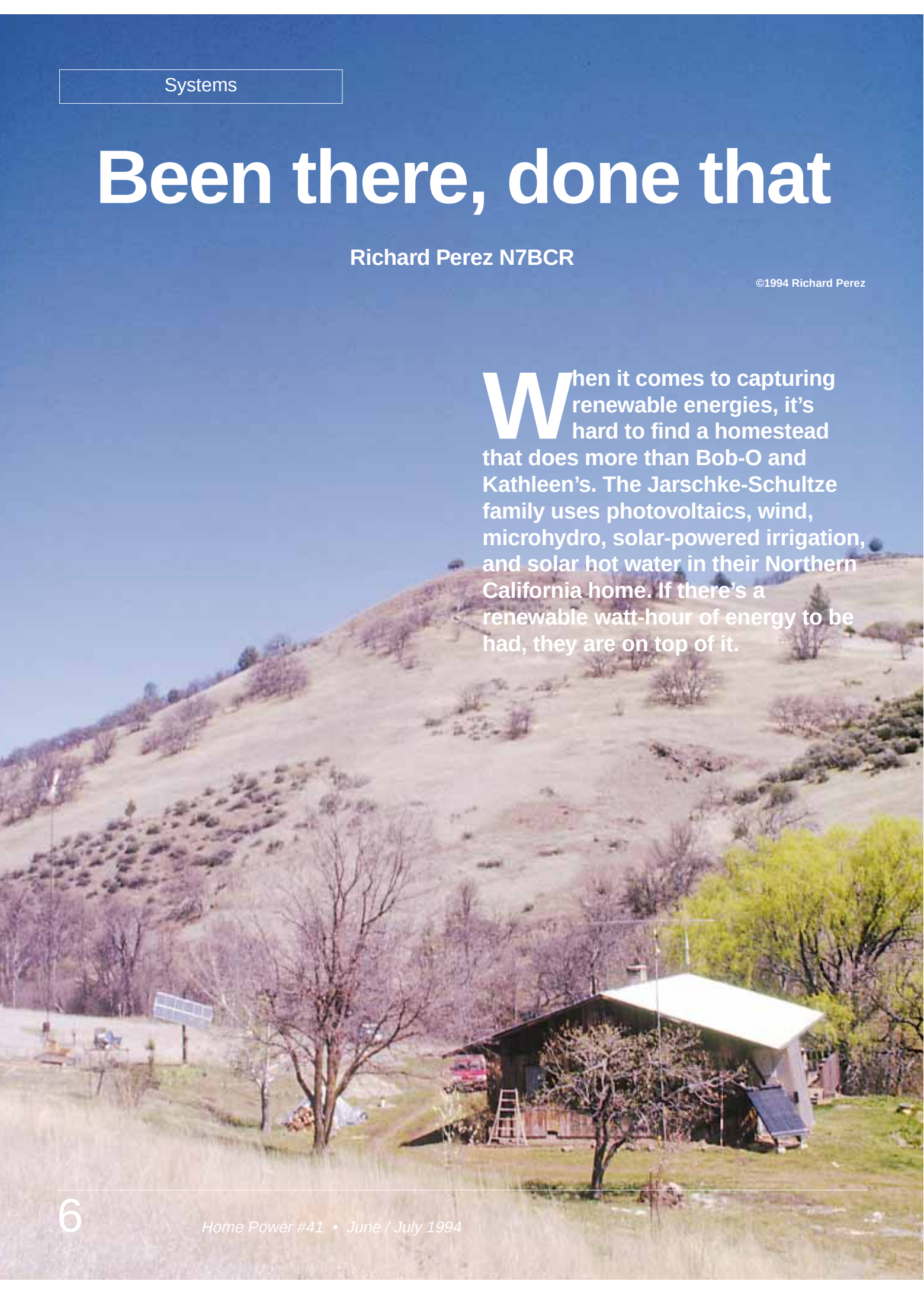
Been there, done that

Richard Perez N7BCR

When it comes to capturing renewable energies, it's hard to find a homestead that does more than Bob-O and Kathleen's. The Jarschke-Schultze family uses photovoltaics, wind, microhydro, solar-powered irrigation, and solar hot water in their Northern California home. If there's a renewable watt-hour of energy to be had, they are on top of it.



A personal note
This renewable energy system displays demented attention to detail. A system as complex as this one takes years to evolve. Very few instantly accomplish what you will see here. In order to understand this system's design, you must first meet the people who live with this system — especially Bob-O Schultze, the system's designer and installer.

Been there
I first met Bob-O and Kathleen in 1988. He and a group of readers visited Agate Flat about Issue #5. They were all living on renewable energy and had to check out this new magazine. Karen and I were amazed. They were the first readers to brave our eight mile long four-wheel driveway.

These hardy folks lived along the banks of the Salmon River in Siskiyou County, California. They were a collection of loggers, tree-planters, gold miners, back to the landers, and refugees from the cultural wars of the 1960s.

I became fast friends with Bob-O. He and I shared common interests in renewable energy, electronics, and radio. Bob-O, Kathleen, and Bob-O's son Allen were living beside the Salmon River on a mining claim aptly named "Starveout" due to the seasonal nature of the water run off needed to mine.

Done that
"Starveout" was powered by a small hydroelectric system that Bob-O installed in 1980. One of the reasons he came to visit us was to thank me for publishing the Mark VI Field Controller circuit (see *HP*#2) which he built to ride herd on his hydro alternator. In 1987, Bob-O and Carl Eichenhofer began manufacturing and selling small hydroelectric turbines called "Lil Otto". Bob-O was busy helping electrify the Salmon and Klamath River dwellers with renewable energy and installed over 20 systems along the rivers in five years. But most of the family's livelihood came from working the woods — brushing, tree planting, and logging.

In 1990, Bob-O had an accident — a tree he was felling kicked back and crushed his leg. After two weeks in the hospital, he was looking for a new job. With a leg full of metal, logging was out. Kathleen gave him the word, "You weren't fast enough to get out of the way last time, you're a lot slower now." Then, the U.S. Forest Service began cracking down on old mining claims along the Salmon. "Starveout", the Schultze's home, was on the hit list. Now Bob-O and Kathleen are serious folks. Rather than wait for the shoe to fall, they listened when Fate spoke. No job, no home. Well, it must be time to move!

And move they did. Bob-O took over Electron Connection, got his California Electrical Contractor's license, and began devoting full-time attention to renewable energy systems. Kathleen came to work with us at Home Power Magazine. They live six miles from Home Power Central and two miles from the end of the power lines. Bob-O uses his home as a test bed for new products and system design ideas. Over the years, I have watched their system grow into its present state.

Above: Kathleen in her greenhouse.
Below: Bob-O in his workshop.

Energy Requirements

Bob-O operates Electron Connection from his home. This means that his computer system is running much of the day to handle the routine business of designing and selling renewable energy systems. Kathleen also has an office in her home with her own computer system. Their renewable energy system supports two full-time business computer systems in addition to their family's domestic power use. The table here details their electric power use.

Renewable Energy Resources

The Schultzes are one of the fortunate few who live at a site that has solar, wind and hydro resources. Bob-O, Kathleen and Allen live next to Camp Creek about seven miles south of the summit of Soda Mountain. A narrow steep valley follows Camp Creek's watercourse and ends at the man-made Iron Gate Lake. From the summit of Soda Mtn to Iron Gate Lake, the land falls over four thousand feet in less than nine miles. The Camp Creek canyon is a natural wind tunnel driven by cooler air on the mountain and the large lake acting as a thermal flywheel. Water flow in Camp Creek is high during all but the depth of summer.

The most interesting aspect of this site's resource survey is that no one of these sources is reliable enough to provide continuous power. During the winter, the nearby lake provides healthy doses of dense fog and low clouds. During midsummer, the creek slows to a trickle. The wind is strong whenever a weather front passes through or whenever the weather is driving Camp Creek's wind tunnel. It's a case of using what Mother Nature offers when she offers it.

Bob-O didn't start out by capturing all these renewable resources at once. First he developed the photovoltaic system, then the hydroelectric turbine, and finally the wind electric generator. It took over four years to build what you see here.

Bob-O and Kathleen's Appliances

Appliance Energy Consumption

No.	*Inverter Powered Appliance*	*Run Watts*	*Hours /Day*	*Days /Wk*	*W-hrs /day*	*%*
1	Bob-O's Sony 1730 Monitor	140	9.0	5	900.0	13.8%
1	Katheen's NEC4FG Monitor	118	8.0	5	674.3	10.4%
1	Bob-O's Mac II Computer	99	9.0	5	636.4	9.8%
1	Kathleen's Mac II	101	8.0	5	577.1	8.9%
2	Answering Machines	10	24.0	7	480.0	7.4%
1	Television Set, Signal Amp	100	4.0	6	342.9	5.3%
3	Fluorescent Lights (House)	22	4.0	7	264.0	4.1%
1	Fax Machine	10	24.0	7	240.0	3.7%
2	Kathleen's Desk Lights	15	8.0	5	171.4	2.6%
1	Washing Machine	350	1.5	1	75.0	1.2%
2	DeskWriter Printer (idle)	6	8.0	5	68.6	1.1%
1	Shoplight	75	1.0	6	64.3	1.0%
2	Incandescent Lights	15	2.0	7	60.0	0.9%
1	Kirby Vacuum Cleaner	400	1.0	1	57.1	0.9%
1	Video Cassette Recorder	16	4.0	6	54.9	0.8%
1	Power Tool	750	0.2	2	42.9	0.7%
1	Main Stereo System	65	1.0	4	37.1	0.6%
1	Microwave Oven	800	0.1	3	34.3	0.5%
1	Shoplight	40	0.3	7	12.0	0.2%
2	DeskWriter (printing)	15	0.5	5	10.7	0.2%
1	Allen's Stereo	5	2.0	7	10.0	0.2%
1	B & K's Radio	5	2.0	5	7.1	0.1%
1	Makita Battery Charger	15	1.0	3	6.4	0.1%
1	Food Processor	380	0.1	2	5.4	0.1%
1	Blender	350	0.1	2	5.0	0.1%
1	KitchenAid Mixer	325	0.1	1	4.6	0.1%
1	Modem Supra V.32bis	14	1.0	2	4.0	0.1%
1	Scanner HP IIp (idle)	8	1.0	2	2.3	0.0%
				Total	4848	Whr/d

Appliance Energy Consumption

No.	*12 VDC Powered Appliance*	*Run Watts*	*Hours /Day*	*W-hrs /day*	*%*
1	Sun Frost RF-16 Frig/Freezer	60	10.0	600.0	9.2%
1	Inverter Standby	16	24.0	384.0	5.9%
1	2 Meter Radio RX	6	24.0	144.0	2.2%
1	2 Meter Radio TX	45	0.5	22.5	0.3%
1	2 Meter Radio Amplifier	200	0.1	20.0	0.3%
1	HF Radio	100	0.5	4.0	0.1%
1	Metering - CE+, Equus	0.1	24.0	2.4	0.0%
1	Soldering Iron	20	0.1	2.0	0.0%
			Total	1179	Whr/d

Energy Sources

Above Left: Twelve Kyocera photovoltaic modules atop a two-axis Wattsun tracker generates over 4 kWh daily.
Above Right: A Whisper 1000 wind generator provides about 2 kWh on windy days.
Below Left: An Energy Systems & Design Hydro produces about 1.2 kWh per day.
Below Center: A Thermomax solar thermal collector provides hot water for the household.
Below Right: Two PV modules on a Zomeworks tracker supply water pumping power for Kathleen's gardens.

System Design

Bob-O was far sighted when he began designing his system. As the system grew to accept all three renewable energy inputs, only one major change required back-tracking — the conversion of the system's battery voltage from 12 to 24 Volts DC. This conversion was complex enough that Bob-O has written an article, on page 16, about the process.

The equipment used in Bob-O's system reads like a list of "Things that Work!" product tests. He wants the best and most cost-effective equipment in his customer's systems as well as his own. He refuses to sell a product that he "hasn't tried to break." And being a dealer means that he is exposed to all types of hardware applied in many different systems. Installing dealers, like the ones near you, quickly find out what works and what doesn't.

PV Electric System

The photovoltaic array consists of twelve Kyocera 51 Watt PV modules mounted on a Wattsun two-axis, active tracker. This array produces 18 Amperes of current at 30 VDC. With the added assist of the Wattsun tracker, the array produces about 4,000 Watt-hours of power on an average sunny day. One hundred and fifty feet (round trip wire length) of 1/0 AWG copper cable feeds the array's power to the house. See *HP*#25, page 56 for a "Things that Work!" review of the Wattsun tracker.

Energy Processing

Left: The new Trace 4,000 Watt sine wave inverter converts 24 VDC power into 120 vac housepower. Center: Eight Trojan L-16 batteries store the energy produced by the photovoltaics, wind generator, and microhydro. Surrounding the batteries are the various safety fuses, circuit breakers, disconnects, and the systems' regulators. Right: The inside portion of the solar hot water system — Rheem solar tank, Myson on-demand heater, pump, and valves.

Hydroelectric System

Bob-O uses an Energy Systems & Design turgo-type hydroelectric turbine. Even though Bob-O manufactures the Lil Otto turbine, he uses the ES&D model because it is more suited to his hydro site. A 3 to 2.5 inch diameter, 800 foot long pipe snakes its way up Camp Creek. The 27 feet of head created by this pipe supplies the turbine with 9.25 psi of working pressure and a flow of 35 gallons per minute. The hydro turbine produces 2 Amperes at 26 VDC or about 50 Watts of power. While this may not sound like much power, remember that the hydro is producing 24 hours a day. During a day's time, this hydro produces over 1,200 Watt-hours of energy. The hydro's electricity is delivered, unregulated, to the battery via 180 feet (round trip) of 6 AWG cable.

Wind Electric System

This spring Bob-O added a Whisper 1000 wind generator to the system. This wind genny sits atop a 63 foot high tower made from 2.5 inch diameter, Schedule 40, steel pipe. The guyed tower is located in a field about 200 feet northeast of the house. This generator produces over 30 Amperes at 28 Volts in 20 mph winds. Bob-O figures that the wind generator has been producing an average of 2000 Watt-hours of energy per day when the wind blows. Power is transmitted from the wind generator to the house by 380 feet (round trip) of 1/0 AWG cable.

Engine/generator

Bob-O comes from the group of RE users that would rather eat a bug than start the generator. Nevertheless, Bob-O had to fall back on his 3.5 kW Miller Roughneck generator/welder several times last winter (before the Whisper 1000 was up and running). He hopes the addition of the wind generator will permanently retire the Miller from generator service.

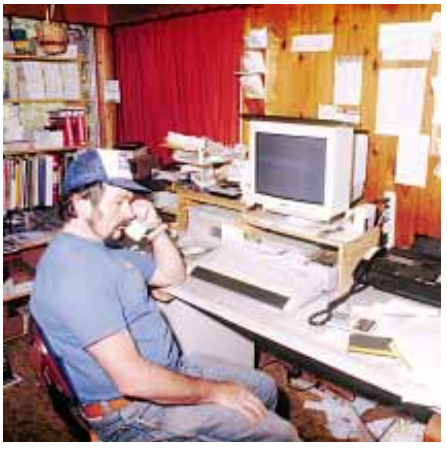
Batteries

This system uses eight Trojan L-16 lead-acid batteries to store energy. Each L-16 battery is rated at 350 Ampere-hours at 6 Volts DC. The battery is configured at 700 Ampere-hours at 24 VDC. Each cell in the battery is fitted with a Hydrocap® which recombines gaseous hydrogen and oxygen into pure water. These Hydrocaps not only keep the system safer by nearly eliminating the potentially explosive hydrogen gas, but reduce cell watering and battery top cleaning. The battery is located in the home's basement along with the inverter and power processing gear. The battery interconnect cables are made from 00 AWG copper cable with soldered ring terminal ends. All the batteries are sitting in Rubbermaid™ plastic tubs just in case there is any spillage of electrolyte.

Inverters

One of the major reasons that Bob-O converted the system from 12 to 24 VDC was to accommodate the new Trace 4,000 watt sine wave inverter. The inverter converts the low voltage power stored into the battery into 120 vac, 60 Hz sine wave power like the utility rents out. This new Trace inverter has been performing faultlessly since installed four months ago. Over the years, Bob-O has used just about every inverter available, and he thinks the new Trace is a definite "keeper". The inverter's output is wired directly into the home's mains panel where it is distributed to all the

Energy Use



Left: Bob-O at work on the phone. His office contains an extensive Macintosh system, FAX, copier, and answering machine — all powered by renewable energy. Center: Kathleen, a solar cooking expert, prepares dinner in one of her many solar ovens. Above Right: The living room contains the usual audio/video gear found in most homes. Below Right: This back country kitchen comes equipped with electric RE powered appliances.

home's branch circuits. Since the inverter produces sine wave power, all of the appliances in the house perform just like they were plugged into the utility.

Regulators

Bob-O uses a Heliotrope CC-60B PV controller (see *HP*#8, page 31) set to regulate at 31 VDC. This is a little high, but the business uses so much power that Bob-O feels he'll take an equalizing charge whenever he can get it. The hydroelectric turbine produces less than 100 Watts and is not regulated. At this point in time, the Whisper wind generator is also not regulated. This has led to several inverter shutoffs from battery overvoltage. Bob-O's next project is getting the load diversion feature of the new Trace inverter to dump his excess power into heating water in the 80 gallon DHW tank. Once this is accomplished, the Whisper will be effectively controlled and all the system's surplus power will be diverted into making hot water.

Converters

When the system changed from a 12 Volt battery to a 24 Volt battery, Bob-O was faced with a decade's worth of 12 VDC appliances. Most were replaced by 120 vac models, but several stubbornly remained 12 Volt. In order to power this 12 Volt gear (like a Sun Frost RF-16 refrigerator/freezer and a whole rack of 12 Volt ham radio gear), Bob-O uses a Vanner Voltmaster. From a system design standpoint, the Vanner Voltmaster is a switching power supply that can efficiently convert power stored in a 24 VDC battery into 12 VDC for appliances. More technical details on this 12 to 24 conversion in the article that follows this one. See *HP*#33, pg. 84 for a review of the Voltmaster.

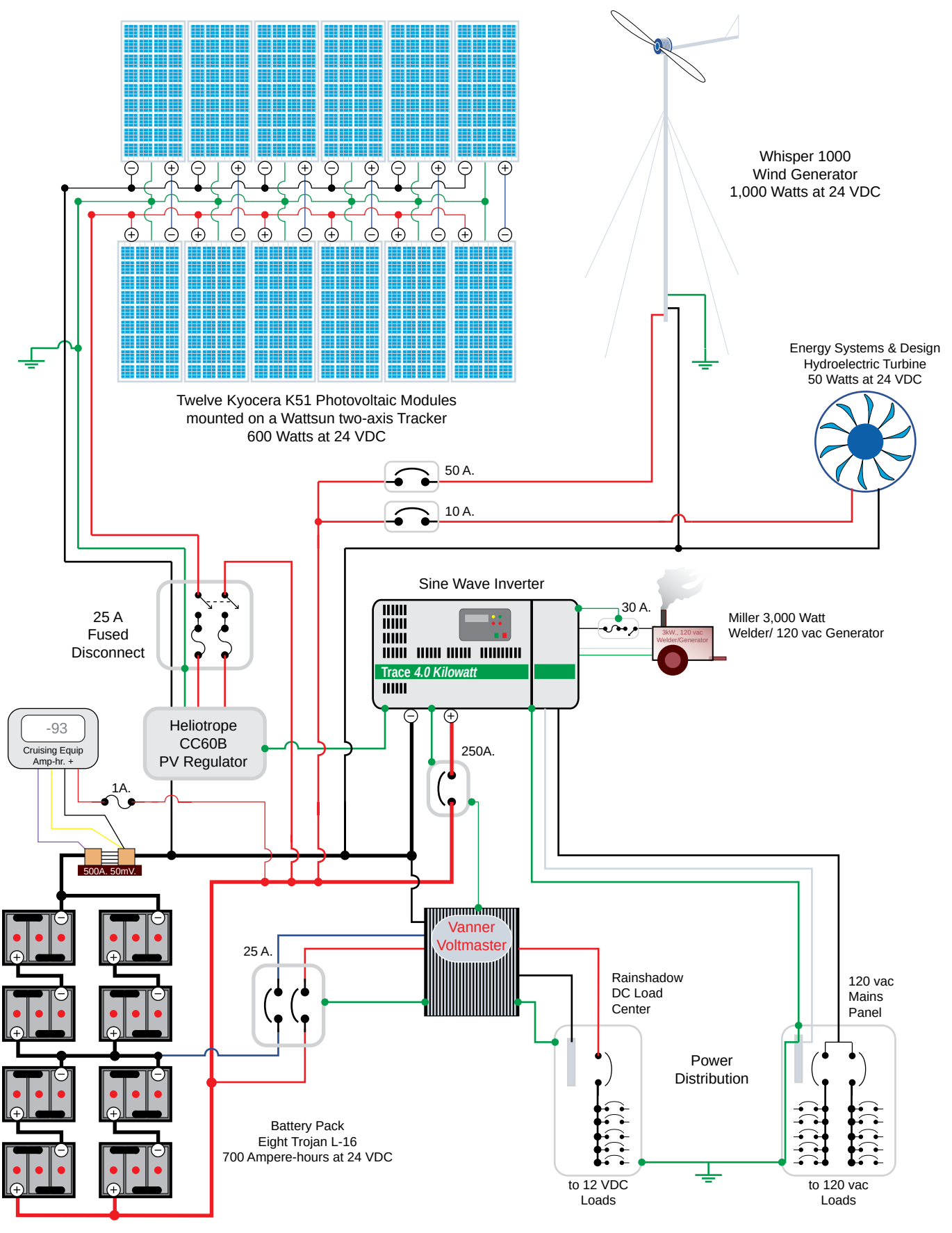
Instruments

Bob-O is an electronics nerd and his home is festooned with instruments of all types. Only two are in daily use to assess the system's performance — a Cruising Amp-hr+ meter, and a home-made expanded scale battery voltmeter. The Cruising Amp-hr+ is a battery Ampere-hour meter that functions like a gas gauge for batteries. In addition to calculating Ampere-hours in and out of the battery, the meter also measures battery current and battery voltage. See *HP*#26, page 59 for a review of this Cruising meter. The analog expanded scale battery voltmeter is a very simple homebrew project. See *HP*#35, page 92 for a schematic of this analog battery voltmeter.

Water Systems

The main water source is a spring located about 200 feet in elevation above the house. This spring provides gravity flow water for the house, but hasn't sufficient flow to supply Kathleen's many gardens. Bob-O uses a PV array direct water pumping system to supply over 1,500 gallons daily to the gardens. This system uses two Kyocera K51 PV modules powering a 24 VDC Flowlight Slow Pump. The PVs are mounted on a one-axis Zomeworks tracker and their power is processed by a Sun Selector LCB before being sent to the pump. This system is simple, effective and uses no battery. The water is pumped from Camp Creek into two 1350 gallon water tanks located about 40 feet in elevation above the gardens.

Bob-O uses a rack of twenty Thermomax evacuated tube, heat pipe, solar collectors to heat water for the house. This system has been operating for over two


Whisper 1000
Wind Generator
1,000 Watts at 24 VDC
Energy Systems & Design
Hydroelectric Turbine
50 Watts at 24 VDC
Twelve Kyocera K51 Photovoltaic Modules
mounted on a Wattsun two-axis Tracker
600 Watts at 24 VDC
50 A.
10 A.
Sine Wave Inverter
30 A.
Miller 3,000 Watt
Welder/ 120 vac Generator
25 A
Fused
Disconnect
Trace 4.0 Kilowatt
-93
Cruising Equip
Amp-hr. +
Heliotrope
CC60B
PV Regulator
250A.
1A.
500A. 50mV.
Vanner
Voltmaster
25 A.
Rainshadow
DC Load
Center
120 vac
Mains
Panel
Power
Distribution
Battery Pack
Eight Trojan L-16
700 Ampere-hours at 24 VDC
to 12 VDC
Loads
to 120 vac
Loads

Bob-O & Kathleen's System Cost

Photovoltaic System

12	Kyocera K51 PV Modules	$4,200
1	Wattsun 12 PV Dual Axis Tracker	$1,575
1	Heliotrope CC-60B Charge Controller	$295
1	C& H 60ADC Fused Safety Switch	$215
1	5"x10' Steel Pipe, Cement, Gravel, etc.	$150
150	feet of 1/0 AWG THHN Main Feeder Wire	$137
1	1 1/4" PVC Conduit, NEMA3J Box	$70
84	feet10 AWG USE PV Interconnect Wire	$27
1	Crimp wire terminals, Split bolts, tape, etc	$25
1	8' Copper Ground Rod, Clamp, Wire	$15
	System Sub Total	$6,708

Hydroelectric System

1	ES&D FT1 Hydro w/24V Low Head Stator	$830
600	feet of 2 1/2" PVC 160 Pipe	$420
200	feet of 3" PVC 160 Pipe	$244
1	Valves, Fittings, etc.	$60
90	feet of 6 AWG Triplex Wire	$45
1	SquareD QOCB Box w/DC Circuit Breaker	$42
	System Sub Total	$1,641

Wind Generator System

1	Whisper 1000 Wind Generator	$1,500
380	feet of Wire 1/0 THHN	$346
8	2 1/2" Flanges	$208
105	feet of 2 1/2" Sch 40 Steel Pipe	$160
700	feet of 1/4" Aircraft Cable	$158
1	1 1/4" PVC Conduit, NEMA3 JBox	$135
1	Sand & Gravel	$130
8	5/8" x 12" Turnbuckles (Surplus)	$96
1	Misc.Steel	$50
1	Misc.Wire, Terminals, etc.	$50
1	Cement	$42
1	SquareD QOCB Box w/DC Circuit Breaker	$42
48	1/4" Cable Clamps	$29
12	5/8" Bolt w/ Nylock Nut	$11
20	1/4" Thimbles	$11
2	3/4" x 6" Bolt w/ Nylock nut	$7
6	5/16 x 5" Bolt w/ Nylock Nut	$2
	System Sub Total	$2,976

Batteries

8	Trojan L-16 Lead Acid Batteries	$1,440
24	Hydrocaps™	$180
11	2/0 AWG,13.5 in. Battery Interconnects	$107
	System Sub Total	$1,727

Inverter

1	Trace SW4024 w/ Conduit Box	$3,045
1	Heinemann 250A Breaker w/ Enclosure	$245
2	Trace BC-5 4/0 Inverter Cables	$150
1	2" PVC Conduit, Fittings, etc	$12
	System Sub Total	$3,452

DC Load Center, Metering, etc.

1	Cruising Equipment Amp Hour+™	$325
1	20 Amp Vanner Voltmaster	$304
1	Rainshadow DC Load Center w/4 CBs	$215
1	SquareD QOCB Box w/DC CBC	$52
	System Sub Total	$896

Solar Irrigation System

2	Kyocera K-51 PV Modules	$700
1	Flowlight® Slowpump	$488
1	Zomeworks 2 Panel TrackRack™	$385
1	Sun Selector LCB model 3MT	$80
	Wire, Fused Disconnect, etc	$75
	System Sub Total	$1,728

Solar Hot Water System

1	Thermomax SOL 20S Thermal Collector	$1,723
1	Myson CF-325-2 Demand Heater	$610
1	Rheem SolarAide 80 gal. tank	$525
1	Heliotrope Delta T Thermostat/Control	$140
1	Laing Circulation Pump	$125
1	Amtrol Expansion Tank	$50
1	Relief Valve- Watts 174A	$44
	Valves, Vents, and Sensors	$120
	System Sub Total	$3,337

Solar Hot Water System Total Cost	$3,337
RE Electric System Total Cost	$19,128
Grand Total	$22,465

years and has survived numerous hard freezes and inch sized hail stones. These evacuated tubes have the insulation value of a vacuum bottle. Inside each two and a half inch diameter glass tube there is a finned heat pipe partially filled with an alcohol/water mixture. Sunshine causes this mixture to boil and heat is transmitted to a glycol mixture which in turn transfers the heat to the home's 80 gallon Rheem SolarAid hot water tank. This DHW system is rather complex with two stages of heat exchange and a single Laing pump (driven by 0.25 Amperes at 12 VDC). The reasons to undergo this degree of complexity are absolute freeze proofing and the incredible cold/cloudy weather performance of the Thermomax collectors. On sunny winter days when the ambient temperature is well below freezing and the wind is blowing, the Thermomax still delivers 180°F to the hot water tank. Bob-O also has a Myson on demand, propane-fired water heater on line. This Myson has the happy ability to moderate its heat output in relation to the incoming

Above: from left to right, Kathleen Jarschke-Schultze, Amelia Airedale, Allen Schultze, and Bob-O Schultze.

water's temperature. If the weather has been sunny and the solar hot water heater has been producing, then the water passes straight through the Myson without any additional heating. Using the on demand heater as a last resort ensures that the house will always have plenty of hot water regardless of the weather or the amount of hot water needed. This hot water system supports two bathrooms, a kitchen sink, and a washing machine. Between the months of May and October the pilot light on the Myson is shut off and the hot water needs are met by the Thermomax alone. Kathleen has a sign above the sink for visitors that reads, "Caution - Solar Heated Water - HOT!"

System Performance

Well, there is never a power outage at Bob-O and Kathleen's place. The photovoltaic array produces about 4,000 Watt-hours of power daily. The wind generator is a new comer to the system and we don't yet have years of data on its performance. If the wind is blowing, then Bob-O reports that the Whisper makes about 2,000 Watt-hours of energy daily. The small hydroelectric turbine produces about 1,200 Watt-hours of energy daily. Bob-O figures that he puts about 25 hours of operating time on the Miller engine/generator yearly. This system is about two-thirds powered by photovoltaics, with the remaining one-third divided between wind and microhydro.

The battery in Bob-O's system contains enough energy to power their homestead for about three days with no RE power input whatsoever. And since every day contains at least some renewable energy, the battery is virtually never fully discharged.

System Cost

The tables here detail the costs of all the renewable energy equipment. Bob-O and Kathleen have invested just about $20,000 in their electric renewable energy systems. While this sounds like a lot of money for power, let's examine the alternative.

Bob-O and Kathleen's property is located 1.7 miles from the end of the utility's power lines. The local utility, Pacific Power, charges $10.35 per foot for new line extensions. The going local rate for electric power is $0.095 per kiloWatt-hour. Bob-O and Kathleen consume an average of about six kiloWatt-hours daily. The table here compares the cost of running in the utility lines versus using renewable energy. This table does make some assumptions. One is that the renewable energy system lasts ten years, which is far more certain than the second assumption, that the utility will not raise its power cost in the next ten years. I figure that Bob-O and Kathleen saved more than $70,000 by using renewable energy for electricity.

If you consider that a new truck costs about twenty thousand dollars, it's easier to understand Bob-O and Kathleen's investment in self-sufficient and clean energy. In terms of performance for money spent, I pick an RE system over a gas guzzler any day.

Being here now

Bob-O and Kathleen live on an energy self-sufficient homestead. Their dedication to a sustainable future that all can share makes them friends of all living on this planet. I salute them!

The Utility versus Renewable Energy

Energy Consumption = 6 kiloWatt-hours daily

Distance from Utility Lines = 1.7 miles

Utility Power Cost	
Line Extension Cost	$88,762
10 Year Power Bill	$2,081
Maintenance	$0
10 Year Cost	$90,842
$/kWh over 10 Years	$4.15

Renewable Energy Cost	
RE Systems Cost	$19,207
10 Year Power Bill	$0
Maintenance	$875
10 Year Cost	$20,082
$/kWh over 10 Years	$0.92

RE saves Bob-O and Kathleen $70,760

Access

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