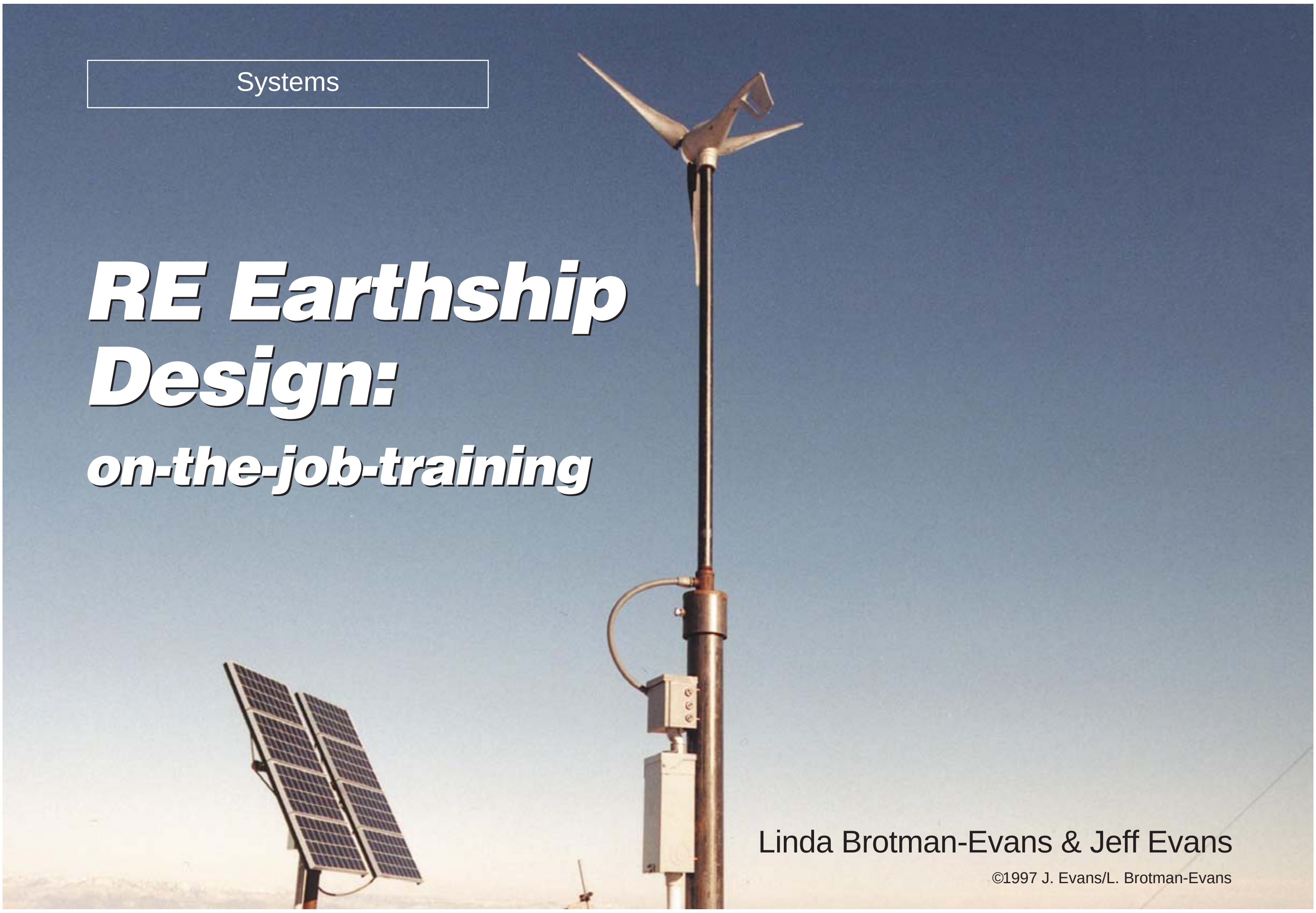
Systems



RE Earthship Design:

on-the-job-training

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Setting up a renewable energy home is a pioneering effort. There are many hurdles and much that must be known to avoid mistakes. It can be frustrating and more expensive than planned, but it is worth the effort. There is great satisfaction in realizing energy from the sun and wind, knowing that your energy use represents a clean and sustainable resource.

When we decided to build a home we hoped our energy system would meet our immediate and future energy needs. We made many initial choices and decisions, much like most novices. We read extensively, spoke to people, listened to their recommendations, and took our chances. If we had known how to better evaluate systems, our uses, and capacity, we would have made different choices in components, size, and system location. The most difficult part is the process of getting useful, clear, and accurate information leading to the right decisions in the beginning, not after you have made your investment.

We built an “Earthship” style home to serve as a self-heating and cooling, thermal mass structure. This eliminated the need for any electric energy for heating or cooling. Initially we installed a small solar system to reduce set-up costs. Our first year in the house began in November of 1995. We started with eight Kyocera 51 Watt multicrystal photovoltaic modules rated at 3.02 Amps and 16.9 Volts each. The array sits on a steel pole atop an earth berm on the north side of the house, about 21 feet high. The panels are as close to the power center as possible, approximately 20 feet. We rotate the panels by hand on a daily basis, usually setting for morning sun the night before, rotating later for midday and late afternoon positions. We also adjust for azimuth on a seasonal basis.

We installed ten Trojan T-105, 6 Volt deep cycle batteries, 220 Ampere-hour rated, and wired in series pairs for 12 Volts. We selected a Trace 2512 modified sine wave inverter, 2500 watts continuous and 6000/8000 watt surge capacity without battery charger. During our first winter we realized we wanted more energy. In March of 1996, we added an AIR 303 wind generator rated at 300 Watts. After we lived in the house for over a year we purchased a Generac 4000 watt gas generator with a Diehard 60 Amp battery charger.

What we have learned in the process is that for every system decision, you alone are responsible, much like designing and building your house. Information is available as are individuals who can help. All the reading and conversation, though, cannot fully prepare you for living with the system's benefits and limitations. If you make a mistake, have cold batteries, or see a change in energy production, you live with the initial and continuing decisions and responses. We call this "on-the-job-training" for novices. Mistakes cost you time, labor, and money while you learn. What you gain is independence.

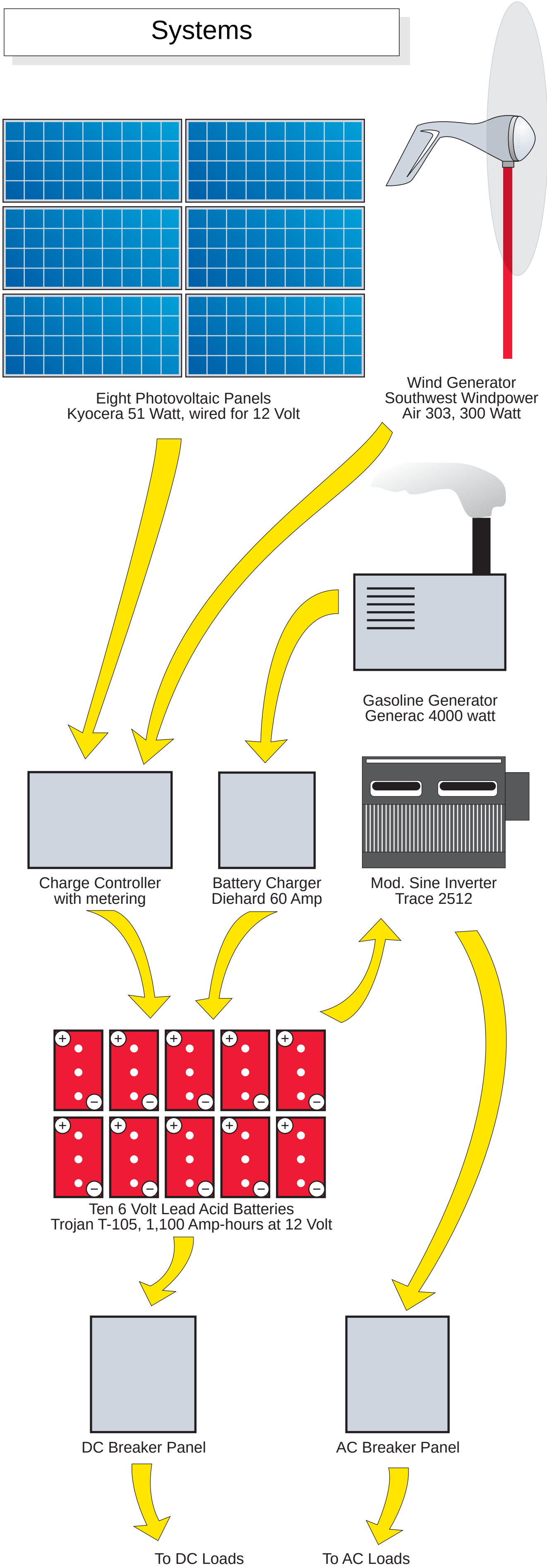
Knowledge is picked up in bits and pieces, corrections and adjustments made as needed. Experience has shown us that most solar home owners require more energy than their systems supply. They continually add to their systems. Weather conditions here and around the country have become less predictable and more variable. This year, for example, we have had more continuously cloudy days than when we originally set up our system.

In peak sunlight our panels produce a maximum of 22 Amps. This translates to 371.8 Watts of actual production in optimum conditions. The panels are rated at 51 Watts each, giving 408 Watts total. Actual production is less than rated by about 9%. At 20 Amps we have 338 Watts per hour flowing into our battery bank, an 18% decrease from rated production on an average sunny day. Actual performance then, is anywhere from 10 to 20% less than manufacturer's rating. With seven good hours of sunlight we can produce about 2,366 Watt-hours of energy in the summer. In the winter sunlight can be as little as three hours per day, or 1,014 Watt-hours. This amount of panel production is the bare minimum for our level of use. Had we known this, our original system design would have been different.

The distinction made between summer and winter production is central. For one month either side of winter solstice we can expect only three to four hours per day of top production on the sunniest days. Ideally you should size your system using minimum production and maximum use period figures. In other words, if you are using 1,500 Watts-hours over 24 hours but producing only 900, you have a problem. Either you have to boost production or reduce consumption. We must reduce consumption during continuously cloudy winter days.

Evans' Electrical Energy Consumption

Appliance	*Qty*	*Each Watts*	*Total Watts*	*Hrs/ Day*	*W-h/ Day*	*Days/ Week*	*W-h/ Week*	*Average W-h/Day*	*% Daily Average*
Washing Machine	1	1450	1450	1.0	1450	3	4350	621	32.6%
Sun Frost Fridge/Freezer	1	60	60	7.0	420	7	2940	420	22.0%
Water pump	1	373	373	0.5	187	7	1306	187	9.8%
TV	1	60	60	2.0	120	7	840	120	6.3%
Compact Fluorescent Lights	3	13	39	3.0	117	7	819	117	6.1%
Pw Cords	2	13	25	4.0	100	7	700	100	5.2%
Electronic Piano	1	90	90	1.0	90	5	450	64	3.4%
Computer	1	55	55	1.0	55	7	385	55	2.9%
Iron	1	1500	1500	0.3	375	1	375	54	2.8%
Gas Dryer	1	250	250	1.0	250	1	250	36	1.9%
Toaster	1	900	900	0.3	225	1	225	32	1.7%
Hair curler	1	750	750	0.3	188	1	188	27	1.4%
Monitor	1	14	14	1.0	14	7	101	14	0.8%
Blender	1	400	400	0.3	100	1	100	14	0.7%
Printer	1	12	12	1.0	12	7	84	12	0.6%
Battery Charger	1	8	8	10.0	80	1	80	11	0.6%
Stereo	1	30	30	0.5	15	4	60	9	0.4%
VCR	1	19	19	0.5	10	4	38	5	0.3%
CD Player	1	10	10	0.5	5	4	20	3	0.1%
Radio	1	10	10	0.5	5	4	20	3	0.1%
Vacuum cleaner	1	78	78	0.1	4	2	8	1	0.1%
				Totals	3821		13338	1905	



Evans System Costs

Quan	*Material*	*Cost*
8	Kyocera 51 Watt PVs w/Frame	$3,000
1	Trace 2512 Mod. SW Inverter	$2,500
	Generac 4000 Generator, Diehard 60 Amp Charger, 5 Yrs. Gasoline	$1,500
	Control Box, Poles, Gauges, Misc.	$1,200
1	Air 303 Wind Genny	$1,000
10	Trojan T-105 6 Volt L-A Batteries	$800
	Total	$10,000

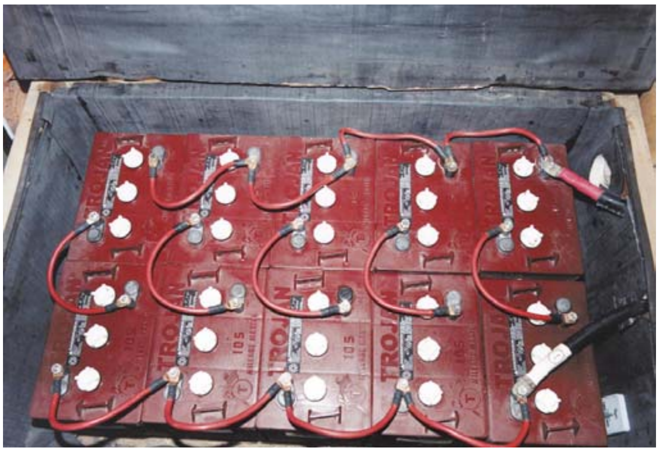
Once we began living with our system we started to learn more about how it functioned, how to evaluate performance, our use patterns, and how to troubleshoot. It is an ever evolving process.

The Air 303 wind generator will produce anywhere from 2 to 30+ Amps depending on wind conditions. It has a voltage range of 13.8 to 17.8. The internal regulator is set at around 15 to 15.5 Volts. This means that the charge will automatically shut off at this level. Theoretically you can equalize with this kind of capacity. It translates to 150 Watts at 10 Amps production in 15 to 20 mph of wind speed and 300 Watts at 25 to 30 mph to as high as 450 Watts in extreme wind conditions. Wind is intermittent, yet it does have the advantage of production at night and during storms on a year round basis. The wind can blow hard during the entire night and give a nice boost to the system. It complements photovoltaic output.

We get more out of our system by using energy as it is produced than we do by pulling it out of storage. Loss through inefficiency is reduced by arranging activities and uses for the strong sunlight periods. We try to strike a balance by keeping a surplus charge in the batteries. In that way we are not deeply cycling the batteries and are gaining maximum energy available before it is lost to battery inefficiency. This is evidenced by the fact that the batteries can show that they are topped off, that is at maximum voltage when the sun is out and charging the system, and immediately drop off in voltage when the sun goes down in the evening. Simply, you can siphon off excess water at the top of the bucket before it evaporates or spills over the side. How far down the voltage drops is also a measure of battery health. Even in the best of conditions there is tremendous drop off when charging ceases at the end of the day. Patterns of use become an important feature when managing your system.

Each of our batteries is rated at 220 Ampere-hours, which means we have an 1,100 Amp hour rating. This is divided by half because 50% of capacity must be

Above: Inverter, instrumentation, and breakers.



Above: Battery—1100 Ampere-hours at 12 VDC.

routinely kept in storage to prevent the batteries from discharging too deeply and aging prematurely. We then have 550 Ampere-hours available for routine use. This times 12 Volts nets 6,600 Watt-hours of usable energy stored in our battery. Theoretically then, in a fully charged state we have just about three days of available energy stored, assuming our current level of use. Actual available energy is probably less due to loss of battery efficiency over time. The batteries have been in continuous operation for over two years since they were in use during the construction phase, and are beginning to show some signs of degradation. Overall specific gravity levels are within adequate performance levels.

Batteries must be monitored and equalized regularly, more so during the winter months and depending on use. During our first year and a half (including construction) we did not do an equalizing charge. We did not understand the need for this and assumed that our panels would equalize during sunny days. This proved to be less than adequate as the panels are regulated to stop production when the batteries are charged at around 14.4 Volts. (This is a regulation setting that I do not yet know how to override). Thus by design, the system does not provide proper equalization. To tune up our batteries requires holding the level of input at or around 15 Volts for an extended period of time, approximately three to five hours. This tends to bring all the cells in line with each other and results in the batteries holding more charge over a longer period of time.

A larger capacity battery would offer a longer and stronger supply of energy. Our initial battery selection was based on cost and the general attitude that the golf cart style battery is a good beginner battery. We do know that our batteries have cycled deeply too often and were not equalized often enough. There is a risk buying the best batteries when you do not have sufficient knowledge of systems, operations, and maintenance to prevent potential damage. Golf cart batteries will take some punishment and save money while you learn, but won't hold as much energy as larger ones. Within the next two to five years, we will step up to a larger battery bank.

In our first year we installed the eight solar panels with no generator for backup. In March 1996, we added the AIR 303 because during the winter months we had less energy that we wanted. Our first winter had many cloudy days and we had no way of compensating for the lack of sunshine for an extended period of time. The wind generator allowed us to expand use by producing during those cloudy periods as strong winds often precede stormy weather.

We were using a 1950 model Servel propane refrigerator. In July 1996, we upgraded to a Sun Frost RF 12. Our energy production through the summer months was adequate. By fall and into the winter our overall production was not enough to meet demand. Adding the Sun Frost tipped the balance in our system toward more demand than supply. We purchased the Generac 4000, gasoline-powered, engine/generator in early 1997 to alleviate this problem.

Our generator is used for equalization and supplemental charging during extended cloudy periods. It will produce anywhere from 20 Amps when the batteries are full to 45 to 60 Amps when the batteries are deeply discharged. It has some equivalent production characteristics to the wind generator. But, it produces continuously, whereas the wind generator is intermittent.

The Sun Frost, while being one of the most efficient units in the world, is rated at 4 Amps. The unit cycles and runs about 30% of the time netting seven hours

Above: The Earthship's roof is used to collect water.

each day. Run time is also dependent on fridge temperature settings and room temperature. This translates to 336 to 420 Watt-hours each day. You should size your system according to the worst case projections, noting how you use energy and calculating the least number of hours of production.

Our water pump required special attention also. The architect of our "Earthship" planned for a DC pump but it burned up in the first five minutes of operation. Our water supply is in an underground cistern, about 20 feet from the filtration area inside the house and must be drawn up five to ten feet to the filtration and pressurization systems. We purchased the minimum size pump for this application, a 1/2 HP centrifugal surface AC unit, rated for continuous use. 1 HP equals 745 watts, so divided by two equals 373 watts. The unit runs three to five minutes at a time with a surge of 1500 to 3000 watts. So a ballpark estimate of use is the best we have come up with. With a surge guess in mind we may use 75 to 100 Watt-hours on each run of the pump. What we know for sure is that the voltage meter drops at least a half Volt with each running. It does recover with about 15 minutes passing. Recovery is greater on the low end of the scale as opposed to the higher voltage range. In other words the drop off rate is faster at higher voltage than at lower. This is due to battery resistance and electrical current flow. The supply at the top of the bucket being more easily drawn off. We are still researching pumps that use less energy and are more efficient, but have yet to make another choice.

Another factor to be considered is the washing machine. We bought a mainstream apartment size unit. Rated draw is a significant 1450 watts. This probably fluctuates with the cycle, with total running time per load at about 18 to 20 minutes. We do four loads per week on average, or about 273.4 Watt-hours daily not counting a surge factor. Surge on the washing machine must be in the 3000 to 4000 watt range based on observations of the system in operation and assuming a 6000 watt surge rating on the Trace inverter. We have seen the inverter kick off with the simultaneous start of the washer and the water pump. They will run together when started alternately, but over-surge the inverter when started at the same moment.

When you add the gas dryer into the equation it becomes more interesting. The washer, dryer, and water pump will run together. If the washer and water pump are running together and the dryer switches on, the surge does not exceed inverter limitations and all will operate. If, however, the washer and dryer are running, the surge of the water pump will exceed the limits and shut down the inverter. Once again, we continue to research efficient equipment alternatives.

It is difficult to quantify the actual energy use in surges. We know it is a factor of consumption and it is usually ignored in sizing information and product advertising. Energy consumption is clearly an area that must be quantified at some level. Load charts are the quickest way to accomplish that. Often the promotional literature will not have the amperage or voltage information, let alone surge ratings and other needed information. So we've learned to call a sales person at the dealership or even the manufacturer directly.

Above: An inside view of the Evans' home.

Very important to understanding and designing a system are patterns of use. For instance, we have found that when doing wash you should do it not only when there is strong sunshine available, but after your system has charged itself. (I mention sun only because it is much more predictable than wind.) In other words, we found that depleting your system just because you have the ability to replace the energy is less efficient.

Roof design was a factor affecting our energy system. Our array was originally installed above the roof line at the back of our house. We hand built two kiva style fireplaces in the house which had backdraft problems. When we put up additional stacks to achieve better draws, the chimney cast a shadow on the array during winter afternoons. A shadow, we learned the hard way, doesn't just slow the panel down, it shuts off the circuitry in the panel. This tends to seriously limit production! We ended up moving the array.

Battery placement is another factor. In addition to ventilation concerns, the batteries need to be easily accessible. Suffice it to say, it can be very uncomfortable testing specific gravity on your hands and knees in a confined space with no lighting. Code in our area created definite restrictions on placement and venting requiring special attention and cost.

In Summary

There are three areas of concern in setting up a RE system: energy production, energy storage, and energy consumption. All three must be understood and analyzed separately and then related to each other. A fourth area to be considered is home design for equipment placement. Each component has to be considered for price and for compatibility. Size your system and your needs carefully before you make purchases.

The more you can anticipate your needs and type of system for all circumstances, the better your chances of saving time, labor, and money. A small PV system in tandem with a wind turbine can be used dependably for a wide variety of purposes. The issue central to system size is lifestyle. If you want to match the capacity of an on-grid home then you will need a very large system. If you decide to limit use and curtail energy related activities then you will be able to live with a smaller investment. Our form of conservation depends on the knowledge that peak power consumption and off-hour use can be successfully balanced.

Access

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