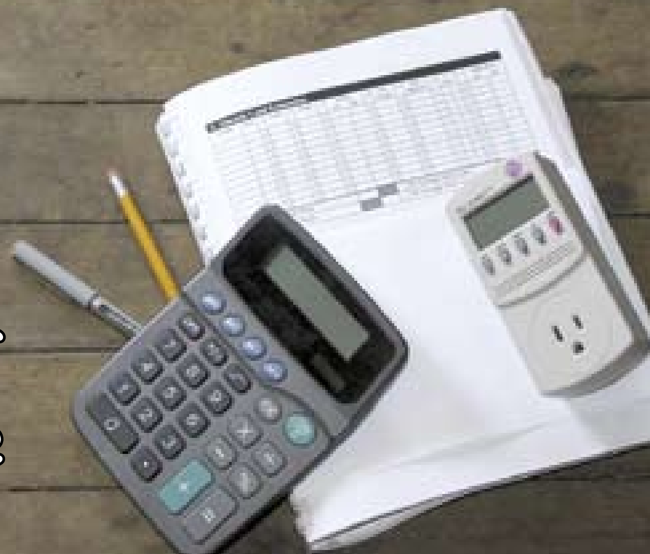
Starting Smart

Calculating Your Energy Appetite



Scott Russell

From solar to microhydro, in Barbados or Barrow, for a hen house or a townhouse, every renewable energy system should begin with a load analysis. This analysis is an assessment of your site's electrical use—your electrical "load profile." You'll need to ponder and juggle a lot of numbers in the process of selecting, sizing, and installing a solar-electric system. A reliable load analysis is essential to get your calculations off on the right foot.

While a load analysis is a necessity for an off-grid system, it's also an excellent idea for a grid-intertied system. For most grid-tied systems, your old electricity bills are an excellent record of how much energy your new RE system will need to produce. But only a thorough load analysis can enable you to target efficiency opportunities and ultimately minimize your system costs. Even if you plan to have a professional installer handle the entire project, your help with this critical task will ensure the highest possible value for your money.

As any RE veteran will tell you, for every dollar you spend on efficiency measures, such as replacing old, energy-hogging appliances or lighting, you'll save US$3 to $5 on the final cost of your system. Note that we're talking about increased efficiency, not necessarily conservation. While conservation is a wonderful thing, you don't need to be a puritan to use less electricity and "buy down" the cost of your system. Most important—you don't need to sacrifice the conveniences that you enjoy to afford an RE-based electrical system!

Where Does My Electricity Go?

The load analysis process can take a little time, but it's easy. A form like the sample featured in this article is available in the Promised Files section on our Web site (see Access) in Microsoft Excel format. This spreadsheet can make the necessary calculations for you. Or you can just grab a calculator and a blank sheet of paper.

The idea is to itemize everything in your house that uses electricity, and then estimate how much each item uses in "watt-hours per day." All the information you need is already either in your house or in your head. Just write it down. Many system articles in *Home Power* include an abbreviated load table, so good examples are readily available.

A complete load analysis collects and calculates several bits of data. What follows is a column-by-column breakdown of the form, describing what each piece of information means and how to get it.

Load

The term "load" refers to an electricity-consuming item—a toaster, DVD player, water pump, alarm clock, lightbulb, or power drill. List everything in your house that uses electricity, no matter how insignificant you think it is. The more complete this list, the more accurate your load profile will be. For multiple, identical loads that are on for the same length of time—for example, ten, 60 watt lightbulbs—list the item once and indicate the quantity in the next column. Multiplication will take it from there.

Load Voltage & Run Watts

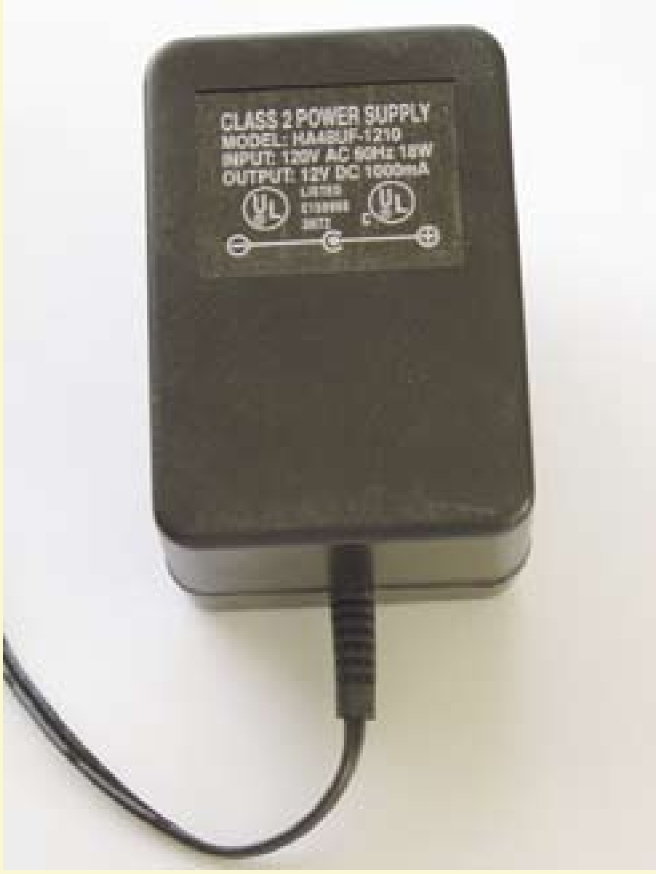
Time for a little legwork. For each item, you'll need to specify both its voltage and wattage ratings. No cause for panic—every electrical load is required to have this information printed directly on it. All you need to do is march around with your clipboard and jot down the numbers.

Voltage, amperage, and run wattage data is usually located on a sticker or plate found on the bottom or back of the appliance. There is no universal standard for how the information appears. Voltage can be listed in a number of forms: 120 volts, 120 V, 120 volts AC, or 120 VAC. Sometimes an appliance nameplate will just list voltage and current, and leave off the watts (W). Current is expressed as amperage, and appears in a number of forms: 0.5 amps, 0.5 A, or 500 mA. To figure out the run wattage, just multiply the volts and amps (V x A = W).

Nearly all of the standard electrical loads found in North America run at 120 volts AC (alternating current). Larger appliances, such as electric stoves, clothes dryers, and electric water heaters usually run at 240 volts AC.

Although increasingly rare, if you happen to have any DC (direct current) loads in your off-grid home, they'll probably operate at 12, 24 or 48 volts DC. Battery operated appliances, such as cordless drills, cordless phones, or (unplugged) laptop computers, operate on DC. But for your load analysis, use the information on their battery recharging units, rather than on the appliances themselves, unless you're running them directly off of DC.

For each load, indicate whether its voltage is AC or DC in the next column of the spreadsheet. Although voltage type isn't terribly important to your load analysis, it's critical for off-grid system design purposes. As long as you're collecting data, better to do it now.



Helpful Tools & Aids

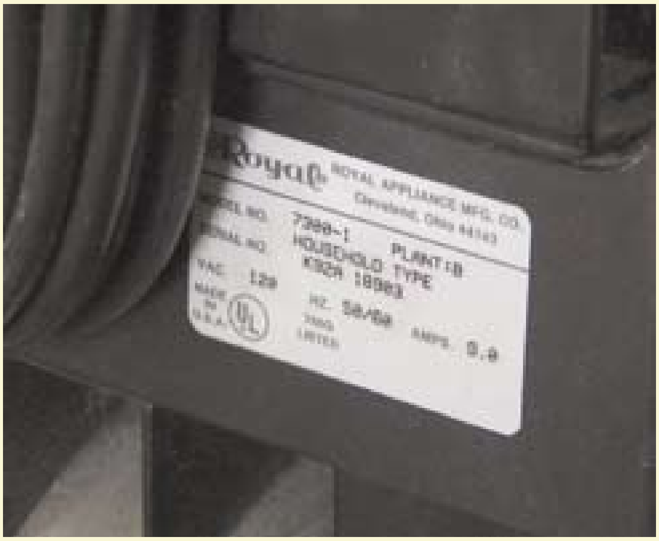
- Load profile chart
- List of approximate wattage for common loads
- Clipboard and pencil
- Watt-hour meter
- Calculator
- Willing assistant (must have opposable thumbs)
- Flashlight
- Stepladder

Run wattage is usually the *maximum* an appliance will draw during operation. The watt rating on the appliance typically represents a "worst case" estimate, but since you rarely watch your television at full volume or use your jigsaw to cut granite, feel free to reduce this number by about 25 percent for "variable wattage" items such as these. For the most accurate readings on these and all of your loads, consider getting a handy watt-hour meter to breeze through the task with digital precision.

Hours & Days

Now comes the sitting-and-thinking part of the exercise. It may involve some collaboration with others in your household to get the most accurate estimates possible. The task simply requires that you approximate how many hours

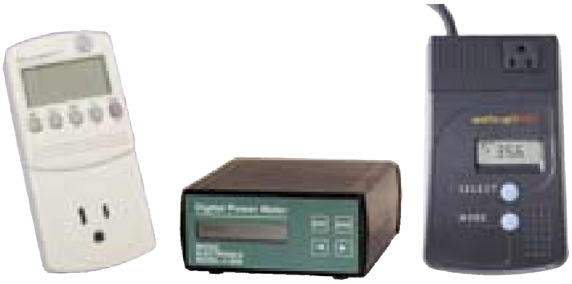
Two typical name plates are shown here.
The sticker on the left lists the running watts as 18 W.
The sticker on the right reports the voltage as 120 V and current draw as 9 A. From this information, we can estimate that this vacuum draws about 1,080 watts.



What's a Watt-Hour Meter?

Watt-hour meters are great tools for anyone interested in collecting and analyzing electrical energy consumption data. Although effective on any 120 VAC electrical load, they're particularly useful for variably cycling appliances, such as washing machines, that are difficult to measure based solely on their run time. Most watt-hour meters can tell you the instantaneous power (watts) and the total energy used (watt-hours or kilowatt-hours) by an appliance. They take the guesswork out of your load analysis by providing actual numbers instead of estimates.

Common models include the Kill A Watt by P3 International, several models by Brand Electronics, and the Watt's Up? meters by Electronic Educational Devices. Meters from all three of these companies have been reviewed in past issues of *Home Power* (see Access). All of these meters are easy-to-use, plug-and-play models. Retail prices range from US$40 to $350, and features vary accordingly.



Three common watt-hour meters (from left to right): the Kill A Watt, Brand Electronics, and Watt's Up?

(or fractions of hours) per day and days per week each of the items you've listed is used or may be used down the road.

In most cases, this is perfectly straightforward, but a couple of notable exceptions will apply. Appliances that turn themselves on and off automatically based on need have what are called "duty cycles." Refrigerators, water pumps, and any thermostatically controlled electrical devices fit this description. You can try estimating the percentage of time that they run by observing how often they turn on and for how long they stay on. But a watt-hour meter is the only way to obtain accurate consumption information for such loads (see sidebar).

The second exception is with "phantom loads" and always-on loads. Phantom loads are electrical loads that use energy even when turned "off." Instant-on TVs, microwave ovens, computer printers and modems, and many other devices consume electricity 24 hours a day unless unplugged or "interrupted" using a plug strip. Always-on loads include answering machines, fax machines, VCRs that you don't want to reprogram, smoke detectors, and others. Some of these loads can be eliminated, for example by using a voicemail service instead of an answering machine.

Unless you plan to get rid of your phantom and always-on loads, they should all be listed in your load profile as 24 hour, 7 day loads. Most phantom loads draw less than 15 watts, but that adds up to a whole lot of energy over a span of weeks or months. Use a watt-hour meter for a precise measurement of phantom loads. Sometimes you will need to list a load twice—once for its phantom load and once for its full, "on" load. The two together should add up to 24 hours.

Before you accept your hours-per-day and days-per-week numbers as final, it might be a good idea to compare them to a few weeks of real life. Pay attention to your electricity habits for two or three weeks and then revise your estimates as needed. You can also check your estimate against your monthly utility bill. It's also important to consider seasonal variations in your electricity use. For instance, you may use your lights much more in winter and fans more in summer. Ultimately, for most grid-connected installations, you want a load profile that represents a year-round daily average.

Average Watt-hours per Day

Light math, anyone? With the essential data now in hand, use the formula below to calculate "Average watt-hours per day" for each item. This is the average amount of electrical energy that each load consumes in a day.

Quantity x run watts x hours per day x days per week ÷ 7 days = average watt-hours per day

Once completed, the sum of this column in your load profile will represent an estimate of the total amount of electricity you use on an average day. This is the consumption rate that your renewable energy system must support if you plan to produce 100 percent of your energy. When you get around to system sizing and component selection, you'll adjust this number to account for a number of seasonal and technological variables.

Lightening Your Load

At this point, it's helpful to add a column for calculating the percentage of your total load that each individually itemized load represents.

Individual load average watt-hours per day ÷ the sum of all items' average watt-hours per day = percentage of average daily load

This information will help you target specific, high consumption loads when taking efficiency measures—your next step following a load analysis. One of the best examples of the potential impact of such measures is described in John Robbins' article, "Recipe for a Solar Office: 1 Part Solar, 5 Parts Load Reduction" (see *HP97*). John reduced his home-office loads by more than 85 percent at a cost of US$1,500, saving him US$5,000 on the cost of his solar-electric system. That's real money.

Home Load Profile

Loads (Before)	Qty.	Volts	AC / DC	Run Watts	Hours / Day	Days / Week	Avg. WH / Day	% of Total WH / Day
Refrigerator, 18 ft.^{3} (old)	1	120	AC	400	7.00	7	2,800.0	35.20%
Well pump 1/3 hp	1	120	AC	850	1.25	7	1,062.5	13.36%
Television, 24 in. color	1	120	AC	170	5.00	6	728.6	9.16%
Incandescent bulbs	12	120	AC	60	1.00	7	720.0	9.05%
Computer monitor	1	120	AC	90	8.00	5	514.3	6.47%
Combined phantom loads	1	120	AC	21	24.00	7	504.0	6.34%
Light fixture (4 incandecent bulbs)	1	120	AC	240	2.00	7	480.0	6.03%
Washing machine (old)	1	120	AC	500	0.75	7	375.0	4.71%
Mac G3 computer	1	120	AC	60	8.00	5	342.9	4.31%
Microwave	1	120	AC	800	0.16	7	128.0	1.61%
Vacuum cleaner	1	120	AC	840	0.50	2	120.0	1.51%
Alarm clock	1	120	AC	3	24.00	7	72.0	0.91%
Toaster	1	120	AC	1,050	0.06	5	45.0	0.57%
VCR	1	120	AC	40	3.00	2	34.3	0.43%
Food processor	1	120	AC	600	0.05	3	12.9	0.16%
Coffee grinder	1	120	AC	150	0.05	7	7.5	0.09%
Power drill, 1/2 inch	1	120	AC	600	0.05	1	4.3	0.05%
Printer	1	120	AC	15	0.30	5	3.2	0.04%
Totals Before Efficiency Measures				6,489			7,954.4	

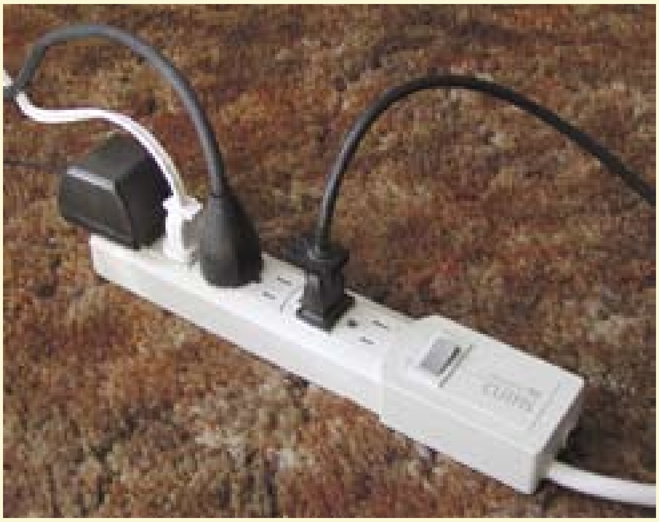
Loads (After Efficiency Measures)	Qty.	Volts	AC / DC	Run Watts	Hours / Day	Days / Week	Avg. WH / Day	% of Total WH / Day
Refrigerator, 20 ft.^{3} (Energy Star)	1	120	AC	175	7.00	7	1,225.0	29.62%
Well pump 1/3 hp	1	120	AC	850	1.25	7	1,062.5	25.69%
Television, 24 in. color	1	120	AC	170	5.00	6	728.6	17.61%
iMac G4 computer w/ LCD display	1	120	AC	45	8.00	5	257.1	6.22%
Light fixture (4 fluorescent bulbs)	1	120	AC	80	2.00	7	160.0	3.87%
Compact fluorescent lights	12	120	AC	13	1.00	7	156.0	3.77%
Microwave	1	120	AC	800	0.16	7	128.0	3.09%
Vacuum cleaner	1	120	AC	840	0.50	2	120.0	2.90%
Washing machine (Energy Star)	1	120	AC	120	1.00	7	120.0	2.90%
Alarm clock	1	120	AC	3	24.00	7	72.0	1.74%
Toaster	1	120	AC	1,050	0.06	5	45.0	1.09%
VCR	1	120	AC	40	3.00	2	34.3	0.83%
Food processor	1	120	AC	600	0.05	3	12.9	0.31%
Coffee grinder	1	120	AC	150	0.05	7	7.5	0.18%
Power drill, 1/2 inch	1	120	AC	600	0.05	1	4.3	0.10%
Printer	1	120	AC	15	0.30	5	3.2	0.08%
Totals After Efficiency Measures				5,551			4,136.4	

If John could save that much money on RE equipment by making his office efficient, think of the potential for a whole house. Compare the tables above for the electrical loads of a modest home before and after efficiency measures. By replacing incandescent bulbs with compact fluorescents, replacing the old refrigerator and washing machine with modern Energy Star appliances, replacing the desktop computer and separate CRT monitor with a model that has an LCD screen, and switching off phantom loads, the home's energy use was reduced by nearly 50 percent.

A few of the ideas in Zeke Yewdall's article in *HP101* focus on home electricity efficiency, and many more solutions can be found. The U.S. government's Energy Star and energy efficiency and renewable energy Web sites are great places to start (see Access).

An Essential Cornerstone

Without a load analysis, designing a renewable energy system is a shot in the dark. It's like trying to plan your weekly food shopping trip without knowing how many



This plug strip is used to control multiple phantom loads with the flip of one switch.

guests you'll have and how much they'll eat. It's also where you'll save the most energy and money. Many people get excited about making their own electricity, and lose sight of the fact that analyzing energy usage and increasing efficiency is where you get the most bang for your buck. Don't skip this step!

It's easy to make the case for a comprehensive load analysis. So take the time to do a good job and then reap the rewards. Not only will it tune you in to how and where you use the electricity you pay for, but it enables you to construct a lean, green foundation on which to build your renewable energy system.

Access

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Brand Electronics, 421 Hilton Rd., Whitefield, ME 04353 • 888-433-6600 or 207-549-3401 • Fax: 207-549-4568 • info@brandelectronics.com • www.brandelectronics.com • Brand watt-hour meters

Electronic Educational Devices, 2345 South Lincoln St., Denver, CO 80210 • 877-928-8701 or 303-282-6410 • Fax: 303-282-6411 • info@doubleed.com • www.doubleed.com • Watts Up? meters

P3 International Corp., 132 Nassau St., New York, NY 10038 • 888-895-6282 or 212-741-7289 • Fax: 212-741-2288 • sales@p3international.com • www.p3international.com • Kill A Watt meter

U.S. DOE energy efficiency and renewable energy info • www.eere.energy.gov/consumerinfo

Energy Star • www.energystar.gov • Info on energy efficient products & tips for home energy efficiency

Load Calculation Excel spreadsheet • www.homepower.com/magazine/downloads.cfm

"Watts Up? Pro KWH Meter" by AJ Rossman & Joe Schwartz, *HP95*

"Things that Work: P3 International's Kill A Watt Watt-Hour Meter" by Joe Schwartz, *HP90*

"Things that Work: Brand Electronics' Digital Power Meter," by Richard Perez, *HP67*

"Doing a Load Analysis: The First Step in System Design," by Ben Root, *HP58*

Doing a Load Analysis: *The First Step in System Design*

Benjamin Root

It's not that we really care about electricity. We don't even care about the appliances that the electricity powers. Our wants and needs are even more basic than that. We want to read after dark, hear good music, and learn about what is happening in the world. We want water on demand and unspoiled food. We don't need the electricity like we don't need the drill. What we need is the hole.

Electricity is merely a tool used to meet our needs and wants. When planning a renewable energy (RE) system it is important not to lose sight of what our needs actually are. Only once our needs are defined can we then begin to design an RE system to meet them. We must analyze each need and determine how much energy it takes to meet that need. Long before we start comparing prices on photovoltaic modules we must first create a list of needs called a "load profile." This article will first discuss some important considerations in choosing appliances to meet certain needs. Then we will go through a step by step discussion of the various elements in a load profile.

Why Do a Load Profile?
RE systems are expensive. Costs to produce one's own electricity from renewable sources average between $0.25 and $1.15 per kilowatt hour (kWh). This is many times the price of buying power from the electric utility. Off grid, it is a waste of money to use more energy than we need to and a waste of money to produce energy that is not used.

If done correctly, your load profile's average daily kWh figure can be quite accurate. Careful load analysis can assure that we size our RE system appropriately.

Which Loads are Appropriate Uses for Electricity?
Most of us need to eek out as much functionality from as little energy as possible. For example, electricity is an expensive way to produce thermal energy. The electricity needed to provide space heating is generally cost prohibitive. Passive solar, wood heat, and propane furnaces are all much more practical. Domestic hot water heaters and cookstoves are also best powered by passive solar, wood, or gas.

Certain loads can be powered by electricity or by other sources. Refrigeration is a good example. Propane refrigerators are available but have their own set of pros and cons. In an energy efficient home the electric refrigerator (even the energy efficient kind) is usually the largest single load. Many RE systems use electric well pumps, but wind-powered mechanical pumps have effectively provided domestic water for generations. These choices are ours. Do we need a 1,200 watt hair dryer or will a towel do just as well? Is using candles or kerosene for light really a smart (or safe) alternative to compact fluorescents?

Some needs are surprisingly appropriate for use with renewable energy systems. Power tools, microwave ovens, toasters, and other kitchen appliances can draw a lot of power and are often mistakenly considered to be too much for an RE system. Actually, these appliances are used for short periods of time and the energy consumed is rather small.

Why Pay Extra for Efficiency?
It might sound like we must do without certain luxuries in order to live with a renewable energy system. This is not the case! RE systems can provide the same amenities that our city cousins enjoy. The trick is to carefully choose how these luxuries are implemented. The most cost effective way to produce one's own energy is to first reduce one's needs for that energy. Richard Perez has a saying that sums it up quite well, "Every watt not used is a watt that doesn't have to be produced, processed, or stored." When buying grid power we can dip into a limitless supply and pay as we go. But with RE systems the cost of the energy is the up front cost of expensive system components. Choosing energy efficient appliances is cheaper than renewable energy system components.

For example, compact fluorescent light bulbs have improved immensely. The light is natural colored, flicker free, and very efficient. A 15 watt compact fluorescent produces the same amount of light as a 60 watt incandescent bulb—at one fourth of the power consumption. They cost about $22 but last 10,000 hours, about ten times longer than a standard incandescent bulb. More important is the money saved by power that doesn't have to be produced. Saving 450 kWh of electricity, at $0.65 per kWh (a hypothetical middle ground cost for RE based on a well designed photovoltaic system with generator back-up), over the bulb's lifetime translates to about $292 dollars. More than enough savings to cover the $7 price difference between one compact fluorescent and ten incandescents!

Refrigeration is another good example of energy efficiency paying for itself. It is often the largest load in a RE-powered home. A sixteen cubic foot Sun Frost fridge may cost $2,500 but uses only about 540 watt hours each day. A typical major brand, non-efficient fridge may cost only $600 but will use 1,500 watt hours per day. Assuming $0.65 per kWh for an RE system, the electricity to operate the non-efficient fridge for ten years costs about $3,558. The electricity to operate the Sun Frost for ten years costs about $1,281. The difference is $2,277 worth of renewable energy system components that never need to be purchased, and more than covers the $1,900 difference in price.

"Every watt not used is a watt that doesn't have to be produced, processed, or stored."

A good rule of thumb says that for every extra dollar spent on energy efficient appliances, three dollars will be saved in energy system components. It becomes obvious that before one dollar is spent on photovoltaic panels, wind generators, or hydro turbines we must streamline our electrical demands.

Are Phantom Loads Really a Big Deal?

If you read many *Home Power* articles then you know phantom loads are one of our biggest pet peeves. Phantom loads use electricity while providing nothing in return. A phantom load is any appliance that consumes power even when it is turned off. While they may seem small they use power twenty-four hours a day. A 4 watt phantom load can cost about $22 a year on an RE system, a lot for an appliance that is supposed to be off.

Any appliance with an electronic clock or timer is a phantom load. If we want a clock we should use one that is mechanically wound, battery powered, or even electrical. But a clock in an appliance keeps the appliance's entire power supply "alive" just to tell us the time. Very inefficient.

Appliances with remote controls remain alive while waiting for the "on" signal from the remote. Any appliance with a wall cube is also a phantom load. A wall cube is a small box that plugs in to an AC outlet to power appliances. Wall cubes consume 20 to 50% of the appliance's rated power even when the appliance is off.

"One human One Light"

Most modern TVs, VCRs, stereos, computers, Fax machines, and other electronics are phantom loads. They may contain a transformer, much like a wall cube, that stays alive even when the appliance is off and consumes between 50 and 200 watt-hours per day. They may also contain a filter or line conditioner, to clean up incoming power for the sensitive electronics inside, consuming 8 to 40 watt-hours per day.

Modern televisions have an "instant on" feature so we don't have to wait for the picture tube to warm up. We might as well call these TV's "always on."

The most direct way to overcome phantom loads is to unplug the appliance when it's not in use. A more convenient technique is to use a switched plug strip. These short extension cords with multiple receptacles allow us to cut all power to multiple appliances with one flip of a switch.

Use care when shopping for appliances that will run on a renewable energy systems. Models that are not phantom loads often have the fewest bells and whistles but are the least expensive.

For more information on detecting and avoiding phantom loads see *HP* 55, page 36.

How to Do a Load Analysis

On page 41 is a load profile form. It is available as a Microsoft Excel spreadsheet on the Home Power web site (http://www.homepower.com). Every appliance in your household that receives regular use should be logged onto this form. When completed you will have an accurate estimate of your average daily kWhs used. This is the foundation on which to build an RE system.

You may be planning for a future RE system at a home that is not yet completed or fully inhabited. Is is important to estimate your future loads as accurately as possible. Try to be realistic about your lifestyle and energy usage habits (Americans watch twice as much TV as they think they do). Be aware of possible appliance purchases in the future, like for growing families. Remember obscure loads such as well pump, satellite dish, garage door opener, etc. The accuracy of the final estimate is dependent on the accuracy of your initial data.

In a load analysis we evaluate a variety of parameters for each appliance. By combining this data we will be able to see this appliance's impact on your energy needs as a whole, and in comparison with other appliances. What follows is a discussion of each parameter (vertical column on the form) and how to obtain the data.

Column A: Appliance
Simply, what appliance are you testing?

Column B: Number
How many of these appliances? An example of multiple identical appliances is lights. There is no need to list every light bulb in the house separately. Richard Perez has a super analogy of one light for every member of the household. Imagine each person has a light that follows them around the house as they move. This is just an analogy, and until technology improves, it is up to each person to throw the switches to get their light to follow them. Ideally then, a three person family should be able to enter 3 in this column for personal lighting. Lights of different wattages should get separate entries. A light on a timer in the driveway should get its own entry, as should a night-light that stays on all night in the hall.

"Every dollar spent for an efficient appliance saves three dollars in renewable energy system components."

Column C: Load Voltage
At what voltage does this appliance operate? RE systems are moving away from 12 Volt systems. Modern RE-powered homes often run on 24 or even 48 Volt systems. Some DC appliances are available for 12 Volt, less so for 24 Volt. Most inverter-powered AC appliances run at 110 Volts (117 Volts rms) but we must not forget about the indispensable 220 volt power tool.

Column D: AC or DC
Does this appliance operate on inverter power or directly from battery power? Inverters consume power by just being on. However, many renewable energy system users are finding that the advantages of constant ac power easily offset inverter losses. Here at Home Power we run all our communications equipment directly on DC for emergency reliability reasons.

Column E: Inverter Priority
Does this appliance spend a large amount of time on? The purpose of this column is to get a feel for the normal operating wattage of the inverter. If an appliance spends a good deal of time on or if we want to be sure that this appliance will always have access to inverter power, then we consider it to be an inverter priority load.

Any appliance that turns itself on and off must be an inverter priority load because we cannot control its access to the inverter. Some loads are operated infrequently and we can decide what other appliance we will allow to operate at the same time. These loads are not inverter priorities.

Later, when we are designing our RE system, this column will help us choose the size of our inverter. It will also help determine the inverter's average operating efficiency.

Column F: Run Watts
How much power does the appliance consume when in use? The most accurate way to determine this is to measure current through the appliance then multiply by 117 volts if it's an ac appliance. If the appliance is DC, multiply the measured Amps by the system voltage to determine Watts. Measuring Amps involves getting an ammeter in series with the load. *HP* 33 page 82 illustrates an effective little gismo for breaking into ac wiring to measure amperage.

Another technique for measuring amps, if your meter has limited amp capability, is to use a shunt. A shunt is a small resistor of known value. It, like an ammeter, must be placed in series with the load being tested. Once in place, measure voltage across the shunt, then use Ohm's law to determine the amperage. If you don't want to buy a shunt then make one out of #10 wire. One foot of #10 copper wire has a resistance of 0.001 ohms. Set your voltmeter to the millivolt scale and measure the voltage drop across the makeshift shunt. For more information on using wire as a shunt see *HP* 6 page 35. To review Ohms law see *HP* 52 page 64.

Electrical appliances display their power use data on a plate or sticker. The noted watt value represents a worst case scenario, the most power that the appliance will ever draw. We generally don't listen to the stereo with the volume all the way up (punk rockers aside), or juice marbles in the blender. If you want accurate numbers you should measure actual watts. If you can't measure then derate the sticker wattage by about 25%.

Column G: Hours per Day
How much is the appliance used each day? In some ways this information is easy to figure: The radio plays

A Appliance	B Qty.	C Volts	D AC DC	E P Y/N	F Run Watts	G Hours /Day	H Days /Week	I W-hours /Day	J Percent of Total	K Surge Watts	L Ph-L Y/N
Espresso Maker (example)	1	117	AC	N	1350	0.20	7	270.0	6.8%	1350	N

Total Daily Average Watt-hrs [ ]

Inverter Priority Wattage [ ]   Max. ac Wattage [ ]   Max. ac Surge Wattage [ ] every morning for forty-five minutes while you get ready for work. The washing machine takes twenty minutes to complete a cycle. Other appliances are more tricky, for example the three light bulbs for your three person family. You need to guess how much time each day that each light is on.

Some appliances turn themselves on and off automatically. Refrigerators start up when the temperature inside gets too warm. They run until they are cooled down to certain temperature when they turn themselves off. This is called a "duty cycle" and can be estimated by direct observation. Just pay attention to how often that fridge comes on and how long it stays on.

When determining energy use, the time element of column G is interconnected with the power element of column F. We can ignore duty cycle by using a recording ammeter and a stopwatch. Simply divide total amp-hours consumed by the number of hours tested to obtain a constant amps rating. Multiply amps times appliance voltage (column E) to get watts (column F). Then use 24 hours per day in column G.

"If you want a clock, then buy a clock."

Column H: Days per Week
Do you do wash every day? Do you only watch TV on Saturday mornings? This helps determine average energy use per day.

Column I: Average Watt-hours per Day
Number (Column B) x Watts (Column F) x hours (Column G) x days (Column H) ÷ 7 days per week = average watt-hours per day for this appliance.

$$B \times F \times G \times H \div 7 = I$$

This amount tells us, on average, how much electricity is consumed each day by this appliance. The total at the bottom of this column tells us how much electricity we use on an average day.

Column J: Percentage of Total Electricity Use
Just for your information, what percentage of total electrical use does this appliance represent? Column I ÷ the total sum of column I for all appliances.

Column K: Starting Surge in Watts
Does this appliance have a starting surge? How much? Any appliance with a motor has a starting surge. This means that before the motor is up to operating speed it is drawing more than its rated operating power. This is especially true if the motor is starting under load. Refrigerators, well pumps, and most power tools have starting surges. Motors surge between three and seven times their rated wattage.

Other appliances that may have starting surges are TVs, computer monitors, and any appliance with an internal power supply. These loads have large capacitors that charge themselves when the appliance is first turned on. They can surge up to three times their rated wattage.

Because they are relatively short—in the millisecond range—starting surges don't make much of a difference in the amount of energy that an appliance consumes. Starting surges are important, however. Inverters must be sized to handle the starting surge of ac appliances. Battery banks must also be sized to handle the voltage depression caused by a high amp surge. Voltage depression can cause an inverter to shut down even if the inverter itself is large enough to handle the surge.

Measuring the starting surge of an appliance requires a meter with a peak hold (maximum) capability.

Column L: Phantom Load
Does this appliance consume power even when turned off? Home Power is ruthless with phantom loads! Our offices are totally controlled by plug strips. No phantom load is allowed to haunt the system. Column L will do three things. First, it reminds us to check each appliance while doing our load profile. Second, it reminds us later that this appliance is a phantom load and must be dealt with as such. Third, if for some reason this appliance is allowed to operate as a phantom load, we will remember that a separate entry must be made in the load table to reflect its energy usage (whenever the appliance is not in use).

The Completed Load Survey
You have combed your house testing loads. You have estimated future loads and maybe even made purchase decisions based on this load survey. But what does the table really tell you? The total at the bottom of column I.is most important. This number represents the average daily electricity that your household uses. This is also the amount of power that your RE system must generate daily.

Some days you do wash and some you don't. Some days you run a lot of power tools. Some days the sun shines and some it doesn't. There are inefficiencies in batteries and inverters. There are a lot of other variables involved in system design. However, average daily kWh is the basic need that must be met. All system design starts here!

Other information in this table (inverter priority wattage, max ac wattage, and max ac surge wattage) will become useful during system design. Do you install 220

Examples

Here are load tables for two example households. Both of these homes provide the same functionality, meeting the same needs and luxuries for their inhabitants. The only difference between these two homes is the efficiency of the electricity use.

Home 1 represents the use of some inefficient appliances: a name brand refrigerator and incandescent lights are used. Also, the inhabitants of this home ignore the phantom loads, allowing them to run constantly. Notice that each phantom load has its own entry on the load table representing the power used by that appliance when turned off.

Home 1 uses an average of almost 7.4 kWh of electricity each day. At 65¢ per kWh this adds up to about $4.80 per day for electricity!

Home 2 represents a more efficient use of electricity: Compact fluorescent lights and an efficient refrigerator. Also, phantom loads are completely eliminated by the use of switched plug strips. These are the only differences between Home 1 and Home 2. However, Home 2 only uses an about 4 kWh per day of electricity. At 65¢ per kWh this is about $2.53 per day for electricity.

The $2.27 daily difference between Homes 1 and 2 is substantial. Over $828 dollars saved each year can easily pay for the expense of efficient appliances.

Remember, the accuracy of the final energy use estimate is only as accurate as the data within the load analysis table.

Home 1 (inefficient)

Appliance	Qty.	Volts	AC DC	P Y/N	Run Watts	Hours /Day	Days /Week	W-hours /Day	Percent of Total	Surge Watts	Ph-L Y/N
Incandescent Lights	4	117	AC	Y	60	5.0	7	1200.0	16.3%	0	N
Refrigerator RCA 16 cu. ft.	1	12	AC	Y	141	10.0	7	1410.0	19.1%	1300	N
Blender	1	117	AC	N	350	0.1	2	10.0	0.1%	1050	N
Microwave Oven	1	117	AC	N	900	0.3	7	225.0	3.1%	1200	Y
Phantom Load-Microwave	1	117	AC	Y	4	23.8	7	95.0	1.3%	0	
Food Processor	1	117	AC	N	400	0.1	5	28.6	0.4%	1200	N
Espresso Maker	1	117	AC	N	1350	0.1	7	135.0	1.8%	1350	N
Coffee Grinder	1	117	AC	N	150	0.1	7	7.5	0.1%	200	N
21" Color Television	1	117	AC	Y	125	5.0	7	625.0	8.5%	570	Y
Ph/L-TV	1	117	AC	Y	20	19.0	7	380.0	5.2%	0	
Video Cassette Recorder	1	117	AC	Y	40	2.5	7	100.0	1.4%	80	Y
Ph/L-VCR	1	117	AC	Y	15	21.5	7	322.5	4.4%	0	
Satellite TV System	1	117	AC	Y	60	2.5	7	150.0	2.0%	1600	Y
Ph/L-Satellite Sys.	1	117	AC	Y	22	21.5	7	473.0	6.4%	0	
Stereo System	1	117	AC	Y	30	8.0	7	240.0	3.3%	60	Y
Ph/L-Stereo	1	117	AC	Y	3	16.0	7	48.0	0.7%	0	
Computer	1	117	AC	Y	45	6.0	3	115.7	1.6%	135	Y
Ph/L-Computer	1	117	AC	Y	3	21.4	7	64.3	0.9%	0	
Computer Printer	1	117	AC	N	120	0.3	3	12.9	0.2%	360	Y
Ph/L-Printer	1	117	AC	Y	3	23.9	7	71.7	1.0%	0	
Power Tool	1	117	AC	N	750	0.5	3	160.7	2.2%	2250	N
Radio Telephone (receive)	1	12	DC	N	6	24.0	7	144.0	2.0%	0	N
Radio Telephone (transmit)	1	12	DC	N	20	1.0	7	20.0	0.3%	0	N
Phone Answering Machine	1	117	AC	Y	6	24.0	7	144.0	2.0%	0	N
Washing Machine	1	117	AC	N	800	0.5	4	228.6	3.1%	100	Y
Ph/L-Washer Timer	1	117	AC	Y	8	23.7	1	27.1	0.4%	0	
Clothes Dryer (motor only)	1	117	AC	N	500	1.0	4	285.7	3.9%	1500	Y
Ph/L-Dryer Timer	1	117	AC	Y	8	23.4	7	187.4	2.5%	0	
Sewing Machine	1	117	AC	N	80	2.0	1	22.9	0.3%	400	N
Vacuum Cleaner	1	117	AC	N	650	0.5	4	185.7	2.5%	1950	N
Hair Dryer	1	117	AC	N	1000	0.2	7	200.0	2.7%	1500	N
Ni-Cd Battery Charger	1	117	AC	Y	4	15.0	2	17.1	0.2%	25	Y
Ph/L-Batt Charger	1	117	AC	Y	2	19.7	7	39.4	0.5%	0	
							Total Daily Average Watt-hrs	**7376.8**			

Inverter Priority Wattage 599 Max ac Wattage 1350 Max. ac Surge Wattage 2250

Home 2 (efficient)

Appliance	Qty.	Volts	AC DC	P Y/N	Run Watts	Hours /Day	Days /Week	W-hours /Day	Percent of Total	Surge Watts	Ph-L Y/N
Fluorescent Lights	4	117	AC	Y	15	5.0	7	300.0	7.7%	0	N
Fridge Sun Frost 16 cu. ft.	1	12	DC	N	48	11.3	7	540.0	13.9%	1300	N
Blender	1	117	DC	N	350	0.1	2	10.0	0.3%	1050	N
Microwave Oven	1	117	AC	N	900	0.3	7	225.0	5.8%	1200	Y
Food Processor	1	117	AC	N	400	0.1	5	28.6	0.7%	1200	N
Espresso Maker	1	117	AC	N	1350	0.1	7	135.0	3.5%	1350	N
Coffee Grinder	1	117	AC	N	150	0.1	7	7.5	0.2%	200	N
21" Color Television	1	117	AC	Y	125	5.0	7	625.0	16.0%	570	Y
Video Cassette Recorder	1	117	AC	Y	40	2.5	7	100.0	2.6%	80	Y
Satellite TV System	1	117	AC	Y	60	2.5	7	150.0	3.8%	1600	Y
Stereo System	1	117	AC	Y	30	8.0	7	240.0	6.2%	60	Y
Computer	1	117	AC	Y	45	6.0	3	115.7	3.0%	135	Y
Computer Printer	1	117	AC	N	120	0.3	3	12.9	0.3%	360	Y
Power Tool	1	117	AC	N	750	0.5	3	160.7	4.1%	2250	N
Radio Telephone (receive)	1	12	DC	N	6	24.0	7	144.0	3.7%	0	N
Radio Telephone (transmit)	1	12	DC	N	20	1.0	7	20.0	0.5%	0	N
Phone Answering Machine	1	117	AC	Y	6	24.0	7	144.0	3.7%	0	N
Washing Machine	1	117	AC	N	800	0.5	4	228.6	5.9%	100	Y
Clothes Dryer (motor only)	1	117	AC	N	500	1.0	4	285.7	7.3%	1500	Y
Sewing Machine	1	117	AC	N	80	2.0	1	22.9	0.6%	400	N
Vacuum Cleaner	1	117	AC	N	650	0.5	4	185.7	4.8%	1950	N
Hair Dryer	1	117	AC	N	1000	0.2	7	200.0	5.1%	1500	N
Ni-Cd Battery Charger	1	117	AC	Y	4	15.0	2	17.1	0.4%	25	Y
							Total Daily Average Watt-hrs	**3898.4**			

Inverter Priority Wattage 325 Max. ac Wattage 1350 Max. ac Surge Wattage 2250 volts worth of inverters or do you run your single 220 vac load on your generator? Do you want an inverter that can run your ac well pump at the same time as the washing machine? What happens when someone turns the microwave oven on too? If you run the fridge and the well pump on DC, can you get away with a smaller inverter? These kinds of questions will come up during system design. Being able to refer back to a complete and detailed load profile will help with the answers.

Access:

Ben Root is still trying to remember to turn off his stereo at night while writing and doing graphics for *Home Power* at Agate Flat.

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