Independent Power & Light!

David Palumbo

When we decided to make our home in the beautiful Green Mountains of northern Vermont, we had no idea where this new adventure would take us. Looking back at our decision of six years ago to produce our own electricity for our new homesite, I am amazed at how this one choice had such a profound effect on our lives.

The Palumbo Family

Our family is comprised of my wife Mary Val, our son Forrest (four years old), our daughter Kiah (two years), our latest addition Coretta (ten months), and myself.

Mary Val and I purchased land in Hyde Park, Vermont during the summer of 1984. At this time that we began researching the alternatives to paying the local utility $6,000 to connect us to their line one-half mile away. We were encouraged by friends who produced their own power and a visit to Peter Talmage's home in Kennebunkport, Maine. We decided to "take the road less traveled, and that has make all the difference" as Robert Frost (a Vermonter) put it so well. Talmage Engineering supplied the majority of the hardware, and Peter answered my questions. We now use alternative energy at all three of our buildings. Let's look at each in turn, as they occurred in time.

The Palumbo Family, David, Mary Val, Kiah, Forrest, and Cory.
Photo by Jay Kennedy, Village Photographer.

The Cherry House System

In the spring of 1985, while living out of a tent, we built what we call the "Cherry House". This is first of three buildings designed by M.B. Cushman Design of Stowe, Vermont. The Cherry House is a two-story saltbox with 950 square feet of living space, heated by a small wood stove. Power for constructing the Cherry House was supplied by a Winco 4,000 Watt, slow speed, engine/generator that runs on propane. Energy consumption for the completed house was estimated at 1,300 Watt-hours per day. As our primary power source we purchased ten Solenergy 30 Watt PV panels that were on the market as seconds in early 1985. The array was cost efficient, but not really large enough to satisfy our growing power needs. Our battery bank, for the Cherry House, consists of eight Surette T-12-140 deep cycle lead-acid batteries totaling 1,120 Ampere-hours at 12 Volts. Our loads for this house included our Dometic 12 VDC refrigerator/freezer (seven cubic feet). We added rigid insulation to reduce the Dometic's power consumption to 420 Watt-hours per day. Other loads in the Cherry House include a variety of REC Thin Lite DC fluorescents and a 10 inch Zenith color TV set consuming 4.5 Amperes at 12 Volts. When our children began arriving, we added a washing machine and a clothes dryer. The washer and dryer are powered by the Winco generator through the automatic transfer switch built into our Trace 1512 inverter/charger. The transfer switch and charger in the Trace inverter allow us to charge our battery bank and wash the diapers at the same time, all powered by the Winco generator.

The Trace 1512 could not handle the surges of the washing machine. The newer model Trace 2012 will handle most washing machines. We used the Winco propane fired generator to do the laundry and to help our undersized PV array charge our batteries. The generator was also essential (until we later developed our microhydro site) because we are located in one of the cloudier parts of the country. For example, during our first November here we had one day of full sun followed by a delightful December with three full days of sunshine. Wow! We eventually decided to add a hydro system, since rainfall is generally plentiful here, and our site has the elevation differential to support the hydro.

The Barn & Shop System

During the summer of 1987 we built The Barn with three horse stalls, a 500 square foot work shop, and plenty of storage space on the second floor. The Barn is located 450 feet from the Cherry House and 250 feet from the site for the Big House. The distances between these buildings presented us with two choices for the overall power plan. First, we could centralize a battery bank and inverter large enough to handle all of our power needs via 115 vac.

The Cherry House with ten Solenergy 30 Watt PV modules on the roof.
Photo by Jay Kennedy, Village Photographer.

The second choice was to have a separate battery bank in each of the three buildings. I went with the second option because we were building incrementally and the "whole" was only a fuzzy image in our mind's eye early in the project. Also, I was entering a new business, as a designer and installer of alternative power systems. The added experience of three separate systems was desirable and influenced my decision.

Three separate systems may not be the most efficient way to go. I am presently working on another large remote site, with three buildings, several miles north of our land. This installation will take advantage of the products available today. Specifically, NiCad batteries and a powerful inverter located in the garage/shop serving as the power center for all three buildings. The advantages of this approach include saving time & money in wiring, and the ability to use a higher battery bank voltage. This higher system voltage allows the charge source (in this case, PVs) to be located further from the batteries without using the more costly, large diameter wires. For this site, I am designing the system with a 48 Volt battery bank.

Our Barn's power system consists of four Trojan L-16W deep-cycle, lead-acid batteries with a capacity of 700 Ampere-hours at 12 Volts. We are using the Heliotrope PSTT 2,300 Watt inverter. This inverter has worked well in the shop, powering all of the tools expect those requiring 240 vac, which are sourced by the generator. We sold the 4,000 Watt Winco and replaced it with a Winco 12,500 Watt, slow speed, propane engine/generator. We did this because our carpenter needed to use a high powered air compressor with a six horsepower electric motor. The other machines powered by the generator include a large table saw, an eight inch planer, and a six inch joiner. We wired the big Winco so that we are able to turn it on or off from any of the three buildings, using remote four way switches activating the 12 Volt solenoid and starter switch at the generator. The remainder of the electrical loads in the Barn/Shop are all lighting. We used Thin-Lite brand DC fluorescents throughout and are very happy with them. Since the shop is the only heated space in the Barn, cold weather light operation was a must. The Thin-Lites work well in the cold. They are efficient, for example they produce 3,150 lumens of light from a standard 40 Watt fluorescent tube. At 78.7 Lumens per Watt, this is 25% higher than the highly praised PL lights. The 40 Watt tubes are inexpensive, locally available, and come in a wide variety of spectral outputs.

The Heliotrope inverters do not contain battery chargers (like the Trace models). We use a Silver Beauty battery charger that charges the Trojans quite well from the Winco. However, this battery charger must be turned on with a timer switch as it doesn't have the programmable features of the sophisticated charger built-into the Trace inverter/chargers.

The Big House

We felt a traditional, New England, colonial home design offered the features we wanted at a reasonable cost. We were looking for a lot of space, energy efficiency, and country charm. By using all of the space under the roof, we have been able to build a home with 5,300 square feet of heated space. All of this sits on a "footprint" of 2,160 square feet. The Big House has a full basement, except under the garage, that houses the boiler room, the battery & control room, a large play area for the kids, and the cold, root & wine, cellars. Without cramping, we can store up to six cords of wood in the basement to augment the wood sheds outside the garage, which hold seven cords.

We have over 100 acres of good forest land that we are managing for both timber production and wildlife habitat. Our woodlots have a sustained yield of over 1 cord per acre per year to supply our buildings with heat from this renewable resource. "Big's" heat is produced by an Essex Multifuel boiler rated at 140,000 BTUs. We use it as an oil burner only very occasionally, it is mostly fueled by wood. The Essex has a ten cubic foot firebox and cycles on and off to satisfy the thermostats in our four heating zones within the Big House. The Essex burns by a gasification process and is 95% efficient on wood while producing no creosote emissions. We also get all of our domestic hot water from this 1,500 pound beast's two 6 GPM heating coils. We use about 15 cords of hardwood per year to heat the Big House and its water. I hope to install a solar hot water heater soon so I can take a summer vacation from loading firewood and shoveling ashes out of the Essex.

MicroHydro

I began to think about water power after the first rainy fall of 1985, and by 1987 we began work on our microhydro project. We built a pond on the highest site on our property. The pond is situated on ideal soils (heavy silt on top of glacial hardpan) for pond construction. Our pond is kept full by below surface springs and surface run off.

The pond's surface is 210 feet in elevation (known as head) above our turbine. The pipeline (penstock) is buried under the pond's dam and to a depth of four feet for its entire 1,250 foot run. The inside diameter of the pipe is two inches. I vary the water's flow rate depending on how much power we need, while trying to keep the pond reasonably full. By changing the hydro's nozzle from 1/4 to 3/8 inches, I change the flow rate from 17.5 to 38 GPM.

The turbine is an Energy Systems & Design IAT-1 1/2 Induction Generator. It was chosen for this application because of the cost of the long wire runs going from the turbine building to the three buildings. The induction generator makes 3 phase, high voltage ac current, and the higher voltage requires smaller gauge wire on long runs. The longest of these runs is 450 feet to the Cherry House. In retrospect, I would have been better off swallowing the additional expense of larger wires (≈$600) and going with a 24 Volt DC high output alternator, instead of the 200+ vac induction unit.

The Big House during the winter with David standing out front. Note the twenty-four Kyocera PV modules on two, roof-mounted Zomeworks trackers.

Photo by Jay Kennedy, Village Photographer.

What I have now is a more complex system because of the three phase ac induction generator. This generator requires just the right amount of capacitance at the generator, and it requires properly sized transformers & rectifiers at each of the battery banks. The biggest problem is that neither the manufacturer, nor anyone else, could accurately specify what was needed for capacitors, transformers, or rectifiers. This is highly site specific, and in our system complicated because we are using the power at three places, each with its own transformer. I finally got the system to put out the power we needed by replacing the induction generator, capacitors and transformers with different sizes. This setup was determined experimentally. It was very frustrating, time consuming and expensive.

Our hydro system is now producing 240 Watts with a 1/4 inch nozzle installed at a net head of 203 feet; this works out to an overall efficiency of 36%. With the 3/8 inch nozzle installed the system produces 430 Watts at a net head of 187 feet; this is an efficiency of 31%.

The Big House's PV Array

As you can see in the photos, putting trackers on the roof is an interesting design feature and a challenging installation. I first got the idea while visiting Richard Gottlieb and Carol Levin of Sunnyside Solar near Brattleboro, Vermont. They have an 8 panel Zomeworks tracker mounted on their garage roof. Why put the tracker on the roof? There are three advantages for us in this application. First, it gets the PV array way up high-- the top of our arrays are 32 feet above the ground. This drastically reduced the number of trees we had to clear to get the sun on the panels. And second, it saves space on the ground for other things like sand boxes and gardens. Thrid, we don't have to look our over the trackers from our windows.

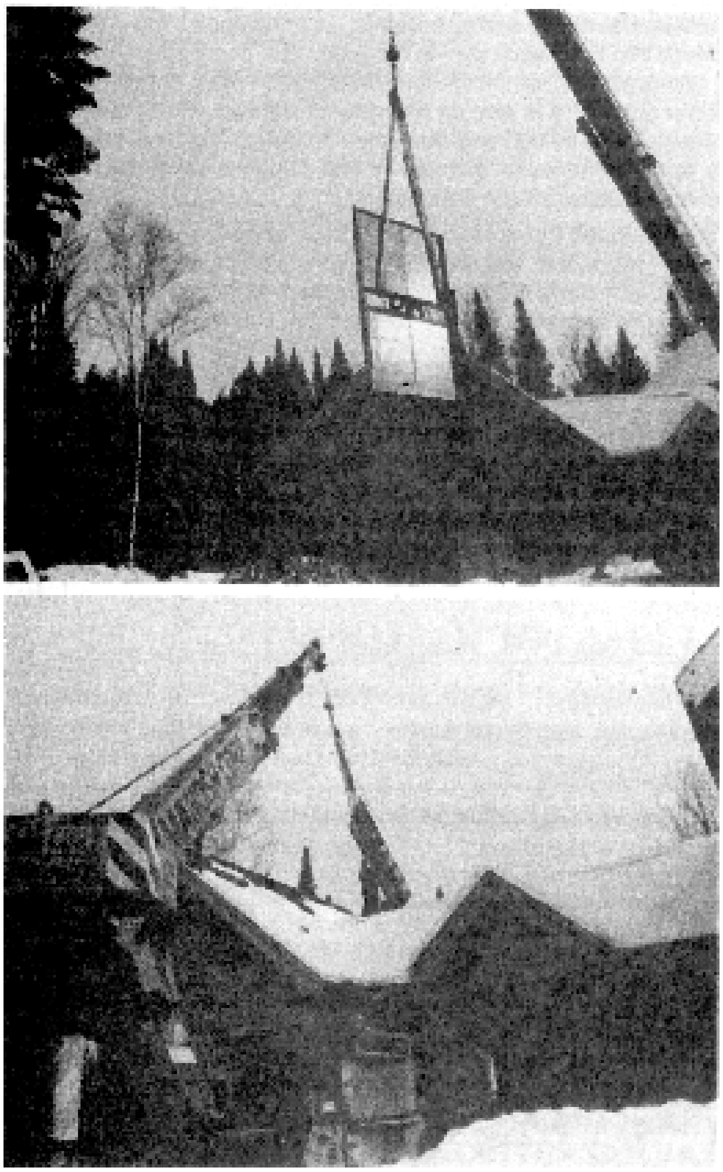
Why use trackers this far north? Usually we do not specify them here because at our latitude (45°N.) they add only ≈6% to the PV power production during the winter and ≈22% of the year. The reason we went with the Zomeworks Track Racks is because we have a hybrid system. I sized the PV arrays to meet all of charging needs during the summer. Our summer is a dry time and our hydro system cannot be relied on then. The trackers add ≈33% to the PVs' power production during the summer. Therefore, I reduced the total number of panels from 32 to 24 by using the trackers. The cost of the trackers was offset by the reduced cost of the downsized PV arrays.

PV Installation

Each of the two arrays above our garage roof holds 12 Kyocera 48 Watt PV modules for a total of 1,152 peak Watts of solar produced power. Over the year our Kyocera panels have consistently outperformed their manufacturer's ratings. On a recent April day, I observed an array current of 42 Amps at 28 VDC. This occurred on a day when the sky had many puffy, white clouds (known as cloud enhancement). On a clear sky, typically I measure 37.7 Amperes charging our 24 VDC battery bank. I have an analog ammeter installed in the cover of the fused PV disconnect for quick checks. For more accuracy, I use the millivolt scale on my Fluke 23 multimeter to measure the voltage drop across the precision (0.25%) 50 millivolt shunt on our Thomson & Howe Ampere-hour meter (see HP#11, "Things that Work!" article). A 48 Watt Kyocera panel is rated at 2.89 Amperes, but I measure 3.14 Amperes per panel.

The 24 Kyocera J-48 modules are mounted on two Zomeworks pole-mounted Track Racks. Each tracker was placed on its pipe mast by a crane operated by an expert and a crew of three helpers on the roof. Hiring the crane cost $210 and was worth that and more. Installation in any other fashion would have been asking for trouble- possibly fatal damage to the PV/Trackers and/or potential injury to yours truly and my crew.

The pipe masts themselves are 5 inch schedule 40 steel, each 17 feet long. The masts were cut seven feet from the base and later spliced with a four foot section of 4 inch pipe inside the 5 inch pipes. The splice was necessary because the full 17 feet length would not fit into my shop easily nor would it push up through the roof easily. The lower section of the mast (7 ft.) had a 18 inch by 18 inch plate



Using a crane to install the trackers with PV modules already attached and wired. Photo by Jay Kennedy, Village Photographer.

of 1/2 inch steel welded on its bottom. The steel plate was drilled out for 3 one-half inch lag bolts along each side. The masts were bolted down with eight bolts per mast. The lag bolts went through the 3/4 inch tongue & groove plywood decking and into the 2X10 floor joists and added box bridging. The upper section of the mast (10 feet) was lowered through the hole in the roof by two men to a third man guiding it into the splice insert. A standard roof flange of aluminum and rubber was then placed over the top of the pipe mast and seated onto the roof where it sits under the high shingles and over the low shingles. The seam where the roof flange and pipe meet is sealed with a type of butyl tape called Miracle Seal. This thick, pliable tape expands and contracts with the steel pipe during changes in temperature.

The last detail of the mast's installation was fastening the pipe to the roof rafter for stability. Absolute rigidity is as important here as it is at the base plate. Consult with a local building expert or structural engineer if there is any doubt about your roof mounted tracker. We placed the masts right next to a 2X12 roof rafter, added shims there to tighten this union, and then securely bolted the pipe to the rafter with a large steel U bolt. With the pipe fastened securely at its base and at ten feet (leaving seven feet above the roof), we met the Zomeworks installation requirement that half of the mast be buried in concrete below grade. I have witnessed wind gusts of over 55 MPH make the arrays flutter from side to side (buffered by the shock absorbers on the trackers), but the same gusts do not move the pipe masts at all.

We drilled a small weep hole at the very bottom of the pipes to drain condensation and prevent rusting from inside. The pipe masts were grounded for lightning protection with #4 bare copper wire at the base plates. The ground wires were bonded together with a split bolt connector. to a common wire which ended in an eight foot driven ground rod bonded to the main system ground.

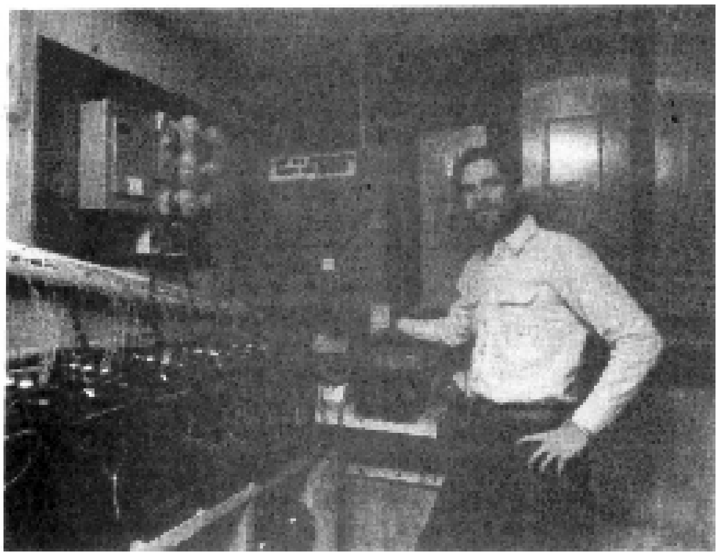
The arrays were mounted on their trackers in our garage and wired in series and parallel for 24 Volt operation. Module interconnections were made with #10 sunlight resistant, 2 conductor, Chester Cable terminated in a junction box on each tracker. Once the arrays were in place, we came out of each junction box with #8 ga. Chester Cable. We clamped the cable to the tracker for strain relief and fed it down through a hole tapped on the top of the Track Rack's pipe fitting. A weatherproof connector was used here. Of course, a loop of cable was used as slack before entering the pipe, to be taken up during the tracker's movement over the course of the day. The cable was then fished out of the pipe via another hole tapped at ceiling height and a Romex connector was used here. The two cables were run to the center of the room where a junction box fed with #0 ga. copper cable awaited them. The length of each #8 ga. cable is 26 feet. The length of the #0 ga. copper cable run from the junction box, back through the house, and down to the battery is 90 feet.

Battery Bank and Big House Loads

Our storage batteries at the Big House are Trojan J-185 deep-cycle, lead-acid types. We use 14 of these 185 Ampere-hour batteries in a 24 Volt configuration for a total of 1,295 Ampere-hours (31 kiloWatt-hours) of storage. In our system they are an economical choice because we normally do not cycle them below 50% of capacity. The Big House receives 4.8 kWh per day from the hydro when the 1/4 inch nozzle is being used, and 8 kWh per day with the 3/8 inch nozzle. The hydro power is often switched off at the Big House when the sun is shining, and all the power goes to the Barn and the Cherry House. The PV panels produced an average of 3.9 kWh per day as measured during March and April of 1990 by the

T&H Amp-hour accumulator.

Voltage is controlled at all three of our battery banks by Enermaxer shunt regulators. I chose the Enermaxer because all of our battery banks are charged by multiple sources. The Cherry House is charged by PVs, hydro and an engine/generator. The Big House is also charged by these three sources, while the Barn is charged by hydro and engine/generator. The Enermaxer is connected to the battery bank and to shunt loads. It doesn't matter what the charging sources are as long as the current rating of the shunt loads are equivalent to the highest possible amperage of all charging sources combined at that particular battery. The Enermaxer works well because it smoothly tapers the voltage of the batteries to optimum float voltage (user adjustable to a tenth of a volt).



David Palumbo in the power room of the Big House.
Photo by Jay Kennedy, Village Photographer.

We average about 4.8 kWh per day of power consumption in the Big House, with 6 kWh peak during a busy, winter-time wash day. We are able to satisfy our power requirements and keep our battery bank quite full without using the generator because of our hybrid PV/microhydro system.

The loads in the Big House (14 rooms plus a full basement) are typical for a busy family of five. Various lighting products (all DC) have been used with good results including LEDs for night lights. During our long winters, we average around 140 Ampere-hours or 3,360 Watt-hours used on lighting per day. Other 24 VDC loads include a Sun Frost R-19 (19 cu. ft. refrigerator) and a Sun Frost F-10 (10 cu. ft. freezer). I recently recorded their individual power consumption on my portable T&H Amp-hour meter over a test period of 3 days averaging a room temperature of 70°F. The R-19 used 23 Ampere-hours (552 Watt-hours) per day. The F-10 used 28.65 Ampere-hours (688 Watt-hours) per day.

Our 120 vac loads include a washing machine (350 Watt-hours per use), a clothes dryer (propane fired with electric motor- 150 Watt-hours per use), an automatic dishwasher (275 Watt-hours per use), a stereo system, a 19 inch color TV that uses 80 Watts with the VCR (65 Watts alone), the controls on the Essex boiler (40 Watts), and other appliances/tools. Our total average 120 vac power consumption per day has been running around 2.5 kWh per day.

The inverter we are using is the Trace 2024 with stand-by battery charger, turbo cooling fan and remote digital metering. It is able to handle the washer, dryer, and dishwasher all at the same time. We do the laundry during the sunny days whenever possible because the batteries are full by the afternoon and the Enermaxer would just be shunting off the power surplus. A better use of the sun's energy is cleaning our 14 loads of laundry per week!

The Big House has more than satisfied our goals for an energy efficient, comfortable, and versatile home for our family and my growing alternative energy business. It has helped bring alternative energy into the mainstream in our area. Our home power system is a demonstration for those considering alternative energy as their power source. It is also an example for bankers who are hesitant about lending on non-grid connected property. We have been able to open some eyes and get a few projects going that would otherwise never left the drawing board.

I wish to thank those contributors I have already mentioned. Also all the fine people who worked on the project, most notably, Gary Cole (Electrician), George Stone (Carpenter), and David Vissering (Jack of All Trades).

Total System Costs

The below total includes all of the excavation, conduit, and wiring used for the underground burials between the three buildings.

Access

David Palumbo operates as Independent Power & Light, RR#1, Box 3054, Hyde Park, VT 05655 • 802-888-7194.

COST	ITEM
$22,400	Wire, cables, conduit, fuses, breakers, distribution panels, disconnects, boxes, fans, & all labor
$5,600	Cherry House System- including generator, refirgerator, lighting, all wiring and labor.
$4,500	Winco 12,500 Watt Generator setup.
$4,377	Microhydro System- includes everything except building the pond and turbine shed
$3,700	Barn System- everything included
	Big House System Specifics
$9,500	Tracked PV Arrays- 24 @ Kyocera J48 Modules, 2 @ Zomeworks Trackers, installation, etc.
$3,800	Sun Frost R-19 Refrigerator and Sun Frost F-10 Freezer
$3,125	DC Lighting- high efficiency 24 VDC fluorescent lighting
$2,250	Battery Bank- 14 @ Trojan J-185 lead-acid batteries
$1,650	Trace 2024 Inverter with battery charger, turbo, & remote metering
$695	Controls and Instrumentation
$61,597	GRAND TOTAL OF ALL THREE SYSTEMS INCLUDING INTERCONNECTION