RE Novices Tackle PV/Gen Design and Installation

Chip and Clara Boggs

Clara Boggs (center), with friends Rick Rogers and Jim Beaver, in front of the power shed.

Three years ago, we knew almost nothing about renewable energy (RE) systems. Since then, we've gone through the process of choosing to build a renewable energy system, and designing and installing it. Our RE system has allowed us to go online with our computer, step up homestead progress, and enjoy some amenities. We'd like to share with you what we learned on this journey, focusing on the decision-making process, the power shed, and how these can relate to each other.

Where, When, & Why
RE systems differ from centralized power generation in their site dependency and sensitivity. Our homestead is located on 360 acres of rainforest in Oregon's Coast Range. The land is a long, hilly east-west valley in the Coquille River watershed. About half the land faces south, including the main homestead.

The climate is typical of western Oregon. The dry season lasts for about four months. Most of the 68 inch (173 cm) average annual precipitation falls from October to May. Being only fifteen miles (24 km) from the coast, temperatures are mild overall, and snow is an unusual event.

All projects on our property have been low capital, high labor input. The buildings are made of salvaged or native materials, with wood heat, gravity flow water, organic gardens, composting latrine, and other back-to-the-land amenities.

We bought the land in 1989. We had no intention of bringing grid power in, but as a tactic in negotiating for the land, we priced it anyway. US$15,000 would bring power 1/2 mile (0.8 km) from the corner of the land to the homestead. No thanks!

For two years, we lived with no phone or electricity. Generally, we enjoyed non-electric living (with a few exceptions). In 1992, we planned to leave the land for a year to make money. The future caretakers needed a phone for their business. We dug the trench, and the phone company gave us the cable.

Have you noticed that life is what happens while you make other plans? Well, our "one year" absence dragged out to five years, during which time we became involved in defending wrongly convicted people, which was mostly online work. We returned to Oregon in 1997, but two obstacles prevented us from moving back onto our land. First, the homestead was in acute disrepair. Second, even though there was a phone, there was no electricity for our computer, and our online justice work was becoming critical to more and more people.

The RE Decision Process
The first thing we needed to do was research. We had botched a few projects in our brief career as homesteaders. The lessons learned usually cost us more time than money. However, an RE system costs a lot, so we wanted to do it right. It justified a proportionately greater amount of research. We ordered all the back issues of *Home Power.*

PV, wind, or hydro? Wind was not a realistic option. Hydro held the greatest potential, but seemed more complex than solar. Admittedly, we didn't know enough

The vented battery box is built onto two small pallets to keep the batteries off the floor. Twelve Interstate 6 volt, 350 AH batteries provide 1,050 amp-hours at 24 volts.

about either resource to make a truly informed decision. However, we did know that hydropower would involve laying lots of pipe through thick vegetation on steep, unstable slopes. Then, too, there are clogged intakes, moving parts, and regular maintenance. Finally, the creek is 600 feet (180 m) from the house, while there's sun on the front porch.

Our immediate need was for a few KWH per day—not for the ultimate potential of the site. We do hope to have microhydro power in the future. But PV, with no moving parts and some siting flexibility, seemed like the way to go.

Who & How
Since we are inveterate do-it-yourselfers, we had always assumed that we would install the system ourselves. However, after reading *What to Expect from Your RE Dealer (HP61,* page 40), we had second thoughts. The article did help us clarify our options:

DC power comes in from the modules, through the safety disconnect (left) and charge controller (right), and then goes to the batteries. Power for DC loads comes directly off the batteries through the DC load center (below).

- Have a dealer/installer do the whole works.
- Contact a full service dealer to design the system, supply the components, and advise us on installation.
- Design our own system, shop competitively from discount RE suppliers, and order everything and install it ourselves (possibly with no advice from the supplier).

With our experience level, we never seriously considered the third option. If we hired a dealer, we wanted to do the low-tech labor ourselves, as suggested in the article. Typically, the low-tech labor comes *after* load analysis and system siting, but *before* system installation. We did not know of a local RE dealer, so this presented another set of options:

- Perform the load analysis, system siting, and low-tech labor ourselves. Have the dealer install the system, paying for only one travel trip.
- Pay the dealer for two trips; first for the load analysis and siting and later for the installation.

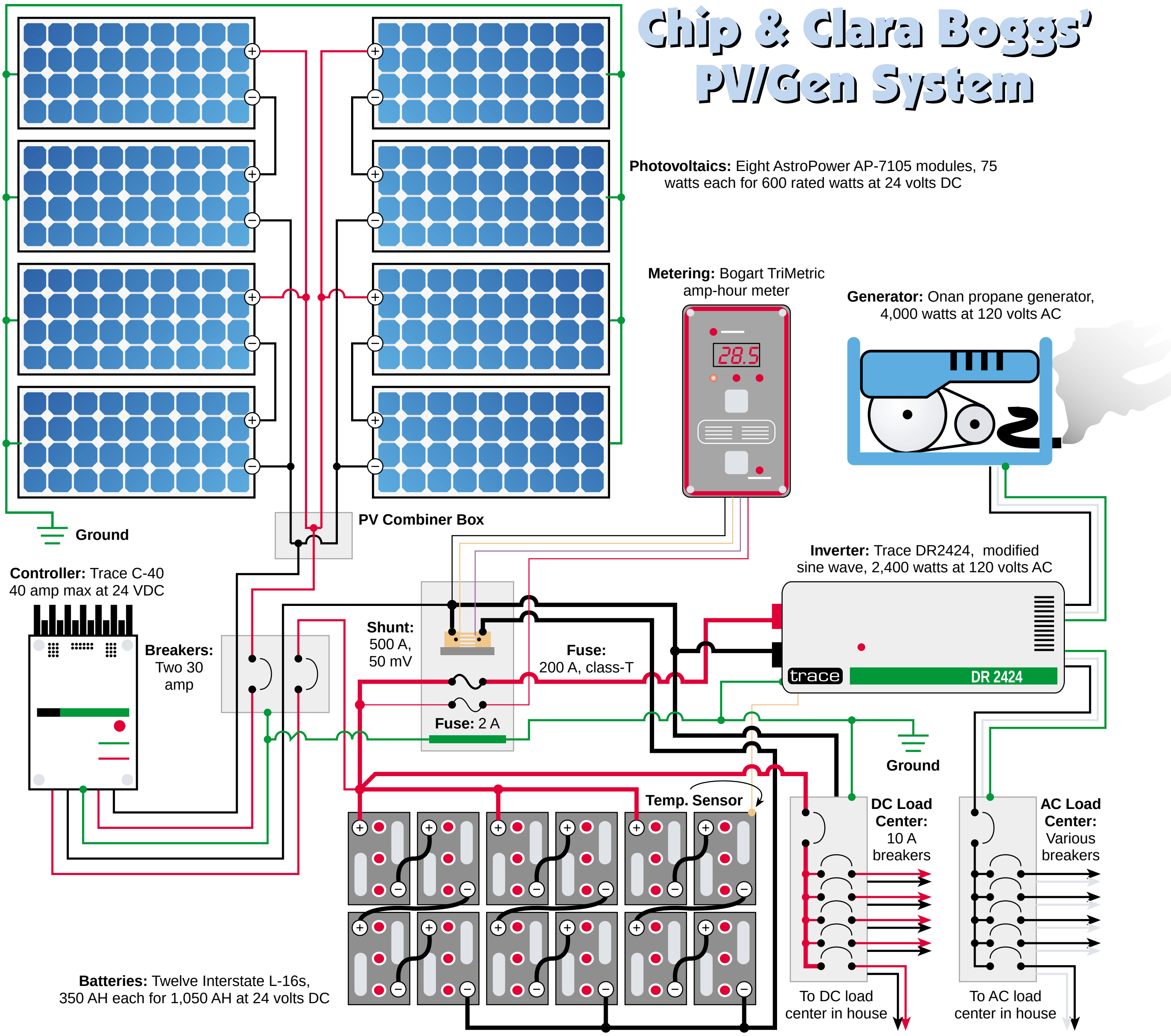
Load analysis and siting seemed easy compared to installation, so we chose the first option.

We ordered a Solar Pathfinder *(HP57,* page 32), and made a homebrew ammeter *(HP33,* page 82). Only the eventual users of the system can carefully analyze their loads, and determine what their lifestyle and electrical consumption will be. Doing this analysis was fun and easy *(HP58,* page 38).

The homebrew ammeter worked just as the article said it would. We measured the amperage of each appliance and multiplied by 110 volts to find the watts. We estimated the time each appliance was used. Adding standard losses for the inverter and overall system, we arrived at 1,769 watt-hours per day. With this data, we could generically size the system and estimate the cost. It appeared that we could afford a system sized to meet our needs.

I started wandering around the homestead with the Solar Pathfinder. At first, my self confidence wavered as I contemplated the numerous variables. Gradually, I realized that I had my own site knowledge that no

The AC output from the inverter feeds the AC load center. One circuit breaker goes to Chip & Clara's cabin, with lots of room for more breakers.



expert could duplicate. The Pathfinder quantifies the most important variable (solar access), but other variables can be integrated by more intuitive means.

I knew that PV modules, batteries, and inverter should be as close to each other as possible. So by siting the modules, I was spatially arranging the whole system. The best alternative was to build a power shed above and behind the homestead. Mentally summarizing the "low-tech labor" part of the project, I decided to:

1. Design and build the power shed.
2. Build and install the module racks.
3. Build the battery enclosure and place the batteries in it.
4. Dig the trench between the power shed and the house.
5. Run conduit and pull cable from the power shed to the house.

During this time, we met someone who had ordered a PV system from Real Goods and had installed it himself. The psychic pendulum started to swing back towards installing the system ourselves. At about this point, I realized that if I trusted myself to do the load

Clara Boggs at her PV-powered computer workstation.

Boggs System Loads

Item	*WH/day*	*%*
Computer	1,106	56.3%
3 CF lights	343	17.4%
Coffee maker	187	9.5%
Inverter, standby	160	8.1%
Laser printer/copier	31	1.6%
Word processor	32	1.6%
Visitor's computer	29	1.5%
Radio	24	1.2%
Washing machine	24	1.2%
Power saw	17	0.9%
Power drill	5	0.3%
Juicer	5	0.3%
Blender	3	0.2%
Total WH/day	1,966	

and site analysis and low-tech labor, that with some outside advice, I might as well attempt the entire installation.

Our next decision was which RE dealer to purchase our equipment from. We did not research this much, but called Real Goods, with whom we were most familiar. We knew that they could design the system, select the components, and advise us on installation. On the phone, we met Roger Breslin, who became our personal consultant.

Once we decided to cast our lot with Real Goods, we were not bashful about asking advice. Roger even helped us compare sites for the power shed and PVs (over the phone!). He recommended the site 50 feet (15 m) behind the house, even though a site 100 feet (30 m) away had slightly better sun. (Pruning can improve the nearer site over time.)

The Power Shed

In our county, a 10 by 12 foot (3 x 3.7 m) building is allowed without a permit. The system would not require this large of a building, but we knew the extra space would be handy. The nice thing about building a power shed is that you don't have to compromise on the design. Every element of shed design supports or enhances a feature of the RE system.

Equipment layout, doors, and floor plans were adjusted to the nearest inch to maximize use of the space. The building is oriented due solar south, and has a concrete slab floor for thermal mass and to support the battery bank. It has a large double-glazed window for passive solar heat, and a roof overhang that gives it sun in the winter but shade in the summer. Batteries don't like to get cold, and we didn't want to provide a heating system.

With the rack design in *HP57,* page 32, you can't adjust the summer angle *below* the roof angle. Our latitude is 43 degrees, so the ideal summer angle is 28 degrees. Also, airflow behind the modules is necessary, particularly in summer, so you don't want them lying flat on the roof. A roof angle of 11 degrees (2.5 in 12 pitch) provides summer airflow, but is also steep enough to shed our abundant rainfall.

We wanted to provide room for future modules. The roof overhangs 4 feet (1.2 m) on the north side and about 1-1/2 feet (0.45 m) on the other sides, giving a total surface area of about 16 by 15 feet (4.9 x 4.6 m). This will accommodate six racks, each holding four modules, or 24 modules total. Our initial system has two racks (eight modules), so we could triple the size of our array in the future if need be.

Generator

We focused on safety in our power shed design. A lengthwise interior wall separates the generator from the batteries and controls. This also doubles the wall surface inside the shed. The interior door is placed at the end of the wall to maximize unbroken wall space. Propane tanks are placed outside, under the 4 foot (1.2 m) roof overhang, separating them from the generator.

We put the generator in the room away from the house to minimize noise. The interior was plastered with a gypsum/perlite mix for acoustical absorption. The exhaust pipe runs out the north side of the shed. It then

The 4 KW Onan generator in the north room of the power shed. The air intake is under the wooden stand.

runs underground through a protective shroud of old stove pipe, ending at the top of a drainage ditch. The north door is 36 inches (91 cm) wide to facilitate generator removal for servicing. A 1/2 inch (13 mm) eyebolt is screwed into a rafter for hanging a chain hoist.

The generator only occupies 6 square feet (0.5 m^2) in the 50 square foot (4.6 m^2) room (the north half). This leaves enough space for the Staber washer and a clothes sorting table. There was even room left over for a few shelves for food storage. The exterior doors open out instead of in, to conserve space. In the south half, this leaves room for tool shelves.

System Design and Installation

I recommend generically sizing the system yourself, even if someone else is designing your system. *(The Solar Electric House* and *Real Goods Sourcebook* have good formulas.) Then let your dealer select the specific components. They will know product compatibility, application, and the best value for your budget.

Our inverter, charge controller, and battery bank were oversized so that only more PV modules would be needed to expand the system. Roger recommended eight 350 AH batteries, but we decided to go with twelve. We wanted to build easy expandability into the system, but knew it is best not to add more batteries later.

All the equipment arrived in excellent condition. Pulling everything out of the boxes, I was still unsure of how it was all going to fit together. After all the low-tech jobs were done, I finally had to start wiring. Roger sent me a

Boggs System Costs

Item	*US$*
8 AstroPower AP7105 75 W modules	$3,032.40
12 Interstate batteries, 6 V, 350 AH	2,239.92
Onan generator, 4 KW, used	1,738.00
Trace DR2424 inverter	1,220.75
Wire, conduit, & misc. supplies	244.00
PV rack materials	215.00
Power shed construction	200.00
Trace C-40 charge controller	175.00
13 battery interconnect cables, #2/0	146.25
150 ft. twisted pair wire (for TriMetric)	138.00
TriMetric 2020 monitor	132.05
AC service panel, 200 A with breakers	120.00
DC service panel with breakers	120.00
2 inverter cables, 10 ft.	85.45
Cable, #2 & #4,140 ft. each	60.00
Safety equipment & hydrometer	50.30
Lightning protector	47.45
Junction box, 10 x 8 x 4 inches	37.95
Safety disconnect, 2 pole, 30 A	33.25
Power distribution block, 2 pole	28.45
Shunt, 500 amp / 50 mV (for TriMetric)	27.55
Trace battery temperature sensor	18.95
2 RK5-30 fuses, 30 A	7.50
Total	$10,118.22

wiring diagram, and it took me about a week to hook everything up. I was also helped by Chapter 12 of the *Solar Electric Independent Home Book,* which gives a step-by-step generic procedure for PV/Gen system installation.

Even during installation, I was still a little skeptical about whether everything would actually work. Finally, I removed the coverings from the modules and started charging the batteries—I got a real charge out of that. An electrician friend came over to install the final fuses, energize the breakers, and connect power to the house. We found a few shorts in the house wiring, but no errors in the RE system. In a few hours, we emerged from the "smelly darkness" forever!

System Operation

We record generator run times, battery waterings, and propane tank changeouts. We ran the generator 240 hours the first year, exceeding the break-even point of genny vs. PV module cost *(HP51,* page 66). In December 1999, we added eight more modules, doubling the array size. Generator use has been

Chip Boggs flips the AC load center's main breaker in the house.

reduced by two-thirds, and we have excess power for over half the year.

The larger than expected usage comes from Clara running her computer twice as much as I thought she would. But I can't complain, since the main reason we installed the system was to support the justice work she does on the Internet. Although the computer processor stays on most of the day, Clara turns off the monitor whenever possible.

We are not running any pumps, motors, compressors, or resistive loads (except for the coffee maker). The washing machine is usually run when the generator is on. There is no television. Most lights are compact fluorescents. The buildings are also wired for 24 VDC—we'd like to have a few LED lights which could be used without the inverter. A TriMetric system monitor is mounted on the front porch, where everyone can see it.

Lessons Learned

I would not make any changes in the system design, siting, or power shed. Most of the lessons came during installation.

The 1-1/2 inch conduit was tight for the main cables running from the power shed to the house (two #2 (33 mm^2) cables for AC and two #4 (21 mm^2) cables for DC). Both AC and DC cables were sized for 5 percent or less voltage drop. AC cable was rated for about 100 amps, and DC cable was rated for about 10 amps. Direct burial cable was used—the conduit was for physical protection only. The straight lengths were OK, but the wire seems to expand when it makes a turn. We also overlooked running the system monitoring (TriMetric) wires. So I had to dig up the conduit, already stuffed with wires, and force the cable through it.

I designed the power shed before the equipment arrived. I did not take into account which side of the inverter the battery cables must attach to. This made a difference of 3 feet (0.9 m), so my 10 foot (3 m) inverter cables wouldn't reach. This necessitated redesigning the entire layout of the battery and control room.

I built the PV racks as shown in *HP57,* page 32, but didn't take into account the large corrugations of the metal roofing. So I had to add 4 inch (10 cm) legs between the skids and the bottom of the rack, lifting the bottom of the rack over the corrugations. I also built the battery box before I understood the battery wiring. The positive main terminal is twice as far (10 feet; 3 m) from the inverter as the negative terminal (5 feet; 1.5 m). Oh well, that's how it's gonna stay.

Thanks

We are grateful to Roger Breslin at Real Goods for his patience with us. We called him about once a week for six months. He always returned our calls, and got other help when necessary. In a word, the service was exemplary.

In the same room as the generator, there's plenty of room for a Staber washer, laundry table, and food storage.

We are also grateful for *Home Power* magazine. We would not have attempted this without their decades of wisdom, experience, and inspiration. Specifically, our "top ten" most helpful *HP* articles were (not in order):

- *Grounding Separate Structures, HP65,* page 70.
- *Two In Maine* (power sheds), *HP40,* page 6.
- *What to Expect from Your RE Dealer, HP61,* page 40 (commentaries in *HP62,* page 99).
- *Generators as a Backup Power Source, HP51,* page 66.
- *Where and How to Mount PV Modules, HP57,* page 32.
- *Battery Rooms—a Cellular Home, HP33,* page 42.
- *Doing a Load Analysis, HP58,* page 38.
- *A Beginner's AC Ammeter Project, HP33,* page 82.
- *Buying and Using a Digital Multimeter, HP60,* page 42.
- *Are Photovoltaics Right for Me?, HP1,* page 11.

Pioneering with RE

The decision to install the system ourselves was protracted. Someone else's decision tree will be different, though it might resemble ours in some respects. Our installation goofs only cost us extra labor, and did not compromise the safety or efficiency of the system.

Looking back, we're glad we did it ourselves. The project certainly built our technical self-confidence. Adding the extra PV modules was a snap, and we're looking forward to microhydro. Even with such user-friendly equipment available these days, there is still a pioneering aspect to RE, an aspect which is enriched by doing it yourself.

Access

Authors: Chip & Clara Boggs, 95245 Rink Creek Ln., Coquille, OR 97423 • 541-396-4764
chipnclara@aol.com • www.justicedenied.org

Real Goods Trading Corporation, 200 Clara Ave., Ukiah, CA 95482 • 800-762-7325 or 707-468-9292
realgoods@realgoods.com • www.realgoods.com

The Solar Electric Independent Home Book ©1998, US$19.95 postpaid from New England Solar Electric, Inc., 3 South Worthington Rd., Worthington, MA 01098
800-914-4131 or 413-238-5974 • Fax: 413-238-0203
nesolar@newenglandsolar.com
www.newenglandsolar.com