DOCUMENT RESUME

ED 259 929 SE 045 900

AUTHOR	Smith, Diane.
TITLE	Homemade Electricity: An Introduction to Small-Scale Wind, Hydro, and Photovoltaic Systems.
INSTITUTION	National Center for Appropriate Technology, Butte, Mont.
SPONS AGENCY	Department of Energy, Washington, DC. Appropriate Technology Program.
REPORT NO	DOE/CE/15095-10
PUB DATE	Mar 84
CONTRACT	DE-AC01-82CE15095
NOTE	32p.
AVAILABLE FROM	Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.
PUB TYPE	Reference Materials - General (130) -- Reports - General (140)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Alternative Energy Sources; *Electricity; Energy; Energy Conservation; Power Technology; *Solar Energy; *Technological Advancement; Technology; *Wind Energy
IDENTIFIERS	*Appropriate Technology; *Hydroelectric Power; Photovoltaic Systems

ABSTRACT

This report consists of three parts. The first part provides advice (in the form of questions and answers) to prospective individual power producers who are considering investing in electricity-producing systems and in generating their own power. A list of Public Utilities Regulatory Policies Act (PURPA) regulations is included. This legislation requires utilities to buy electricity from small power producers (or qualifiers as they are called). The second part presents (in separate sections) discussions on the use of wind energy, flowing water (hydro energy), and photovoltaic systems to generate electricity. Each section includes background information, a case study, recommendations, and a list of selected grant projects from the Department of Energy (DOE) Appropriate Technology Small Grants Program. Most of the information and recommendations in this part is based on the final reports from and interviews with individuals who received DOE Appropriate Technology Small Grants Program awards. The third part provides sources for additional information, suggested readings, and a glossary of key terms. (ML)

HOMEMADE ELECTRICITY
An Introduction to Small-Scale Wind, Hydro, and Photovoltaic Systems

Prepared for:
U.S. Department of Energy
Assistant Secretary, Conservation
and Renewable Energy
Small Scale Technology Branch
Appropriate Technology Program

PREFACE

From 1978 to 1981, the U.S. Department of Energy (DOE) awarded more than 2,000 small grants to individuals, organizations and small businesses across the nation to research and demonstrate appropriate technologies. Grants were given in the general areas of conservation, solar, biomass, wind, geothermal and hydro power. In 1982, the National Center for Appropriate Technology (NCAT) was placed under contract to review final reports from each DOE grantee in an effort to extract new ideas and other proven concepts that could be of value in applying appropriate technologies to energy problems.

This booklet is one in a series of publications that focuses on appropriate technologies and their application in the home and the work place. These publications combine a qualitative assessment of the DOE grant projects by the NCAT technical staff along with the results of current research for the particular technology highlighted in this document. Each chapter of this publication has a list of selected projects reviewed in preparation of this document.

Prepared by:

Ncat the National Center for Appropriate Technology
PO Box 3838 Butte Montana 59701 (406) 494 4572

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

DOE/CE/15095-10
January 1984

HOMEMADE ELECTRICITY

An Introduction to Small-Scale Wind, Hydro, and Photovoltaic Systems

ACKNOWLEDGEMENTS

While it is impossible to mention every individual who has helped in the development of this document, the following individuals are recognized for their contributions: Diane Smith, author; Ray Schott and John McBride, technical specialists; George Everett, editorial assistant; Hans Haumberger and Jim Duran, technical illustrators. Acknowledgement should also be given to Joel Davidson, Photovoltaic Power Systems; Christopher Turner, Appalachian State University; John Volkman, Idaho Department of Water Resources; and Steve Willey, Backwoods Cabin Electric Systems, for their valuable suggestions in the preparation of this publication. All photographs were provided by the grantees unless otherwise noted.

CONTENTS

INTRODUCTION

More and more Americans are generating their own electricity. Faced with higher energy prices, and encouraged by government regulations which require utilities to buy power from small producers, individuals around the country are investing in electricity-producing systems. The sources of energy used by these systems are diverse, ranging from geothermal water to industrial and agricultural wastes, but by far the most popular have been wind, water, and the sun.

But utilizing this "free" energy does not come cheap. As many of the grantees in the DOE's Appropriate Technology Small Grants Program discovered, producing power with wind machines, micro-hydro systems, and photovoltaics can involve a large commitment of time and money, not to mention coping with the various problems encountered along the way. As one grantee commented, "Many of the unforeseen pitfalls that must be overcome are not generally known until a project of this type is underway."

For this reason, DOE grantees from around the country were asked what advice they would give to individuals who are considering a wind, hydro, or photovoltaic system. Some grantees were optimistic about the potential of homemade electricity, others were more cautious; but all were willing to offer practical advice, based on their individual experiences.

Based on this advice, *Homemade Electricity* leads prospective power producers through a series of questions that will help them decide if generating their own electricity is right for them. Each technology—wind, micro-hydro, and photovoltaics—is also introduced, describing preliminary considerations and emphasizing the lessons learned through the in-the-field testing of the grants projects. Finally, additional sources of information are included to help novice electricity producers answer questions that will arise, and a glossary to explain some of the terms associated with the three technology areas.

"Many of the unforeseen pitfalls that must be overcome are not generally known until a project of this type is underway."

PART I: PRELIMINARY CONSIDERATIONS

Regardless of whether you are considering wind, hydro, or photovoltaics, there are certain questions you should consider before investing in any electricity-producing system. Although these steps seem fairly straightforward, they can, and should, involve a considerable investment of your time. Making that investment before a system has been purchased will help avoid problems or disappointment [illegible] the system in the future.

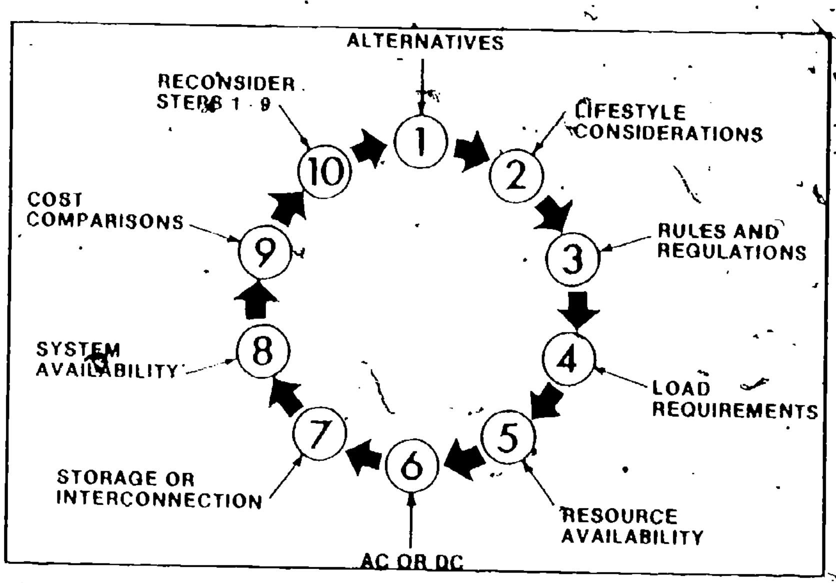


FIGURE 1: Ten Preliminary Considerations

Step 1.

What alternatives are available?

Before considering an electricity-producing system, it is important to look first at alternatives. Many individuals considering a wind, hydro, or photovoltaic system are anxious to save money on their energy bills. So the first thing to consider is whether or not it will be more cost-effective to use less energy rather than generate more. Many energy-conserving appliances are now available which can cut electricity consumption by up to one-half of that used by your current appliances. Weatherizing and insulating your home will also cut down on energy consumption and cost much less in both time and money. Whether or not you decide to proceed with an electricity-producing system, conservation will help you use energy more efficiently.

Step 2.

Will this system fit into your lifestyle?

Although this question may seem inconsequential, in the end it could be the most important consideration. If you are unwilling to make a substantial investment of time maintaining and repairing a system, you should reconsider before proceeding further. As many grantees cautioned, when you make the choice to install your own electricity-producing system, you are assuming the duties normally provided by utility companies. As one grantee summed it up, "It's no longer as easy as turning on a switch."

Step 3.

What are the potential legal and/or environmental problems connected with the system?

Find out exactly what permits are necessary to produce your own electricity and become familiar with the complete array of regulations. For example, if there are zoning ordinances prohibiting any structure over 30 feet, and you are not able to obtain a variance, you can probably dismiss a wind system. Or, if you have a stream on your property but can't secure the water rights, it's better to know before investing time and money in a hydro system. One grantee discovered, after installing a small hydro system, that he could only operate eight months out of the year because of the system's potential impact on stream fish habitat. As he emphasized, it's important to investigate every potential restriction and regulation before proceeding.

"It's no longer as easy as turning on a switch."

Step 4.

How much electricity do you need?

Understanding exactly how much electricity you consume yearly is important if you finally decide to install an electricity-producing system. The best way to determine electrical consumption, or load, is to look at power bills for the last year. The bills should indicate the number of kilowatt-hours your household consumes every month. A year-round analysis of your power needs is necessary because electricity consumption changes with the seasons. For example, in the northern United States, most households consume more electricity during the winter months; in the South, electrical consumption is often greatest during the summer if air conditioners or fans are used. If you're building a new home and can't refer to past power bills, you can estimate your consumption by making a list of all your electrical appliances, recording how much power they require and the amount of time each is used. Several of the general books on the suggested reading list (Part III) include such information for typical use patterns.

Step 5.

What are your resources?

The importance of accurate and long-term measurements of potential energy resources can't be overemphasized. Frequently, systems have been installed with insufficient energy resource data—or no data at all—and the systems simply didn't perform to the owner's expectations.

First, check with state energy offices, local, state or federal weather bureaus, or even your local utility company for any long-term data that is available for your site's vicinity. Next, unless data is already available for your specific site, be prepared to invest at least a year in gathering the information you'll need. Then compare your data with long-term data collected nearby. This is an important step for, as anyone who has observed the weather will tell you, a single year's data may not be at all representative of what you can expect on a long-term basis. Climatic fluctuations, even on an annual average basis, can be extreme and if you base your decision to install a renewable energy system on data that is atypical you could be very disappointed. It's also helpful to talk to anyone who is producing his or her own power in your area, or to someone who is familiar with weather conditions, to get a complete understanding of the resources.

Step 6.

Will you use Alternating Current (AC) or Direct Current (DC)?

This can be the most troublesome decision you will make when planning your electricity-producing system. Everyone you talk to about the benefits of one or the other will have different, and equally convincing, arguments. One of the factors influencing your decision is the distance between the generating facility and the site of application. Direct current can be easily transmitted over short distances, but over long distances for equivalent power generation, electrical losses are greater than with higher voltage AC. Another factor to consider is the convenience and expense involved in actually using the electricity. Basically, the argument can be settled like this: If you're planning a home in a remote site where no utility backup is available, plan to store excess electricity in batteries, and plan to power lights and small appliances, go DC. Many DC appliances are available, such as those used in recreational vehicles. An inverter, although expensive, can be added to operate the appliances only available in AC. Go AC if you are adding a system to an existing home with utility service, or can produce electricity year round, 24 hours a day and do not require battery storage, as with some hydro systems.

Another alternative is to use both AC and DC electricity simultaneously. One grantee wired his basement for DC and uses his small wind charger to power energy-efficient DC fluorescent lights. As he expands his battery bank, he plans to wire the upstairs for DC and add other DC appliances.

Step 7.

Storage and/or utility interconnection?

While trying to resolve the question of whether to design a system to use AC or DC electricity, you will also need to decide how to provide storage and/or backup electricity for the times when your system isn't producing. The options vary depending on the site, the technology, and the end-use of the electricity produced. For example, one grantee who uses wind to pump water provides storage by pumping the water into a tank for later use. One small hydro user constructed a pond for effective storage. But for most energy producers, the options come down to using batteries or interconnecting with the utility.

Interconnection proved to be the most popular option with the grantees since it avoids the expense and inconvenience of batteries (although an expensive synchronous inverter is required), and it ensures that there will be electricity on demand. However, interconnection does have its disadvantages. As one grantee pointed out, if the power company goes down (a real possibility in some locations), most systems also shut off. And unless you receive a reasonable buy-back rate, interconnection is less attractive.

If you are considering utility interconnection, it is imperative that you contact both your utility and public service commission early for guidelines, restrictions, and, of course, the buy back rates before proceeding with your system (see PURPA Regulations).

Step 8.

What electricity-producing systems are available that match your electrical needs?

This is the step where one grantee suggests you "read everything you can get your hands on." Although a few vocational schools teach classes in wind, hydro, or photovoltaics, for the most part, you will have to teach yourself the basics of homemade electricity.

The more you learn about the technology's history, development, and poten-

"Read everything you can get your hands on."

PURPA Regulations

In 1978, Congress passed legislation requiring utilities to buy electricity from small power producers, or qualifying facilities as they are called. This legislation, entitled the Public Utilities Regulatory Policies Act (PURPA), has encouraged thousands of Americans to become small power producers.

Basically, the legislation states that a utility must purchase power from a qualifying facility (QF) at the utility's "avoided cost." The avoided cost is the amount of money the utility saves by not having to generate the same amount of power. As of May, 1983, avoided cost had been determined by public utility commissions, or their equivalent, in all but three states (Mississippi, West Virginia, and Wisconsin). Rates range from 0.03 cents per kilowatt-hour to 9.98 cents, and some states pay more for different sources of power. But even with buy back rates established, small power producers may still have to enter into negotiations with utilities to determine rates for any long-term contract.

Aside from your state energy office, which may help you get started, there are two basic contacts for more information, if you are considering utility interconnection.

Public Utility Commission (or its equivalent)

The utility commissions can help you get started in the right direction, "setting the scene" for the transactions that will be taking place. They also have copies of the Public Utility Commission Rules for PURPA within your state which should be one of the first things you read. In addition, some of the questions you should find answers to include:

1. Does PURPA apply? (In some utility districts, with co-operatives for example, PURPA may not apply.)
2. What is the established buy back rate?
3. What are the utility's obligations, by law?
4. What contractual obligations are necessary?
5. What are the methods of appeal?
6. Who has what responsibility in the negotiations?

Local Utility Company

Since you will be negotiating with the utility, be sure to maintain a professional relationship with them. Record all contacts made with the utility, including dates, names of persons talked to, the information requested, and the answers received. Because utilities hear from hundreds of potential power producers, they may treat your initial inquiries as general in nature. Any serious request for information should be put in writing and directed to the person who can act on that information. And be sure to request that the information you need be provided in writing. Questions you should have answered early in the process include:

1. Does the utility have any guidelines or handbooks for power producers and, if so, how can you obtain a copy?
2. Who can speak for the company and has the authority to sign contracts?
3. What period of time does the contract cover?
4. Who can provide buy-back rates? (To obtain buy-back rates may require a *formal* written request, with a clear statement of what is required.)
5. How long will it take the utility to provide this information?
6. What metering options are available?
7. What are the charges for meters, including charges for installation and monthly reading?
8. How much insurance does the utility require you to maintain?
9. What kind of equipment (inverters, locks, etc.) does the utility require that you purchase?
10. What drawings, schematics, and/or maps are required?
11. What provisions are there should your system break down? Can they permanently disconnect your system from the grid?

Some grantees experienced initial difficulties in establishing a relationship with their local utility. Find out early what is involved, and how that will affect your electricity-producing system and its economic potential, *before* investing in the system.

tial, the better prepared you will be to choose a system that will work at your specific site. Also, the more you know about the technology before talking to manufacturers or sales representatives, the more likely you will get the answers you are looking for when investigating the system.

Step 9.
How much does the system cost?

If you've proceeded this far in the process, now is the time to sit down and add up the costs. Most manufacturers or sales representatives should be able to give you an estimate of the costs involved if you are able to give them an accurate assessment of the resources available, or where the equipment will be sited, and what your load will be.

Although the initial costs of these systems are high, the actual lifetime costs may turn out to be quite reasonable. Performing a simplified life-cycle cost analysis of the proposed system will help you determine whether or not the system is a good investment. Take the initial cost of the system (including installation costs, shipping, any legal fees that may be necessary, and any other miscellaneous expenses), add to that the estimated operation, maintenance and repair costs over the life of the system (including insurance, taxes, finance charges if you have to borrow money for the system, and any other miscellaneous expenses), subtract any federal or state tax credits that might apply, and divide that figure by the lifetime of the system. Twenty years is a common assumption for the life of a system, although some components, like batteries, may have a five to ten year life. (Manufacturers should be able to provide you with more specific information.) This calculation will give you a rough estimate of how much it will cost you to operate your system every year. Divide that number by the projected yearly output of your system in kilowatt-hours and you should have an idea of how much your electricity will cost per kilowatt-hour.

Using this technique it is possible to compare different systems. For example, how would a photovoltaic system compare with a wind system over twenty years? Or, if your house is a short distance from the utility power lines, how would the cost of connecting with the utility compare with the alternatives? Of course, once you begin to compare alternative systems with utility costs, the problem becomes more complex. You know how much utility-generated electricity costs today, but how much will it cost tomorrow? How about twenty years from now when your system is still producing using a renewable source of energy? To make a valid comparison, you need to figure an annual utility cost increase into your calculation. Using utility price increases for the last ten years, utility estimates of future price increases, standard projections, common sense, and intuition will all be helpful, but remember, you cannot make a wise investment in your energy future on intuition alone. If you are uncertain about the figures, seek help from a professional. It makes good sense to calculate the viability of this investment before making any purchase.

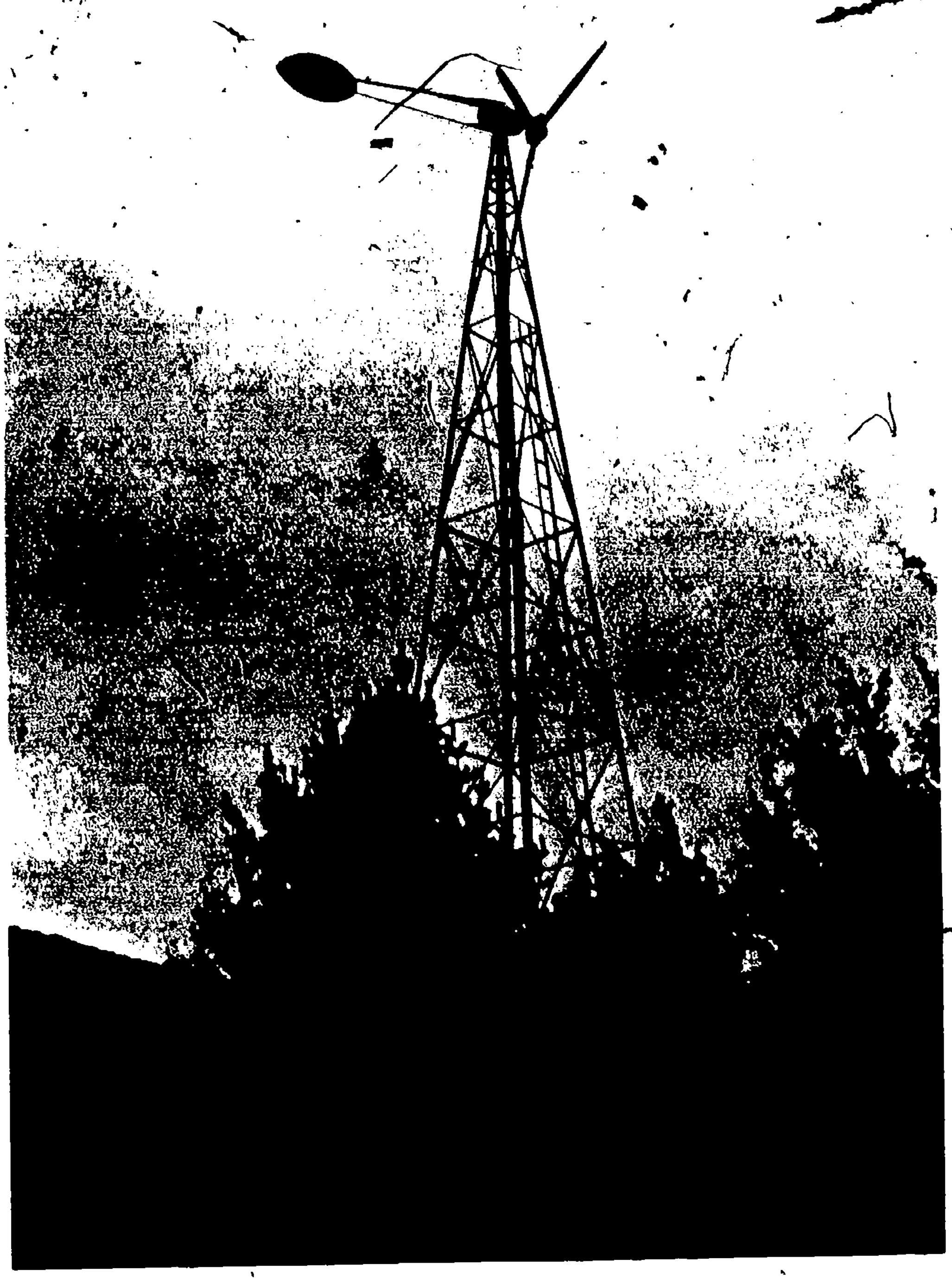
Step 10.
Reconsider Steps 1-9.

If the costs seem too high, even over a long term, it's time to go back to Step 1. What are the available alternatives? Or, going back to Steps 2 and 4, are you willing to adjust your lifestyle to reduce your need for electricity and thus the size of your system? Or, Step 8, have you overlooked other systems available that will meet your load and resource needs? It may be necessary to go through this process several times, evaluating different resources, considering different systems, or adjusting your lifestyle or electricity consumption in order to find a system that meets your needs and fits your pocketbook. Or you may decide that producing your own power is simply impractical and that conservation is the best investment.

Whatever your final decision, it should be made with a realistic appraisal of your financial and time limitations. The decision to produce your own electricity should be made like any other long-term investment: rationally and comprehensively, without emotional bias.

PART II: TECHNOLOGY REVIEW

Much has been written on wind, micro-hydro, and photovoltaic systems but little is available on what it's like to actually live with the systems. Based on final reports and interviews with grantees, this section is an attempt to highlight the lessons learned in the field. Because each technology has its own potential problems, each section is unique to that technology. But all of the information is based on the day-to-day experiences of power producers and should be of value to anyone considering a similar system.



Technology Review: Wind

> *"If the wind doesn't blow your hat off when you walk out the door, forget wind systems."*

WIND

Wind machines, or windmills as they are still often called, have played an important role in the electrification of America. Even with the growth of utility companies, which provided electricity to city dwellers, farmers still relied on the power of the wind to pump water and to provide a limited amount of electricity for their homes. In 1935, windmills began to disappear from the American landscape as the Rural Electrification Administration (REA) helped bring cheap, utility-generated electricity to rural residents.

But as electricity prices have increased, Americans are again turning to wind power. And as the technology advances, wind power in certain locations becomes more promising as a reliable source of electricity for both large-scale wind farmers and the average homeowner.

The key, of course, is the right location. Knowing the wind resources that are available—or not available—at your particular site will make the difference between having a successful wind-generated electrical system and just "an expensive lawn ornament."

Rules and Regulations for Wind

Federal regulations usually do not apply to home-sized wind machines, except in certain locations. For example, the Federal Aviation Administration (FAA) may have certain requirements if the wind system is built near an airport or if the proposed tower rises over 200 feet. The Federal Communications Commission (FCC) would also have jurisdiction if the wind machine causes any interference with radio or television reception. In addition, if the tower is to be anchored within the high water mark of a river, the Army Corps of Engineers will need to be consulted.

State and local regulations are usually more important with wind machines. The first consideration in urban and suburban areas is zoning. A common requirement is that towers be sited so that if they fall, they will not land on a neighbor's property. Other local regulations can prohibit structures over certain heights or require that they be approved by an architectural board for aesthetic standards. Also, state and local electrical and building codes will apply.

Obviously, restricting a wind machine's height and placement can seriously affect its performance so it's good to know before proceeding if such regulations apply. Some grantees worked successfully with local officials to obtain variances for their wind machines; others enlisted the support of neighbors to help change regulations that prevent the optimum placement of a wind tower.

Evaluating the Wind Resources

Many wind machine owners expressed disappointment with their systems because they didn't adequately measure the wind resources available at their site. One grantee commented, "If the wind doesn't blow your hat off when you walk out the door, forget wind systems." This comment may be simplistic; but it does reinforce the importance of knowing you have sufficient resources before investing in a wind machine.

Some wind experts recommend measuring the wind resources at your site for five years, others recommend three, but for the average homeowner, monitoring the wind speeds twice a day for one year should be sufficient. However, wind speeds for one year can be off ± 30 percent from long-term averages so these numbers should then be compared with wind data collected at the nearest weather station.

By comparing data collected at the site with long-term data collected nearby, it is possible to shorten the collection time. However, the less you know about the actual wind conditions at the site, the more you leave to chance when installing a system. Remember, too, that wind measurements should be taken at each site being considered and at a height comparable to the proposed tower.

What constitutes a good site? The first criteria, of course, is the availability of adequate wind. It is, however, possible to have good wind resources and a good machine and still not have a good site. Ideally, the wind machine should be placed as far as possible (at least 300 feet) from obstructions that can slow or create turbulence in the path of the wind and/or at least 30 feet above any obstacle to maximize the energy potential.

How much wind is enough? One grantee recommends that winds average at least 12 miles per hour before a wind system is considered, while another recommends 13 miles per hour. One state energy officer recommends an average wind speed of 14 or 15 miles per hour. As one energy consultant points out, average wind speeds are just that, averages between extremes. He recommends having at least 12 to 18 miles per hour "power winds" on a weekly basis if considering a wind system.

Obviously the amount of wind needed is open to interpretation, and depends on specifics such as wind turbine design, energy use, storage requirements, the type of machine, and the cost of alternatives. A good rule to remember when calculating the potential of your site is that the *power* of the wind is directly proportional to the wind speed cubed. For example, a 10 miles per hour wind (10 × 10 × 10 = 1000) has 8 times more power than a 5 miles per hour wind (5 × 5 × 5 = 125). The higher the wind speed, the greater the possibility of generating usable amounts of electricity. A 2 or 3 miles per hour difference in wind speed can have a major impact on your system's output and overall efficiency.

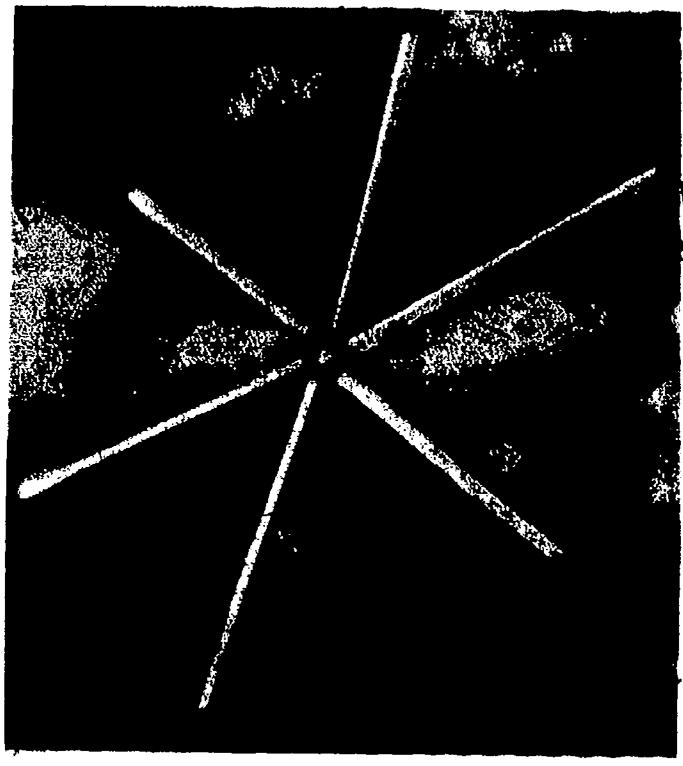
Wind Machine Maintenance

Like an automobile, wind machines require regular maintenance. This can be as routine as changing the oil and greasing the bearings, to checking the braking mechanism to be sure it's functioning properly. And then there are the unexpected repairs. As one grantee cautioned, "Remember, these are heavy machines, operating at high speeds, and they're subject to damage."

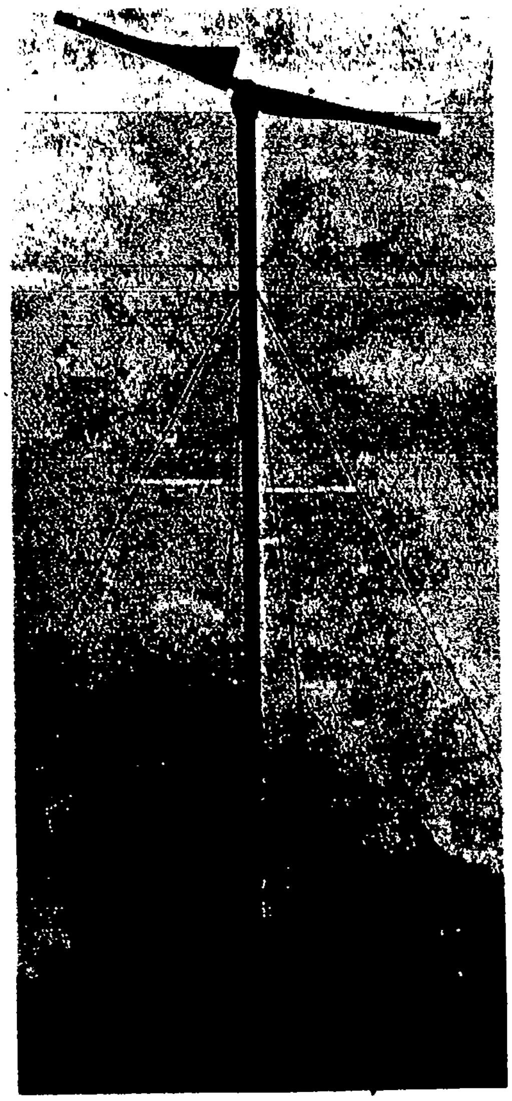
But unlike an automobile, which can

"Remember, these are heavy machines, operating at high speeds, and they're subject to damage."

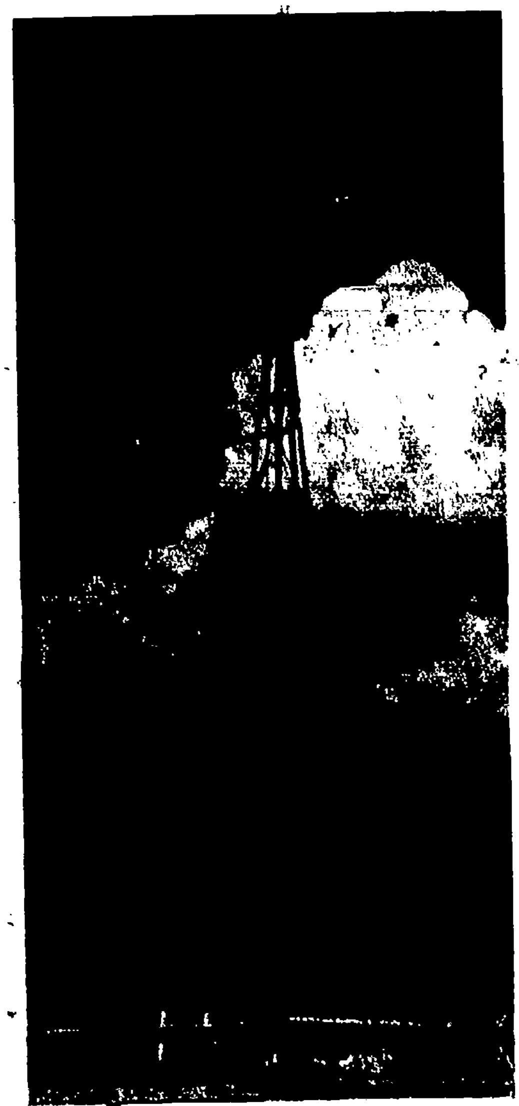
Many farmers still rely on the power of the wind to pump water.



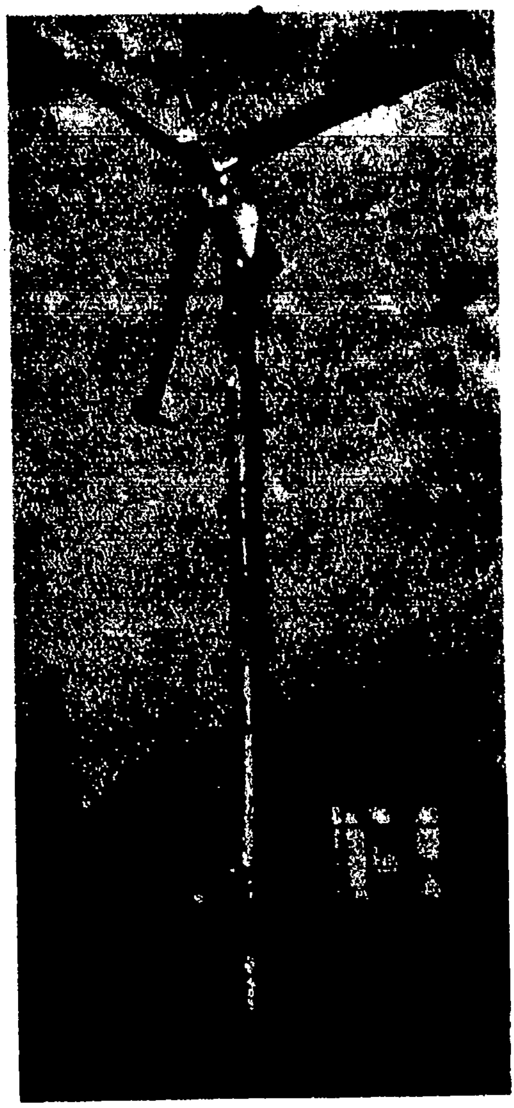
This 20-kilowatt wind turbine in Lincroft, New Jersey has been plagued with downtime. The owners of the machine refer to it as a very beautiful but very expensive lawn ornament.



The first criterion of a good wind site is the availability of wind. The wind machine should also be placed as far as possible from obstructions and/or at least 30 feet above any obstacle.



Non-mechanical land lovers may want to [illegible] twice before investing in a wind [illegible].



Wind machine towers should be fenced off to keep people, young and old, from climbing on them.

be taken to the shop, the wind machine is perched atop a 40- to 100-foot tower which can be very dangerous to work on. If you like to tinker with machines and are not afraid of heights, this cautionary note should not present problems. But non-mechanical, land lovers should be prepared to spend money to hire trained personnel to maintain the machine. As one grantee pointed out, people understandably charge a lot of money to climb wind towers when performing even routine checks.

Towers

A main function of the tower is to position the wind machine in the path of the wind. Like wind machines, there is a variety of towers to choose from and it pays to do your homework. It also pays to enlist the help of an expert in selecting and installing the tower. When investigating which tower to buy it will help to keep the following in mind:

- *Height*. Remember, there is usually more wind available at 100 feet than at 40 feet, so a taller tower may be a better investment than a larger wind machine.
- *Accessibility*. Some towers are designed to be easily raised and lowered so that repairs can be made at ground level. This feature may be worth the added cost if you are reluctant to climb the tower.
- *Strength*. The tower must be designed to withstand the severest wind ever recorded in your area, and then some. Just because winds haven't reached 100 miles per hour in over 50 years doesn't mean it can't happen again. The tower should also be galvanized to prevent rust.
- *Safety considerations*. Nothing attracts attention like a wind machine tower, so it should be fenced off to keep people, young and old, from climbing on it. It should also be grounded. Be sure these costs are included when estimating the overall economics of the system.
- *Manufacturer's recommendations*. Often wind machine manufacturers recommend that their wind machines be installed on a certain kind of tower. In fact, some manufacturers won't guarantee their machine unless it is installed on an approved tower. Be sure to seriously consider a manufacturer's recommendations before deciding on a different kind of tower.

Shopping for a Wind Machine

Because there are so many wind machine designs available, and each application is so site specific, the most important thing to do is to learn all you can by researching the various designs and talking to as many wind machine owners as possible. Remember, you're planning to invest thousands of dollars in a system that you expect to perform under certain conditions. Don't learn the hard way, by investing in a machine that is inappropriate for your needs. Learn all you can *before* investing.

While researching the various designs, also investigate different manufacturers and their products. General questions that should be asked of all manufacturers include:

How long has the company been in business? While new, promising technologies and companies should not be overlooked, their lack of experience should be weighed against companies with successful track records.

What is the machine's warranty? Obviously, a company that stands behind their machine for five years is preferable to a company with a one year guarantee. Two year warranties should be considered a minimum. Also, is the company bonded?

What is the machine's recorded down time? Some machines have been known to be down as much as 70 percent of the time.

Is there an owner's manual or troubleshooting guide and/or is there someone nearby who is authorized to maintain the machines? If not, be prepared to live with downtime unless you're a good mechanic. If you're not mechanically inclined, another important question is whether or not service contracts are available.

Are spare parts readily available? Waiting for spare parts can limit a machine's output and it's cost-effectiveness.

What are the machine's design specifications? Knowing the wind machine's power output, survival wind speed, type of control system, performance data, interface requirements, and auxiliary electrical equipment requirements will help you evaluate a potential machine.

What are the names and addresses of individuals in your area who own similar machines? As one grantee commented, nothing sells a wind machine better than someone who owns one, and is happy with it.

One final note: When, and if, you purchase a wind machine (or any other electricity-producing system) keep all your receipts and a record of maintenance and repairs. Maintaining thorough records will help if any problems should arise with the machine and, again like an automobile, they could be invaluable should you ever want to sell the system.

CASE STUDY

Richard Klinzman
West Palm Beach, FL
DOE Contract No.
DE-FG44-80R410319
ATMIS ID: FL-80-002

Richard Klinzman's double-rotor wind machine stands as a constant reminder that wind systems are possible in residential neighborhoods. The machine is quiet, hasn't, as some neighbors feared, interfered with television reception, and is providing the Klinzman household with most of its electricity except during the relatively windless months of June and July. But designing and installing the system was a time-consuming process. Like many grantees, Klinzman found it difficult to locate the information he needed because everyone from government officials to electricians lacked a working knowledge of wind-generated electrical systems.

The system.

Klinzman's system includes an eight-bladed, twin-rotor wind generator, mounted on a 3-inch steel pipe mast. The mast is implanted in the concrete garage floor and extends a total of 50 feet in the air. The mast is secured with a four-point guying system (Figure 2).

The grantee designed his wind system to allow for both utility interconnection and battery storage back-up. When the system is producing more than his household requires, excess electricity is sold to the utility. When the wind dies down and the system is no longer producing, Klinzman draws from the ten-battery storage system which is connected to a DC-to-AC inverter. Klinzman estimates that with conservative use, the batteries can provide five days of electricity.

Problems encountered.

When Klinzman designed his wind system he planned for all contingencies except one: time to comply with all regulations. From the initial designing of the system to the final interconnection with the utility it took two years for the system to come on line.

The greatest delays came in complying with all the necessary permits required to operate a wind system. The grantee's first application for a building permit was rejected due to a local planning regulation prohibiting wind systems on all lands other than agricultural. This rule could be waived by applying for a "special exception" which required a new survey of his property, a list of all property owners within 300 feet, maps and drawings of the system, and four public town meetings. The additional cost of this procedure included a review and signature of his drawings by a professional engineer, a $120 fee for a new survey, and a $100 fee for an issuance of the special exception.

In addition to the special exception, a variance was required to allow the tower to exceed 35 feet in height. The variance required the same documentation as the special exception. The grantee also had to prove that the tower would withstand winds of 120 miles per hour and, if it did fall, that it would land on his property. To meet these requirements, the system was redesigned and additional drawings were presented for approval. Costs included a $50 fee for the variance, a $35 fee for the building permit, and a $60 fee for the engineering survey. The grantee could have avoided redesign costs had he fully explored the permit system before beginning.

Once the local permits were acquired, Klinzman began negotiations with the local utility. Again, the process was more time-consuming and costly than anticipated. Drawings had to be approved by an electrical engineer (a $250 fee), the

Klinzman's wind machine stands as a constant reminder that wind systems are possible in residential neighborhoods.

Photo by Todd Lantz McInturf

system had to be approved by the county and shown to meet code (electrical permit $20), and the grantee had to add $300,000 liability coverage to his homeowner's insurance. In addition, the utility company required the installation of a special meter and lock (at a cost of $100).

Because the grantee plans to sell electricity he is classified as a private utility by the Internal Revenue Service, and therefore any income from electricity sales must be declared. For that reason, Klinzman is lobbying the public service commission and his utility to accept a single metering system. A meter that runs backwards when Klinzman is feeding surplus electricity into the utility grid would serve a two-fold purpose: the grantee would no longer be considered a seller of electricity and the monthly charge for the utility to read his extra meter would be eliminated.

Grantee recommendations.

1. Use utility interconnection as your storage system. Unless a residence is located in an isolated area without utility service, Klinzman does not recommend battery storage. Interconnection saves the cost of the batteries and the bother of maintaining them.

2. Investigate metering options. If utility interconnection is being considered, first investigate all of the metering options available. Some are definitely more cost-effective than others.

3. Investigate equipment and equipment manufacturers. Although the grantee's machine is working well, the manufacturer has not responded to specific questions about the machine, therefore maintenance and repair service might be difficult to obtain. The grantee also had trouble with a DC-to AC inverter which reportedly blew out his television, TV cable converters, and microwave oven. These problems may have been avoided with more research into the equipment.

4. Be prepared for lengthy delays, both in the permitting process and in equipment delivery.

5. If possible, have the wind system professionally designed and installed. Information on various systems is often unavailable which means that the novice will have to spend considerable time in tracking down the necessary resources. "If you can afford it, it makes a lot more sense to have the system installed. It will save you a lot of frustration," according to Klinzman.

Klinzman's System

	Costs
Fees	
Special exception	$100
Variance	50
Building permit	35
Engineering survey	60
Engineering approval	250
Electrical permit	20
Survey	120
Subtotal	635
Wind Machine and Tower	
I-Beams	180
Reinforcing rod	79
Cable and parts	1,160
Zinc primer	51
Hardware	112
Pipe and couplings	190
Concrete and pumping service	452
Machining and welding	394
Wind speed indicators	378
Wire	69
Wood	46
Roof flashing around mast	18
Wire clamps and shackles	37
Wind generator	7,104
Labor and materials	1,270
Subtotal	11,540
Storage System	
10 batteries @ $220 each	2,200
Electrical equipment	500
Welding	48
Voltage sensor and relay	121
Synchronous inverter	4,411
Enclosure material	31
Shipping costs	227
Utility meters and lock	102
Switch materials	199
Sign and seal electrical drawings	250
Isolation transformer	755
Subtotal	8,844
Total	$21,019

> *"If you can afford it, it makes a lot more sense to have the system installed. It will save you a lot of frustration."*

FIGURE 2: Klinzman's System

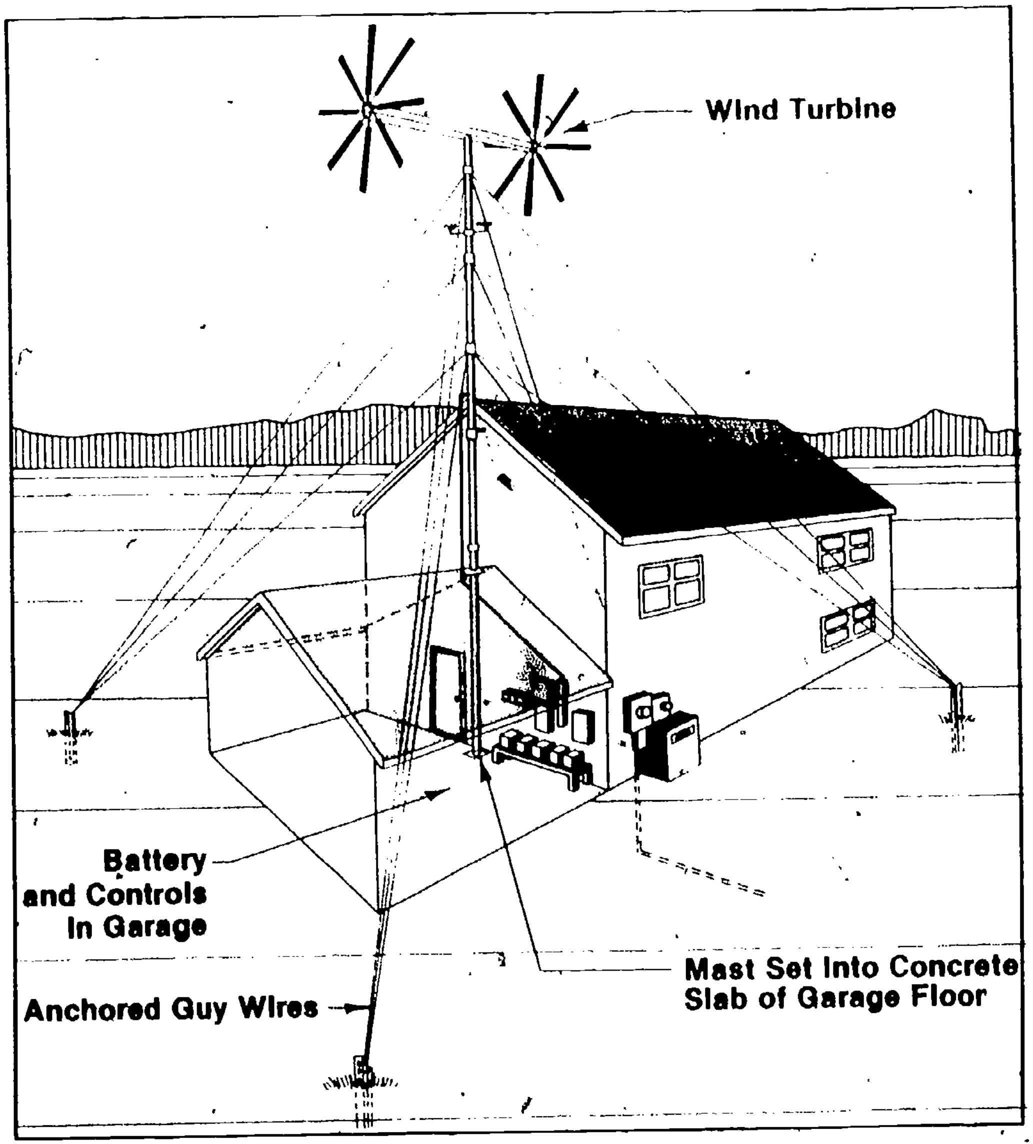


Photo by Todd Lantz McInturf

Klinzman's system includes a synchronous inverter for utility interconnection and a ten battery storage system for back-up power.

WIND PROJECTS

The following are selected grant projects from the DOE AT Small Grants Program relating to wind systems

Vic's Mobil-Arc, Inc — DOE Contract No. DE-FG48-80R801398
Lafayette, CO — ATMIS ID. CO-80-012

A utility-interconnected wind machine was designed and constructed by the grantee The grantee estimates that the wind machine provides at least one-half of his household's annual electrical needs and all of his electricity in the winter

Granby 4-H Club — DOE Contract No DE-FG41-80R110365
Granby, CT — ATMIS ID CT-80-007

The grantee installed a small wind generator as part of a demonstration project on renewable energy technologies In spite of a good location and a 100-foot tower, the grantee concluded that the wind potential at the site is not adequate.

David Racine — DOE Contract No. DE-FG43-79R306052
Rehoboth Beach, DE — ATMIS ID: DE-79-006

A small wind electric generator was installed at the grantee's home to provide radiant electric space heating The grantee reported problems with machine noise and machine maintenance He recommends passive and active solar heating as a cost-effective alternative

Evanston Environmental Association — DOE Contract No DE-FG02-79R510109
Evanston, IL — ATMIS ID. IL-79-010

A 4-kilowatt wind generator was installed to test wind machines in urban environments Power is sold directly to the local utility An educational program was also implemented.

Donald Fluhrer — DOE Contract No. DE-FG47-80R701107
Charles City, IA — ATMIS ID: IA-80-008

The grantee installed a 10-kilowatt, AC wind generator on a 100-foot, fold-down tower to circulate hot water to several farm buildings In 18 months the system generated 20,879 kilowatt-hours of electricity, of which 9,737 were fed to the utility.

Josyth Mills — DOE Contract No DE-FG43-81R308068
Jarrettsville, MD — ATMIS ID MD-81-007

A wind machine was installed to heat water in conjunction with a solar hot water heater. Excess power is fed to the local utility Several problems with the wind machine were encountered

Edward Johanson — DOE Contract No DE-FG41-80R110411
Andover, MA — ATMIS ID MA-80-017

A wind machine was installed on a 98-foot tower at the grantee's home. Despite the tower's height, the turbulence caused by nearby trees resulted in less than anticipated power production. The grantee recommends that an anemometer be installed at potential sites and at the proposed height of the wind machine for at least a year.

David Amon — DOE Contract No. DE-FG02-80R510226
Williamsburg, MI — ATMIS ID: MI-80-004

A 20-kilowatt wind turbine was installed at the grantee's cherry orchard The system is connected to the local utility and is currently being monitored for power production The grantee estimates production of 20,000 kilowatts a year.

Thomas Griffin — DOE Contract No. DE-FG02-79R510134
Cannon Falls, MN — ATMIS ID: MN-79-006

A 10-kilowatt wind generator was installed on a Minnesota farm Data was collected on system operation and power production

James Miller — DOE Contract No DE-FG47-80R701172
Kearney, NE — ATMIS ID: NE-80-008

A wind machine to provide radiant electric back-up heat and lighting was installed in a passive solar home. The grantee reported problems with utility interconnection agreements and concluded that unless a person can use all the power produced, when it's produced, a wind system is not economical.

This 4-kilowatt wind generator in Evanston, Illinois was installed to prove that wind machines can operate in urban environments.

WIND PROJECTS Continued

Monmouth Museum and Cultural Center
Lincroft, NJ
DOE Contract No DE FG42 79R205052
ATMIS ID NJ 79-023

A 20-kilowatt wind turbine was installed by the grantees Low tower height (40 feet), poor siting, and excessive downtime have contributed to the machine's low power production

Willard Rhoads
Rochester, NY
DOE Contract No DE FG42 79R205041
ATMIS ID NY 79-006

The grantee designed and constructed a 12 kilowatt wind machine which was installed at his home The project design includes a large battery bank for storage

R Elliott Whitesides
Lincoln, NC
DOE Contract No DE FG44 80R410212
ATMIS NC-80-001

A direct current wind generator was designed and installed to provide supplemental power to the grantee's home The system includes heavy-duty commercial batteries for storage

Raymond Miller
Cincinnati, OH
DOE Contract No DE FG02 79R510147
ATMIS ID OH-79 011

The grantee installed a 4-kilowatt wind machine on a 60-foot folding tower to supply power to a residence Excess power is fed to the local utility The wind machine has experienced considerable downtime

Gene Kohring
Hamilton, OH
DOE Contract No DE-FG02-80R510242
ATMIS ID OH-80 001

A utility interconnected, 1 8 kilowatt wind machine was installed at the grantee's farm The machine produced a net of 450 kilowatt hours over a 14-month period, with winds averaging 5 2 miles per hour The grantee stresses the importance of collecting sufficient wind data

Jerry Rosenthal
Louisa, VA
DOE Contract No DE-FG43-79R306104
ATMIS ID VA-79-003

A wind powered irrigation system was installed on the grantee's farm with excess energy sold to the local utility A zoning variance was required to construct the tower and the wind machine has been subject to vandalism.

White Mountain Cooperative
Wauconda, WA
DOE Contract No DE-FG51-79R000070
ATMIS ID WA-79-011

Ten horizontal axis wind machines were installed and tested at various sites in a small community Twelve-volt deep cycle batteries were used for electrical storage

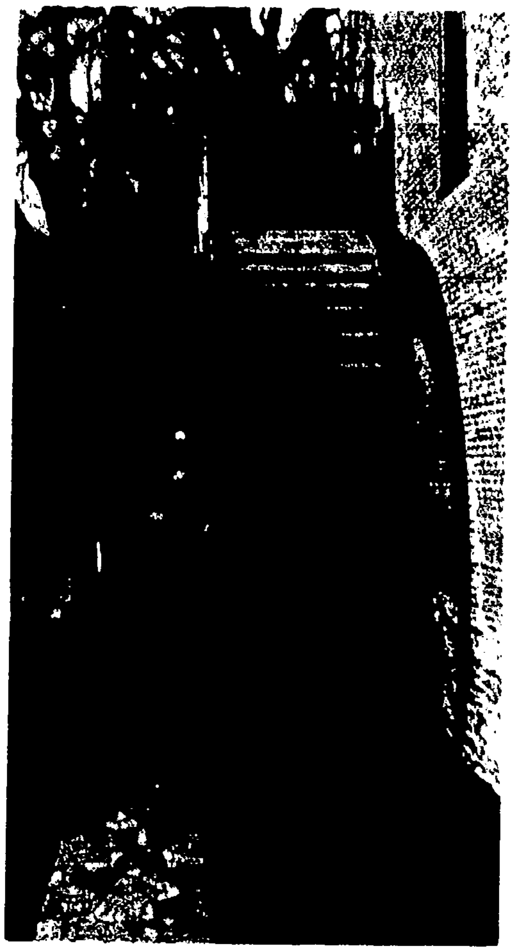
Carl Brown
Casper, WY
DOE Contract No DE-FG48-81R808004
ATMIS ID WY-80-008

The grantee installed a 1500 watt wind machine which is interconnected with the local utility In spite of wind speeds averaging over 13 miles per hour, the grantee doubts that his wind machine is economical

Roger Peterson and Josephine Porter
Cheyenne, WY
DOE Contract No DE-FG48 81R808001
ATMIS ID WY-80-002

A wind energy system was designed and installed for a passive solar house in an off-grid location Because of maintenance problems with the wind machine, the grantee plans to expand his system using photovoltaics

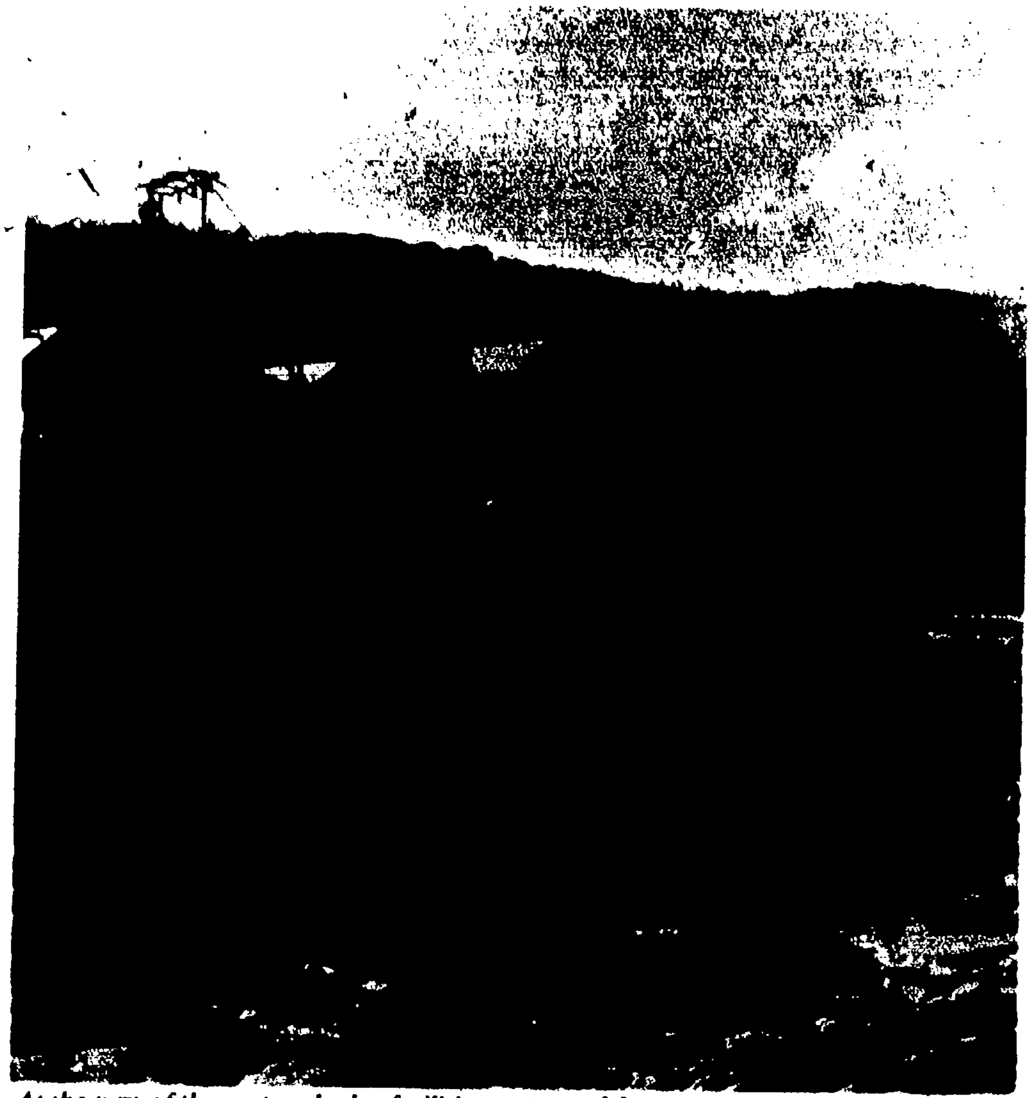
MICRO-HYDRO



Technology Review: Hydro

Flowing and falling water is one of the world's oldest and most common sources of energy. At the turn of the century hydro facilities accounted for more than half of all electricity being generated in the United States. Although this percentage has fallen off considerably, the interest in hydro potential is still very much alive.

This interest is particularly great in "micro" hydro systems that produce up to 100 kilowatts of electricity and especially those that use high-head, low-flow streams. For individuals who are fortunate to have streams flowing through their property, hydro systems can be an economical and efficient source of electricity, often providing all of the household's electrical needs. Micro-hydro systems can be designed to fit a wide variety of streams from a fast-moving creek to a lazy, meandering river and in many instances, stream disruption due to a micro-hydro installation is minimal. However, as more and more small hydro systems are constructed, fish and wildlife agencies are examining their potential cumulative impact on a stream's habitat.



At the turn of the century hydro facilities accounted for more than half of all electricity being generated in the United States.

Rules and Regulations for Micro-Hydro

Just because you live adjacent to a stream or river doesn't necessarily mean you have the right to dam it up, divert it, or even use the water in any form. For unlike the wind, which is relatively free for the taking, water is protected by many rules and regulations that either limit or prohibit its use. Obviously, it's important to know which regulations apply before investing in a micro-hydro system.

The Federal Energy Regulatory Commission (FERC) issues licenses for all non-federal hydroelectric projects regardless of size if: 1) they are on federal land; 2) they use water stored behind government dams; 3) they affect navigable waters; or 4) they affect interstate commerce (which would include any utility-interconnected system). This covers most potential sites. It normally takes 10 to 13 months to obtain a license from the FERC, despite a short application form available for projects under 5000 kilowatts. Add an additional year if an environmental impact statement is required.

Exemption from FERC licensing is available under certain conditions for systems under 100 kilowatts. For example, if your site is located on private land, uses an irrigation canal or a stream that is not considered navigable, and all power produced will be consumed on site, it may be possible to receive an exemption. For further information, study the FERC publication, *Application Procedures for Hydropower Licenses* (see Part III, *Resources* for full citation).

If your project includes a dam or requires any riverbed dredging, it may require a permit from the Army Corps of Engineers. Also, if any of the project crosses federal land, additional permits will be required.

Several different state and local agencies may also have jurisdiction over a micro-hydro project, ranging from environmental and fish and wildlife agencies, to state historical societies, to local building or zoning commissions. In Massachusetts, for example, a large number of agencies may have jurisdiction over micro-hydro projects including: the Massachusetts Environmental Protection Act Unit; local conservation commissions; the various divisions of the Department of Environmental Quality, including Wetlands, Waterways, and Water Pollution Control; the Department of Environmental Management; the Massachusetts Historical Commission (to protect historical and cultural resources); the Massachusetts Department of Fisheries, Wildlife and Recreational Vehicles; the Office of Coastal Zone Management;

and even the Department of Food and Agriculture.

Obviously, even a small hydro project can involve substantial, time consuming paper work, so it's best to start early and plan for potential delays. One grantee maintains that had he understood the complexities of the permitting system he "might not have undertaken the project at all." He recommends planning on at least two years to process the necessary permits, although he believes that "these processes can be streamlined as more experience is gained on the part of government agencies."

Evaluating the Micro-Hydro Resources

The power production capability of any hydro system relies on two essential variables: 1) *flow*, the volume of water available in the streambed (usually measured in cubic feet per second), and 2) *head*, the vertical distance the water drops (measured in feet).

Flow. Unless your potential site is on a stream or river where accurate flow records have been recorded by the U.S. Geological Survey (USGS) or a local agency, you should plan on spending a good deal of time measuring the stream's flow. Measuring flow once a week for an entire year is not unreasonable considering the size of the potential investment and the system's expected performance. During this time you need to assess the quality and quantity of the stream's flow, the duration of high and low water, and the stream's dependable average flow.

But even after a year, additional information will be needed. One grantee measured his stream's average flow at 6 to 8 cubic feet per second, constructed a system, and has since had two consecutive years with stream flows averaging 3 to 4 cubic feet per second. So once the measurements are taken it's important to find out whether you measured during a wet year or a dry one. To find out, contact the USGS or local monitoring agencies for long-term flow rates for a nearby stream or river and compare your figures with theirs. For example, if the nearby stream was 30 percent below average for the year you measured, chances are your stream was also approximately 30 percent below its long-term average. Using long-term data for a nearby stream will also enable you to identify high and low water trends which will give you some idea of what to expect in the long term.

If stream flow data is unavailable for nearby streams, talk to as many people as possible who are familiar with the stream to find out how high it has been over the years and, just as important, how low. The more you know about the long-term characteristics of the stream, the better equipped you will be to design an effective micro hydro system.

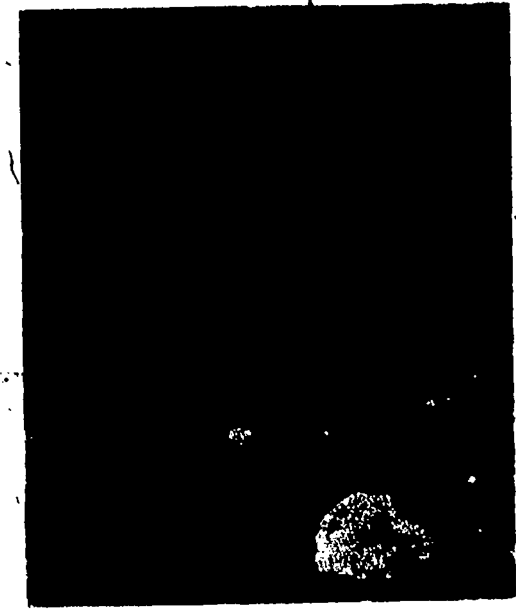
Head. You also need an accurate assessment of how far the water drops vertically between the source of collection and the turbine site. This can be done using topographical maps, photographic surveying techniques, or an altimeter but in most cases these tools will only provide you with a preliminary estimate. For an accurate assessment of the head, surveying equipment should be used. Unless you know how to use this equipment, it is a good idea to hire a surveyor.

Net head. Whenever pipe is used to transport water, some head losses occur. A common mistake is to either underestimate or ignore these losses, resulting in a hydro system that is improperly sized. Any reputable pipe manufacturer or supplier will be able to provide you with the pipe sizes and friction loss information for your particular flow conditions. Don't forget to account for these head losses (including losses from pipe bends and valves) when sizing your system.

Maintenance of a Micro-Hydro System

If the intake structure is properly designed, sediment settles out before entering the system. The trash rack is designed to screen out leaves, rocks, and other debris, reducing system maintenance to a minimum. Still, like any mechanical device, the turbine should be kept clean and the shafts and bearings lubricated according to the manufacturer's recommendations. The mechanical system should also be routinely checked for signs of unusual movement or wear.

Whenever pipe is used to transport water, some head losses occur. A common mistake is to either underestimate or ignore these losses, resulting in a hydro system that is improperly sized.



Weather and seasonal changes can also affect system maintenance. Routine seasonal tasks include cleaning debris from the trash rack during the spring runoff, clearing leaves from the rack in the fall, and clearing ice in the winter to prevent blockage of the intake.

Dams and Impoundments

Generally speaking, a micro-hydro project will be easier to construct and obtain permits for if stream disruption is kept to a minimum. Many successful small hydro systems avoid using dams, and instead take advantage of natural pools or backwaters for siting the intake structure. Others have maximized the usefulness of natural pools by adding a simple diversion.

But in some instances small dams will be necessary to maximize head or to provide storage. A word of warning, however. There is more to building a dam than piling up a wall of rock. One grantee, for example, chose a rock-crib dam because he assumed it would be inexpensive and easy to construct. As it turned out the process was extremely labor intensive and time consuming. In retrospect the grantee reported he would opt for a concrete dam, in spite of the extra cost.

> *"These processes can be streamlined as more experience is gained on the part of government agencies."*

Routine seasonal tasks include cleaning debris from the trash rack.

CASE STUDY

Mark Drabick
Orford, NH
DOE Contract No.
DE-FG41-80R110382
ATMIS ID: NH-80-008

Mark Drabick, owner of Homestead Energy Systems, Inc., has joined the growing number of individuals and small businesses that are successfully developing small hydro sites. With his background in small energy development, Drabick understood and followed all the proper steps, from accurately measuring his stream's head and flow to filing for the proper permits, but for various reasons he still experienced costly delays. Despite the setbacks, however, Drabick maintains that with proper planning and understanding of the resources at hand, a successful micro-hydro system can be installed with minimal problems, resulting in a system that will be almost maintenance free.

The system.

Drabick's system consists of a 4.75 inch Pelton wheel turbine, directly mounted to a 1500-watt induction generator. Both are housed in an 8- by 12-foot wooden shed. Water is fed into the system through a 4-inch diameter PVC pipe, or penstock, which is buried underground 2- to 3-feet. The water flows a distance of 1700 feet from a first intake, and a second intake was added 1700 feet from the first intake to test the difference in power production. Both intakes are covered with wire mesh to keep debris out of the system. When water reaches the turbine it flows into two 2-inch nozzle feed pipes from where it is directed to the ½-inch nozzles. Depending on the brook's rate of flow, the water can be directed to either one nozzle only or it can be split and directed to two nozzles, almost doubling the system's production (Figure 3).

Problems encountered.

Drabick ordered his penstock in October, 1980. Expecting delivery in early November, he began excavating the trench. Within four days of completing the excavation, the penstock materials arrived, but without the needed elbows to make the connections. While waiting for the connectors, Drabick began to work on the turbine house which was completed December 1. On December 2, the penstock elbows finally arrived, but they were too late; the trench was snowed in. At this point all he could do was wait for spring.

Unfortunately, when spring arrived, the trench was destroyed. "What was once a smooth, loam-filled trench was now a washed-out, rock-filled chasm," Drabick reported.

Lining the trench with hay to protect the pipe and removing the large rocks and boulders by hand took several months. Laying the pipe took additional time as erosion ate away at the pipe bedding.

With so many hours already invested, Drabick hired a bulldozer to do the backfilling. It started at the turbine house and worked its way up the hill. Halfway up it got bogged down in swampy ground, tried to free itself, and crushed several pieces of the pipe. In the meantime, winter had once again settled in so repairs were delayed.

In the spring, a 15-foot path was clearcut around the swampy section of land to permit access to the site for the bulldozer. Although the bulldozer still had trouble, the new trail and an unusually dry spring made the job easier. The excavation work was finally completed, two years after the project had begun.

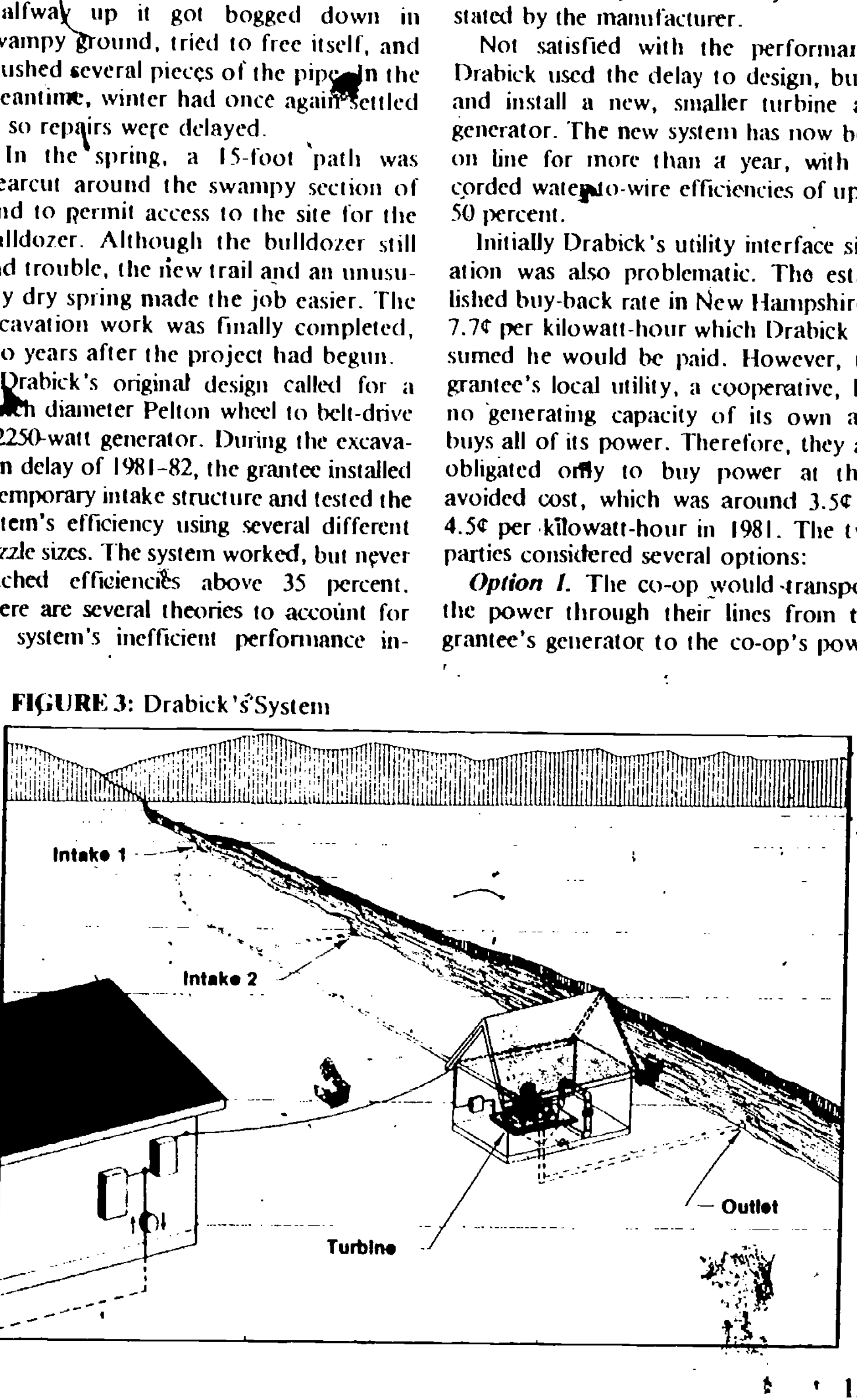
Drabick's original design called for a 9-inch diameter Pelton wheel to belt-drive a 2250-watt generator. During the excavation delay of 1981-82, the grantee installed a temporary intake structure and tested the system's efficiency using several different nozzle sizes. The system worked, but never reached efficiencies above 35 percent. There are several theories to account for the system's inefficient performance including: the generator and/or the turbine were too large for the available stream flow; the nozzles were improperly designed; or the system efficiency was overstated by the manufacturer.

Not satisfied with the performance, Drabick used the delay to design, build, and install a new, smaller turbine and generator. The new system has now been on line for more than a year, with recorded water-to-wire efficiencies of up to 50 percent.

Initially Drabick's utility interface situation was also problematic. The established buy-back rate in New Hampshire is 7.7¢ per kilowatt-hour which Drabick assumed he would be paid. However, the grantee's local utility, a cooperative, has no generating capacity of its own and buys all of its power. Therefore, they are obligated only to buy power at their avoided cost, which was around 3.5¢ to 4.5¢ per kilowatt-hour in 1981. The two parties considered several options:

Option 1. The co-op would transport the power through their lines from the grantee's generator to the co-op's power

FIGURE 3: Drabick's System



supplier. The co-op would not charge for this service, and the second utility would buy Drabick's power at 7.7¢ per kilowatt-hour. However, this arrangement required an expensive magnetic tape metering system.

Option 2. The co-op would buy all the power for 4¢ a kilowatt-hour.

Option 3. The co-op would allow "net energy billing," which means that the grantee's meter runs forward when he's using the co-op's electricity and backwards when he's feeding excess electricity to the co-op. With this arrangement, the co-op does not pay for any surplus electricity it receives. The co-op and Drabick settled on this option.

Grantee Recommendations

The grantee sums up his experiences this way, "After two years of hard work, Homestead Energy Systems, Inc. finally has an operating micro-hydroelectric plant that it is pleased with. However, getting there wasn't easy." From his experience, Drabick makes the following recommendations:

1. Before investing in any hydro project, individuals should thoroughly investigate site hydrology, topography and accessibility, soil composition, boundary lines, water rights, permits required, local weather problems, financing, and availability of equipment.

> *"After two years of hard work, Homestead Energy Systems, Inc. finally has an operating micro-hydroelectric plant that it is pleased with. However, getting there wasn't easy."*

2. Read everything you can find on the subject and talk to someone who has done it to see what's involved. There's nothing like experience to help you avoid costly mistakes.

3. Always place your intake structure and turbine house to maximize head. As the grantee explains, "Every inch counts. We gave up 30 feet to make our turbine house more accessible. Now we wish we had developed that extra 30 feet."

4. Make maximum use of your resources. Drabick designed his system to run year round and provide base load power. But, as he points out, $15,000 is a large investment for base load power. For $20,000, he could have had a system capable of producing five times as much electricity, even though it would not be operable during the summer.

5. Size your penstock accurately. Friction loss through the pipe can be devastating to any hydro project. Drabick estimates his system loses only 2 to 9 feet of head depending on flow. On low-head systems a loss of even a few inches will result in a loss of power.

6. And finally, remember these systems can be expensive. But, according to Drabick, if you do your homework, and do it right, you will be rewarded.

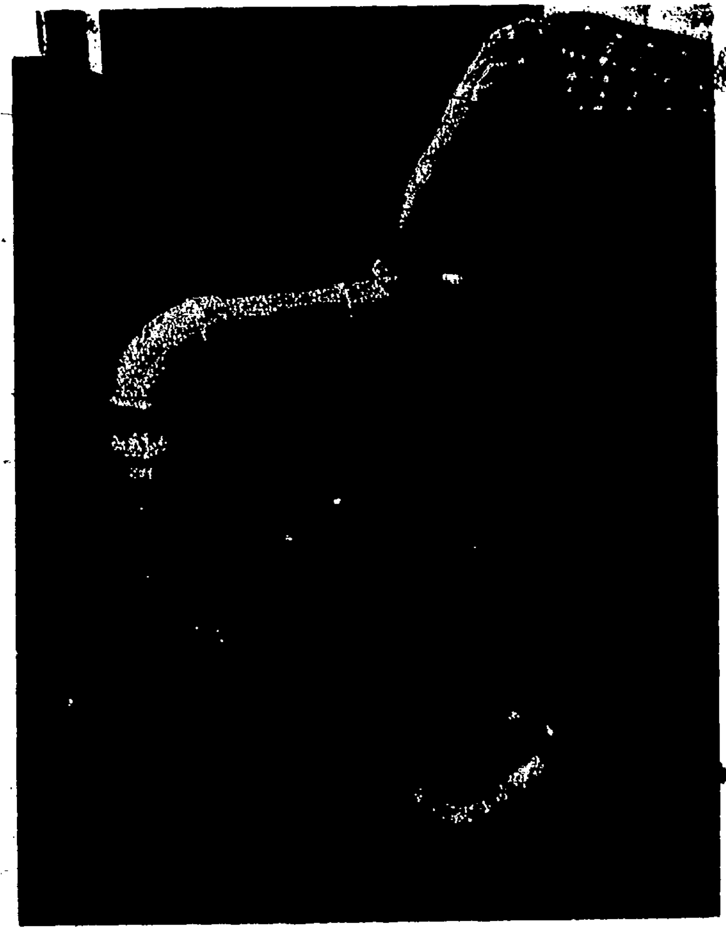
Drabick's System

	Costs
Penstock	$ 4,743
Excavation	4,500
Turbine	1,400
Turbine house	1,225
Generator	428
Controls	173
Wire	1,411
Miscellaneous	25
	Total $13,90[illegible]

> *"What was once a smooth, loam-filled trench was now a washed-out, rock-filled chasm."*

The grantee clears debris from the trash rack.

Drabick's system consists of a 4.75-inch Pelton wheel turbine, directly mounted to a 1500-watt induction generator.



HYDRO PROJECTS

The following are selected grant projects from the DOE AT Small Grants Program relating to micro-hydro systems

Bobby Kennedy DOE Contract No DE-FG44-81R410478
Guntersville, AL ATMIS ID AL 81 001

A Pelton type impulse turbine with a speed responsive governor was designed and constructed by the grantee A general booklet on micro hydro power was also produced

David Inouye DOE Contract No DE-FG48-79R800434
Crested Butte, CO ATMIS ID CO-79-005

A small-scale, hydroelectric power plant was constructed at the Rocky Mountain Biological Laboratory using equipment purchased from various manufacturers The plant uses a water source that also supplies domestic water supply for the laboratory to power a Pelton wheel turbine A maximum of 7.5 kilowatts can be generated, supplying electricity to the laboratory's dining hall for space heat, cooking, and hot water

Neil Seitz DOE Contract No DE-FG48-80R801005
Villa Grove, CO ATMIS ID CO 80 013

A 30 kilowatt Pelton turbine micro-hydro power system was installed on a stream near Villa Grove, CO The installed system cost was around $2 37 per peak watt Among the problems encountered during the project were pipe failure, a hertzmeter that failed immediately; and a loud Pelton wheel that was muffled by installing a piece of steel to soften the impact of the water

Verne Trostle DOE Contract No DE-FG03-78R901942
Molokai, HI ATMIS ID HI-78 012

The grantee installed a small hydroelectric system at his remote farm on the island of Molokai, HI Water from a spring-fed pond is channelled through 2,000 feet of 1½ inch PVC pipe Water passes through a 3/8 inch fire nozzle and drives a Pelton turbine which is coupled to an automobile generator Twelve volt DC current is used to power lights, a radio, and for battery storage A 1600-watt inverter is used when AC current is required

Lloyd Wallace DOE Contract No DE FG51-80R000452
Sandpoint, ID ATMIS ID ID-80-020

An off-grid hydroelectric system was constructed near Sandpoint, ID The 17-inch diameter Pelton wheel turbine coupled to an alternator produces 3 kilowatts continuously with a net head of 125 feet The Pelton wheel was purchased as a kit and the housing was fabricated on site The 2-inch feed line to the turbine reportedly is too small and the grantee plans to replace it with a 4-inch feed line

Suzanne and Robert Kelly DOE Contract No DE-FG41-80R110350
Enfield, ME ATMIS ID ME-80-009

A 75-foot long, 8-foot high, rock-crib timber dam was constructed to store water for a low-head hydroelectric system The water flows 380 feet through a 15-inch diameter culvert to a home-built crossflow turbine An automobile cruise control was modified to control the speed of the turbine under varying load conditions.

David Brown DOE Contract No. DE-FG41-79R110047
Shutesbury, MA ATMIS ID MA-79-006

A 4-kilowatt, double-impeller, crossflow turbine and generator set was installed at an existing dam site on the grantee's farm The system was estimated to produce approximately 15,300 kilowatt-hours per year with a payback of 7½ years

Appalachian Mountain Club DOE Contract No DE-FG41-80R110423
ATMIS ID: NH-80-004
Gorham, NH

A 1500-watt AC induction generator coupled to a Pelton impulse-type turbine uses a head of 202 feet to produce electricity for a mountain hut near Twin Mountain, NH The electricity powers lights, a refrigerator, battery chargers for two-way radios, a food warmer, a beverage water heater, the main water heater, and tempering tanks Propane consumption has been reduced by 70 percent One of the system's interesting features was the use of internal baffles to prevent foreign material from causing premature wear on turbine cups

H G Ayers DOE Contract No DE FG44 80R410214
Boone, NC ATMIS ID NC 80 011

A 17 kilowatt micro hydro plant was installed on Laurel Creek A 15 inch Pelton wheel turns a 30-horsepower induction motor generator to produce 60 cycle, 220 volt power which is fed to the local utility The grantee also monitored 20 streams in Watauga County for a year to determine annual usable stream flow

Bernard Bradach DOE Contract No DE FG44 80R410118
Marshall, NC ATMIS ID NC-79 001

The grantee designed and constructed a low-head hydro system with the help of students The system uses a crossflow turbine with power production of approximately 560 watts at 20 amps The system was designed to feed excess power to the local utility, however, the grantee recommends using batteries to have back up power should the system go down

Thomas Roy DOE Contract No DE-FG51-80R000540
Philomath, OR ATMIS ID OR-80-026

The grantee designed and constructed a hydro system on a high-flow, low-head stream in western Oregon Due to state restrictions that required a concrete sill and wooden flashboard arrangement, an undershot wheel was chosen for its higher efficiency in high winter tailwater The head was 3½ feet Due to heavy winter flooding, problems were encountered with the dam, flashboards, and wheel race arrangements

Loring Woodman DOE Contract No DE-FG48-79R800482
Jackson, WY ATMIS ID WY-79-004

The grantee installed an 11-kilowatt Pelton wheel micro hydroelectric generation plant in a gravity-fed irrigation system in rural northwest Wyoming The grantee reported the importance of understanding water rights, environmental impact, and the large amount of paperwork required to get a system approved by the proper authorities

A grantee in Maine chose a rock crib dam because it was made of local rock and wood and because the grantee thought it would be inexpensive and easy to build. It wasn't easy. The grantee and about 40 friends had to cut and peel 200 logs, build the 8×8×8-foot cribs, and fill them—by hand—with about 4,000 cubic feet of stone.

PHOTOVOLTAICS

Photovoltaics are a product of the space age. Used to provide electricity for space craft and communication satellites, the technology has now firmly landed on the earth. Photovoltaics are clean, reliable, and don't pollute while being used. In addition, they are modular, so the system can be added to as the need arises and the budget allows. And, because photovoltaics have no moving parts, they are virtually maintenance free. But probably the most amazing thing about photovoltaics is what they do: they convert sunlight into electricity.

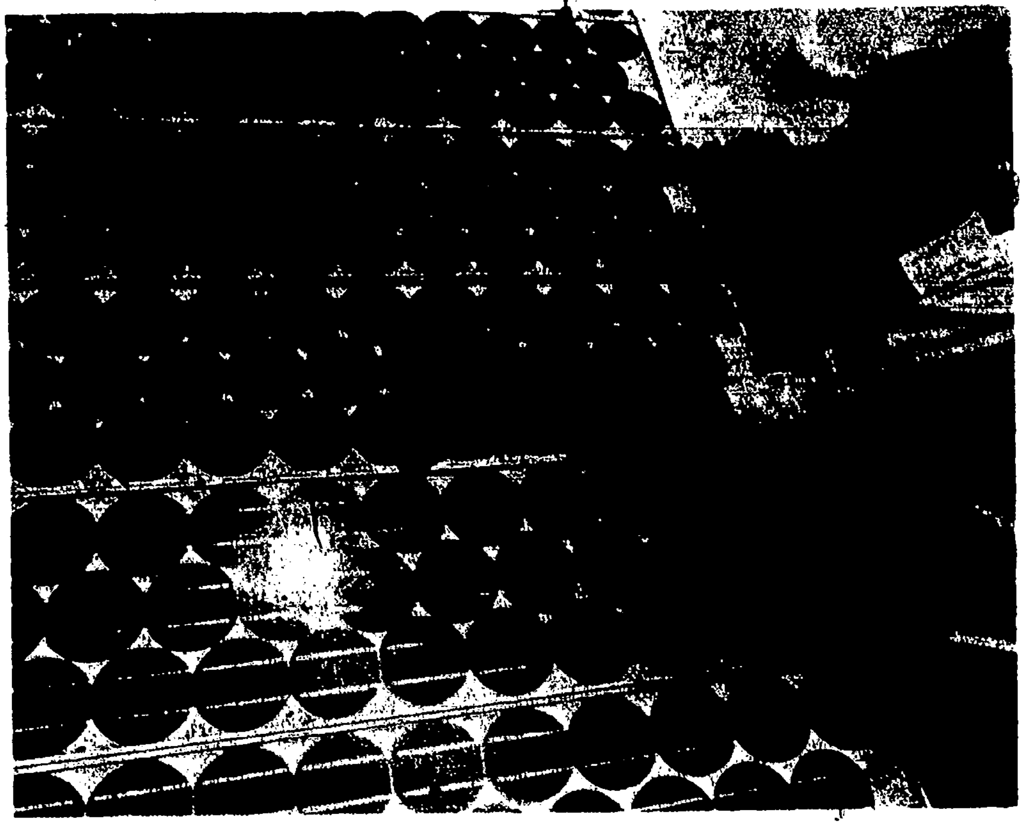
In fact, the only real deterrent to the technology is its cost. Currently photovoltaics are expensive, ranging from $10 to $15 per peak watt. And yet one grantee reported that, dollar for dollar, his photovoltaic panels produced more electricity than his wind system. And many predict that photovoltaics will soon be fully economical for the average homeowner, on- or off-grid.

Even as the price of photovoltaics comes down, however, they will still have certain limitations. For example, they only make electricity when the sun shines, so at night when you need electricity the most, the system is not producing. In addition, they only produce DC electricity which requires either converting to DC appliances (which many "PV" households have done) or purchasing an inverter to convert to AC. Even with these limitations, however, the technology has been used by grantees in applications as diverse as powering an emergency radio station to electric lights and a TV in a remote-site home.

Rules and Regulations for Photovoltaics

Like any electricity producer, a photovoltaic system will need to conform to state and local electrical codes and, if mounted on the roof, they will also have to pass building codes. Planning and zoning boards may also have to approve any photovoltaic system.

While checking with the planning board it's a good idea to find out if any multi-storied buildings are allowed in your neighborhood which might block your access to sunlight. It's also helpful to know if there are any rules or regulations restricting vegetation. Trees can quickly grow into as formidable a block to the sun as any multi-storied building. Some states have "sun rights" or solar easements available. If you're planning to install photovoltaics in an urban or suburban area, be sure to investigate your sun rights before investing in PVs.



Technology Review: Photovoltaics

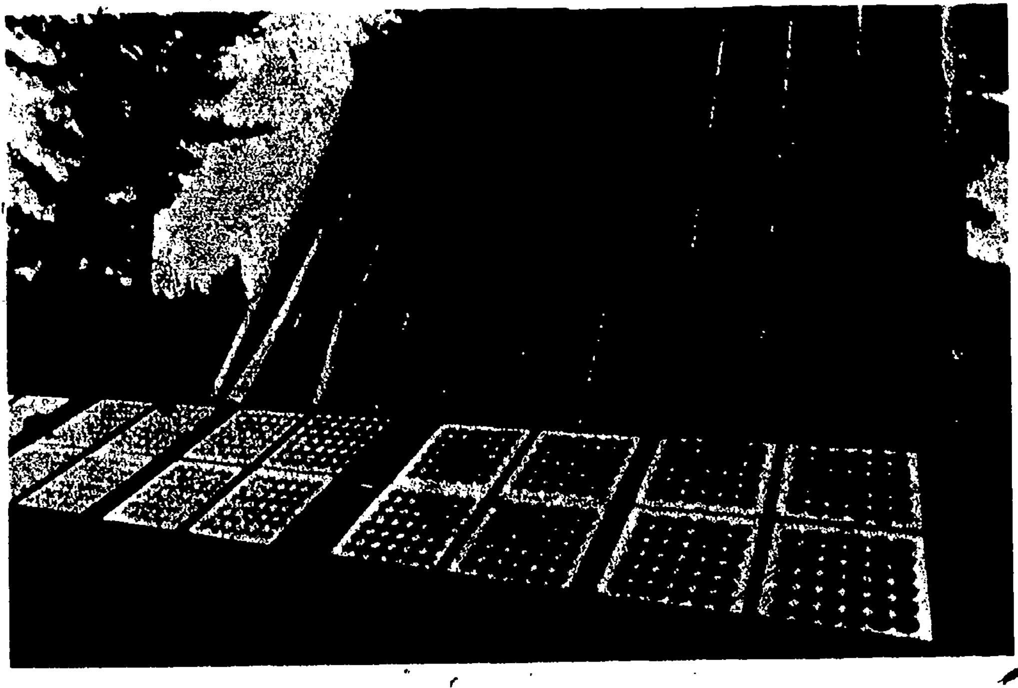
Evaluating the Solar Resources

Photovoltaics will make electricity anywhere the sun shines, so generally any shade-free site will work. And this is one technology where the resource information may already be gathered for you. Unlike wind or hydro resources, solar radiation data which can be applied to your site is available in basic solar energy textbooks, through the National Weather Service, or through your state energy office. As one solar consultant commented, "There's plenty of accurate solar radiation data available. The hard part is to find it."

Maintenance of a Photovoltaic System

Because photovoltaic modules have no moving parts, they are virtually maintenance free. Panels must be kept clean, but in most instances an occasional rain is enough to do the job. One grantee reported having to clear snow from his panels, but at many unattended sites the panels are known to shed themselves of snow once the sun shines. Routine maintenance should include a yearly check of the entire system, particularly the wires and connections, and, if they are used, a routine check of the batteries.

Photovoltaics are used to power the circulation system in this off-grid solar wood dryer.



Support Structures

There are many ways to install photovoltaic panels: mounting them on the ground, elevating them on pole supports, installing them on the side or top of a building, or using them in place of conventional roofing material.

Like wind towers, photovoltaic support structures must be designed to survive the most severe winds in your area. One grantee designed a support structure with quick-release clamps so that the module could be easily adjusted for maximum solar gain. Unfortunately, the first day the panel was installed it was lifted off the roof by gusting winds.

The support structures should also be designed to last the life of the system. For example, one grantee designed an adjustable support system based on greenhouse framing. Made of redwood, the frame is mounted on 2-inch metal pipes with clamps which enables the system to tilt up and down to gather optimum seasonal sunlight. But because it's wood, the grantee estimates that the frame may have to be replaced in approximately ten years, depending on weather conditions. In addition, should more modules be added, a new frame will be required. For that reason, he recommends buying from a manufacturer who also supplies compatible metal support structures.

Both these grantees found that adjustable support structures help maximize the system energy production. Although sophisticated tracking devices may not be cost-effective for the average homeowner, the ability to manually adjust the angle of the modules of a small array to maximize its exposure to the sun could improve your system's yearly output by as much as 40 percent.

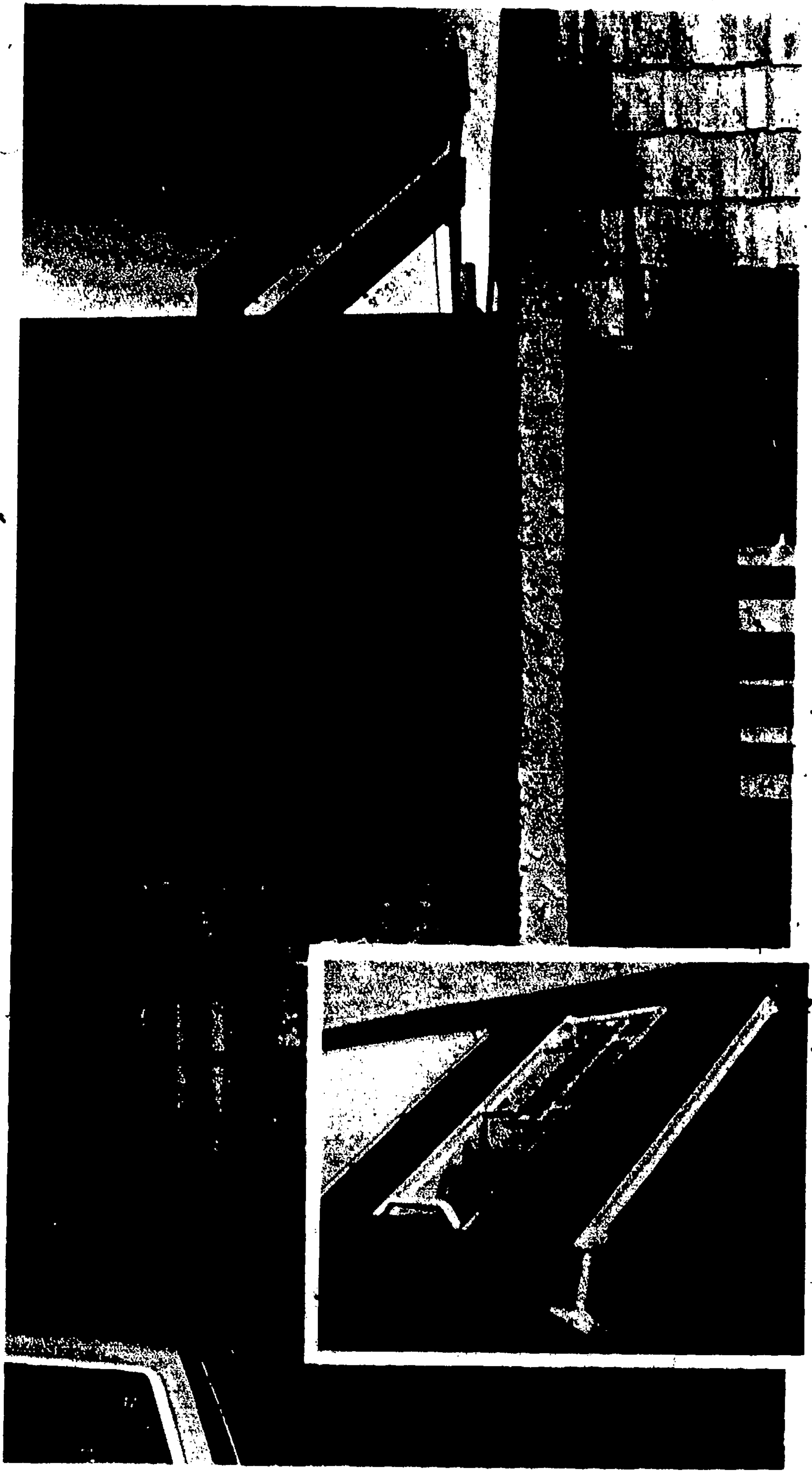
Shopping for Photovoltaics

With knowledge of your load and site characteristics, you shouldn't have any problem choosing an appropriate photovoltaic system. One grantee simply wrote to every manufacturer he could find, requesting information on panels that would meet his particular needs. With prices and specifications in front of him, he was able to make his choice.

Several grantees commented on the importance of buying from a company with a good reputation, and one that will stand behind its product. A "good deal" in the short term may not be a good investment in the long run. Also, be sure to check panels for good water sealing and for the availability of warranties and users' guides before purchasing.

"There's plenty of accurate solar radiation data available. The hard part is to find it."

Power from the photovoltaic panel (between the collectors) is used to pump water in the grantee's solar hot water system. Many predict that this will be the first real cost-effective application of photovoltaics in on-grid homes.



CASE STUDY

Dennis Feller
Fredricksburg, TX

DOE Contract No.
DE-FG46-79R610967
ATMIS ID: TX-79-013

Although many Americans are beginning to use photovoltaics to provide electricity for their homes, the most cost-effective use of this technology is still in remote applications. A good example is the PV-powered water pump which provides water for Werner Feller's livestock.

Like many farmers and ranchers, Feller had relied on the wind to pump water, but during the summer months, when livestock need the water the most, there is little or no wind. Many farmers and ranchers have installed electric pumps for use during the summer, but extending power lines can be expensive. Feller and his son Dennis, who designed the system, estimated that to extend power lines to the well would cost $15,840 ($1 per foot for 3 miles). The cost to install a photovoltaic system was estimated at $12,094. As it turned out, the photovoltaic system (including the fence and control shed) eventually cost almost $15,000, but now the Fellers have a practically maintenance-free system, which uses the sun to provide electricity.

The system.

Feller's system consists of 24 modules, four batteries connected in parallel, and a ½-horsepower DC motor which drives the water pump. Water is pumped into a 3,300-gallon storage tank which feeds a water trough by gravity flow. In addition, there is a charge controller which disconnects the photovoltaic panels from the batteries when they are fully charged, and a blocking diode to prevent discharge of the four batteries at night (Figure 4).

Feller's well can only be pumped for 15 minutes at a time, and then needs to be shut off for approximately 30 minutes to allow the aquifer to replenish the well. To accomplish this, Feller installed a DC timer to control the pumping. It is estimated that the system can easily pump over 1,000 gallons a day.

Problems encountered.

The major problem the Fellers encountered was finding the equipment they needed. The original design included a DC-to-AC inverter to power an AC water pump. However, inverter manufacturers were very reluctant to honor their specifications and warranty if an AC motor was the only load. After encountering this problem with several manufacturers, the system was redesigned to use a DC motor which eliminated the need for the inverter.

Waiting for delivery of the DC motor did delay the project, however. Feller was able to locate several DC motors in catalogs, but the quickest delivery time he was able to secure was more than ten weeks.

Maintenance has been unnecessary except for one problem: spiders have made webs in the tank float switch. These have to be cleaned out occasionally and the switch has had to be replaced, but as Werner Feller points out, spiders would be a problem no matter what the source of electricity.

Grantee recommendations.

1. Don't oversize your system, since you can always add to it later. Because little information on sizing was available when the Fellers designed their system, they designed it on paper and hoped for the best. As it turned out, they are producing more electricity than they need. Feller reported that if he had it to do over again, he would probably install three or four less panels, and then, if the batteries weren't maintaining a full charge, he would add more panels.

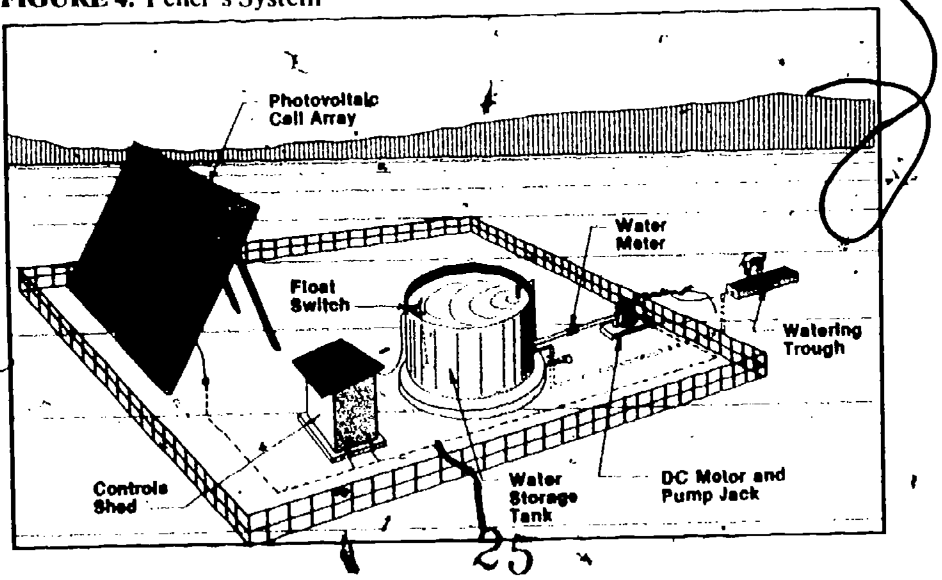
2. Use DC equipment whenever possible with PVs, and be prepared for delays in the shipping of any equipment.

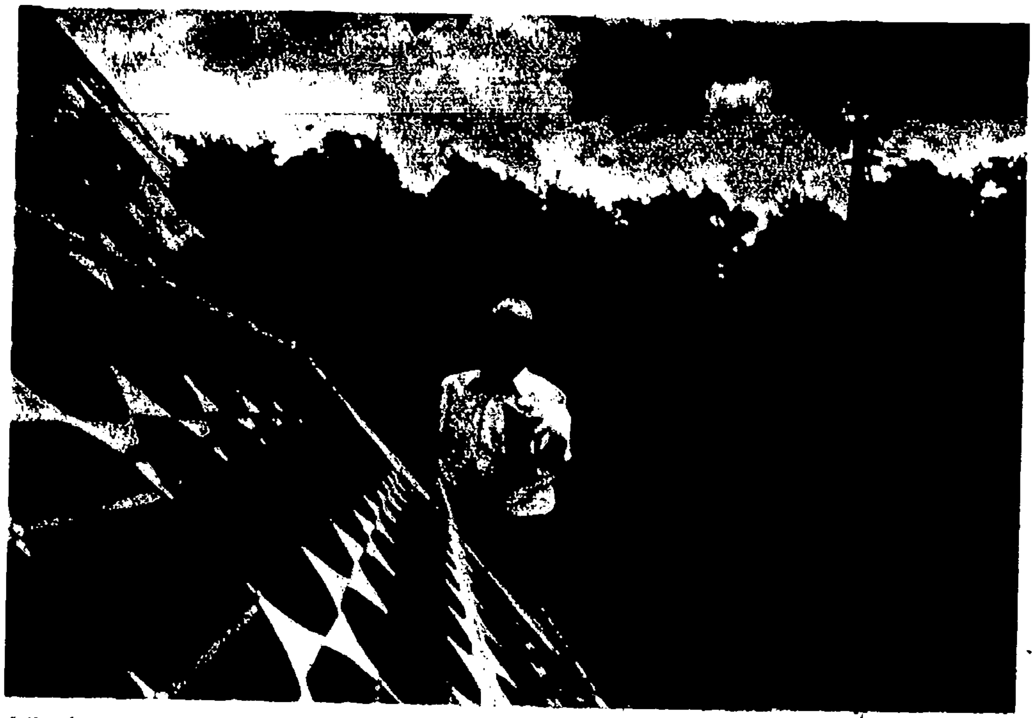
3. Cost has always been the biggest deterrent to photovoltaics, according to Werner Feller. But even though the initial costs can be high, once the system is installed it works unattended. And now that the price of photovoltaics is coming down, it's an even more attractive alternative for ranchers and farmers. "Livestock need that water," Feller concluded. "This kind of system assures that they'll have it."

Feller's System

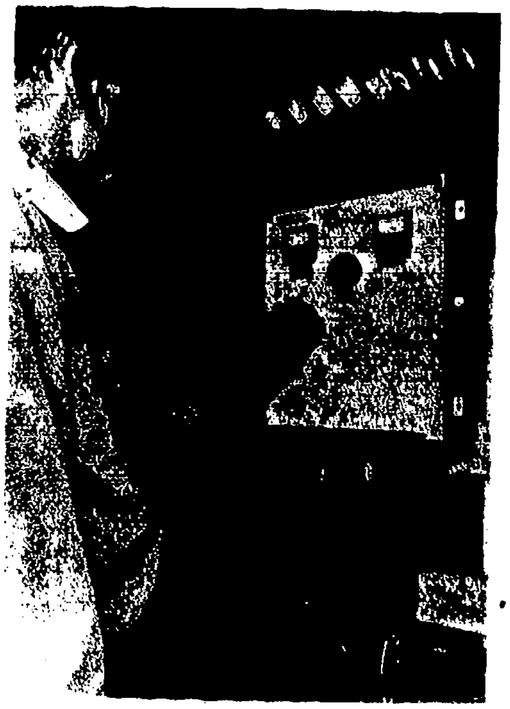
	Costs (Approximate)
Tools	$ 164
Control panel	425
DC pump	300
Fence	1,200
Control shed	300
Water meter	55
24 PV panels (600 watts)	9,586
Salaries	2,250
Subcontractor fee	114
Miscellaneous costs	540
	Total: $14,934

FIGURE 4: Feller's System





Like many ranchers, Feller has relied on the wind to pump water, but during the summer months, when livestock need the water the most, there is little or no wind.



Werner Feller checks the DC timer which controls the water pumping.

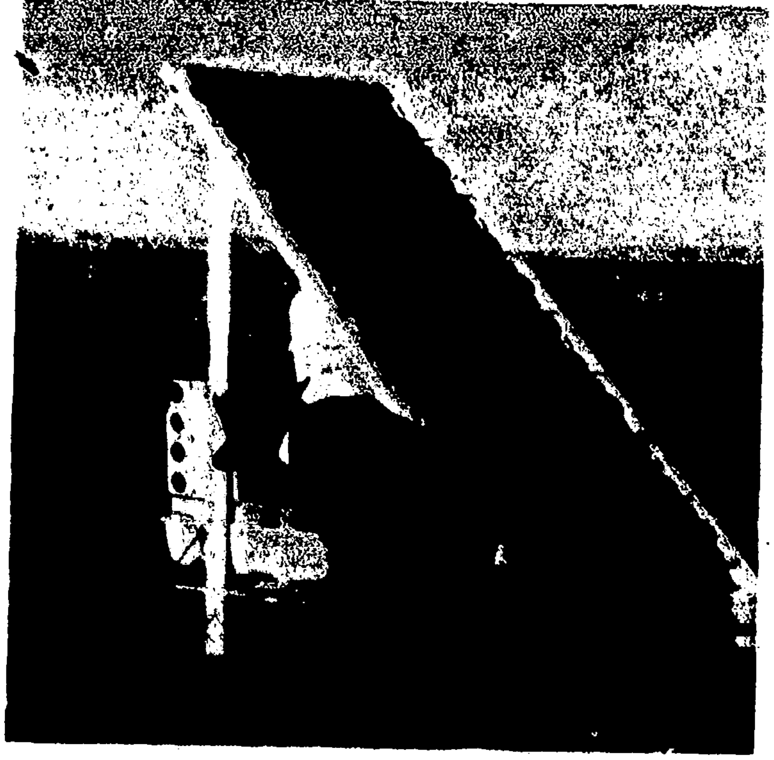
PV PROJECTS

The following are selected projects from the DOE AT Small Grants Program relating to photovoltaics.

James Schwarber
Fairbanks, AK
DOE Contract No. DE-FG51-81R001341
ATMIS ID: AK-81-012

The grantee added a 4-module photovoltaic array to an already existing wind system at his remote-site home. The grantee reports that photovoltaics are safe, reliable, and, unlike his wind system, can be left unattended. It also fully complements the wind system's output, according to the grantee.

This photovoltaic system on I-70 in Utah is used to power a flashing sign which warns truckers of a dangerous section of road. To have extended the power lines to the site would have cost the state of Utah $125,000; this system cost approximately $12,000.



Allen Kagel
Newark, DE
DOE Contract No. DE-FG43-80R302402
ATMIS ID: DE-80-006

A photovoltaic module was installed to circulate water in an active solar hot water system. The high-impedance pump had to be replaced with a new, low-impedance pump, and the module had to be replaced after being lifted off the grantee's roof in a strong wind. The system was reported as successful but not cost-effective.

This single panel, mounted above a storage area for batteries, provides enough electricity to power lights at Wichita State University's observatory.

Don Plank DOE Contract No DE-FG44-80R410165
St Petersburg, FL ATMIS ID: FL-79-015
The grantee installed a photovoltaic-powered display at the St Petersburg, FL main post office A window in the back of the display has volt and amp meters to monitor the system's output

Don Plank DOE Contract No DE-FG44-80R410318
St Petersburg, FL ATMIS ID. FL-80-004
The grantee equipped an electric Citi-Car with six photovoltaic panels The panels charge a 36-volt battery system which can power the car at 24 to 28 mph for 10 miles on one day's solar charge

Henry Unruh DOE Contract No DE-FG47-80R701164
Wichita, KS ATMIS ID: KS-80-015
An adjustable photovoltaic panel, with battery storage, was installed to provide electricity at Wichita State University's observatory. The panel is covered with plexiglass to protect it from hail and vandalism.

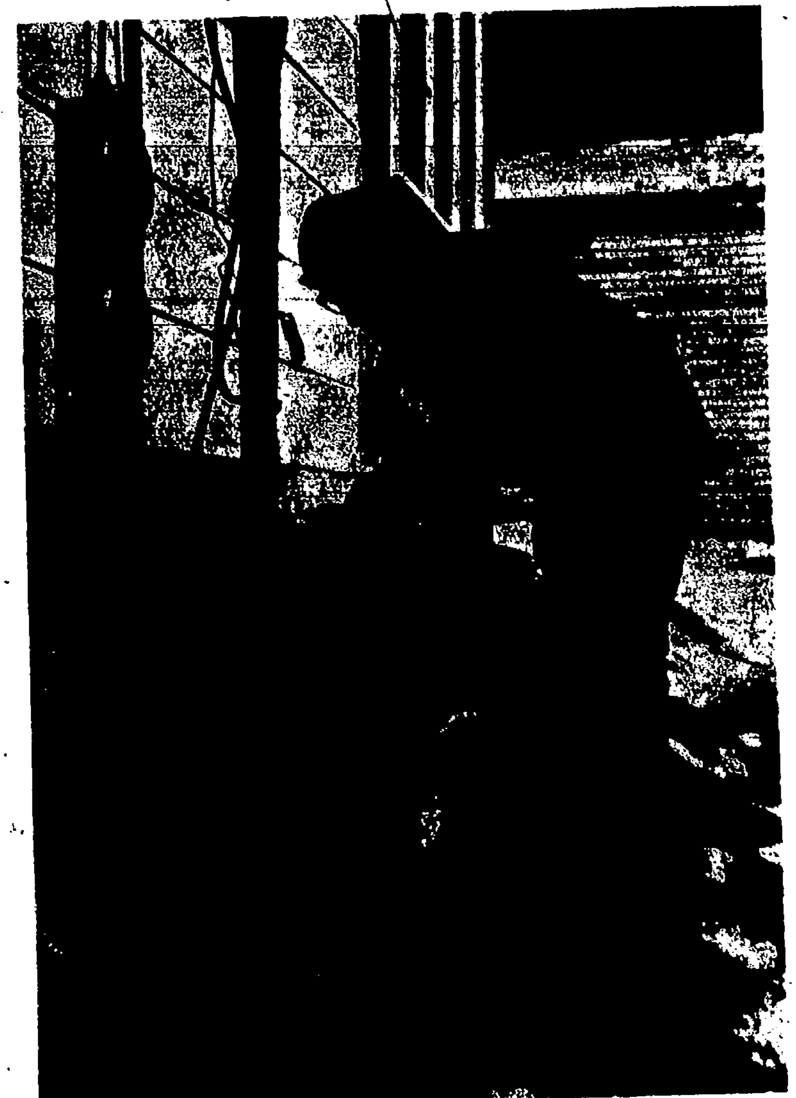
Brian Kent DOE Contract No. DE-FG41-80R110359
Litchfield, ME ATMIS ID: ME-80-005
The grantee installed two photovoltaic panels to an already existing wind system at his remote-site home. The system provides electricity to power lights and a television.

Michael Drooker DOE Contract No. DE-FG41-80R110380
Sandborneville, NH ATMIS ID: NH-80-005
A photovoltaic panel was installed at the grantee's home to provide back-up for an emergency radio station. The system includes two 6-volt deep cycle batteries for storage.

Albert Bates DOE Contract No. DE-FG44-81R410435
Summertown, TN ATMIS ID: TN-81-009
The grantee developed two portable photovoltaic systems for demonstration at the 1982 World's Fair. One system uses reflectors and is mounted on a folding tripod. The other system is mounted on a photovoltaic-powered golf cart.

Utah Department of DOE Contract No. DE-FG48-81R807001
Salt Lake City, UT ATMIS ID: UT-80-001
A photovoltaic-powered flashing sign was installed on Interstate 70 to warn trucks of dangerous road conditions. The system includes 8 modules and two batteries for storage.

Jeff Gold and Bruce Boyd DOE Contract No. DE-FG03-80R950025
Nevada City, CA ATMIS ID: CA-80-004
Photovoltaics were used to provide the electricity necessary to power a D.C. motor which circulates air through an off-grid solar wood dryer



A routine check of the batteries is all that is required to maintain this photovoltaic system in Sandborneville, New Hampshire.

27

PART III: RESOURCES.

WHERE TO GO FOR MORE INFORMATION

In working through the 10 steps described in Chapter 1, it is easier if you have help. Several sources may be able to provide assistance.

State energy offices, energy extension services, and/or county extension services should be the first stop for anyone considering an energy-producing technology. They often have up-to-date information on conservation and energy production techniques, names and addresses of individuals who have electricity-producing systems, rules and regulations in effect in your particular state, the names and addresses of local contacts for federal agencies, and renewable energy resource data for the state (and in some instances guidelines for measuring them and/or equipment-lending programs). And, in many instances, these offices have useful handouts to educate individuals considering specific technologies.

Libraries.

Most libraries have developed and maintained collections on energy conservation and alternative energy. If you are considering an electricity-producing technology, a good place to start your research is at the local library.

Local utility companies.

Local utility companies often have information on conservation techniques (including energy-efficient appliances), records of your electricity consumption or information on how to determine it, and guidelines for interconnection.

Additional sources of information and assistance

These organizations, associations and agencies can often help you locate resource information, provide you with information about manufacturers, and/or provide helpful information products.

American Solar Energy Society
(ASES)
1230 Grandview Ave.
Boulder, CO 80302

The purpose of this professional society for engineers, architects, builders, and others interested in the various forms of solar energy is to advance the use of solar energy. Membership, which is open to everyone, includes a subscription to the monthly magazine, *Solar Age*. The society holds annual technical meetings, sponsors the annual *Passive Solar Conference*, and publishes conference proceedings and numerous technical books and journals.

American Wind Energy
Association
1050 17th St. NW
Washington, DC 20009

This non-profit corporation was established to advance the art and science of using energy from the wind. Membership is open to anyone with an interest in wind energy. Members come from industry, government, academia, and the general public. The society publishes *Windletter* and the *Wind Technology Journal* and sponsors annual technical conferences.

Conservation and Renewable
Energy
Inquiry and Referral Service
(CAREIRS)
Suite 728
1001 Connecticut Ave., NW
Washington, DC 20036

This organization provides information on the full spectrum of renewable energy technologies and energy conservation. In addition, they maintain contact with a nationwide network of public and private organizations which specialize in highly technical or regionally specific information.

Federal Energy Regulatory
Commission
Division of Licensed Projects
825 N. Capitol Avenue NE
Washington, DC 20002

Formerly the Federal Power Commission, this agency within the U.S. Department of Energy is responsible for regulating the use of hydroelectric power. The agency provides detailed information required to apply for a hydropower license.

National Hydropower Association
2010 Massachusetts Ave., NW
Washington, DC 20036

This trade association, with membership open to the entire hydropower industry, serves its members by alerting them to significant developments in Congress, the FERC, and other administrative agencies. The association also works with regional and state hydropower associations to form a network that deals with both national and regional issues.

National Oceanic and
Atmospheric Administration
Environmental Data and
Information Service
Federal Building
Asheville, NC 28801

All national weather data, including wind speed and solar radiation information, is stored and distributed at this center. The center offers a large amount of data to the public at low cost. Your local U.S. Weather Service Office (usually at the local airport) can also provide local climatic information.

Rocky Flats Small Wind Systems
Test Center
Rockwell International Energy
Systems Group
P.O. Box 464
Golden, CO 80402

The objectives of the center, which has been administering projects involving wind machines of less than 100 kilowatts since 1976, are: 1) establish and maintain sources of small wind system technical data; 2) reduce development risks through the conduct of a development and evaluation program; 3) reduce the capital and life-cycle costs of wind systems; 4) help increase the reliability of small wind energy systems; 5) establish and operate a national small wind energy systems' testing facility; and 6) disseminate technical information generated by the program.

Solar Energy Industries
Association
1001 Connecticut Ave. NW
Suite 800
Washington, DC 20036

This association's role is to accelerate and foster the commercialization of solar energy conversion for economic purposes. Members include manufacturers and installers of solar energy systems and components, distributors, contractors, and engineers. The association publishes a biweekly newsletter and a monthly magazine as well as holding a semiannual conference and trade show. The association is also developing standards and certification procedures for testing solar collectors.

Solar Energy Research Institute
(SERI)
1536 Cole Blvd.
Golden, CO 80401

SERI was created by Congress to provide a national laboratory dedicated to serving the needs of the public and industry in the development of solar energy. SERI conducts and manages research, provides planning support to the Department of Energy, conducts market analyses and assessments of institutional barriers to the introduction of solar technologies, collects and distributes information about solar energy, and conducts education and training programs.

U.S. Geological Survey (USGS)
12201 Sunrise Valley Drive
Reston, VA 22001

The USGS performs surveys, investigations, and research covering topography, geology, and national mineral and water resources. It also classifies land as to mineral character and water and power resources. The agency maintains a network of stream-gauging stations and is the principal repository for measured stream flow data in the country.

Suggested Readings

Books — General

Other Homes and Garbage and *More Other Homes and Garbage*, Jim Leckie, et al., Sierra Club Books, San Francisco, CA, 1975, 1981.

These books provide a good introduction not only to electricity-producing technologies, but to the entire spectrum of available alternatives. You can't design and install a system with these books alone, but they will provide you with a good introduction to the alternatives available.

Energy Primer: Solar, Water, Wind, and Biofuels, Richard Merrill and Thomas Gage, eds., Dell Publishing Co., New York, 1978.

This book provides a comprehensive introduction to the various technologies that can be used to generate your own electricity. It is readable and easy to understand yet it provides enough detail for the beginner to gain an understanding of the technology. Lists of manufacturers, books and pamphlets, and other resources make this book particularly useful.

How to Design an Independent Power System, Terrance D. Paul, Best Energy Systems for Tomorrow, Inc., Necedah, WI, 1981.

This primer provides an excellent introduction to the AC/DC argument (AC wins). Also, it contains good, basic information on batteries, inverters, and how to determine your electrical load.

How to Be Your Own Power Company, Jim Cullen, Van Nostrand Reinhold Co., New York, 1980.

An excellent introduction to the DC side of the AC/DC argument, Cullen's book contains useful information on all aspects of DC systems, from tools you will need, to wiring your house, to living with a DC system. One grantee commented that he couldn't have installed his DC system without the guidance of this book.

Better Use of Your Electric Lights, Home Appliances, Shop Tools—Everything That Uses Electricity, Michael Hackleman, Peace Press, Culver City, CA, 1981.

This book provides useful information on DC appliances (including converting AC to DC) as well as using AC appliances more efficiently.

Books — Wind

Harnessing the Wind for Home Energy, Dermot McGuigan, Garden Way Publishing Co., Charlotte, VT, 1978.

A simple, yet technically sound, introduction to small-scale wind/electric generation is provided in this useful book. The section on planning energy needs is particularly useful to the novice and contains information on such topics as site selection, wind measurement, wind energy estimation and home wind equipment components.

Wind Power for the Homeowner, Donald Marier, Rodale Press, Emmaus, PA, 1981.

This guide to selecting, siting, and installing a wind system provides a good introduction to the technology. It contains valuable information on the rules and regulations that may be encountered, and the basics of wind system economics. The book also contains appendices with detailed information on different wind machines, their characteristics, and estimated power production.

Home Wind Power, U.S. Department of Energy, Garden Way Publishing Co., Charlotte, VT, 1981.

This thorough introduction to wind power includes good chapters on site selection, load estimation, possible legal hurdles, and information on wind system towers and how they can potentially fail.

Books — Micro-Hydro

Application Procedures for Hydropower Licenses, License Amendments, Exemptions, and Preliminary Permits, Federal Energy Regulatory Commission, Washington, DC, 1982.

Available from the FERC, this book is essential reading for any potential hydropower developer. It provides all the information necessary to apply for a license or an exemption. It is published in loose-leaf form in a three-ring binder and updates are routinely prepared and distributed.

Micro-Hydro Power: Reviewing an Old Concept, NCAT, Butte, MT, 1979.

This publication walks you through a "decision tree" supplemented with detailed guidelines to help you determine if micro-hydro power is suitable for you. It also contains detailed information on flow and head measurement, power calculation, and the types of turbines and water wheels available.

Harnessing Water Power for Home Energy, Dermot McGuigan, Garden Way Publishing Co., Charlotte, VT, 1978.

This is an excellent book describing all manner of material related to small- and micro-scale hydro systems. It gives a number of examples of installations of the various types of water wheels and turbines in the United Kingdom and the U.S. Manufacturers are listed with their products and outputs. Equipment costs are often included and it contains a good bibliography.

The Idaho Micro-Hydro Handbook, The Idaho Department of Water Resources, Boise, ID, 1983.

This publication contains information on site analysis methodology, flow and head measurement, equipment, economics, and regulatory requirements. It also contains brief forms and checklists to guide potential micro-hydro developers, and a list of micro-hydro equipment suppliers.

Microhydro Power Handbook, Vol. I and II, U.S. Department of Energy, Idaho Operations Office, Boise, ID, 1983.

This two-volume handbook should be required reading for anyone seriously considering a small micro-hydro installation. It contains chapters on design, equipment, safety requirements, construction, installation, economic considerations, and a thorough discussion of the legal, institutional, and environmental considerations. Supporting documentation and examples are also included.

Books — Photovoltaics

The Solar Electric Home: A Photovoltaic How-to Handbook, Joel Davidson and Richard J. Komp, AATEC Publications, Ann Arbor, MI, 1983.

This book covers the step-by-step procedures involved in sizing, installing, and maintaining a photovoltaic system, including information on inverters, batteries, and wiring. It also contains useful appendices, including a glossary and a description of electrical calculations used in sizing photovoltaic systems.

Solar Electricity: Making the Sun Work for You, Monegon, Ltd., Gaithersburg, MD, 1981.

This book is a good introduction to photovoltaics, including the technology's history, explanation of how the technology works, and its potential applications. Also, it includes useful information on solar law, tax credits and incentives, and an introduction that helps readers decide if photovoltaics are appropriate for them.

Periodicals

Alternative Sources of Energy, 107 S. Central Ave., Milaca, MN 56353.

Hydro Review, P.O. Box 344, Cambridge, MA 02238.

The PV News Network: Solar Electric Information for the Solar Electric User, 10615 Chandler Blvd., North Hollywood, CA 91601.

Renewable Energy News, P.O. Box 182, 1377 K St. NW, Washington, DC 20005

Solar Age, Harrisville, NH 03450.

Wind Power Digest, 398 E. Tiffin St., Bascom, OH 44809.

New Shelter, 33 East Minor Street, Emmaus, PA 18049.

GLOSSARY

Alternator—a device which supplies alternating current.

Anemometer—a device for measuring wind speed.

Crossflow turbine—a drum-shaped water turbine with blades fixed radially along the outer edge. The device is installed perpendicularly to the direction of stream flow.

DC to AC inverter—a device which converts electrical current form direct to alternating. Allows you to run AC appliances from DC battery bank.

FERC—The Federal Energy Regulatory Commission was established by Congress to regulate non-federal hydroelectric projects.

Flow—the quantity of water, usually measured in gallons or cubic feet, flowing past a point in a given time.

Generator—a device that converts mechanical energy into electrical energy—a large number of conductors mounted on an armature that rotates in a magnetic field.

Head—the vertical height in feet from the headwater (with a dam) or where the water enters the intake (no dam) to where the water leaves the turbine.

Induction generator—an alternating current generator whose construction is identical to that of an AC motor.

Intake structure—a structure that diverts the water into the penstock; a small dam.

Isolation transformer—a device used to isolate the utility grid system from an earth-grounded electric generating system.

Net energy billing—this refers to an electric metering system in which the meter turns backwards when electricity flows from the generating system to the utility lines and forward when the utility is supplying electricity to the residence.

Net head—the gross head minus losses due to pipe friction.

Pelton wheel—a water turbine in which the pressure of the water supply is converted to velocity by a few stationary nozzles, and the water jets then impinge on buckets mounted on the rim of the wheel.

Penstock—the pipe that carries pressurized water from the intake structure to the turbine.

Photovoltaic array—several photovoltaic modules connected together, usually mounted in a frame.

Photovoltaic module—several solar cells connected together on a flat surface.

PURPA—Public Utility Regulatory Act, a federal regulation requiring utilities to buy back power generated by small producers.

Solar easements—a written agreement with a person's neighbors that protects his/her access to the sun through the prohibition of any structures that might block their access.

Synchronous inverter—a device that links the output from a wind generator to the power line and the domestic circuit. The varying voltage and frequency generated by the windmill is instantly converted to exactly the same type of electricity distributed by a utility's power grid.

Trash rack—a grate that is placed in front of a penstock to stop debris (wood, leaves, etc.) from entering the penstock.

Turbine—a machine for generating rotary mechanical power from the energy in a stream of fluid (air or water).

Voltage sensor and relay—a device which senses the amount of voltage and controls its range; used to warn the operator if batteries are discharging too much.

Watt—measure of power used by an electric appliance. Amps × Volts = Watts.

Wheeling power—transporting power through lines from one producer to another.

LEARN FROM EXPERIENCE

From 1978 to 1982 the U.S. Department of Energy provided about 2,200 grants to a cross-section of Americans with good ideas for saving energy. Their projects reveal how a broad range of appropriate technologies actually work -- from the farm to the country's largest cities.

Their experiences have been examined and presented in a series of thirteen informative publications. Your State energy offices have a limited number of these publications available without charge. Additional copies are on sale at U.S. Government Printing Office Bookstores near you.

APPROPRIATE TECHNOLOGY AT WORK: Outstanding Projects Funded by the U.S. Department of Energy Appropriate Technology Small Grants Program (1978-1981).

Highlights twenty of the many success stories that are found in the DOE grants program

GPO 061-000-00608-7

WASTES TO RESOURCES: APPROPRIATE TECHNOLOGIES FOR SEWAGE TREATMENT AND CONVERSION

Presents background information on conventional and alternative sewage treatment in the United States and the key issues facing municipal sewage managers.

GPO 061-000-00611-7

DRYING WOOD WITH THE SUN: HOW TO BUILD A SOLAR-HEATED FIREWOOD DRYER

Shows the over 14 million firewood users in America how to build an efficient, low-cost firewood dryer and contains suggestions for more efficient burning of the dry wood

GPO 061-000-00613-3

MOISTURE AND HOME ENERGY CONSERVATION

Focuses on detecting moisture problems in the home and how to correct them and includes a training supplement on how to conduct a moisture audit in a home.

GPO 061-000-00615-0

PHOTOVOLTAICS IN THE PACIFIC ISLANDS: AN INTRODUCTION TO PV SYSTEMS

Helps teachers, adult educators, and community leaders in the Pacific Islands explain the basic parts of a PV system

GPO 061-000-00616-8

USING THE EARTH TO HEAT AND COOL HOMES

Provides a guide to using the earth as a readily available, low-cost resource for space heating and cooling with a focus on installation, economics, reliability and performance of systems utilizing low-grade geothermal energy and earth-tempered air systems.

GPO 061-000-00620-6

INTRODUCING SUPPLEMENTAL COMBUSTION AIR TO GAS-FIRED HOME APPLIANCES

Shows consumers and building trades people how to increase heating system efficiency by using outside or supplemental combustion air and also includes a set of basic how-to instructions to allow consumers to build necessary ducts and vents. Code and safety implications of these actions are thoroughly addressed.

GPO 061-000-00621-4

SOLAR GREENHOUSES AND SUNSPACES: LESSONS LEARNED

Focuses on the experiences of hundreds of DOE grantees who designed and built greenhouses, and examines individual greenhouse components, including framing, glazing, storage, ventilation and control mechanisms

GPO 061-000-00622-2

HEAT-RECOVERY VENTILATION FOR HOUSING: AIR-TO-AIR HEAT EXCHANGERS

Teaches owner-builders, building trades people, and designers how to size ventilation systems for energy efficient housing. Major emphasis is placed on the air-to-air heat exchanger

GPO 061-000-00631-1

MAJOR ENERGY CONSERVATION RETROFITS: A PLANNING GUIDE FOR NORTHERN CLIMATES*

Contains state-of-the-art strategies for the builder, architect, and skilled homeowner in deciding the most cost effective procedures for insulating roofs and walls. This decision-making manual allows users in northern climates to determine the most cost-effective means for increasing the thermal efficiency of their specific building envelope

HOME MADE ELECTRICITY: AN INTRODUCTION TO SMALL-SCALE WIND, HYDRO, AND PHOTOVOLTAICS

Introduces the use of wind, water, and the sun as electricity producers and, based on the experiences of grantees, helps the reader make a realistic appraisal of these systems.

GPO 061-000-00630-3

WINDOW INSULATION: HOW TO SORT THROUGH THE OPTIONS*

Focuses on the major decision and problem areas with the technology including choosing the right design for the window, how to choose a workable installation method, and how to size up your window-insulation needs given climate, cost, and home orientation.

AN INTRODUCTION TO BIOGAS PRODUCTION ON THE FARM*

Introduces farm-size biogas production and includes a brief discussion on how to evaluate the biogas production potential of a specific ranch or farm.

***(Will be available by March, 1984)**


Gardening for Food and Fun
Health Careers Guide
The Dye Is Now C
James Madison
MARINES