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I NOW use alternative energy (check one that best applies to your situation).

- ☐ **As my only power source**
- ☐ **As my primary power source**
- ☐ **As my backup power source**
- ☐ **As a recreational power source (RVs etc.)**

I want to use alternative energy in the FUTURE (check one that best applies to your situation).

- ☐ **As my only power source**
- ☐ **As my primary power source**
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My site has the following alternative energy potentials (check all that apply).

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- ☐ **Water power**
- ☐ **Wind Power**
- ☐ **Other** ______________________

I now use OR plan to use the following alternative energy equipment (check all that apply).

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☐	☐	**Wind generator**	☐	☐	**Batteries**
☐	☐	**Water power generator**	☐	☐	**Inverter**
☐	☐	**Battery Charger**	☐	☐	**Control systems**
☐	☐	**Instrumentation**	☐	☐	**PV Tracker**

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Please Allow Me to Introduce Myself...

An Open Letter to Home Power Readers

Home Power in a free monthly magazine about alternative energy (AE) systems. It's for people who make their own electricity. Home Power will contain all the departments you see in this issue in every issue. Our next issue will be published during January 1988, and thereafter on the 20th of every month.

All the people who work on Home Power actually live on alternative energy. In fact, the computers and other equipment used to produce Home Power are exclusively powered by alternative energy. Our information about AE comes from direct personal experience. Our technically adept staff can help you better understand your own AE system. Read this issue and see!

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Richard Perez

Small Water Power Siting

by
Paul Cunningham


There are small streams running over much of the countryside. Perhaps you are wondering if a brook in your area is suitable for developing into a power source. The following is intended to show the procedure I used in my case to arrive at solutions to various problems. Discussing the thinking involved will provide some interesting

How Much Is Enough?

A small scale water power system requires a more specific site than either a wind or photovoltaic one. You do need to have some flowing water. On the other hand, it isn't necessary to have very much, or much pressure, and it doesn't have to be very close to the point of use. My situation will illustrate this.

Here in the Canadian Maritimes it is difficult to go very far without finding some type of stream. I live in an area of rugged topography which enhances the water power potential. My house is located near a brook that most times of the year has a fairly low flow rate. There is normally little water in the stream above the house while water from springs which come to the surface steadily increase the flow as the water runs downhill.

One logical place for the intake and beginning of the pipeline is near my house. Although flow increases further downstream, the slope decreases. Near the house the brook drops around 8 feet for every 100 horizontal feet. So running a pipeline downstream 1,000 feet produces a combined drop or "head" of 75 feet. This looked like a reasonable place to start although the site permits running a pipeline 3,000 feet before the brook meets another one running almost level.

1000 ft. of 1.5 in. polyethylene pipe was purchased (in 1978) and simply laid on the ground. A small screened box served as the intake and was set in the brook with a "dam" of earth and rocks sufficient to raise the water level about one foot. At this site, the maximum power will be produced at a flow rate of about 20 gallons per minute (GPM). This is the point where the dynamic (running or net) head is equal to two thirds of the static head. So there will be 50 feet of net head at the end of the pipe when the water is running with a suitable nozzle at the end.

Losses within the Pipe

Any increase in flow will result in a decrease in power available due to increased pipe friction losses. Right away one third of the precious power potential is lost. At lower flow rates the pipe loss decreases which results in an increase in efficiency as flow decreases.

So why don't I use a larger pipe? Well, it costs more and sometimes 20 GPM is all there is in the brook. Also a larger pipe would aggravate the problem of freezing at low temperatures with no insulating snow cover. This is because the residence time would increase with larger pipe. In my case, the water entering the pipe is (slightly) above freezing and cools as it travels along (when temperatures are very low).

So why don't I bury it? Yes that would be nice and hopefully I will when I can afford that and larger pipe too. It is a case of the shoemaker being inadequately shod as I content myself with the present system. Besides, it has spurred me on to other possibilities that we will look at later in future articles.

Nozzle Velocity

Back to the 20 GPM at 50 foot head. A 3/8 inch diameter nozzle is about the right size for this, giving 19 GPM According to the spouting formula the velocity of a jet of water will be:

$$V = \sqrt{2gH} = \sqrt{2*32.2*50} = 56.7 \text{ ft/sec.}$$

g = 32.2 feet/sec/sec (acceleration due to gravity)
H = head, expressed in feet

Moving Water as Energy!

How much potential power is this? A U.S. gallon of water weighs 8.34 lbs. and the flow is 19 GPM; then 8.34 lbs.per gallon X 19 gallons per minute = 158 lbs per minute. Now, 158 pounds of water per minute falling 50 feet has 7,900 foot-pounds/minute of energy (simply multiply the factors). Conversion to horsepower is accomplished by division by 33,000., thus 7900/33,000 = .24 horsepower. Since 746 Watts of energy is equivalent to one horsepower, .24 hp. X 746 Watts per hp. = 179 Watts of potential squirting out the nozzle. This means that the potential power was .36 horsepower or 269 Watts before going through the pipe. Since nozzles tend to be very efficient not much loss is expected. But keep in mind that every time the energy goes through a change, power is lost. All right, how about a 9 Watt loss to make an even 170 Watts.

This may appear a little sloppy. But you must realize that these systems do not have to be very precise-- they are quite forgiving. Also many of the measurements are difficult to determine with high accuracy. So close approximations are sufficient.

Thus far things are reasonably straightforward - a pipeline with a nozzle at the end. Now what? Conventional practice would suggest some sort of impulse turbine such as a Pelton or Turgo. It would also be possible to use a reaction machine. It would have to resemble one of those spinning lawn sprinklers rather than say, a propeller type. This is because of the very small nozzle area. The impulse type looked easier to build.

Low Voltage DC Hydro

At this site it is necessary to send the power back upstream 1,000 feet to the house. I wanted to use 12 VDC and wanted some way to transmit the power other than the very large wire that would be required at this voltage.

In the spring, when the flow in the brook was very high, various 12 VDC generators were operated with the pipeline ending near the house. But this could only be temporary, as ways of solving the transmission problem had to be discovered. Of course using wires wasn't the only possibility. I could always charge batteries downstream at the generator and then carry them up to the house. Or perhaps a reciprocating rod kept in tension could be used to transmit the power. But all things considered, producing electricity at a voltage higher than 12 VDC looked the easiest.

Let 's Raise the Voltage

I thought generating AC electricity at 60 Hz. like regular commercial power would permit using standard transformers and make it easy to change the voltage. For this I bought a "Virden Permabilt" 120 VAC generator. This produces 1,200 Watts rated output and 60 Hz. at 3600 RPM. These machines are reworked DC auto generators with rewound field, rotor with a slip ring and brush to carry the output.

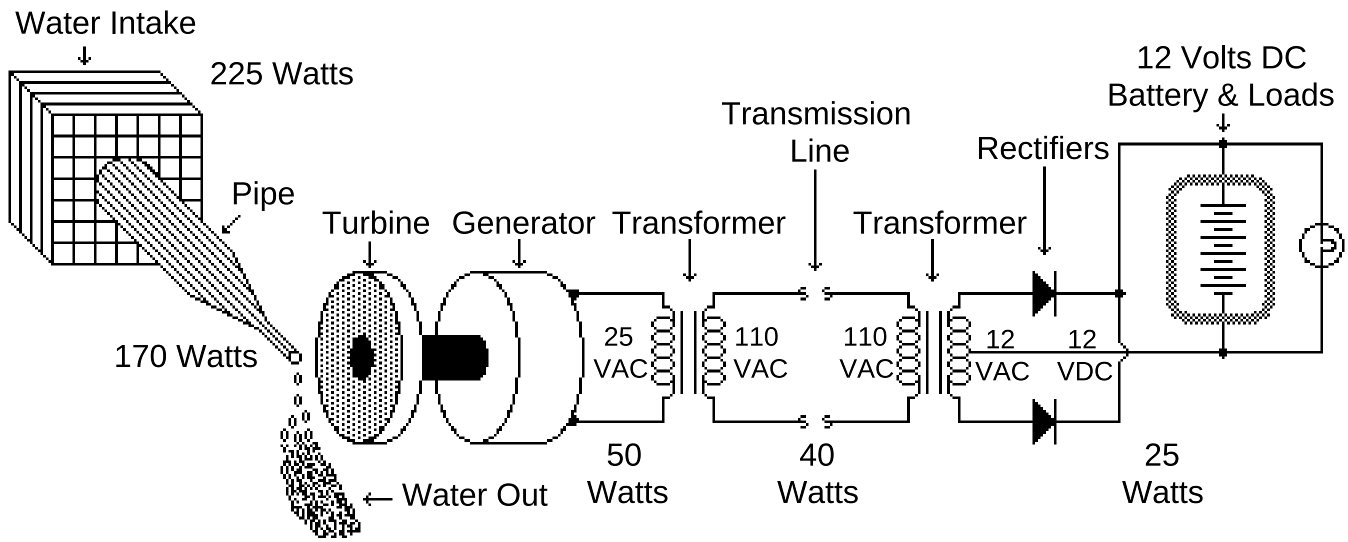
An impulse turbine should have a surface speed of about half the jet velocity. So at 56 feet per second, a turbine wheel slightly less than 2 inches in pitch (hydraulic) diameter is required. This is a little on the small side but I did make a Turgo wheel of this size so the rotational speed would be right for direct drive. Yes it's possible to use speed increasers with a larger turbine but I didn't think there was anything to gain and only power to be lost. It turned out that the alternator would not generate 120 VAC at a low power level. The field required 10% of the rated 1200 Watts output to put out 120 VAC regardless of the load. Therefore a lower output voltage was necessary to properly balance the system. It was determined that under the site conditions an output of 50 Watts at 24 to 25 Volts was required to be in the correct ratio: 120 VAC/10 Amperes = 24 VAC/2 Amperes or 48 Watts.

Now you are probably wondering how come only 48 Watts was being produced. Well that is what that combination of turbine and generator put out. And this isn't the end either. Next the juice went through a 25-110 volt transformer, through 1000 feet of 18 gauge wire (two strands), another transformer down to 12 volts and then through rectifiers to give DC. In the end only 25 Watts or about 2 Amperes actually found its way to the battery.

This setup didn't last long enough to make many improvements. It was hard just keeping it alive. The alternator used only one slip ring. The other conductor was the bronze tail bearing! Both items had limited life under 24 hour service. Besides the efficiency was low anyway.

A Functioning Higher Voltage System

I still needed a reasonable system. At least one with a longer life. In the next attempt a 4 inch pitch Pelton Turbine was cast in epoxy using a silicone rubber mold. This directly drove a car alternator with a rheostat in series with the field to adjust the output. Transformers (3) were connected to the three phase output to raise the voltage for transmission with the (now) 3-18 gauge lines. Then a similar set of three transformers were used at the house to lower the voltage and a rectifier to make the DC conversion. About 50 Watts was still generated (4 Amperes at 12 volts) but more made it into the battery--about 3 Amperes. The reason for this is the automotive alternators have more poles (12 Ford, 14 Delco) and generate at a higher frequency. This improves



the efficiency of small transformers even though they are "designed" to work at 60 Hz. Now the system has an efficiency of around 21% (36 Watts/170 Watts) using the power available at the nozzle as the starting point.

What Can Be Done With 25 Watts?

Three Amperes in a 12 VDC system doesn't sound like much. But this is sufficient to run the lights, a small fridge (Koolatron) and a tape player-radio. My house is small and so are my needs. There was sometimes even extra power and I could run Christmas lights or leave on things just to use the extra power.

At some point it occurred to me that I might generate more than electricity if I could produce turbines for others in a similar situation. Peltons were made first for sale. Originally these were made of epoxy and later of a high-strength and abrasion resistant Polyurethane. This endeavor busied me some but it soon became apparent that to survive doing this sort of thing would mean producing complete generating units.

Turgos

Turgo turbines looked more reasonable than the Peltons for this, due to their greater flow handling capability for a given size. Using a 4 inch pitch diameter turbine wheel allowed as many as four one inch diameter nozzles to be used. This resulted in a very versatile machine.

The first production models used automotive alternators (Delco) since they are inexpensive, dependable, available and most people wanted 12 VDC output. But these couldn't operate with heads of less than 20 feet or so. Also the efficiency of these alternators is in the 40-50% range and I thought there was room for improvement.

Back in the R and D department, work was proceeding to develop a better machine. The Turgo turbines operate in the 60-70% efficiency range. These are made in re-usable silicone rubber molds. This placed certain constraints on their design and so limited the efficiency. But other tests showed there wasn't much to be gained by changing the shape of such a small wheel.

Permanent Magnet Generators

However, the generators used so far had efficiencies in the 50% range or less. They also had electric field coils which made for easy adjustment of the output but also took part of the output to operate. It looked like the use of a permanent-magnet (PM) field would be a help and could make operation at very low-heads feasible. Yes, DC motors with PM fields could be used as generators. But my experience with machines where brushes carried the full output was disappointing. Longevity was a problem -- remember these are going to run 24 hours a day. If alternating current could be generated then transformers can be used to alter the voltage to suit the site.

It is well established that the most efficient generator type, especially in small sizes and at low speeds, is the PM-rotor alternator. Just like a bicycle generator. There is also nothing to wear out besides two ball bearings. That would be a feature and a half.

After a few tries, standard induction motors were used by keeping the stators and building new PM rotors. This produced a machine capable of generating power with an efficiency of over 80%. Standard 60 Hz. AC output was possible at 1800 RPM for these 4 pole machines. Experience suggested that frequencies of 50-400 Hz. would operate standard transformers quite well. This, combined with the reconnectable output wiring, produced a machine able to generate almost any voltage.

Meanwhile Back At The Ranch...

So how is it looking back at my site? Using the new PM rotor alternator about 100 Watts of power is produced. This is an efficiency of 100 Watts/170 Watts or about 59%. Dynamometer testing of the alternator shows it has an efficiency of 85% at this condition which means the turbine is running at 69%. Now 120 VAC is generated so no transformers are used at the generating site. The same transformer set used with the Delco installation is used at the battery end. About 6 Amperes are delivered to the 12 volt battery. This gives an overall efficiency of 72/170 or 42% water to wire (water to battery?).

With this system appliances can be run directly off the alternator output as long as this requirement is less than the available power. This creates a hybrid setup that produces both 120 VAC @ 60 Hz. and 12 VDC. A future article will discuss how to deal with more difficult sites.

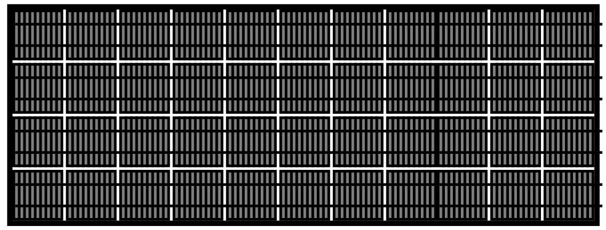
Paul Cunningham is CEO of Energy Systems & Design. He manufactures water machines and lives on hydro power.

Are Photovoltaics Right for Me?

An Economics Approach to Solar Power

by Richard Perez

See why and how photovoltaics can save you money in your system. All swell details such as initial cost, payback time, & operating cost are revealed. Come see what PVs can do for you.



In the coming months we will be talking about a wide variety of topics relating to solar generated electricity: the PVs themselves, trackers, mounting racks, controllers, instrumentation, and how the PVs fit into the entire alternative energy system. This first solar article is about one of the most commonly asked questions about PVs. "Are PVs right for me? Will they work in my system. Will PVs save me money?" This is an economic examination of the use of photovoltaics in a small alternative energy system.

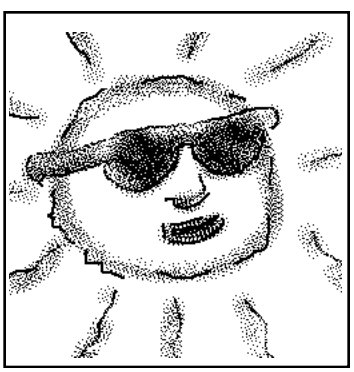
It's A System!

An alternative energy system is just that-- a system. It is composed of several parts, and each of these parts must be properly proportioned in order to economically function together as a system. A high degree of harmony and proportion between these individual parts is just as necessary in an alternative energy system as it is for say, an orchestra or a football team. So in order to discuss the economics of solar, we must examine the economics of the entire system.

In this example system the question we are asking is, "Is it economical to add photovoltaics to this system?" Well, first we need to know more about the people using the system, how much and what type energy they are planning on using.

Meet the Smiths

For this example, let's discuss a family of four members, Mom, Pop and two children. Assume that this family, let's call them the Smiths, are considering moving to the country on their dream property. The only problem is that their dream property is located some 1 mile or more from the nearest electrical utility line. The power company gives Mr. Smith a quote of say $30,000. to



run the power lines to his property.

The actual rates for running in commercial electrical service vary with locality. In the Western US, the rate is about $5.50 per foot. In some US locales, the rate may be over $10.00 per foot. The Smiths are considering using a gasoline powered mechanical generator because as Mr. Smith puts it, "You can burn up a lot of generators and gas for $30,000."

Well, Mr. Smith is just about right. If the power company wants this much just to run in the power lines, then he can definitely generate his own electricity cheaper than he can buy it from the utility. Once Mr. Smith has firmly decided this, he then needs to consider what type of hardware and how much hardware he needs to roll his own power. Mr. Smith is hesitant; he is unsure if he knows enough about alternative energy to put the system together himself, have it work, and meet his needs.

The Smiths are also not pleased with the idea of a noisy generator running all the time. Noise is one thing they are moving to the country to get away from. The Smiths' property has neither wind or water power potential. Mr. Smith asks a company that specializes in alternative energy systems what his options are.

Planning Ahead is the Key

The first step in any alternative energy system is a realistic estimation of how much power and what type of power is needed. This estimate assures that the completed system will, in fact, meet the Smith's electrical needs.

Mr. Smith talks with his family and they decide that they are willing to limit their power consumption to essential uses only. The family needs electricity for such essential uses as pumping water from their deep well, lighting, refrigeration, a washing machine, a vacuum cleaner, sewing machine, kitchen appliances, and entertainment electronics. The company helping Mr. Smith suggests that since the deep well pump and the washing machine are such large and intermittent loads, they be powered only by a mechanical generator. This reduces the size of the batteries and inverter required for the system, and reduces the overall cost. Mr. and Mrs. Smith decide that they are willing to start their generator for water pumping and clothes washing periods.

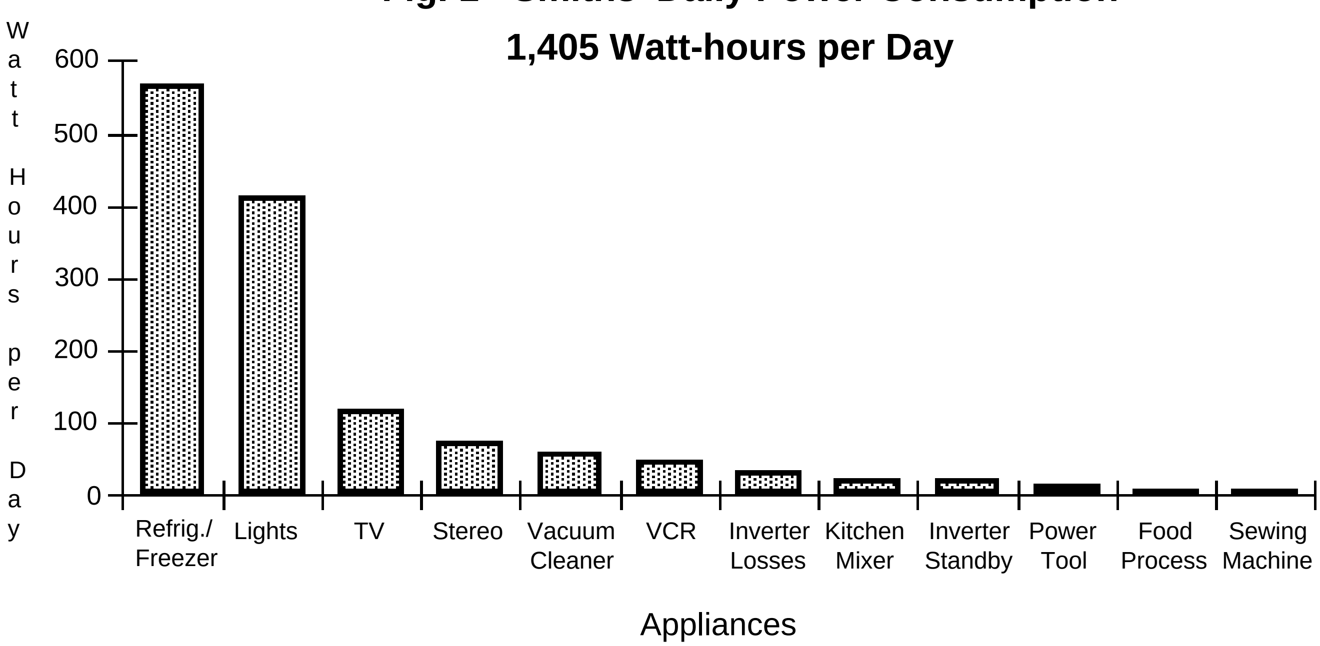
This still leaves many appliances which will be operating on the battery/inverter portion of the system. Appliances like lighting, TVs, and Stereos are relatively small consumers but operate for hours at a time. The refrigerator turns itself on whenever necessary, and must have a continuous source of power. Small appliances such as the vacuum cleaner, sewing machine, food processor, VCR, and kitchen mixer are used intermittently, and it's not worth starting the generator just for them. Items such as these are prime candidates for battery/inverter supplied power. It is convenient, silent, and available 24 hours a day without the generator running at the time. The batteries are periodically recharged by the generator through the battery charger built into the inverter.

The Smiths draw up a list of each and every appliance they are planning on powering from the battery and inverter. On this list each appliance has its wattage noted, and an estimate of how many hours per day it will be operating. The sum of the wattages determines the size of the inverter, and the operating times determine the capacity of the battery pack. The company helping the Smiths suggests that their lighting and refrigeration be powered by 12 VDC directly from the battery. This reduces the size of the inverter, and once again saves the Smiths money.

The Smith's Electrical Consumption

Fig. 1- Smiths' Daily Power Consumption

1,405 Watt-hours per Day



Well, by now, the Smiths have a fairly detailed picture of what and how much they are going to run from their alternative energy system. Figure 1 shows this information. Note the variety of standard 120 VAC appliances that the Smith's are using with their inverter. While they may be many miles from the power line, the Smiths still have all the electricity they really need. Their total electrical consumption is estimated to be 1,405 Watt-hours per day. 397 of these W.-hrs./day is 120 VAC usage through the inverter, while 1,008 W.-hrs./day is consumed as 12 VDC directly from the battery. The well pump and washing machine do not appear on this estimate as they are powered strictly by the generator. The Smith's are being very frugal in their electrical usage. Their consumption of less than 1.5 kW.-hrs. per day is a small fraction of the average U.S. household consumption. Reduction of consumption to this low level, while still providing all you see in Fig. 1, demands the use of the most efficient appliances. For example, the Smith's 12 cubic foot refrigerator/freezer is a special 12 VDC model that consumes only 71 Watts of energy when running.

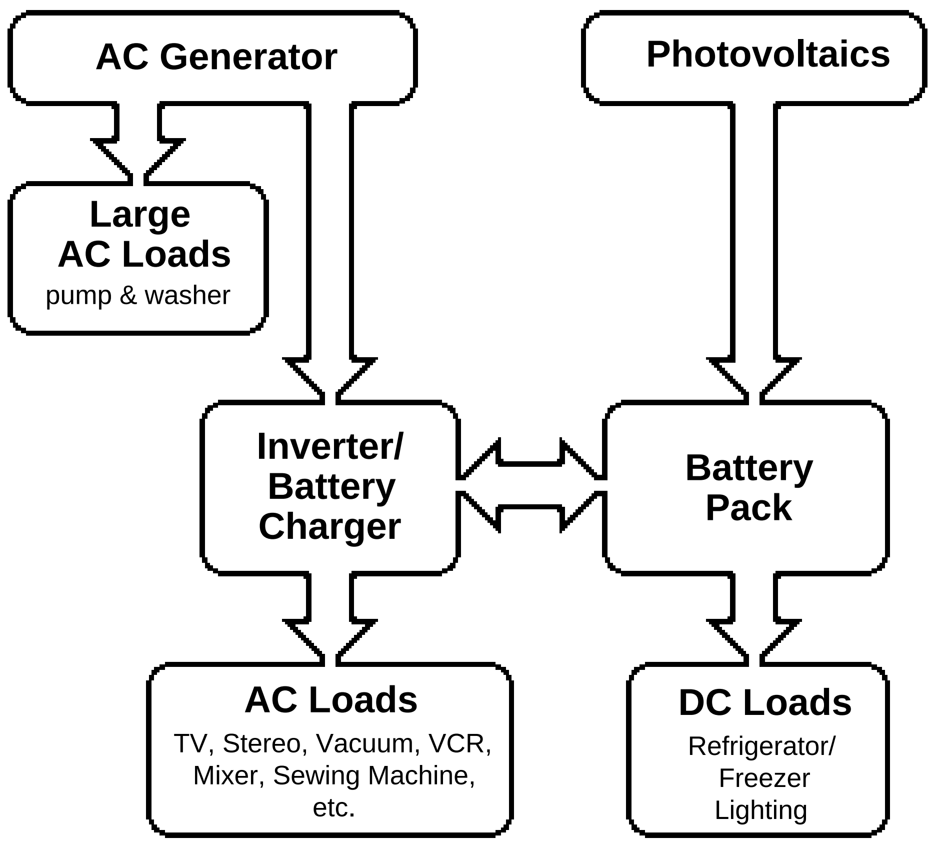
The Hardware Options

Now, the alternative energy company helping the Smiths takes the consumption estimate and produces a series of hardware options. The company uses a computer to model two different system options for the Smiths. One is based on the generator power input only. The other is based on both solar and generator power inputs to the system. Each of these models considers the operation of the system over a 10 year period. The computer supplies such information yearly generator operating time, yearly system operating costs, average days of energy storage within the battery, and other system details. The financial bottom line of each estimate is a cost figure in dollars per kiloWatt-hour for system operation over a ten year period.

Let's look at the Smith's system modeled with only motorized input. This system uses 4 batteries to provide 700 ampere-hours of storage at 12 VDC. This battery provides the Smiths with about 4.78 days of energy storage within the battery pack. The cost of these batteries is $840. The inverter/battery charger supplies 1.5 kW. and costs $1,310. The motorized generator specified has 6,500 Watts available in either 120 or 240 VAC. This generator has enough power to pump water, run the clothes washer, and recharge the batteries all at the same time. The generator cost is $2,448. With battery and inverter cables, the total initial hardware cost is $4,695. Mr. Smith is relieved; this is far lower than the $30,000. the power company wants. But what about fuel and maintenance? How much will he run this generator?

Well, the computer simulation of the motor input only system gives us the facts of the matter. The generator will have to be run about 1,263 hours per year. This means that even a high quality generator like the Honda will have to be replaced or rebuilt after five years at this operating level. The model also tells us how much fuel, oil and maintenance expenses will be. Bottom line is that generator operation at this level is going to cost the Smiths about $36.82 monthly, or $4,418.40 over a ten year period. This includes the fact that they will wear out another generator, in addition to their original generator, within the 10 year period. This operating cost estimate is very accurate as it includes all details such as fuel, oil changes, and other generator maintenance items. If the initial hardware cost is added to the operating cost, then this system is going to cost the Smiths $9,113.00 over a ten year period. This amounts to $1.78 per kW.-hr for the electricity consumed over the ten year period. Mr. Smith is still relieved. He was right. He can run his generators for 10 years and still only spend one third of the money the power company wanted just to run in the power lines.

Figure 2
Smiths' Alternative Energy System



Now let's look at what PVs can do for Mr. Smith. Consider the addition of 6, 48 Watt photovoltaic panels to Mr. Smith's system. All other hardware stays the same: 4 batteries, 1.5 kW inverter/charger, and 6.5 kW. mechanical generator are still present in the system. Figure 2 is a block diagram of Mr. Smith's solar/motor system. The additional energy supplied by the 6 solar panels reduces the Smith's generator operating time from 1,263 to 272 hours yearly. This reduces the system's operating cost to $8.74 monthly, or $1,049. over the ten year period. The photovoltaic panels cost Mr. Smith an additional $2,100. The initial hardware cost for the solar version of the Smith's system is $6,795. This added to the ten year operating cost of $1,049. gives a total system cost of $7,844. over a ten year period. This amounts to an electricity cost of $1.53 per kiloWatt-hour over this period.

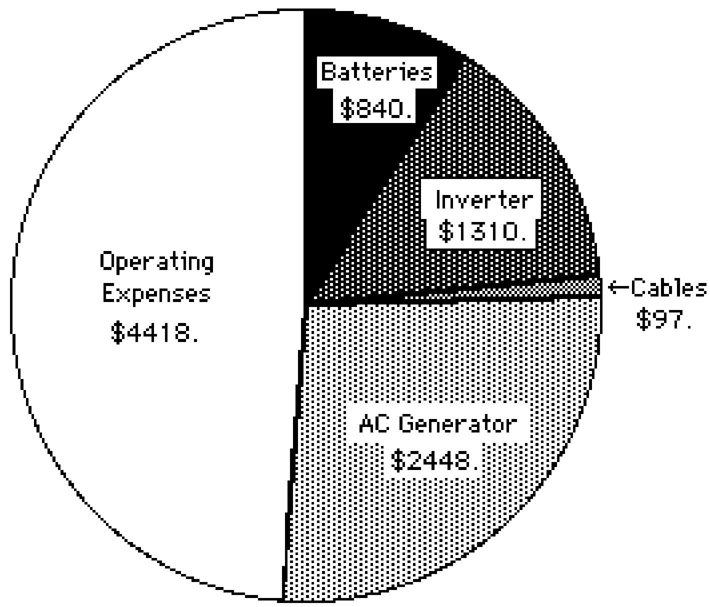
Let's See What PVs can do!

A comparison of the two models, one motor only and one solar/motor, shows that the addition of the PVs has saved Mr. Smith money. The motor only system produces its power for $1.78 per kiloWatt-hour, while the solar/motor system produces its energy for $1.53 per kiloWatt-hour. Over a ten year period, Mr. Smith pays out $9,113. when using motors alone, or $7,844. with the added solar. Mr. Smith saves $1,269. over what it initially cost to add the 6 PV panels to his system. While the solar does add to the initial cost of Mr. Smith's system, it pays for itself within 6.3 years. Mr. Smith can't lose with solar power. The panels pay for themselves in 6.3 years, and the energy they produce for the next 3.7 years is free. While the PV manufacturer warranties its panels for ten years, it is not unreasonable to expect the PVs to last longer. Figure 3 is two pie graphs that show the financial differences between the motor and the solar/motor systems.

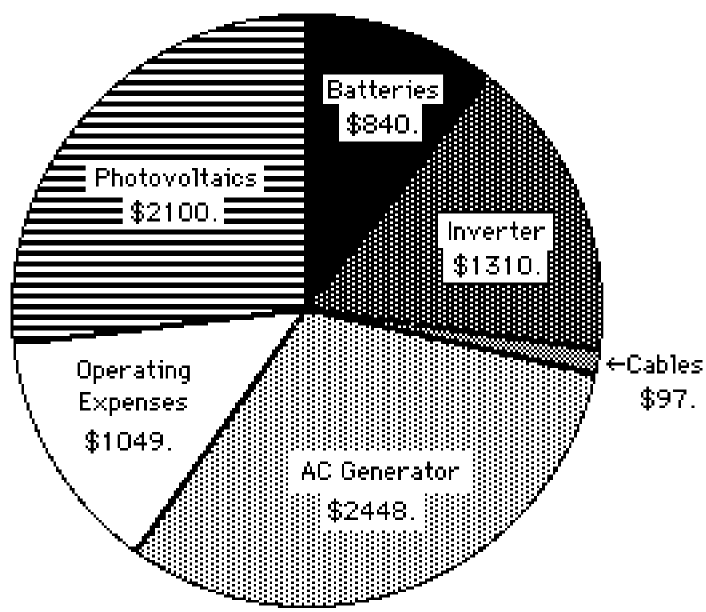
The addition of the solar has benefits other than just financial for Mr. Smith's system. Under the motor only scenario, Mr. Smith is going to have to recharge his batteries on the average of every 4.78 days. The addition of the PVs, with their daily power input, increases the average days between generator supplied battery rechargings to 17.82 days. His generator is only required to run 272 hours yearly, and will last much longer than the ten year amortization period. The family will have to listen to the generator running 78% less with the PVs on line. Another feature of the PV panels is their quiet and maintenance free nature. They just sit there in the sunshine and silently do their job. The PVs offer Mr. Smith more freedom from the gas pump, and fluctuating gas prices. The reduced generator operating time means that Mr. Smith spends 78% less time with a wrench in hand maintaining the generator.

PVs can certainly save the Smiths money, noise, and time. If you are in a similar situation then they will do the same for you. At first, most folks are hesitant about photovoltaics. It seems like a lot of money for a slim solar panel. What actual users of PVs realize is that they have bought more than just a solar panel. What they have is a reliable, silent energy source that will produce its power for at least ten years with no additional cost or maintenance. In most alternative energy systems the PVs will pay for themselves before they are out of warranty. When you buy a PV, you are paying for your energy in advance. And once you've done this, then your power is as dependable

Figure 3
Smiths' System Cost-- Motor Input Only
$9,113. over 10 years



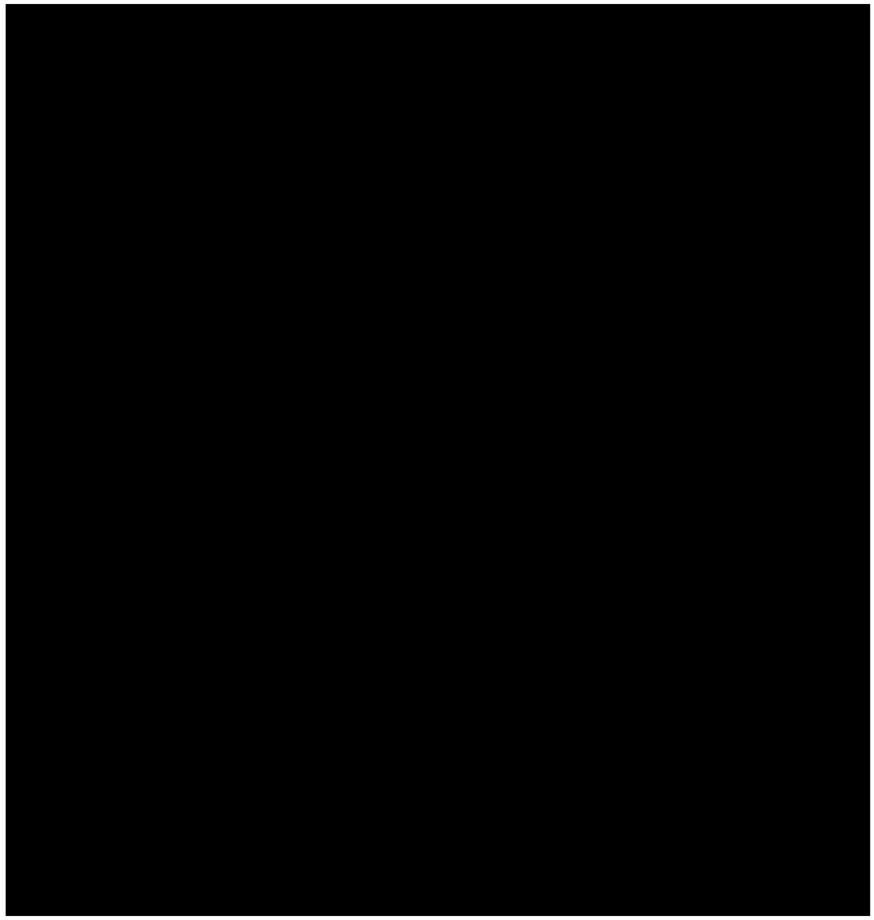
Smiths' System Cost-- Solar/Motor Versior
$7,844. over 10 years



and free as the Sun.

Any alternative energy system must be engineered for specific needs, and for specific locales; only then can it be cost effective. If you are considering solar, seek the help of a reputable company that can help you with the details of consumption estimation, local solar insolation, and hardware specification.

Richard Perez is CEO of Electron Connection Ltd., and has lived on alternative energy since 1970.



Wind Power Siting

by Larry Elliott

For many people the idea of producing household electrical power from a wind turbine is a romantic notion, a dream that rarely becomes a reality. Still for others, especially those living far from an electrical line or experiencing outrageous utility bills, it becomes a necessity. There are thousands of homes across the country now being powered by a wind turbine or combination of wind and other alternative electrical power inputs. Each installation's success or failure depends heavily on planning and correct installation. It is the critical planning and siting stage of an installation that will be discussed in this article.

Wind As Fuel

Cars, boats, planes, power plants or garden tractors, these all have something in common, they are machines that produce useable work or power by consuming a fuel. The amount of work they do or power they produce is directly related to their size and how much fuel is available for their consumption. In the case of a wind turbine, its fuel is the wind. The power available from any turbine is dependent on how much wind is available to drive the turbine. The quantity of wind is expressed in terms of wind speed or velocity. The higher the wind speed, the greater the potential output power we may expect from a wind turbine.

Betz's Equation

In order to illustrate just how important this relationship between wind speed and power output can be, a little math and physics is in order. A formula that describes power to wind speed relationship in a wind turbine was developed in 1927 by a German scientist George Betz. This formula states that the power available from a turbine is proportional to the cube of the wind's speed. In this equation P is the power produced in watts, E is the efficiency of the wind turbine in

$$P = \frac{E\,r\,A\,S^3}{2}$$

percent, Rho (r) is the density of air, A is area of the areo turbine in silhouette in square feet, and S is the wind speed in miles per hour. The power which can be expected from a wind turbine is equal to the efficiency of the turbine multiplied by the energy delivered per unit time by the wind to the turbine. The energy delivered per unit time is equal to:

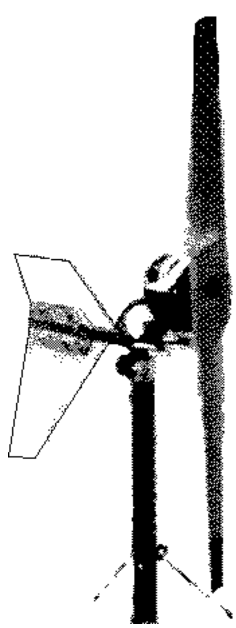
$$\frac{m(t)\,S^2}{2}$$

where m(t) is the mass of the wind impinging on the turbine blades per unit time and S is the wind's speed. The quantity m(t) is equal to rAS.

A combination of these two equations yields Betz's equation. In an average form this equation can be reduced to:

$$P = 0.0006137\,A\,S^3$$

by assuming standard air density and normalized turbine efficiency.

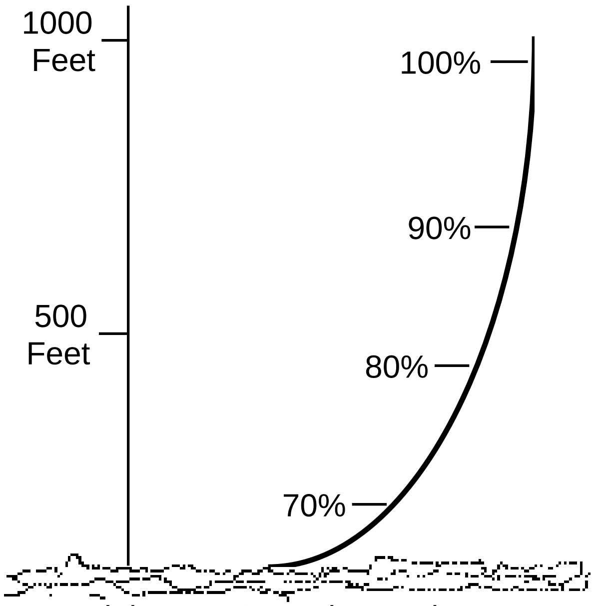


Power by the Cube!

Basically all this math boils down to: the power available from the wind is proportional to the cube of its speed. As an example of this, let's assume we have a turbine that produces 100 watts in a 8 mph wind. At 16 mph you may expect this turbine to double its output to 200 watts, but instead it will produce over 800 watts. Thus it can be seen that a doubling of wind speed increases power available by a factor of eight times. A very small change in wind speed translates to a rather large increase in available power. A more dramatic look at this change would be the following. Assume that you have a wind turbine located at a marginally windy site that produces 100 watts in an 8 mph wind. If you had an increase in wind speed of only 1 mph your output would be 133 watts or an increase of 33%. Even small changes in annual average wind speed can determine whether or not your site is a cost-effective candidate for wind power.

How To Determine Wind Speed

Average wind speed is the critical factor that determines the economic effectiveness of wind machines. Let's look at some methods of determining wind speed. For those individuals who have lived for several years at a particular site, you probably have some idea of how



Height over Smooth Terrain Vs.
Percentage of Maximum Wind Speed

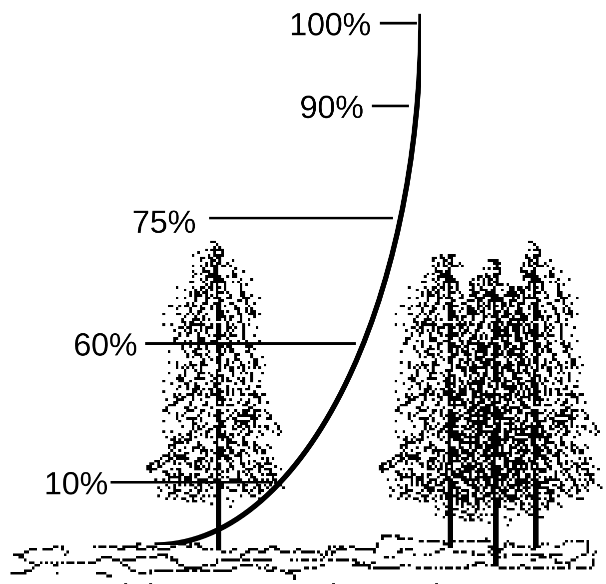
often you have windy days. For instance, how many days per week do you experience winds that raise dust, extend flags and streamers, or blow paper and cardboard about the yard. These winds are usually in the area of 8-12 mph. Another good indicator of your average wind speed would be trees and shrubs permanently deformed in the direction of the prevailing winds. Normally an average wind speed of at least 10 mph is needed to cause permanent deformation. If your site exhibits these characteristics, then perhaps further investigation is warranted. For those of you who have a site that really couldn't be described as windy, based on these observations, an alternative to wind power should be considered.

Use A Recording Anemometer!

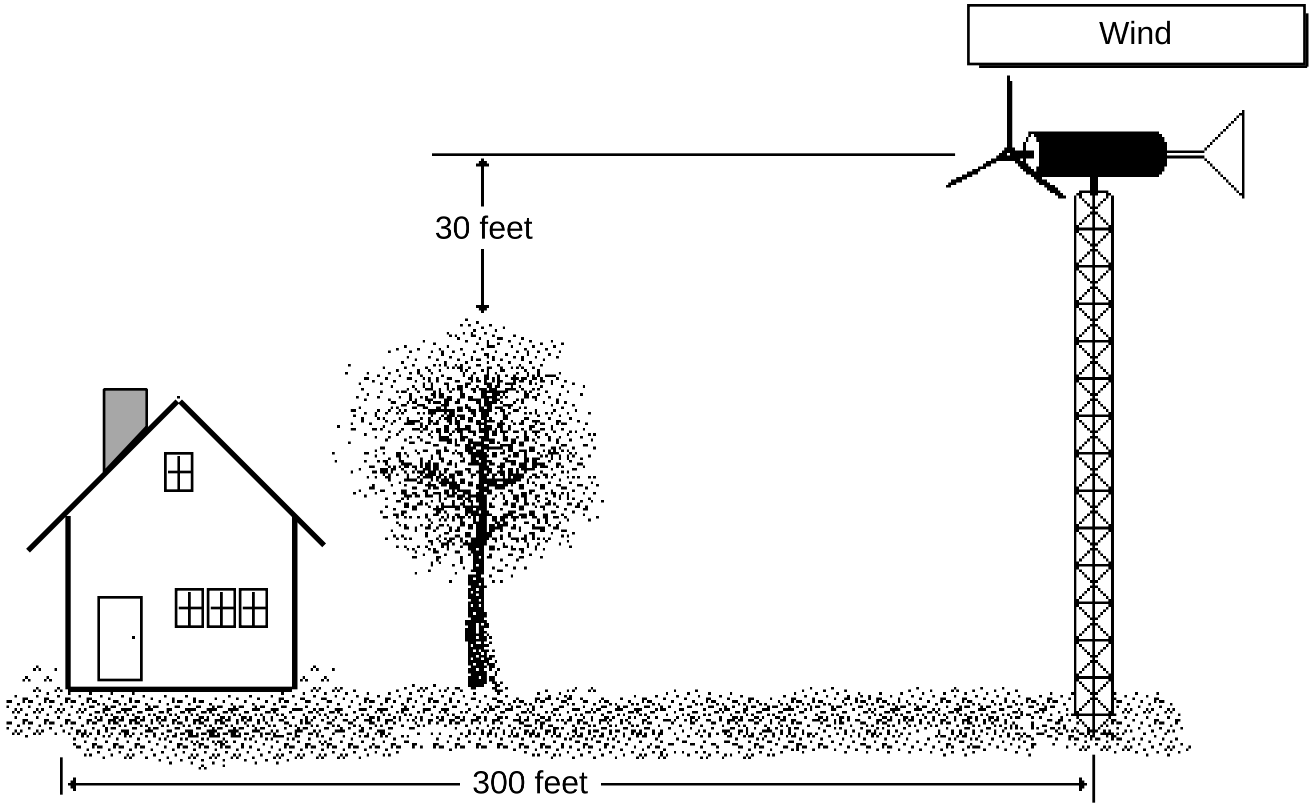
If you feel your site is windy, and you are serious about installing a wind turbine, there is no more accurate method of site assessment than to install a recording anemometer. In an area of the country such as the great plains states or along a sea coast, a check with the local weather station might be sufficient to determine average wind speeds. But in most cases, the anemometer is truly your only source of accurate information on average wind speed. Don't consider wind power without a thorough measurement of the wind speed at your specific location. A recording anemometer should not be confused with an anemometer which measures only instantaneous wind speed. Rather than measuring a wind speed at any given moment in time, a recording anemometer measures cumulative wind speed. It constantly records wind speeds as a numerical count and then you simply need to divide this numerical count by the period of time over which you have been recording. This gives you an average wind speed over an extended period of time. In most cases, four months should be the minimum recording interval and one year is preferred. If you are going to spend a lot of hard earned money on a wind system, this extra eight months could mean the difference between a good investment and a bad one.

Proper Tower Placement

Although a recording anemometer is a very accurate instrument, its output will only give you wind speeds at a specific location. In areas of rolling hills or tree cover, the wind speeds can vary 30% or more between sites only 100 feet apart. The location of an anemometer on a specific site, as well as height above the ground and any obstruction, is critical to recording the highest winds available. For those of you who may be living in a very flat and wide open area this may not be as critical, but in rough terrain turbine location is everything. Referring to Figures 1 and 2, you can see how terrain can have an effect on wind speeds at certain elevations. Figure 1 shows a percentage of maximum wind speed to be expected over smooth terrain. At less than 50 feet above the ground, over 70% of maximum winds can be expected. In Figure 2 we see that less than 10% can be expected at the same elevation when installed over rough terrain. On level land with no nearby obstacles, a 40 foot tower should be the minimum height for your anemometer or turbine. It is essential to measure windspeed at the actual height you plan on installing your turbine. Figure 3 illustrates a rule of thumb for tower height above obstacles and should not be ignored if maximum power is to be achieved. Remember, an increase of only 1 mph in wind speed gives a 33% increase in power. Obstacles or short towers are only robbing you of power. If you are considering placing your turbine on a hill to gain wind speed, you must be careful exactly where you place the turbine. Place the turbine high enough on the hill to enter the smooth undisturbed windstream.



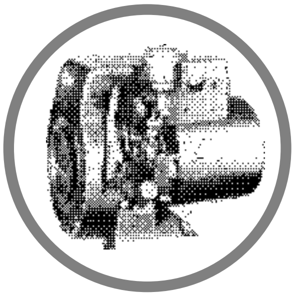
Height over Rough Terrain Vs.
Percentage of Maximum Wind Speed



As you can see the siting of a wind turbine is not a matter of simply erecting a tower and putting a generator on top. Only through accurate wind speed measurements on your particular site can you hope to install a wind system that is capable of supplying the power you need. In future articles we will look at methods of sizing your system and selecting a proper turbine output voltage. May your days be windy.

Larry Elliott is CEO of Cascade Wind Electric and is an expert in Jacobs windmachines and windmachine siting.

Engine Driven Generators for Home Power



Our old friend the engine powered generator has been around for a long time. Read how its use with alternative energy sources gives the mechanical generator new life. For inexpensive and high powered backup electricity the engine is hard to beat!

The choice of an engine driven generator, or generator as I will refer to it here, is one of the most important choices those considering alternative power can make. You might say to yourself, "I have chosen wind, water or photovoltaics as my alternative power source. What do I need a generator for?" Well, that's what we are here to talk about.

An Old Friend

The generator has been the backbone of home power generation since the early 1900's. Many farms, ranches, and homes were modernized by the addition of only electric lights. In this day and age of public power, it is hard to imagine not having power lines to every house, everywhere. But in reality, the public power grid has only reached consumers in rural areas over the past 40 years or thereabouts. Many homesteads are still beyond the power grid even today. In the past, the most common way to have these modern electric lights was to use a generator. Early generators were crude by our standards but, never the less, they moved many rural families into the 20th century with electricity.

During the 1920's many people living in the mid-West asked, "Why can't we use the wind to create our electricity? After all, the wind has been pumping our water for years." The wind did, and still does, generate electricity for these people. The U.S. government created the REA or Rural Electrification Act just for this purpose. This government plan helped to subsidize the wind power industry and to finance these wind/motor generator systems for the end users. Along with these windmills came the generator. That's right, generators were used along with windmills. The generator was used on days the wind didn't blow enough and the batteries needed recharging. Energy produced by either the windmill or the generator was stored in batteries. The batteries provided a constant source of power, where a windmill or generator could only supply an intermittent source of power. They needed the generator to back up the windmill.

Backup Electricity

This brings us to one of the prime reasons for needing a generator for your home power system. Backup electricity. Let's say your choice of alternative power involves wind, PVs, or water. All these sources depend on Mama Nature doing her thing, and sometimes she doesn't. If for instance your windmill, solar panels or water generator cannot temporarily meet the demand on your system, you can use a generator to make up the difference. The generator allows the alternative source to be sized for average consumption rather that peak consumption. It also reduces the need to oversize the alternative energy source so that the system will recover quickly from periods of no alternative power input. This saves money and provides a second, backup, energy source to boot.

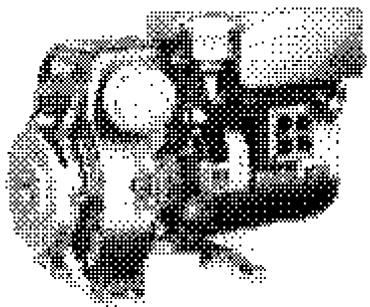
Most people want their home power system to meet all their needs without the temporary inconvenience of too little power for peak consumption periods. The generator meets this need in the most cost effective manner. It can be wired into your battery-inverter system so it senses the increased load, starts itself, and carries the increased load until it is removed. The only way to handle this problem without a generator is to increase the size of your alternative energy source, battery pack and inverter. This latter decision will cost more. In many cases, you still wouldn't have the luxury of a back-up electrical system.

Another reason for using generators in home power systems is to provide energy for battery equalization. During the use of a battery/inverter system, there is often the need to equalize the battery's individual cells. Equalization is a steady, controlled, overcharge of the batteries. The controllable and constant power output of the generator is ideal for battery equalization. In this instance, the generator will help pay for itself due to increased battery life, and greater system efficiency.

At some time, any system that uses wind, water, and even solar will need to be shut down for maintenance. Wind mills periodically need gear oil levels checked, load brushes on the pivot serviced, propeller maintenance, and general nut/bolt tightening. Water power systems need periodic inspection of impellers, generators, water nozzels, and trash racks. Solar systems are virtually maintenance free, but even these require washing and the occasional rewiring job. The generator gives us a low cost, high powered, energy source to backup any other alternative energy source.

Generators Offer High Powered Security

The world we live in is as unpredictable as a child in a candy store. Natural disasters can flatten windmills with high winds. Ice can clog waterways and stop windmills as well as blanket solar panels. Lightning can do damage to any power source, including the public power grid. With your trusty generator providing a ready source of electricity, any household can be powered to suit your family's needs. If your main power system is the public utility, you just added independence to your household with a generator. You won't have to worry about when the power will come back on. You simply start your generator, and flip the load switch that has been installed between the power line and circuit breaker panel (for safety). Life goes on as usual.



If you are considering home generated electrical power because of your remote building site, a generator can be useful from the initial ground breaking to the finished house. Power tools that are needed in the construction process can be run off of the generator. When the building is finished the generator is then used as your backup power source, practical and initially cost effective.

What if, after considering all the available sources of alternative electrical power, you decide a generator should be you main source of electricity? Well, your decision isn't all that radical from a practical aspect. It is probably the most chosen source of alternative electricity today. Generators offer high power for a minimal initial investment. Generators come in many sizes and shapes to suit the consumer's many varying needs. In future issues of this column we will discuss all available types and sizes of generators. I want to aid you in selecting the one that best fits your needs and is most cost effective.

So Which Generator Is Right For Me?

Which generator will meet your needs? The first consideration is the amount of electricity it will produce. The output of a generator is measured in watts. The number of watts you need depends on the number of appliances you will be using and their energy consumption in watts. By adding the appliances' ratings in watts, you can determine the size of generator needed.

Choose Your Appliances Carefully

Give careful consideration to appliances which are selected for generator power. Appliance efficiency really counts when you are making your own electricity. Most people who are considering a generator, or any form of alternative electricity, try to stay away from electric heating devices. Electric heat uses lots of energy. Heating chores can be better handled by propane or wood fuel in rural situations.

In addition to the running wattage rating of the generator, also consider its surge rating. The surge rating determines how much the generator can be temporarily overloaded and for how long. This factor is critical in determining the size of electric motor that can be started by the generator. Well pumps, refrigerators, washing machines, and capacitor started electric motors typically take up to three times their rated watts to start them. Some types of electric motors can consume over seven times their rated wattage during startup periods. This considerable amount of extra energy will make a larger generator necessary in some cases.

What to Look For In A Generator

It is a good idea to purchase your generator with more capacity than you actually need. This does two things. One, it insures that the generator is not working too hard-- greatly increasing generator life. Two, it allows for the inevitable expansion of your system.

Another consideration in generator selection is the speed, measured in RPM (revolutions per minute), at which the generator operates. The 3,600 RPM generators are usually lighter duty than their 1,800 RPM counterparts. This is not always true, but in most cases this does apply. Smaller engines develop their power at the higher RPM. For this reason, they can be made smaller in size and lighter in weight. These small generators are typically air-cooled. The RPM at which an engine runs determines its overall life expectancy. Higher speeds wear the engine's moving parts more quickly, and thus the engine has a shorter life expectancy. The less expensive air cooled small engines will run for between 500 and 2,000 hours before major overhaul. Better made (and more expensive) small engines, such as those made by Honda, will run over 5,000 hours without major maintenance. The greater longevity of the better made engines makes them very much more cost effective.

The speed of the generator also determines the amount of noise it will produce. The slower it runs the quieter it will be. Noise is an important factor in making the decision on which generator to buy. **GET A GOOD MUFFLER!** It is more than worth the few extra bucks it costs. A noisy generator will not only bother you, but it potentially will cause problems with any neighbors you may have.

When you buy a generator, consider how you will start it. Many small generators are started by hand (recoil rope) only. The larger generators usually are electric (battery) start with a recoil starter as backup. The electric start generators can usually be operated by any member of the family, whereas hand started generators require the strength of an adult to turn them over.

A last thought about generators would be about safety. Safety for you and for the generator. Personal safety for the operator is an important consideration many manufacturers take seriously. Some generators (usually cheaper models) don't have muffler guards and simple one knob operating controls. Imagine stopping the generator, like a lawn mower, by pressing the metal bar over the spark plug. Have you ever been shocked by this method?

Most medium priced generators have operator safety as top priority. They have automatic chokes, belt guards, circuit breakers instead of fuses, and adequate muffler guards to prevent burns. These medium priced generators also protect themselves if they are somewhat neglected. They have fuel filters, automatic low oil level shut down, automatic overtemperature shut down, and exhaust spark arrestor screens in their mufflers. These items should be included in any generator used in home power service.

Well, there you have it, a few ideas to stimulate more informed decisions about generator use in home power systems. In the coming months we will discuss many specific types of generators, complete with our own test reports. We are looking forward to bringing you information on generator selection, maintenance, utilization, and longevity. I wish to emphasize that all this information is based on actual experience in the field, and is not a parroting of manufacturer's claims. I am looking forward to hearing from you generator users out there. Drop me a line and tell me about your system and experiences.

Alan Trautman is a professional mechanic living on his rural homestead in Oregon. He has been making all his own electricity, using mechanical generators since 1974.

Power Inverters

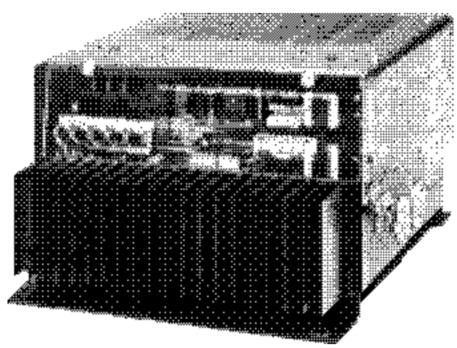
by Richard Perez

The modern power inverter has revolutionized the usage of battery stored electrical power. An inverter changes the low voltage DC energy of the batteries into 120/240 volt, 60 cycle, AC housepower. Just like the energy available downtown. The idea here is to use the battery stored energy in regular household appliances.

The Problem With Low Voltage DC

The low voltage DC supplied by the batteries will not run standard consumer appliances, which accept only 60 cycle, 120/240 volt, AC power. Until the advent of modern inverters, battery people had to content themselves with 12 VDC appliances. These are specialized and very expensive. In many cases there are no 12 VDC appliances made for a particular job. The inverter has changed this; now battery users can run just about any standard commercial appliance.

In practical terms, the inverter allows us to run electric drills, power saws, computers, printers, vacuum cleaners, lighting, food processors, and most electrical appliances that can be plugged into the wall. If the battery/inverter system is big enough, then large appliances such as freezers, refrigerators, deep well pumps, and washing machines can be accommodated. All these standard 120/240 volt AC appliances can be powered from the batteries by using the appropriate inverter. The inverter draws its energy from the batteries, it does not require any other power source. Inverter operation is quiet and its power is available 24 hours a day, whenever it is needed.



The addition of an inverter to a motorized system greatly improves the system efficiency. Power costs can be cut to 25 cents on the dollar by using an inverter instead of constant generator-only operation. The generator can be run for only several hours per week, but the inverter's 120/240 VAC power is constantly available. It is simply not efficient to run a large generator for a few lights and maybe a stereo. The generator is used to recharge the batteries, and to power large intermittent loads. This approach results in the generator being run more heavily loaded, where it is much more efficient.

Different Types of Inverters

Inverters are manufactured in 3 basic types. These types are named for the kind of power they produce. The question is, "How close does the inverter come to reproducing the waveform of standard commercial power?" There are trade-offs involved in inverter design. The more closely the inverter replicates commercial sinusoidal power, the less efficient the inverter becomes. This is a sad, but true, fact of physics. As the primary power source, efficiency is a very important factor in inverter operation. When we consider running large appliances such as freezers and washing machines on battery stored power, even small percentages of wasted energy are not acceptable. Battery stored energy is simply too expensive to waste.

Square Wave

Of all types of inverters, the square wave inverter produces power that least resembles commercial power. This inverter is the cheapest type to buy. It will not run many appliances which require cleaner forms of power. Stereos, televisions, computers, and other precision electronics will not accept square wave power. The power produced by square wave inverters varies considerably with the voltage changes of the batteries as they are discharged. These inverters are designed to be inexpensive, and as such their efficiency is low, less than 70% when fully loaded. If the square wave inverter is only partially loaded, its efficiency drops to less than 30%. These inverters cost about $0.50 per watt and are available in sizes up to 1,000 watts. The square wave inverter is not suitable for homestead usage. It is neither efficient or versatile enough.

Modified Square Wave

The modified sine wave inverter represents a compromise between efficiency and utility. The modified sine wave inverter is the best type to use in home power service. This type of inverter is capable of powering almost all commercial electrical appliances, even very delicate electronics such as computers. The power this inverter produces is not identical to commercial power, but it is close enough to fool almost all appliances. The efficiency of the modified sine wave inverter is the highest of all types of inverters, in some cases consistently over 90%.

For example, we use a 1,500 Watt Trace Inverter. This inverter is over 90% efficient at output levels between 100 and 600 watts. Its no load power consumption is less than 1 watt. We leave it on all the time, ready for instant service. We have yet to use an appliance that will not accept its modified sine wave power. The inverter is fully protected against overloading. It even contains a circuit that prevents overdischarging of the batteries. The output power of the Trace inverter is very clean, far cleaner and more dependable than commercially produced electricity. These inverters are also available with built-in battery chargers. The battery charger senses when you have turned on the AC powerplant and recharges the batteries. It also automatically transfers the household to generator produced power, and returns the household to inverter power when the motorized powerplant stops.

The cost of modified sine wave inverters is about $1.00 to $1.50 per watt. This type of inverter is available with output wattages between 300 and 25,000 watts. In most cases, the inverter is capable of surge wattages about 3 times its rated output wattage. Many of the larger modified sine wave inverters have outputs of both 120 and 240 volts AC. This surge capability is very important when powering large motor driven appliances such as refrigerators, washing machines, and deep well pumps.

Sine Wave Inverters

The sine wave inverter exactly duplicates the sinusoidal waveform of commercially produced power. It accomplishes this at the expensive of efficiency. The sine wave inverter is necessary only for very delicate electronics. These inverters are usually sold to hospitals, airports, and government installations. They are the only ones who can afford to buy them and run them. Efficiency for sine wave inverters is less than 60% at optimum loading. At light and heavy loads the efficiency drops to less than 30%. These inverters are expensive, around $2.50 per watt. The sine wave inverter is not suitable for homestead power, it is too expensive and inefficient.

Inverter Sizing

Modern power inverters are available in many sizes. The process of determining the right size for a particular homestead can be confusing. The process is really simple-- just make a survey of all the appliances you wish to run from inverter supplied power. List each appliance, its rated wattage, and the number of hours per day that the appliance will be operational. It is best to allow each person in the household the usage of a light-- one person,one light. We seem to average about five hours of lighting per day. If this estimation process is to be effective all appliances must be included, be realistic. Be sure to allow some margin for future expansion.

Average Consumption

Put a star beside all appliances that are required to operate at the same time. Include in this starred list all appliances with automatic controls, for example refrigerators and freezers. Add the total wattage of all the appliances on the starred list. This wattage figure is the smallest amount of power that will do the job. The inverter must be sized larger than this figure if the system is to work as planned. If the inverter is undersized, it may shut itself off due to overloading and leave you in the dark. The wattage of each appliance multiplied by the number of hours per day it is operational gives an estimate of energy consumption in watt-hours per day. This figure is used to determine the capacity of the battery pack necessary to do the job.

Surge Consumption

Appliances which use electric motors require more power to start themselves than they require to run. This high starting power consumption is called starting surge. Many motorized appliances require over 3 times as much power to start than to run. These starting surges must be considered in sizing the inverter's wattage. If these surges are not allowed for then the refrigerator starting up may overload the already loaded inverter and shut it off. Most power inverters worth having are capable of delivering 3 to 5 times their rated wattage for surges.

If there are several large motors in the system that may start themselves, then the situation becomes more complex. Consider a system where both a deep well pump and a refrigerator are being used. Both the pump and the refrigerator may turn themselves on at the same time. The resulting surge demand may be high enough to shut down the inverter. It is best to assume that all appliances on automatic control are starting at the same time. Add their surge wattages and be sure this figure is less than the surge capability of the inverter being considered.

Inverter Wiring

The inverter's output should be wired into the house's main distribution panel. A quick reference to books on house wiring will aid you in getting the power into the house with low loss and safety. Remember that all the power being used in the house is traveling through these connections-- use big wire (6 to 2 gauge) and low loss connections.

AC Wiring

One of the major attractions of inverter produced power is that it is at normal 120/240 voltages. This is very important when placing older homes on alternative energy. The wiring within the walls is designed for 120 volt operation. It has too much power loss to be used with low voltage DC energy directly from the battery. The wiring, switches, outlets, and all their interconnections have too much resistance to efficiently transfer the batteries' energy directly.

DC Wiring- Battery to Inverter Connection

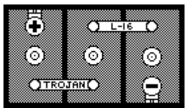
The wiring that supplies the energy from the battery to the inverter is of critical importance and deserves special attention. These wires must be capable of transferring over 200 amperes of current efficiently. This means that the wiring must have very low resistance-- use 0 to 000 gauge copper wire. Keep the length of these heavy gauge wires to an absolute minimum. Most inverters are located within five feet of their batteries.

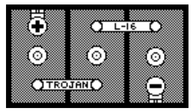
The actual connections on the battery terminals are subject to corrosion. It is common practice to use battery cables from automobiles. These cables have ring connectors mechanically crimped to their ends. The sulphuric acid in the batteries eventually corrodes the mechanical connection between the actual wire and its ring connector. If a more permanent connection is desired, make your own connectors by soldering copper tubing over the ends of the heavy wires. Flatten this assembly and drill the appropriate hole in it. This soldered connector is vastly superior to any other type. These heavy wire sets with soldered connectors are available commercially from the Electron Connection Ltd., P. O. Box 442, Medford, Oregon, 97501.

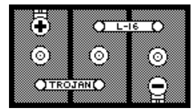
Next month we will discuss in detail the specifics of inverter sizing. Tune in and find out the inverter size that best fits your individual needs.

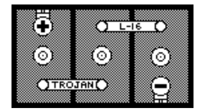
Lead-Acid Batteries

by Richard Perez









In 1970, we realized that our dreams depended on cheap land. The only desirable property we could afford was in the outback. Everything was many miles down a rough dirt road and far from civilized conveniences such as electricity. The 40 acres we finally bought is 12 miles from the nearest paved road, telephone, or commercial electrical power. We were ready to do without. This is not, however, an account of doing without-- it is a story of having one's cake and eating it too.

We solved the problem of the rough road with a 4WD truck and countless hours of mechanical maintenance. The electrical power problem was not so easy to solve. We had to content ourselves with kerosene lighting and doing all our construction work with hand tools. The best solution the marketplace could offer was a motordriven generator. This required constant operation in order to supply power, in other words expensive. It seemed that in America one either had power or one didn't.

We needed inexpensive home power. And we needed it to be there 24 hours a day without constantly running a motor. We decided on a 12 volt battery system. A lawnmower motor driving a car alternator recharges the batteries. To this we added a homemade control system. Later, we installed an inverter. We now have all the power we need, both 12 volts DC and 120 volts AC.

This information on batteries is based on my over 17 years of actual experience with battery based alternative energy systems.

Battery Terms

The battery is the heart of all alternative energy systems. A battery is a collection of cells which store electrical energy in chemical reactions. Not all batteries are the same. They have evolved into different types to meet different needs. We are primarily interested in the true "Deep Cycle" lead-acid battery. This type is the most cost effective for home energy storage. In order to discuss these batteries, we need to agree on certain terms. The more we know about batteries, the better we can use them, and the cheaper our power will be.

Voltage

Voltage is electronic pressure. A car uses a 12 volt battery for starting. This voltage is the addition of the six lead-acid cells which make up the battery. Each individual lead-acid cell has a voltage (or electronic pressure) of about 2 volts. Commercial household power has a voltage of 120 volts. Batteries for alternative energy are usually assembled into packs of 12, 24, 32, or 48 volts.

Current

Current is the flow of electrons. The rate of this flow per unit time is the ampere. A car tail light bulb draws about 1 to 2 amperes. The headlights on a car draw about 8 amperes each. The starter draws about 200 to 300 amperes. Current comes in two forms-- direct current (DC) and alternating current (AC). Regular household power is AC. Batteries store power as direct current (DC).

Power

Power is the amount of energy that is being used or generated. The unit of power is the Watt. A 100 watt lightbulb consumes 10 times as much energy as a 10 watt lightbulb. The amounts of power being used and generated determine the capacity of the battery pack required by the system. The more electricity we consume the larger the battery must be. The power source must also be larger to recharge the larger battery pack.

Battery Capacity

Battery capacity is the amount of energy a battery contains. This is usually rated in ampere-hours at a given voltage. A battery rated at 100 ampere-hours will deliver 100 amperes of current for 1 hour. It can also deliver 10 amperes for 10 hours, or 1 ampere for 100 hours. The average car battery has a capacity of about 60 ampere-hours. Alternative energy battery packs contain from 350 to 4,900 ampere-hours. The specified capacity of a battery pack is determined by two factors-- how much energy is needed and how long must the battery supply this energy. Alternative energy systems work best with between 4 and 21 days of storage potential.

A battery is similar to a bucket. It will only contain so much electrical energy, just as the bucket will only contain so much water. The amount of capacity a battery has is roughly determined by its size and weight, just as a bucket's capacity is determined by its size. It is difficult to water a very large garden with one small bucket, it is also difficult to run a homestead on an undersized battery. If a battery based alternative energy system is to really work, it is essential that the battery have enough capacity to do the job. Undersized batteries are one of the major reasons that some folks are not happy with their alternative energy systems.

Battery capacity is a very important factor in sizing alternative energy systems. The size of the battery is determined by the amount of energy you need and how long you wish to go between battery rechargings. The capacity of the battery then determines the size of the charge source. Everthing must be balanced if the system is to be efficient and long-lived.

State of Charge

A battery's state of charge is a percentage figure giving the amount of energy remaining in the battery. A 300 ampere-hour battery at a 90% state of charge will contain 270 ampere-hours of energy. At a 50% state of charge the same battery will contain 150 ampere-hours. A battery which is dicharged to a 20% or less state of charge is said to be "deep cycled". Shallow cycle service withdraws less than 10% of the battery's energy per cycle.

State of Discharge

State of discharge is the inverse of state of charge. A battery at a 90% state of charge is also at a 10% state of discharge. These terms are important. It is critical for users to know when the battery is nearly empty and should be charged. We also need to know when the battery is full and when it is time to stop charging. We must know the battery's state of charge (or discharge) in order to properly cycle the battery.

Lead-acid batteries

Lead-acid batteries are really the only type to consider for home energy storage at the present time. Other types of batteries, such as nickel-cadmium, are being made and sold, but they are simply too expensive to fit into low budget electrical schemes. We started out using car batteries.

Automotive Starting Batteries

The main thing we learned from using car batteries in deep cycle service is DON'T. Automotive starting batteries are not designed for deep cycle service; they don't last. Although they are cheap to buy, they are much more expensive to use over a period of several years. They wear out very quickly.

Physical Construction

The plates of a car battery are made from lead sponge. The idea is to expose the maximum plate surface area for chemical reaction. Using lead sponge makes the battery able to deliver high currents and still be as light and cheap as possible. These sponge type plates do not have the mechanical ruggedness necessary for repeated deep cycling over a period of many years. They simply crumble with age.

Types of Service

Car batteries are designed to provide up to 300 amperes of current for very short periods of time (less than 10 seconds). After the car has started, the battery is then constantly trickle charged by the car's alternator. In car starting service, the battery is usually discharged less than 1% of its rated capacity. The car battery is designed for this very shallow cycle service.

Life Expectancy and Cost

Our experience has shown us that automobile starting batteries last about 200 cycles in deep cycle service. This is a very short period of time, usually less than 2 years. Due to their short lifespan in home energy systems, they are more than 3 times as expensive to use as a true deep cycle battery. Car batteries cost around $60. for 100 ampere-hours at 12 volts.

Beware of Ersatz "Deep Cycle" Batteries

After the failure of the car batteries we tried the so called "deep cycle" type offered to us by our local battery shop. These turned out to be warmed over car batteries and lasted about 400 cycles. They were slightly more expensive, $100. for 105 ampere-hours at 12 volts. You can spot these imitation deep cycle batteries by their small size and light weight. They use automotive type cases. Their plates are indeed more rugged than the car battery, but still not tough enough for the long haul.

True "Deep Cycle" Batteries

After many battery failures and much time in the dark, we finally tried a real deep cycle battery. These batteries were hard to find; we had to have them shipped in as they were not available locally. In fact, the local battery shops didn't seem to know they existed. Although deep cycle types use the same chemical reactions to store energy as the car battery, they are very differently made.

Deep Cycle Physical Construction

The plates of a real deep cycle battery are made of scored sheet lead. These plates are many times thicker than the plates in car batteries, and they are solid lead, not sponge lead. This lead is alloyed with up to 16% antimony to make the plates harder and more durable. The cell cases are large; a typical deep cycle battery is over 3 times the size of a car battery. Deep cycle batteries weigh between 120 and 400 pounds. We tried the Trojan L-16W. This is a 6 volt 350 ampere-hour battery, made by Trojan Batteries Inc., 1395 Evans Ave., San Francisco, CA (415) 826-2600. The L-16W weighs 125 pounds and contains over 9 quarts of sulphuric acid. We wired 2 L-16Ws in series to give us 12 volts at 350 ampere-hours.

Types of Service

The deep cycle battery is designed to have 80% of its capacity withdrawn repeatedly over a long period of time. They are optimized for longevity. If you are considering using battery stored energy for your homestead, this is the only type to use. Deep cycle batteries are also used for motive power. In fact more are used in forklifts than in alternative energy systems.

Life Expectancy and Cost

A deep cycle battery will last at least 5 years. In many cases, batteries last over 10 years and give over 1,500 deep cycles. In order to get maximum longevity from the deep cycle battery, it must be cycled properly. All chemical batteries can be ruined very quickly if they are improperly used. A 12 volt 350 ampere-hour battery costs around $400. Shipping can be expensive on these batteries. They are corrosive and heavy, and must be shipped motor freight.

Deep Cycle Lead-acid Battery Performance

The more we understood our batteries, the better use we made of them. This information applies to high antimony, lead-acid deep cycle batteries used in homestead alternative energy service. In order to relate to your system you will need a voltmeter. A Radio-Shack #22-191 Digital Multimeter (DMM) is a good deal. An accurate voltmeter meter is the best source of information about our battery's performance. It is essential for answering the two basic questions of battery operation-- when to charge and when to stop charging.

Voltage vs. Current

The battery's voltage depends on many factors. One is the rate, in relation to the battery's capacity, that energy is either being withdrawn or added to the battery. The faster we discharge the battery, the lower its voltage becomes. The faster we recharge it, the higher its voltage gets. Try an experiment- hook the voltmeter to a battery and measure its voltage. Turn on some lights or add other loads to the battery. You'll see the voltage of the battery is lowered by powering the loads. This is perfectly normal and is caused by the nature of the lead-sulphuric acid electrochemical reaction. In homestead service this factor means high powered loads need large batteries. Trying to run large loads on a small capacity battery will result in very low voltage. The low voltage can ruin motors and dim lights.

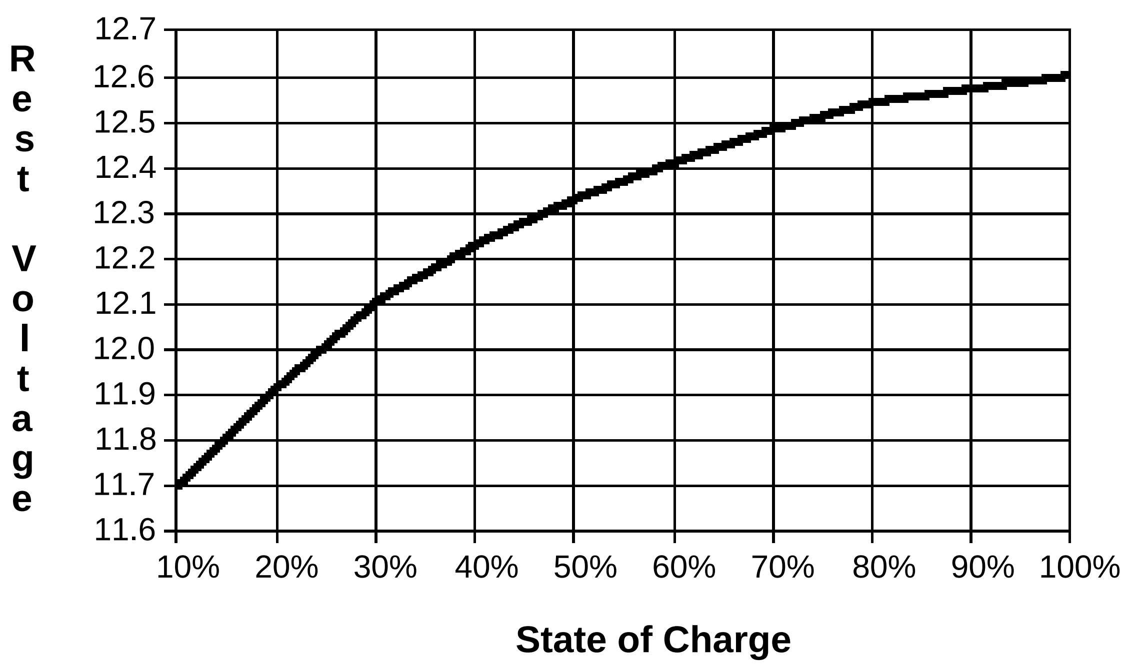
Voltage vs. State of Charge

The voltage of a lead-acid battery gives a readout of how much energy is available from the battery. Figure 1 illustrates the relationship between the battery's state of charge and its voltage. This graph is based on a 12 volt battery at room temperature. Simply multiply the voltage figures by 2 for a 24 volt system, and by 4 for a 48 volt system. This graph assumes that the battery is at room temperature, and is at rest; it is not being either charged or discharged. After recharging, the battery must rest for 6 to 12 hours before the voltage measurement will accurately indicate the state of charge. While discharging it is sufficient to let the battery rest for 10 to 60 minutes before taking the voltage reading.

Voltage vs. Temperature

The lead-acid battery's chemical reaction is sensitive to temperature. The chemical reaction is very sluggish at cold temperatures. Battery efficiency and usable capacity

Fig. 1- Rest Voltage vs. State of Charge
for 12 Volt Lead-Acid Batteries at 78° F.



drop radically at temperatures below 40° F. We keep our batteries inside, where we can keep them warm in the winter. Batteries banished to the woodshed or unheated garage will not perform well in the winter. They will be more expensive to use and will not last as long. The best operating temperature is around 78° F.. Lead-acid batteries self-discharge rapidly at temperatures above 120° F. Consider running your batteries within a temperature range of 55° F. to 100° F.

Determining State of Charge with a Hydrometer

A hydrometer is a device that measures the density of a liquid in comparison with the density of water. The density of the sulphuric acid electrolyte in the battery is an accurate indicator of the battery's state of charge. The electrolyte has greater density at greater states of charge. We prefer to use the battery's voltage as an indicator rather than opening the cells and measuring the electrolyte's specific gravity. Every time a cell is opened there is a chance for contamination of the cell's inards. Lead- acid batteries are chemical machines. If their cells are contaminated with dirt, dust, or other foreign material, then the cell's life and efficiency is greatly reduced. If you insist on using a hydrometer, make sure it is spotlessly clean and temperature compensated. Wash it in distilled water before and after measurements.

Rates of Charge/Discharge

Rates of charge and discharge are figures that tell us how fast we are either adding or removing energy from the battery. In actual use, this rate is a current measured in amperes. Say we wish to use 50 amperes of current to run a motor. This is quite a large load for a small 100 ampere-hour battery. If the battery had a capacity of 2,000 ampere-hours, then the load of 50 amperes is a small load. It is difficult to talk about currents through batteries in terms of absolute amperes of current. Battery people talk about these currents in relation to the battery's capacity.

Rates of charge and discharge are expressed as ratios of the battery's capacity in relation to time. Rate (of charge or discharge) is equal to the battery's capacity in ampere-hours divided by the time in hours it takes to cycle the battery. If a completely discharged battery is totally filled in a 10 hour period, this is called a C/10 rate. C is the capacity of the battery in ampere-hours and 10 is the number of hours it took for the complete cycle. This capacity figure is left unspecified so that we can use the information with any size battery pack. For example, consider a 350 ampere-hour battery. A C/10 rate of charge or discharge is 35 amperes. A C/20 rate of charge or discharge is 17.5 amperes. And so on... Now consider a 1,400 ampere-hour battery. A C/10 rate here is 140 amperes, while a C/20 rate is 70 amperes. Note that the C/10 rate is different for the two different batteries; this is due to their different capacities. Battery people do this not to be confusing, but so we can talk in the same terms, regardless of the capacity of the battery.

Let's look at the charge rate first. For a number of technical reasons, it is most efficient to charge deep cycle lead-acid batteries at rates between C/10 and C/20. This means that the fully discharged battery pack is totally recharged in a 10 to 20 hour period. If the battery is recharged faster, say in 5 hours (C/5), then much more electrical energy will be lost as heat. The heating of the batteries plates during charging causes them to undergo mechanical stress. This stress breaks down the plates. Deep cycle lead-acid batteries which are continually recharged at rates faster than C/10 will have shortened lifetimes. The best overall charging rate for deep cycle lead-acid batteries is the C/20 rate. The C/20 charge rate assures good efficiency and longevity by reducing plate stress. A battery should be completely filled each time it is cycled. This produces maximum battery life.

We often wish to determine a battery's state of charge while it is actually under charge. Figure 2 illustrates the battery's state of charge in relation to its voltage for several charge rates. This graph is based on a 12 volt battery pack at room temperature. For instance, if we are charging at the C/20 rate, then the battery is full when it reaches 14.0 volts. The digital voltmeter measures state of charge without opening cells and risking contamination.

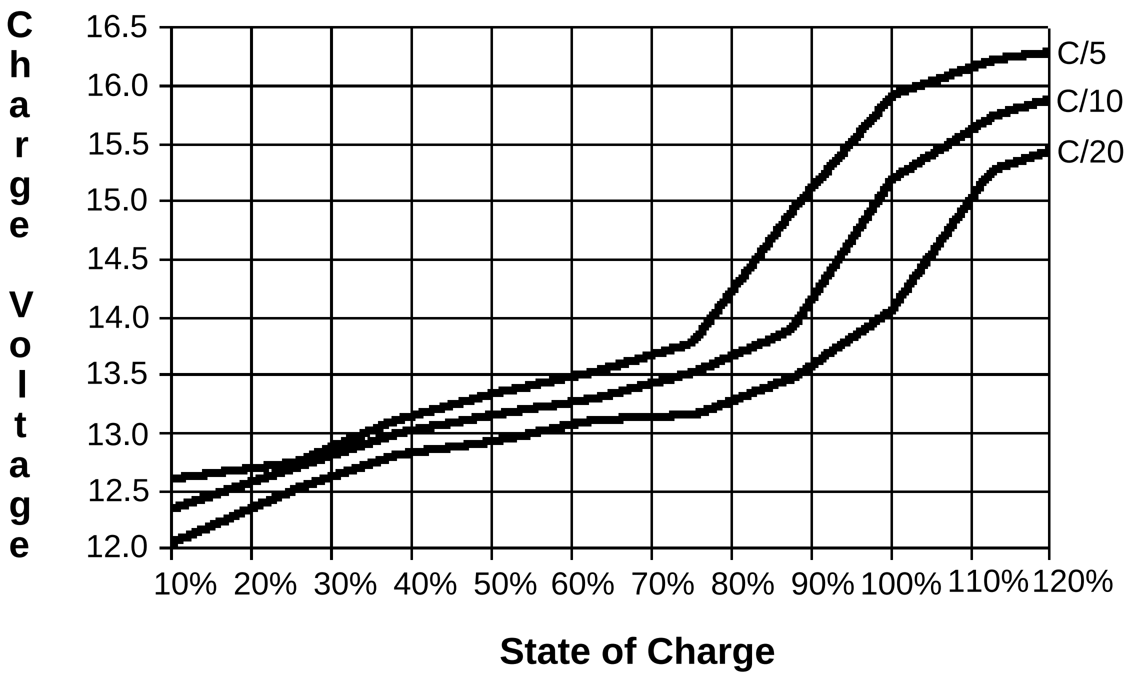
The Equalizing Charge

After several months, the individual cells that make up the battery may differ in their states of charge. Voltage differences greater than 0.05 volts between the cells indicate it is time to equalize the state of charge of the individual cells. In order to do this, the battery is given an equalizing charge. An equalizing charge is a controlled overcharge of an already full battery. Simply continue the charging process at the C/20 rate for 7 hours after the battery is full. Batteries should be equalized every 5 cycles or every 3 months, whichever comes first. Equalization is the best way to increase deep cycle lead-acid battery life. Battery voltage during the equalizing charge may go as high as 16.5 volts. This is too high for many 12 volt electronic appliances. Be sure to turn off all voltage sensitive gear while running an equalizing charge.

The users of wind machines and solar cells are not able to recharge their batteries at will. They are dependendent on Mama Nature for energy input. We have found that all alternative energy systems need some form of backup motorized power. The motorized source can provide energy when the alternative energy source is not operating. The motorized source can also supply the steady energy necessary for complete battery charging and equalizing charges. The addition of a motorized source also reduces the amount of battery capacity needed. Wind and solar sources need larger battery capacity to offset their intermittent nature. Later in Home Power we will discuss making a very efficient and supercheap motorized 12 volt DC source from a lawnmower motor and a car alternator.

Since most homestead battery packs are sized to last several days or weeks, the rate of discharge is not a concern. The same factors which limit the rate of charge also limit the rate of discharge. Deep cycle lead-acid batteries should not be repeatedly discharged at rates exceeding C/10.

Fig. 2- Voltage under Charge vs. State of Charge for 12 Volt Lead- Acid Batteries at 78° F.



Self-Discharge Rate vs. Temperature

All lead-acid batteries, regardless of type, will discharge themselves over a period of time. This energy is lost; it is not available for our use. The rate of self-discharge depends primarily on the battery's temperature. If the battery is stored at temperatures above 120° F., it will totally discharge itself in 4 weeks. At room temperatures, the battery will lose about 6% of its capacity weekly and be discharged in about 16 weeks. The rate of self-discharge increases with the battery's age. Due to self-discharge, it is not efficient to store energy in lead-acid batteries for periods longer than 3 weeks. Yes, it is possible to have too many batteries. If you're not cycling your batteries at least every 3 weeks, then you're wasting energy.

If an active battery is to be stored, make sure it is first fully charged and then place it in a cool place. Temperatures around 35° F. to 40° F. are ideal for inactive battery storage. The low temperature slows the rate of self-discharge. Be sure to warm the battery up and recharge it before using it.

Battery Capacity vs. Age

All batteries gradually lose some of their capacity as they age. When a battery manufacturer says his batteries are good for 5 years, he means that the battery will hold 80% of its original capacity after 5 years of proper service. Too rapid charging or discharging, cell contamination, and undercharging are examples of improper service which will greatly shorten any battery's life. Due to the delicate nature of chemical batteries most manufacturers do not guarantee them for long periods of time. On a brighter note, we have discovered that batteries which are treated with tender love and care can last twice as long as the manufacturer's claims. If you're using batteries, it really pays to know how to treat them.

Battery Maintenance

There is more to battery care than keeping their tops clean. Maintenance begins with proper cycling. The two basic decisions are when to charge and when to stop charging. Begin to recharge the battery when it reaches a 20% state of charge or before. Recharge it until it is full. Both these decisions can be made on voltage measurement and the information on Figures 1 and 2. These rules apply to deep cycle lead-acid batteries used in deep cycle service.

Lead Acid Battery Rules

1. Don't discharge a deep cycle battery greater than 80% of its capacity.

2. When you recharge it, use a rate between C/10 and C/20.

3. When you recharge it, fill it all the way up.

4. Keep the battery at room temperature.

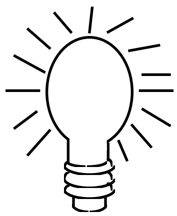
5. Use only distilled water to replenish lost electrolyte.

6. Size the battery pack with enough capacity to last between 4 to 21 days. This assures proper rates of discharge.

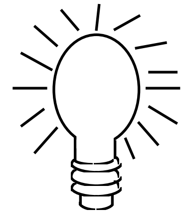
7. Run an equalizing charge every 5 charges or every 3 months, whichever comes first.

8. Keep all batteries and their connections clean and corrision free.

More detailed information on all types of batteries and their usage in alternative energy systems is available in The Complete Battery Book (TAB Book #1757) by Richard A. Perez, its ISBN number is 0-8306-0757-9. This book is available from your local library, your local bookseller, or from TAB Books Inc., P.O. Box 40, Blue Ridge Summit, PA 17214.

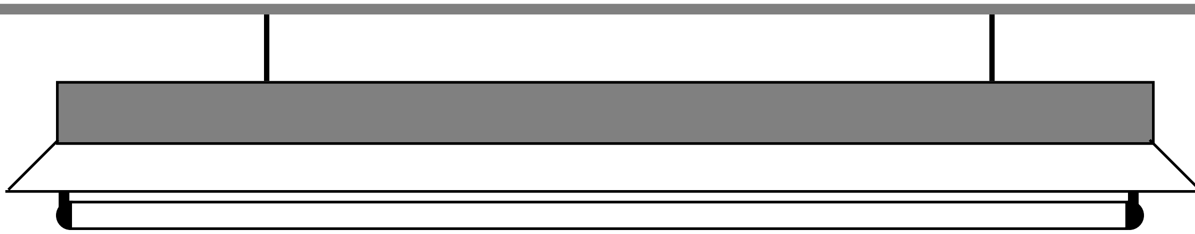


Let There Be Light



by Alan Trautman & Richard Perez

Appliances are why we want the wonderful power of electricity. The most universal electric appliance is lighting. This article begins a discussion of efficient, reliable lighting appliances for alternative energy systems. Read ahead for the facts of this illuminating matter.



Welcome to the first column about appliances and alternative energy systems. In the coming months we will be discussing a myriad of appliances and their application in alternative energy systems. From refrigeration to TVs, stereos to vacuum cleaners, we will cover it all, both AC and DC. The emphasis in this column will be on what is efficient, works and is cost effective. We are going to start with probably the most useful appliance Man has ever developed, the appliance that turns night into day--Lighting. Lighting is not only Man's first appliance, it is the most common. Lighting appliances are one of the prime reason to invite electricity into your household.

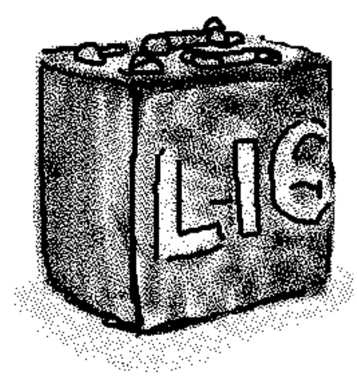
Out Of The Smelly Darkness

In time past, men used to huddle around the campfire for its light and warmth. As technology developed man burned a variety of fuels to produce light. This worked OK, but was smelly, dim, and dangerous. In modern times, man has used the most versatile form of energy to make his light-- electricity. This article is a discussion of lighting devices for use in alternative energy systems. Here we are primarily concerned with getting our lighting chores effectively done with the minimum energy expenditure.

Lighting can be accomplished in alternative energy systems in two ways-- low voltage DC, or 120 VAC through the inverter. In this article we will limit ourselves to 12 VDC lighting. Tune in next month for a discussion on 120 VAC lighting via the inverter. In the world of 12 VDC lighting, we basically have two choices-- incandescent or fluorescent lighting devices. Let's examine the incandescent 12 VDC lamps first.

The 12 Volt Solution

The fine and wonderous selection of 12 VDC incandescent lights come to alternative energy systems from their very close electrical cousins, the automobile and the recreational vehicle. Automotive lamps offer the alternative energy user a wide selection of lights. Everything from very dim to superbright is available, and it all consumes 12 VDC directly from the battery. In general, small auto lamps produce between 50 and 400 lumens. The Lumen is a scientific standard for measuring the visible light intensity. For reference, a standard 23 Watt automotive stop light produces about 400 lumens of light output.



Incandescent Lighting

The incandescent lamp emits light because the electronic motion through its filament heats the filament to a white hot state-- it incandesces and gives off light. The main problem with heating materials to incandescence for light production is inefficiency. Incandescent lighting is less than 10% efficient. 90% of the input energy to the incandescent light makes heat rather than visible light.

Table 1 is a spreadsheet showing the operating characteristics of a variety of small automotive incandescent lamps. This table is arranged with the higher light output lamps first. All lamps are named with their automotive identification number. Note that this table gives us several types of information about these lamps. The lamp's wattage, light output in Lumens, efficiency in Lumens per Watt, longevity (in operating hours), cost, and information about the cost of operating the lamp.

The information related to operating cost comes in two forms--dollars per 1,000 hours of operation, and dollars per Lumen per 1,000 hours of operation. 1000 hours of operation is about a year's use. The figures relating to cost all take the lamps longevity into account. If the bulb is rated to last 200 hours, then we assume that five bulbs will be used during the 1,000 hour period.

These operating costs point out some interesting information about incandescent bulbs. The purchase cost of these lamps is insignificant compared to the cost of the power it takes to run them. Most alternative energy systems produce their electrical power at between $0.65 and $1.75 per kiloWatt-hour. Since this is much greater than the $.07 per kiloWatt-hour that the commercial grids charge, one must be aware of the great importance of efficiency. We have used the power cost at $1.00 per kiloWatt-hour as our standard, and this cost reflects an average for most small alternative energy systems. Note that a 1073 car stop light bulb produces 402 Lumens of light, while consuming some 23 Watts of power to produce this light. This means that the light costs $.07 per lumen per 1,000 hours of operation. It costs the alternative energy user $28. to power and buy one of these lamps for 1,000 hours of lighting. This includes both the cost of five lamps (the 1073 has a lifetime of 200 hours), and the energy to power the lamp over the 1,000 hour period. The 1073 is relatively efficient as incandescent lamps go. It produces about 17.45 Lumens per Watt of input energy.

What Table 1 tells us is that the automotive incandescent lamps are more efficient the larger their light output. Look at the table and see what we mean. The 1073 outputs 402 Lumens at 17.45 Lumens per Watt, while the smaller 89 bulb produces 75 Lumens at 10 Lumens per Watt. This is standard for all car bulbs, the larger they are, the more efficient they are, but the more overall power they consume. So, the alternative energy user is presented with some minimum-maximum type choices. It is a situation of balancing the amount light you need with the amount of power you wish to use. Note that although the smaller bulbs are less efficient, they cost less to operate over a 1,000 hour period. They also put out less light, and this is the reason that they are cheaper to operate.

If you are considering using 12 VDC automotive bulbs in your system, then use this simple rule to select them. Consider the amount of light you need for a particular job. The 400+ Lumen lamps are more than adequate for reading or close work when located within 5 feet of the area being viewed. The smaller sizes may also be adequate if located closer to the work. In alternative energy systems, it is not practical to use large area incandescent lighting. Instead, place the light as close as possible to where it is needed. If area lighting is used at all, it should be of a more efficient type than incandescent lamps.

After you have determined the amount of light you require, browse through the table until you find the one that offers the lowest operating cost over a 1,000 hour period. Let's say that we need a reading lamp with some 200+ Lumens of light output. The table gives us six choices of bulbs to use. The number 1141 bulb can deliver the light at the lowest operating cost, some $20. per 1,000 hours of light. Note that the 1141 has a rated lifetime of 500 hours, so you'll use up two of them within the 1,000 hour period.

One of the major advantages of automotive bulbs is their availability. They are everywhere. Their fixtures can be purchased from RV stores, or you can scrounge sockets from automotive junk yards. Consider the two filament bulbs, like the 1034, used in car tail lights. The high output filament is the stop/directional signal lamp, while the low output filament is the running/tail light. The socket for this bulb can be had inexpensively at just about any junkyard or auto parts store. If both filaments are wired to a two position switch, the user can select either high or low lighting to suit his need. Usage of automotive incandescent lamps is limited only by your imagination. So have fun, make a trip to the junkyard or RV supply and see what you can dig up. Remember, if it works in a car or RV, then it will work on your 12 VDC battery system.

Incandescent lighting is bright and initially cheap, but alas, it is also very inefficient. Considering the expense of electrical power in alternative energy systems, it is more cost effective to use more efficient types of lighting. Fluorescent lighting is the next step. For the same light output, fluorescent lighting averages over 4 times more energy efficiency than incandescent lighting.

Fluorescent Lighting

Again refer to Table 1. Note that the fluorescent lamps have much greater efficiencies (Lumens/Watt) than the incandescent types. This is due to the physical principles behind the fluorescent's operation. While the incandescent lamp makes light via heat, the fluorescent does not use heat to make its light. Instead, fluorescent particles within the lamp are stimulated into light emission by excitation with high voltage electrons. This process is much more efficient and has only minimal losses as heat.

The fluorescent lamp does require high voltage in order to operate. This means that if the lamp is to be powered by low voltage DC, then a mirco-inverter must be used. This micro-inverter is a miniaturized electronic inverter which steps the 12 VDC (from the battery) up to the 100+ volts required to drive the fluorescent tube. The micro-inverter is located within the light fixture, where it presents no hazard to users. The cost of the micro-inverter is the

Table 1

Lighting for 12VDC Alternative Energy Systems

12 VDC INCANDESCENT LIGHTING										
				Candle-		Lumens/	Lifetime		$ per	$/Lumen/
Name	Volts	Amps	Watts	power	Lumens	Watt	in Hours	Lamp Cost	1000 Hrs.	1000 Hrs.
1034 High	12.8	1.8	23.04	32	402.12	17.45	200	$1.01	$28.09	$0.07
1073	12.8	1.8	23.04	32	402.12	17.45	200	$1.01	$28.09	$0.07
1156	12.8	2.1	26.88	32	402.12	14.96	600	$1.25	$28.96	$0.07
1157High	12.8	2.1	26.88	32	402.12	14.96	600	$1.01	$28.56	$0.07
1141	12.8	1.44	18.43	21	263.89	14.32	500	$0.94	$20.31	$0.08
1176High	12.8	1.31	16.77	21	263.89	15.74	200	$1.01	$21.82	$0.08
93	12.8	1.04	13.31	15	188.5	14.16	500	$0.94	$15.19	$0.08
1003	12.8	0.94	12.03	15	188.5	15.67	100	$0.94	$21.43	$0.11
89	13	0.58	7.54	6	75.4	10	750	$0.94	$8.79	$0.12
1176Low	14	0.57	7.98	6	75.4	9.45	1000	$1.01	$8.99	$0.12
67	13.5	0.59	7.97	4	50.27	6.31	5000	$0.94	$8.15	$0.16
1034Low	14	0.51	7.14	3	37.7	5.28	2000	$1.01	$7.65	$0.20
1157Low	14	0.59	8.26	3	37.7	4.56	5000	$1.01	$8.46	$0.22
57	14	0.24	3.36	2	25.13	7.48	500	$0.75	$4.86	$0.19
53	14.4	0.12	1.73	1	12.57	7.27	1000	$0.75	$2.48	$0.20
Averages						11.67	1210			$0.12
12 VDC FLUORESCENT LIGHTS										
				Candle-		Lumens/	Lifetime		$ per	$/Lumen/
Name	Volts	Amps	Watts	power	Lumens	Watt	in Hours	LampCost	1000 Hrs.	1000 Hrs.
F40T12/C	12.8	3.3	42.24	251	3150	74.57	20000	$43.10	$52.99	$0.02
F30T8/CW	12.8	2.2	28.16	175	2200	78.13	7500	$35.30	$37.87	$0.02
FC12T9/C	12.8	2.6	33.28	151	1900	57.09	12000	$49.30	$44.85	$0.02
F20T12/C	12.8	1.8	23.04	99	1250	54.25	9000	$33.20	$32.47	$0.03
FC8T9/CW	12.8	2.2	28.16	88	1100	39.06	12000	$34.80	$37.80	$0.03
F15T8/CW	12.8	1.5	19.2	70	880	45.83	7500	$29.75	$28.17	$0.03
F13T5/CW	12.8	1.5	19.2	65	820	42.71	7500	$33.95	$28.73	$0.04
F8T5/CW	12.8	0.8	10.24	32	400	39.06	7500	$28.70	$19.07	$0.05
Averages						53.84	10375			$0.03

principle reason why the 12 VDC fluorescent lamps cost more that their 120 VAC cousins.

Note that Table 1 gives us a choice of many different intensity fluorescent lamps. Some of these tubes are very bright, and these are the type to consider for area lighting. Only the fluorescent lamps have great enough efficiency to be used in large area illumination. If you are screwing it to the ceiling, then it had better be fluorescent.

The cost of operation of these lamps is much lower than incandescent lamps. Cost analysis of fluorescent lamp usage is not as simple as that for incandescent lamps. The fluorescent fixture has a much higher initial cost. We have based our calculations on a fixture lifetime of 7.5 years. This is about what we are personally experiencing. Most fluorescent tubes are rated with lifetimes in the several thousands of hours. However, our personal experiences show us that about 1,000 hours is an average lifetime for a tube run on micro-inverters. So, all cost calculations relating to the fluorescent lamps are based on a fixture life of 7.5 years and a bulb life of 1,000 hours.

Let's compare the operation cost of two light sources, the 1073 incandescent bulb, and the F8T5/CW fluorescent tube. Both these light sources put out about 400 lumens of light. The 1073 lamp consumes 23 Watts, while the F8T5/CW tube consumes 10.24 Watts. That's right, the fluorescent tube produces the same amount of light with about half the energy consumption. In terms of operating cost over a 1,000 hour period, the F8T5/CW fluorescent costs $19.07, while the 1073 lamp costs $28.09.

Even considering the initially higher cost of the fluorescent lamp and its fixture, its greater efficiency makes it pay for itself by reduced power consumption. The story is about the same for other incandescent versus fluorescent lamps, the fluorescent saves us money every time. Consult Table 1, the fluorescents average $.03 per Lumen per 1000 hours of operation, while incandescents average $.12 per Lumen per 1000 hours of operation. The Bottom Line is that the fluorescents are a FOUR TIMES better deal for your lighting dollar than are the incandescents!

Low voltage fluorescent lighting is manufactured by a variety of companies. Don't be mislead by shopping strictly by cost. The quality of the micro-inverters and fittings in the lights varies greatly from type to type. High quality 12 VDC fluorescent lights will cost you about $30 to $50 each. Such lighting will last for years and will be warranteed for 2 years or more. It will be quiet and will not interfere with your radios and TVs. Our cost estimates here are based on high quality lighting. Don't waste your money on poorly designed and cheaply made 12 VDC fluorescents. These will fail rapidly, interfere with electronics, and are not cost effective.

In conclusion, if 12 VDC is used to directly power lighting, we have two basic choices-- incandescent or fluorescent. Incandescent lighting is initially cheap, but expensive to operate because of its inefficiency. Fluorescent lighting requires a higher initial investment, but quickly pays for itself by saving energy. In general, we recommend using fluorescent light wherever possible, and especially in all lights that operate an hour or more daily.

Power As A Commodity

by Larry Crothers

Power. It's there. We want it. Well, most of us do. Right now I can use all the backwoods power I can afford. There were times when I wanted to live simply on remote property with the cleanest Minimum Impact Electrical System possible. But then and now I find that a basic knowledge of electricity is essential to getting and using Backwoods Power efficiently, safely and reliably.

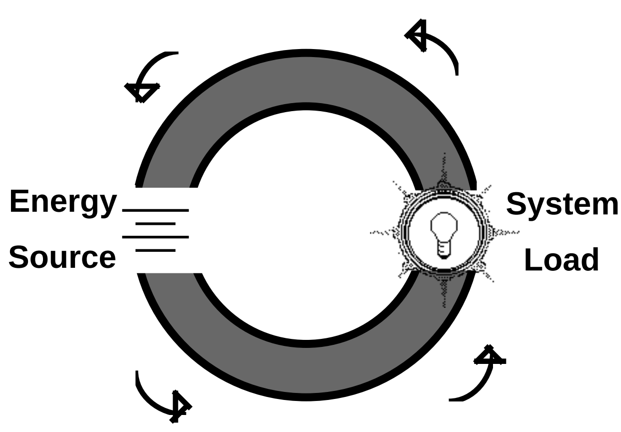
The Basics

Whether your system is large or small, it operates under the same simple electrical principles. If some technological idea seems complicated to you, it seems so because you have not yet broken it down into its basic parts and concepts. For example, if you know the electrical ratings of a light bulb, then you don't need to know things like the metallurgy of the filament to properly use the bulb! The electrical characteristics of the bulb, like all technology, break down into simple relationships. You wouldn't put a 110 Volt household lightbulb into a 12 Volt car, would you? The parts of an electrical system must match each other, and the first consideration is the System Voltage.

Voltage

Figure 1 is a mechanical model to explain Voltage,and other electrical characteristics. There is a circular pipe filled with marbles. The "grip area" on the left is to represent our battery, and the "grip area" on the right is the system load, in this case a light bulb. The marbles represent electrons, each of which has a negative charge. If you act as the battery and push a marble electron in the pipe away from the battery, all the marbles move in a circle and just as many marble electrons will return to the battery " grip area" as left it. One marble in, one marble out, and the circuit must be complete or you lose your marbles! The battery cannot push an electron out one wire unless it gets a replacement electron to push upon supplied by the return line. This is what is meant by the term "complete circuit".

Fig. 1



Now on the right side's "grip area", there is a restriction to the flow of marble electrons, in this case a light bulb. The battery must do the work of pushing electrons through this restriction, and the actual force of "push" applied is the Voltage of the battery, measured in Volts. (Mr. Volta was a battery pioneer some time ago.) As you may know, a 1 1/2 Volt flashlight battery can be tasted on the tongue, while the 120 Volt power line can fry you to a cinder. Correct voltage on a load is of prime importance. If the restriction stays constant, then double the Voltage pressure applied means double the rate of marble flow through the restriction. This seems very logical if you think about it. With fixed resistance, electric current volume of flow is directly proportional to the applied voltage.

By the same wise, if the applied Voltage is kept constant, twice the resistance means half the electrical current flow. This is equally logical. With fixed voltage, electrical current flow is inversely proportional to changes in circuit resistance. So it is completely logical that electrical Current is directly proportional to applied voltage, and inversely proportional to circuit resistance.

Ohm's Law

A fellow named Ohm worked this out, and it is called Ohm's Law. This is the basis of electrical calculations, and you do need to know these three equations. Voltage is measured in Volts. Current flow is measured in Amperes, or Amps. Resistance is measured in Ohms. If you keep to these terms of measurement, Ohm's Law gives you precise answers directly in Volts, Amps, and Ohms, guaranteed!

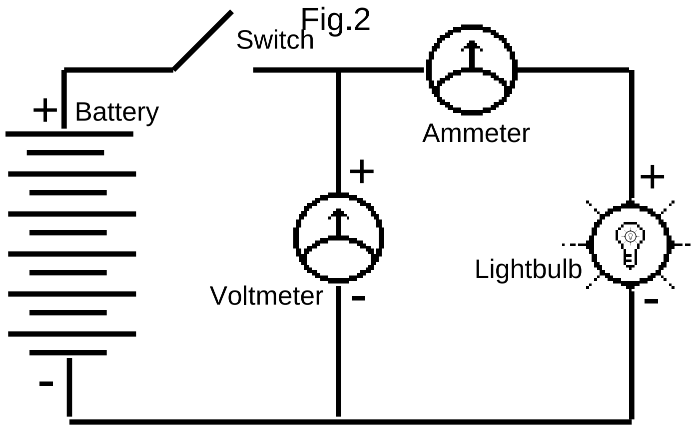
$$I = \frac{E}{R} \qquad \text{Current Flow} = \frac{\text{Voltage}}{\text{Resistance}}$$

By algebraic manipulation of this equation,

$$E = IR \qquad \text{Voltage} = \text{Current X Resistance}$$

You should use a diagram like Figure 2 to show people a battery and lightbulb circuit. It looks official. (You don't have to show the marbles). We just bought a car tail light bulb that is listed as a 12 Volt type which draws 1 Amp of current. What is the resistance of this operation? The resistance of a lightbulb filament changes with its temperature, so one can not tell very much simply by measuring it with an Ohmmeter. In operation, the filament gets quite hot. So you must calculate the resistance based upon known circuit parameters. You need the resistance: you know the Voltage and Current.

Fig.2



As you can see, this was not painful. Check Figure 3. Here you have two lightbulbs on the same battery. The arrows show the flow of electrons from the negative pole of the battery, through the circuit , and returning to the positive pole. Remember that each electron has a negative charge, so a source terminal of them would be a "negative" terminal.

We have Ben Franklin to thank for the decision to call the charge on electrons "negative". He saw all the corrosion on the Positive battery terminals and thought that there was the source of all the action. He guessed wrong, unfortunately.

$$R = \frac{E}{I}$$

$$\text{Resistance } (\Omega) = \frac{\text{Voltage}}{\text{Current (Amps)}}$$

$$12\ \Omega = \frac{12 \text{ Volts}}{1 \text{ Amp.}}$$

Notice that one bulb is a 1 Amp type, and the other is a 2 Amp type. This means the battery is supplying a total of 3 Amps of current. Twelve Volts of system voltage, divided by 3 Amps of battery current equals 4 Ohms of load seen by the battery.

It should be noted that one lightbulb did not affect the other. Each has its own current path between the positive and negative busses. Do you see how the part of the buss wires nearer the battery have more combined current flowing in them than the part further away from the battery? You see how you must provide adequate wire diameter (gauge) to handle currents depending on where it is in the system. Small wire diameters (large gauge numbers) have more resistance per foot. If the wire diameter near the battery is too small, then hooking up the 2 Amp bulb would make the 1 Amp bulb dimmer. This is because of the increased resistance of the small diameter wire. The bottom line is that buss mains should be as large in diameter as it is practical to make them. Small buss mains increase total circuit resistance and create "bottlenecks" which lessen their ability to carry current without "resistance losses".

Electrical Energy

In an operating circuit, electrical energy is transferred from the battery (or other energy source) and into the load at a particular rate. The rate of energy transfer is the Watt, named after the Mr. Watt of steam engine fame. The flow of current in Amps times the applied voltage in Volts equals the energy transfer rate in Watts. 12 Volts times 3 Amps equals 36 Watts. This is a "rate of energy transfer", mind you, not a quantity of energy. You must figure in the elapsed time to calculate the quantity of energy has been transferred. 36 Watts running for 2 hrs. equals 36 X 2 = 72 Watt-hrs. of electrical energy. Half the energy transfer rate in Watts running twice as long is still the same total quantity of energy in W.-hrs.

Ampere-Hours vs. Watt-Hours

A shortcut in battery operated systems is to consider the battery's voltage to be constant in calculations, and ignore it when possible. For example, a given 12 Volt battery will supply 10 Amps for 7.5 hours before it goes dead. 10 Amps at 12 Volts = 120 Watts, which after 7.5 hours = 900 Watt-hours. But if you know the battery voltage is 12 Volts, you can get away with saying the battery can supply 10 Amps for 7.5 hours, which equals 75 ampere-hours. Most deep-cycle Lead-acid batteries and most Nickel-Cadmium batteries are rated in Ampere-hours, so you must be able to work with both systems. It is very easy since Watt-hours =

Ampere-hours X System Voltage. In the example, 75 Ampere-hours X 12 Volts = 900 Watt-hours.

Now, in a real world situation, you should avoid discharging deep-cycle batteries below the last 20% of their charge. Studies have shown that batteries routinely discharged below the last 20% may forfeit half or more of their total life expectancy. In the case of the 900 Watt-hour (or should we say 75 Amp-hour?) battery just discussed, this leaves 720 Watt-hours (60 Amp-hours) of useable capacity.

Our friend just bought land in the mountains. He has a horizontal crankshaft lawnmower engine driving an automotive alternator to make 12 Volt power which is stored in a 75 Amp-hour battery. A user scenario for a typical day at our friend's new place might be as follows.

Radio/Tape Player	0.5 A.	3 Hrs.	18 W-Hrs.
Television- 12VDC	1.5 A.	4 Hrs.	72 W-Hrs.
Light Bulbs- 2	3.0 A.	5 Hrs.	180 W-Hrs.
			270 W-Hrs. per day

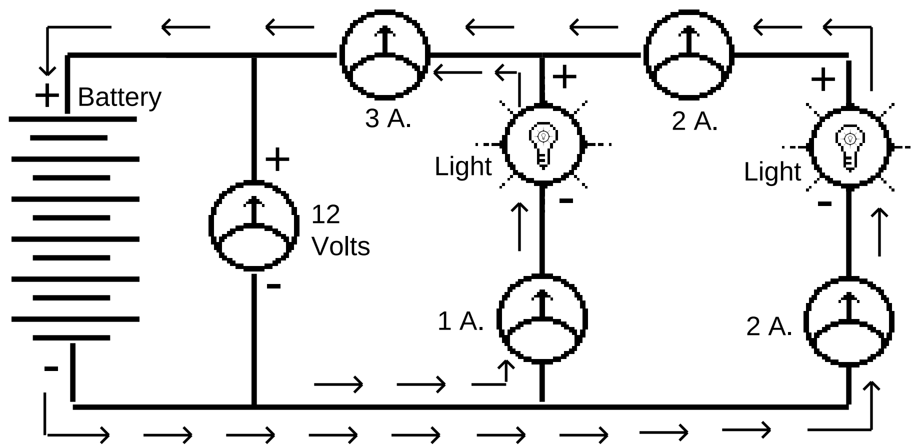


Fig.3

So figure 720 useable Watt-hours divided by 270 Watt-hours per day consumption, equals 2.7 days of average use before the battery must be recharged. Our friend will spend a lot of his time recharging his battery. He must either reduce power consumption, increase battery capacity or add another power source to his system. Which of these solutions is best depends on factors not yet specified.

While our friend has a small alternative energy system, larger systems must endure the very same Karma but on a larger scale. It is simply a matter of size and proportion.

As you can see from our example, there are many overlapping and otherwise connected factors involved in designing an alternative energy system. In order for there to be any hope of efficiency, longevity, and yes, safety of operation, one must calculate all known parameters. This includes everything you have thought of, and maybe a few things you might have to learn, years hence, the hard way.

If you are contemplating installing an alternative energy system, you either learn to calculate the operating parameters yourself, or hire it done. But even if you do get expert help with your system, you can't go wrong by learning how the thing works, and you'll probably have a very good time along the way!

Larry Crothers is CEO of Circle Robotics and has lived on AE since 1976.

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Find the leading edge. Then look beyond it. Perspective affects our vision. Let's look thru three lenses: short, medium, and long term.

Here's a short-term goal-- to serve folks who can't be served in a cost effective way by their local power company. Currently this is accomplished using a mixture of solar, wind, water, generator, inverter and battery technologies. We do the best we can...

A medium-term goal-- replace present-day non-renewable and polluting energy sources with clean renewables. Discard coal, oil, gasoline, and fission technologies. Only a stupid bird fouls its own nest. Implement improved solar, wind and water systems. Develop fusion, cheaper solar, and other creative leaps.

A long-term goal most affects our perception of the edge. Here's mine--the creation of devices that tend toward anti-entropic behavior. Power for nothing and your charge for free.

That's it for now. Short and sweet. In the next column I'll begin a survey of possible anti-entropic devices. Including educated guesses as to the theoretical and technological models needed to realize the free lunch. *Until then, let the future into your dreams.*

I now use OR plan to use the following alternative energy equipment (check all that apply).

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☐	☐	**Wind generator**	☐	☐	**Batteries**
☐	☐	**Water power generator**	☐	☐	**Inverter**
☐	☐	**Battery Charger**	☐	☐	**Control systems**
☐	☐	**Instrumentation**	☐	☐	**PV Tracker**

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I NOW use alternative energy (check one that best applies to your situation).

- ☐ **As my only power source**
- ☐ **As my primary power source**
- ☐ **As my backup power source**
- ☐ **As a recreational power source (RVs etc.)**

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- ☐ **As my primary power source**
- ☐ **As my backup power source**
- ☐ **As a recreational power source (RVs etc.)**

My site has the following alternative energy potentials (check all that apply).

- ☐ **Photovoltaic power**
- ☐ **Water power**
- ☐ **Wind Power**
- ☐ **Other** ______________________