Electric Power Generation for Remote Homesites -- A Systems Engineering Overview

Part I

Duncan Kunz

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Electric Power Generation for Remote Homesites --
A Systems Engineering Overview – Part I

This is part I of a two-part article on generating electricity in a remote homestead. Part I gives an overview of various means of making your own electricity, and also discusses the reasons you might want your own electricity, a basic "design philosophy" for engineering your own electricity, how to evaluate electrical needs, and how to come up with a method to decide the right power sources. In short, this will gave you all the background information you need to make intelligent choices about making your own electricity. Part II is a case study which will take this information and apply it to a real-world homestead.

1. Introduction

1.1 Overview

Many people concerned with preparedness have considered moving to a remote or rural location. Whether for privacy, lower stress level, or simply as a place to get away from it all, a homestead can offer many advantages -- along with some disadvantages. One of these disadvantages is the lack of electricity. Unless you want a return to the days of the nineteenth-century frontier -- with its discomforts and dangers -- you will probably consider electricity as a necessity. Electricity provides us communication with ideas and events, aids in ensuring a safe and reliable food supply, extends productive time, and lowers the level of labor required to maintain life, health, liberty, and comfort. For 99% of us, the need for some reliable electricity is a given.

We take plentiful and reasonably cheap electricity for granted. Most of us assume that it will always be available. But this kind of thinking can be dangerous:

- First, even if we assume the existing social and economic infrastructure will be maintained, increased fuel and transmission costs have resulted in spiraling electricity price to consumers. Dependence of foreign oil, coupled with national anti-nuclear and anti-hydroelectric power sentiment, means that pollution or fuel costs will continue to increase.
- Second, there is real possibility of a major economic or political upheaval. This could destroy or degrade infrastructure and could result in drastic electricity curtailment. We could see rolling brownouts, electrical rationing, or short- and long-term power losses due to damaged generation and transmission capabilities.

No matter which scenario you accept, it makes sense to emphasize low usage of electricity for the remote homestead. If the first scenario above holds, you'll be less impacted by price increases. If the second scenario occurs, low usage will make it easier for you to supplement -- or replace -- your use of grid power.

1.2 Scope

This article provides you with tools to determine your electrical power needs. It includes information on:

1. Common types of electricity generation,
2. Evaluating your electrical needs and wants, and
3. Deciding the best type or mix of electrical generation types based on your needs.

2. Ground Rules

Although grid electrical power may be available, often your remoteness or other considerations require you to choose another form of power generation. If that's the case, you'll probably have to buy or build, as well as maintain, the electrical system. You need to think about two types of costs:

- The system *startup cost* is what you spend to bring the system on line. Since startup cost is tied to the amount of energy produced, it's important to design a system that produces only enough electricity for present and future needs. You can minimize this amount by designing the home-stead to conserve as much energy as possible.
- The system *maintenance cost* is what you spend (in money and time) to keep the system running. Since maintenance costs increase with complexity, the best choice for a power system is operating simplicity.

For these reasons, two goals in designing a remote homestead power system are *power conservation* and *engineering simplicity.*

2.1 Power Conservation

Electricity can do almost anything -- but not always the most cost-effective way. Lights, radio, television, computers, fans: electricity is the best power source for these. But direct sunlight heats water more efficiently, a well-designed house can heat and cool itself, gas, coal, or wood cooks food better and cheaper, and propane-driven refrigerator/freezers offer a viable alternative to electrical ones.

Since electricity is the most costly of the commonly-used power forms, a good rule of thumb is to avoid it wherever and whenever possible.

2.2 Engineering Simplicity

When you live on a remote homestead, you will be (whether you like it or not) the manager of a power generating system. It makes sense to design this system to keep your effort and cost in maintaining, repairing, and replacing system components as low as possible:

- Design your system for long life, avoiding the requirement for consumables such as fuel, expensive spare parts, etc.
- Avoid moving parts wherever possible.
- Make your system mocular for ease of changing components.
- Have one (better yet, two) backup power systems so that you'll have at least some capability while you are repairing or upgrading your primary system.

3. Approaches to Power Generation

This section does two things: (1) it reviews the most common types of electrical power sources, with the advantages and disadvantages of each; and (2) it explains how to apply a method to decide the right power source(s) for your needs.

3.1 Power Sources

The five most common sources of electricity available today are the commercial grid, wind-driven generators, internal combustion engine-driven generators, hydroelectric-driven generators, and photovoltaics. Each source has advantages and disadvantages, and you must weigh your particular needs and capabilities against the candidate power supplies to decide which is the best -- for you.

3.1.1 Commercial Grid. This is the electricity that comes to us courtesy of the utilities, via power poles or underground trenches, and followed by a hefty monthly bill. The power, as is typical for all types of electricity (other than photovoltaics), is produced by generators, which are huge magnets spinning around an iron core. The energy to spin the magnets comes from steam heated by coal, oil, or nuclear fission; or by falling water in a hydroelectric plant. Grid power is the cheapest way (at least in the short run) of producing electricity. Although power companies are the outfits we all love to hate, they do a pretty good job of producing electricity. Most utilities are Government-sponsored monopolies that are more or less regulated to keep prices down to a 'reasonable' level. So...

If you aren't worried about (1) potential infrastructure collapse, (2) increased atmospheric pollution from nuclear waste or burning oil, (3) your power being held hostage to foreign fuel producers, or (4) electricity being controlled by a large company regulated by the Government, grid power is the way to go.

However, if any of the above concerns are important, you should investigate alternative power sources.

3.1.2 Wind-Driven Generators. Wind power can be used to spin an electrical generator. With low enough power requirements, you can build a tower and windmill on your property and have electricity whenever the wind blows. Windmills are a popular approach to power generation, until you examine them in more detail. Windmills have problems that make them questionable as the primary producer for many homesteads. Here's why:

1. Windmills have moving parts besides the generator: the rotating windmill blades, the rudder assembly that keeps the blades into the wind, and often a clutch assembly. Every moving part requires critical engineering analysis; and means additional cost and more things to break or go out of adjustment.
2. Windmills generate electricity only when the wind is blowing. To ensure 24-hour-a-day electricity, you will need a hefty bank of backup batteries. This will require:
    a. A larger windmill and generator (since you need to produce usable electricity and store some at the same time);
    b. Increased operating costs (typically, storage batteries lose most of their storage capability within five years); and
    c. Environmental problems: freezing and cracking batteries, potentially explosive hydrogen produced during battery charging, and storing and disposing of lead and sulfuric acid compounds and by-products.
3. It's difficult to design a wind generator for a particular location, since the amount of wind can vary between two locations a hundred yards apart. You should measure the wind at your

proposed location over at least a one-year period to find out how big the generator should be. This is important, because a windmill strong enough to stand and extract power from a 50-mile/hour wind will not work with light breezes; a windmill efficient enough to extract power from 5-mile/hour breezes will be destroyed by high winds.

This doesn't mean that wind generators are useless. If you're in a place where the wind blows at a constant rate from the same general direction, wind generators can be a good choice. If you're using wind power to pump water into a reservoir, constant and steady wind is not required. If you want to set up a small system to charge batteries for radios, etc., little windmills are easy to build and operate. But as a prime electricity source, windmills will probably not be your first choice.

3.1.3 Internal Combustion Engine-Driven Generators (Gensets). As temporary or emergency power sources, gensets are hard to beat. A 500-watt (W) gasoline generator can cost less than $400 new, is portable, provides both alternating current (AC) and direct current (DC) electricity, gives a lot of electricity in short bursts for fairly low fuel costs, provides that power whenever you need it, and requires almost no engineering expertise to set up and operate. A larger, 3000-W diesel genset offers more power at lower per-watt cost and only slightly less convenience. Everyone should consider a gasoline or diesel genset as a backup power system.

However, gensets are a bad choice for primary electrical power generation. Fuel costs are prohibitive over the long run. There are too many moving parts that can -- and will -- break at the most inopportune times. They are noisy, a key disadvantage if you need a low-profile lifestyle or just want to get some sleep.

3.1.4 Photovoltaics. Photovoltaic (PV) panels (modules) are large (typically 18" X 48") transistor-like devices that turn sunlight directly into DC electricity. PV systems have no moving parts, are silent, can last for at least 30 years, and require almost no maintenance. Unless you live where there's no sunlight, PV can be the ideal power supply -- except for two things.

- First, PV only supplies electricity when the sun is shining. Electrical output is directly proportional to insolation (the amount of sunlight) on the array (bank of modules). Even on a cloudy day, you will get some electricity. But you won't get any at night! This means that if you want 24-hour-a-day electricity, you will need battery storage. As mentioned in the section on wind-driven generators, batteries impose a heavy penalty in cost, engineering, and reliability. PV BOS (Balance Of Systems -- batteries, diodes, support structures, etc.) cost about as much as the PV array itself.
- Second, PV is expensive. A PV module that produces 50 W at full sun conditions can cost up to $400. Double that cost (for the BOS) and 50 W of electricity on demand could cost up to $800. 50 W will give you three high-efficiency DC fluorescent lights or a black-and-white TV.

3.1.5 Water-Driven Generators (Micro-Hydroelectric). Water-driven power generation, or "microhydro," is as close to being the magic bullet" for remote homestead electricity as anything outside science fiction literature. Assuming you have a year-round stream with the right combination of flow rate (how many cubic feet of water pass a given point a second) and head (the drop in water level from one point to another), you can build or buy a reliable, inexpensive turbine/generator system that will produce all the electricity you can use -- 24 hours a day, 365 days a year. Plus, of course, you won't have to drill and pump a well for your drinking and irrigating!

But there's a catch -- you must find property that has a year-round stream. In the West, most of the land with exploitable streams (those capable of incorporating microhydro) belongs to Uncle Sam. In other parts of the country, such as the Missouri Ozarks or the eastern drainage area of the Appalachian Mountains, land with flowing streams is available, but usually costs more than other properties.

Microhydro systems engineering is complex. You need to understand your energy needs and also the topological aspects (the 'lay of the land') of your property. A large, slow-moving stream requires a different turbine setup that a small, fast-moving stream. If the house is a substantial distance (more than 500 feet) from the microhydro turbine, you will probably require an inverter to change the DC electricity into AC, which can be transmitted over longer distances more efficiently.

If the stream is not big or fast-moving, you might have to build a dam. This will probably involve the services of a good civil engineer, a lawyer, and a generous bank president.

All in all, though, if you have access to a property with year-round running surface water, take it. Problems with micro-hydro systems engineering are more than offset by the advantages of this method of electricity generation -- and the knowledge that you won't ever go thirsty!

3.1.6 Other Methods. Several other methods of power generation are possible and have been used in remote locations; small-scale steam turbines and geothermal are the most common.

- Small-scale steam turbines, powered by parabolic solar collectors, wood, or even compost heaps, have been used. However, high operating pressures and the need for creating and moving superheated steam make these devices dangerous for anyone but an experienced designer and builder. Not recommended.

- Geothermal uses high temperatures from underground hot springs or lava to drive steam turbines or stirling-cycle engines which in turn power generators. Impractical unless you live in locations where geothermal energy is available, such as Iceland, New Zealand, Yellowstone National Park, or the slope of an active volcano. Not recommended.

3.2 Method for Determining your Power Source

You now have a basic understanding of the advantages and disadvantages of the major sources of electricity. Your next step is to understand and apply a method for choosing the right source or mix of sources based on your property and budget.

Keep in mind the guidelines of power conservation and engineering simplicity as outlined in Section 2, *Goals*. You will also need to base your choice against (1) criticality of the electrical requirements and (2) budget constraints.

3.2.1 Criticality of Electrical Requirements. Even by eliminating electricity as a source for space heating/cooling, water heating, and cooking, you will find that some requirements are more critical than others.

For example, if you live where no surface water is available, your absolute priority is *pumping water* from a well. Remember, you can grow your own food and make your own electricity, but without a reliable source of potable water, you will die. Unless your water well is less than 100 feet deep, the most effective way to get water is by a pump driven by an electric motor. Water production requires reliable electricity. This is one area you must not skimp on!

Another important requirement is *lighting*. Although high-efficiency fluorescent lighting is available which lowers electrical usage drastically, normal lighting usage makes up about 25-40% of a homesteader's electricity budget. Unless you like candlelight, consider lighting requirements as key for your electrical generation planning purposes.

Some form of electrically-powered *ventilation* is also important. A series of fans to move warm air from a sunspace or stove during the winter (or cooled air from a basement in the summer) increases comfort with a low power usage penalty. Ventilation (as opposed to space heating/cooling) should take up no more than 5% of your electrical budget.

A radio and/or black-and-white TV do not use substantial electricity, although a color TV and rack stereo are electricity hogs. Consider the former as "nice-to-haves" and the latter as luxuries.

Anything that uses electrical motors or compressors is a big electricity-eater. Although a refrigerator/freezer is almost always necessary, think long and hard about blenders, mixers, and microwave ovens. An efficient refrigerator/freezer alone can account for 30% of a small homesteader's electricity budget. Hair dryers? Vacuum cleaners? Invest in several towels and a broom instead.

With the above in mind, you should start by developing a table of electrical *wants* and *needs*. This approach is detailed in Part II of this article, *Case Study: Determining Effective Power Source(s) for a Hypothetical Homestead.*

3.2.2 Budget Constraints. If, like most potential homesteaders, you are on a budget, you must plan realistically for what you can afford. Discriminate between *needs* and *wants* and budget accordingly. Remember, you can upgrade much of your power sources once the necessities are provided for and as more money becomes available. Again, we will detail this approach in Part II.

Electric Power Generation for Remote Homesites --

A Systems Engineering Overview – Part II

This is part II of a two-part article on generating electricity in a remote homestead. Part I gave a quick overview of various means of making your own electricity. It also discussed the reasons you might want your own electricity, a basic "design philosophy" for engineering your own electricity, how to evaluate your electrical needs, and how to come up with a method to decide the right power sources. Part II is a case study which takes all thi information and applies it to a typical, real-world homestead.

4. Usage Study: Determining Effective Power Source(s) for a Hypothetical Homestead

4.1 Overview

This exercise contains subjective material, because it is based on some assumptions which may not apply to your proposed homestead. Your location, climate, altitude, latitude, seasonal average temperatures, and depth of water table are all variables which can change (sometimes drastically) the amount and type of electrical power required.

Also, your level of *wants* vs. *needs* may be different, that is, you may require more or less luxuries than those outlined here. However, you should still be able to come up with a cost-effective plan for design of your own electrical power generation system.

Before buying land and/or designing the power system, you should have a good idea of your needs and how they match with your funds. This will give you an idea of which potential properties, based on the cost of bringing required power, are acceptable.

Below are some rough-order of-magnitude (ROM) estimates for key components of various power generating systems:

1.	Photovoltaics	
	50-W modules, ea.	$400
	support structures, per module	50
	batteries, per module	150
	AC inverter, cost per W 1	
	misc. electronics, per module	25
	wiring harness, per module	50
2.	Microhydro	
	8-kW turbine/generator	$5000
	plumbing	1000
	dam, penstocks, etc. (if needed)	$5000-50,000
3.	Gensets	
	400-W gasoline generator	$400
	1.5-kW diesel generator	1750
	3-kW diesel generator	3000
4.	Windmill	
	1-kW turbine generator	$1250
	tower	750

You can see that, for example, photovoltaics are -- per Watt -- the most expensive way to produce electricity. If you are contemplating a property that has no flowing water for microhydro, is fifty miles from the nearest utility grid, and cannot use wind-power or gensets, the cost of PV would prevent exploitation except for the most basic uses. In this case, you would be advised to scale back your power expectations drastically or look for another piece of property.

Bear in mind, though, that the prices for the components are only preliminary. Shop around, and you could get much lower costs. Also, if you have enough money, you are certainly able to be more flexible in your choices.

Now let's begin our Case Study.

4.2 Baseline Assumptions

4.2.1 Usage. This property will be developed as a self-sufficient homestead. The owner plans to provide for preliminary infrastructure improvements (water well, pump, and basic power generation) within six months of purchase. Over the next 4-1/2 years, the owner will continue to build the infrastructure, with living quarters, fencing, some outbuildings, and garden; along with necessary additional power generation. After five years of the purchase, the homestead will be capable of supporting the homesteader and his family, if he wants or needs it.

4.2.2 Lifestyle. At the five-year anniversary of purchase, the homestead will provide the owner with the capability of a lifestyle roughly similar to a typical suburban homeowner. However, this will require extensive system design and ongoing conservation efforts.

4.2.3 Budget. In addition to the down payment for the property and ongoing financial commitments (including land payments), the homesteader has budgeted $10,000 for initial infrastructure and $500 per month for development.

4.3 Site Survey and Analysis

4.3.1 Site Survey. The property in question is forty acres in east central Arizona. Located in cattle country six miles from the nearest convenience store, twenty miles from a town of 5,000, and 140 miles from the Phoenix metropolitan area, this location qualifies as both rural and remote. Table 4-1 lists key parameters of the property:

Table 4.1 Property Descriptions

Altitude	6000 ft ASL
Access	paved 2-lane to within 1/2 mi, graded dirt road to property line
Electrical Grid	1000 ft to property line
Water	500-year supply at 200 ft; est. production 15 gpm @ 50 ft drawdown
Insolation (full sun)	6.0 hr/day summer 4.5 hr/day winter
Rainfall	12 in/yr. (intermittent)
Wind	non-seasonal, intermittent, typically < 10 mi/hr
Surface water	none
Vegetation	moderately treed in juniper
Climate	mean December daytime temp 66° F mean July daytime temp 87° F
Building restrictions	none

Based on the above information, we can make several key assumptions:

Microhydro: Not possible.

Photovoltaics: With limited cloud cover, potential is excellent for PV to at least some degree. (This is typical of the West.)

Wind: Not feasible except for possibility of low-level water pumping.

Grid: With grid hookup costs between $3000 and $5000, grid is an excellent possibility.

Gensets: Given the size of the land and the absence of building/noise pollution restrictions, gensets are a feasible approach.

4.3.2 Site Analysis. Preliminary analysis shows that the land has a excellent potential for electrical power development. The most likely approach is a mix of PV, grid, and gensets, with the limited use of wind power a possibility.

How this mix of power sources should be used requires you to perform the next step: a needs survey and analysis.

4.4 Needs Survey and Analysis

4.4.1 Needs Survey. A Needs Survey traditionally evaluates power needs for a given set of usage circumstances. In this case, since the circumstances themselves differ, you must first determine those circumstances -- *as you see them.*

For example, if you project little or no degradation in the national infrastructure or standard of living and only want a retirement or summer cottage, you'd probably rely on the utility grid almost exclusively. If you believe that there is a potential for severe infrastructure curtailment or economic dislocation, you will probably opt for a more self-sufficient approach, even though you will pay more at first.

Circumstances. For this example, let's assume that, although the present infrastructure is 'safe' for the next 5-8 years, there is a potential of dislocation in the future. For that reason, the generation system design will be based, *with one exception*, on early use of inexpensive grid power, with a changeover to more self-sufficient power as time and money permit.

The one exception is water pumping. Since access to potable water is imperative, the water well will be pumped by a minimal-size and -cost PV system. If grid power is no longer available even in the short term, you will at least be able to survive if you choose to live on the land.

Several final circumstances: (1) The power system will be designed for a family unit of four people, several dogs, and a few small livestock. (2) Water needs will include the requirement for a low-water-use irrigated garden capable of feeding the family. (3) The systems plan will be flexible enough to allow for power increases if the number of people living on the land increase.

As discussed in Part I of this article, we'll eliminate any uses for electricity that can be met any other way. We won't have to create electricity to heat or cool the house or heat the food and water.

We will need lights, a refrigerator/freezer, an AM/FM/shortwave radio receiver, and a black-and-white TV. Also, a charging device for those appliances and tools that use nickel-cadmium (NiCad) batteries, and some electrical power to operate ventilation between the stove, sunspace, or cellar and the living quarters.

Water pumping will require enough electricity to pump 150 gal/person/day, a realistic usage figure which includes enough water to irrigate a garden capable of feeding you (if you do it properly).

4.4.2 <u>Needs Analysis</u>. Since water usage is critical, we will first determine the power required to deliver it via a PV system. Then, while we're at it, we'll estimate the total minimum power generation requirements for the homestead.

Let's analyze power requirements for the well.

Based on the information in Table 4-1, you should assume that you will need to pump the water three hundred feet straight up. This includes the static water level, draw-down, additional height to a gravity feed tank (if that's your approach), and an allowance for pipe friction.

When you take into consideration the efficiency of the pump (about 50%) and a safety factor (about 15%), it will take 119W to pump one gal/min from your well.

How much water do you need? Based on a four-person family, 700 gal/day should, if used wisely, provide for all your needs, including gardening, small livestock, and a couple of dogs.

PV operates as long as the sun is shining. Typically, a PV array will produce less electricity in the morning and late afternoon, when the sun is low. However, PV engineers measure Afull sun equivalent@ or Afull sun@ when determining how much energy is available. Table 4-1 shows 6 full-sun hr/day in the summer and 4.5 full-sun hr/day in the winter.

This means your 119-W PV system will produce about 270 gal/day in the winter and 360 gal/day in the summer. To produce 700 gal/day during the winter (worst case) would require 119 X (700/270) or 308 W. You probably won't need that much power, since you'll use more water (especially for irrigation) during growing season when you have more sun. However, it's usually better to be conservative in these kind of engineering estimates.

Now let's look at the other electrical requirements.

Choosing the right electric lights provides potential for substantial savings in electricity usage. By using fluorescent lights instead of incandescent bulbs, and by using them only when necessary, you can probably get by with 6 20-W lamps used an average of 2 hr/day (a bit less in the summer -- the days are longer). The daily average in W-hours is 240 W/day.

A refrigerator/freezer is the single biggest user of electricity. 500 W/day for a medium-sized unit is not unreasonable. Specially-insulated units designed for PV applications use less than half that amount, but their capacity is much less and the cost is very high.

An AM/FM/shortwave radio receiver and a black-and-white TV, as long as they do not have a large power amplifier, use about 35 W/hr each Given three hours' use each, your communications and passive entertainment needs can be met with 210 W/day.

A charging device for those appliances and tools that use NiCad batteries should use about 50W/day, and electrical power for ventilator motors, depending on their size and complexity, would be about 100 W/day.

Therefore, your energy *needs* should average about 1380 W/day, of which 308 W <u>must</u> be generated by PV. With a 20% safety factor, you should size your minimum electrical power system at 1,700 W (1.7 kW) of available power per day.

4.5 Cost Survey and Analysis

We now know the minimum energy cost for the homestead. We have also decided that, due to its criticality, water delivery will be powered by a PV system. It would also be advisable -- if we can afford it -- to use PV for *all* our electrical needs.

Therefore, we'll now: (1) figure the cost of a PV system to provide the water, (2) figure the cost to upgrade the PV system to provide all needs, (3) determine alternative methods of electricity production to provide non-water needs, and (4) determine which approach is the most cost-effective.

4.5.1 <u>Cost Survey</u>

<u>*4.5.1.1*</u> <u>*Determining PV Costs for Water Delivery*</u>. Remember, PV only produces electricity when the sun is shining, but you'll probably need water at night, as well. You must make sure water is available 24 hours a day. There are two approaches to ensure full-time availability:

1. Design your PV array large enough to charge a big bank of batteries which will run your pump at night or during cloudy weather. In addition to increasing cost for the additional modules, you'll have to buy batteries and replace them all about every five years.
2. Design your system to pump constantly when the sun is shining. The water will be pumped into a large elevated tank, which will provide you with water by gravity flow. Although you won't have to buy as many modules (since you won't be charging any batteries) you will have to buy a large tank, place it on a hill near your house (or build a tower if you don't have a hill available), and plan for additional piping.

Let's work the numbers for initial (up-front) costs.

For Approach 1, you'll need 308 W for on-demand water pumping, and an additional 200W to charge your batteries. Since most PV modules come in 50-W sizes, you'll need 10 modules to give you the 508 W needed (actually, you'll be about 5 Watts short; but the 308-Watt figure includes a 10% safety factor). You'll need about 12 105-ampere-hour (AH) deep cycle batteries, a wiring harness from the array to the batteries, sensors to automatically switch power between the pump and the batteries to keep them charged, and a 75-gallon pressure tank which will always be kept full and pressurized to provide on-demand water flow. Rough-Order-of-Magnitude (ROM) costs would be:

10 PV modules @ 400 ....$4000
10-module support structure 250
12 105-AH batteries @ 100 1200
Wiring harness 200
Sensors 200
75-gal pressure tank 750
TOTAL $6400

For Approach 2, you'll need the 308 W for constant pumping, a large (3000-gal) tank with shut-off float valve, a concrete pad for the tank (10' X 10') and additional piping. ROM costs would be:

5 PV modules @ 400 ....$2000
6-module support structure 175
3000-gal tank with valves 1750
10' X 10' concrete pad..500
200 ft 4@ sch 80 PVC pipe 100
TOTAL $4525

From a initial cost standpoint, Approach 2 is best.

Now let's look at long-term costs.

Approach 1 will require replacing batteries about every five years. Over a twenty-year life cycle, you'd be paying an extra $3000. Also, you'd be wise to budget $1000 over that time to replace the air bladder in the pressure tank, electronic sensors, and other minor repairs. That brings your total cost to $10,400, or $520/yr over the projected 20-year life cycle.

Approach 2 will probably require no major replacement components at all, which makes your life cycle costs about $225/yr -- a 50% savings over the first approach.

How about reliability?

This is a no-brainer! No batteries to replace, no sensors to troubleshoot and repair, no pressure tank and air bladder to go bad -- Approach 2 is the way to go.

Bear in mind that neither approach includes the cost of the well, a reasonably efficient DC motor pump, and wiring and piping to the pump.

PV costs for water delivery are ROM'ed at $4525.

<u>*4.5.1.2*</u> <u>*Determining PV Costs for Other Electrical Requirements.*</u> This one's going to be easy. Remember, you've budgeted a total of 1,700 W. Since you need your lights, radio, etc., on demand, a PV system would require the same battery/sensor equipment as Approach 1, and would also require more PV modules to charge the batteries. Since 1700W is about six times as much power as needed for the water pumping alone, your PV components would be ROM'ed at:

60 PV modules @ 400	$24,000
60-module support structure	1,250
72 105-AH batteries @ 100	7,200

There's no point in even bothering to calculate the rest. *You're over $30,000 without the electronics*. Obviously, PV-powered everything is simply not cost-effective.

4.5.1.3 Determining Grid Costs for Other Electrical Requirements. As mentioned in Table 4-1, grid power is about 1000 feet from the property line. Assuming that a right-of way exists (and it usually does in these situations), and that you want to bring the grid 250 feet inside your property, you would pay the utility and/or a contractor between three and six thousand dollars (depending whether you used poles or a trench) to bring 110/220 VAC at 200A power to a circuit box on your back wall.

4.5.1.4 Additional Cost Survey Considerations. If you plan to run your well on PV-generated DC electricity and the rest of your house on grid-produced AC electricity, there are no other main power generation costs. (Of course, you have to budget for wiring your house when you build it, and buying the lights, radio, etc.)

If you plan to save the money on PV and use the grid power (which is already going to be there -- right?) for your well, you can save $4500 up front.

If you plan to someday supplement your PV to supply your other needs if the grid goes away, you must wire your house for DC, buy DC appliances, and incorporate a DC rectifier into your grid power line. You can ROM these costs by adding $500 for the AC-to-DC rectifier, an additional $500 for the heavier DC-capable house wiring, and doubling the price of each light, radio, fan, etc.

Or, you can wire your house for both AC and DC (you must use two separate circuits) and use the cheaper AC appliances until you can afford to invest in the DC appliances and the rectifier.

4.5.2 Cost Analysis and Purchasing Plan. Remember that a key cost assumption discussed in paragraph 4.2.3 was that the homesteader has a $10,000 initial infrastructure budget and $500 per month for ongoing infrastructure development. Taking $5000 off the top for a well and pump, we're left with $5000 for immediate use.

This will pay for the basic PV system, including array, water tank, and plumbing, and leave $500. In other words, the $10,000 will permit you to go to your property, turn a spigot, and have all the water you want -- at any time. Of course, you won't have much else, but the absolute basic -- drinking water -- is taken care of.

Your next decision is whether to buy a small genset now or save for installation of the utility grid. Since one of the guidelines is the assumption that the grid will provide reliable power for at least five years, you'd probably want to save your pennies for six to nine months, and bring in grid power. Now you can run the power tools needed to build your buildings, and be assured of power for lights, etc. for the next several years.

With the flexibility of having (1) absolutely-essential power (water pumping PV) for the foreseeable future and (2) cheap power for everything else (grid) for the next five years, you can use your budgeted $500/month for buildings, roads, fences, or whatever else you think important. If you choose to budget $250/month for electricity generation upgrades, your five year plan might look like Table 4-2.

Table 4-2. Five-Year Plan: Electrical Expenditures

Time	Acquire	Cost	Bal.	Comments
Start	Basic PV	4500	500	Absolute essentials taken care of
end of 1st 6 months	grid power	3500	0	Ready for the next 5 years; monthly electricity budget drops to $250
end of 2nd 6 months	gasoline genset	500	1000	Emergency power only
end of 3rd 6 months	nothing	0	2500	A little money in the bank never hurts...
end of 4th 6 months	8 add'l PV modules	3200	800	Increased water capacity or daytime electrical use
end of 5th 6 months	4 add'l PV modules, batteries	2000	300	On-demand PV for lights and radio or refrigerator/freezer
end of 6th 6 months	nothing	0	1800	
end of 7th 6 months	3-kW diesel genset	3000	300	Long-term backup power now available
end of 8th 6 months	fuel/tanks, spares for genset	1500	300	Capable of extended diesel genset use

As you can see, at the end of four years, your key electrical needs are met and paid for. The $6800 balance based on spending $250/month for the five-year period can be applied to other needs, or spent as needed as further electrical requirements are known.

5. Summary

Providing electrical power for a remote homesite can be done effectively, provided you're willing to invest the time to carefully and logically plan your needs and how you will meet them.

I must emphasize, though, that this article should not be used as a "cookbook" to plan for your own home power systems. There are simply too many variables for that. Instead, you must modify the examples to reflect your needs, your property, your schedule, and your budget.

Remember, too, that the costs given in this article are only estimates. You may have to pay only half as much for the PV modules -- or twice as much for a well and pump. Therefore, once you've "pencil-whipped" your own problem based on the examples in this article, go out and price -- from at least two competing sources -- every component and system that you need to buy. You will be surprised -- maybe pleasantly -- at the actual vs. the estimated cost.

Finally, do not consider yourself an expert systems engineer after reading this article and doing the analyses. All I've given is an overview. Carefully review the bibliography and begin reading now. Knowledge is power, and the more knowledge you have, the greater your chance to make your transition to remote electrical power an easy one.

Well, what are you waiting for? Get out there! Make your power -- and your future!