 2633 North Calvert St., Baltimore, MD 21218 • 410-366-1146 Fax: 410-366-1202 • EPDM rubber roofing sheets

R.C. Smoot Construction, PO Box 152076, Austin, TX 78715 • 512-441-0890 • Fax: 512-258-8526 rcsmoot@texas.net • www.earthshelteredhome.com Earth-sheltered building information