area of concentration for which they were hired.

Not everyone agrees that the universities should mobilize their resources to solve the energy crisis. "We don't want to jump on the bandwagon, but would rather make a distinctive contribution," says Harvey Brooks, dean of the engineering school at Harvard University. "This is a political and economic crisis, not a technological one."

But the public attention that has been paid to science and technology as a result of the energy crisis has already lifted the spirits of many U.S. scientists. The travails of too little energy make almost everyone aware of connections between research and public daily life. With multibillion dollar projects, the Administration and the Congress seem to be saying that technology is the answer to the energy crisis, so the importance of science is once again being acknowledged—with improved public esteem and federal funding.

But the energy problem cannot be framed in purely technical terms, so it is unlikely that research alone will solve it. Well-trained people are needed at all levels in the fabric of society, and high-quality basic research is needed to be the nutrient of fossil fuel technologies that will be implemented in the next 10 years and the more advantageous technologies that should replace them in the future. The academic community is uniquely qualified both to train the manpower and to produce the research.

Individual Self-Sufficiency in Energy

Allen L. Hammond

Project Independence is supposed to free the United States from dependence on imports of energy by 1980. Well before that time, some Americans, harking back to an earlier tradition of individual self-reliance, will have become partially or completely independent of utilities and oil companies for their energy supplies. Not for them the blackouts, heating oil shortages, and frustrations of gasoline lines. Of course, not everyone would care to do his or her commuting on a bicycle, pioneer a solar-heated house, or return to an entirely gadgetless style of life. Still, the concept of an autonomous house has considerable appeal, especially for those who live in rural areas. Urban and suburban dwellers might find attractive the prospect of buffering their dependence on conventional energy sources. The possibilities range from the eminently practical to the absurd. In this article, I will look at both kinds of suggestions in the areas of individual lifestyles, food, housing, and transportation.

The revival of interest in self-sufficiency did not start with the energy shortage, but dates back at least to the 1960's search for alternative life-styles and to the concern with the individual's ability to control his own destiny that produced *The Whole Earth Catalogue* and similar volumes. The energy crisis has provided a new focus for these concerns and has spawned a raft of small businesses that sell information on, and sometimes hardware for, everything from windmills and solar-heated houses to methane digestors and household composters. The energy shortage has also brought to the fore a small army of backyard technologists and would-be entrepreneurs promoting electric cars and energy-saving cookware. Other contributors to the growing array of wood stoves, solar collectors, and energy-conserving appliances have proceeded from more purely commercial motives, although some manufacturers, such as the bicycle and long underwear industries, have literally had success thrust upon them. Most of the big companies are actively studying the potential market for solar heating systems and similar equipment and are stepping-up production of heat pumps and other energy-conserving devices, but it is the newcomers who are responsible for most of what is available so far.

What could an individual or a family do now or in the near future to be more self-sufficient in energy? One facile answer is to change personal habits, lifestyles, and philosophies, to adopt what an environmentalist might call "right thinking"—making do with less. The President's request to turn down the thermostat belongs in this category. So do other suggestions, such as wearing warmer clothes, shopping less frequently, and reverting to the old-fashioned ways of doing things by hand—mowing the lawn, mixing batter, brushing teeth. (Many of these, it is true, have a trivial impact on overall energy consumption but may have a significant effect on one's attitudes. Lawns, for example, require energy to cut them and usually fertilizer, produced with natural gas, to make them grow. And there is no better way to appreciate the esthetics of alternative forms of ground cover or of vegetable gardens than mowing a large lawn by hand.) The standard conservation ideas—turning out lights, putting up storm windows, servicing the furnace—deserve mention here, as do some of the less standard ideas, such as the counterculture's injunction to "save water, shower with a friend." Of course, some of the dozens of electrical appliances found in most homes not only save time and effort, but are difficult to replace. Hand-powered washing machines, for example, are rare today. Brooms and nonelectric blankets, however, are not. Clearly, some rethinking of what is essential and what is peripheral in our energy needs will help edge us toward self-sufficiency.

Recreation is another energy consumer. If we could not afford the energy for our television sets, would reading aloud, playing music, and meditation enjoy a revival? Can participation replace spectatorship as the country's

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major sport? And as for the American custom of traveling every weekend and holiday, perhaps a major effort to improve urban environments would make local recreations more attractive.

Agriculture is an energy-intensive industry in the United States, and whereas the individual consumer does not himself use the large amounts of fertilizer, tractor fuel, and process heat that go into making the supermarket product, he nonetheless pays for it. Hence the suggestion, hinted at above, to turn lawns into "independence gardens" that are a source, not a sink, of energy. Cooking also takes energy, and here enthusiasts point out that Chinese methods of preparing food—rapid cooking of small pieces—is preferable from an energy standpoint to the steak on the grill. Finally, for the truly dedicated energy conserver, there is the recipe that appeared in a New England paper some years ago for cooking a roast, wrapped in aluminum foil, on the engine block of the family car while enroute to Grandmother's house.

Solar Heated Houses

Reducing energy use is not the same as having an independent supply, and more autonomous means of providing a house with heat and electricity are being developed, and in some cases revived. Perhaps a score of experimental houses heated with solar energy have been built in this country over the past 20 years, with half a dozen more under construction this year and the beginnings of a minor boom in sight. The advantage of heating with sunlight, of course, is that it is free. (One Southern California utility did approach the Federal Power Commission a couple of years ago to ask if it could secure rights to sunlight in that state.) The equipment to capture and store heat from the sun, however, is relatively costly and can be unsightly. It need not be sophisticated: Some solar collectors consist of a blackened sheet of metal covered with panes of glass.

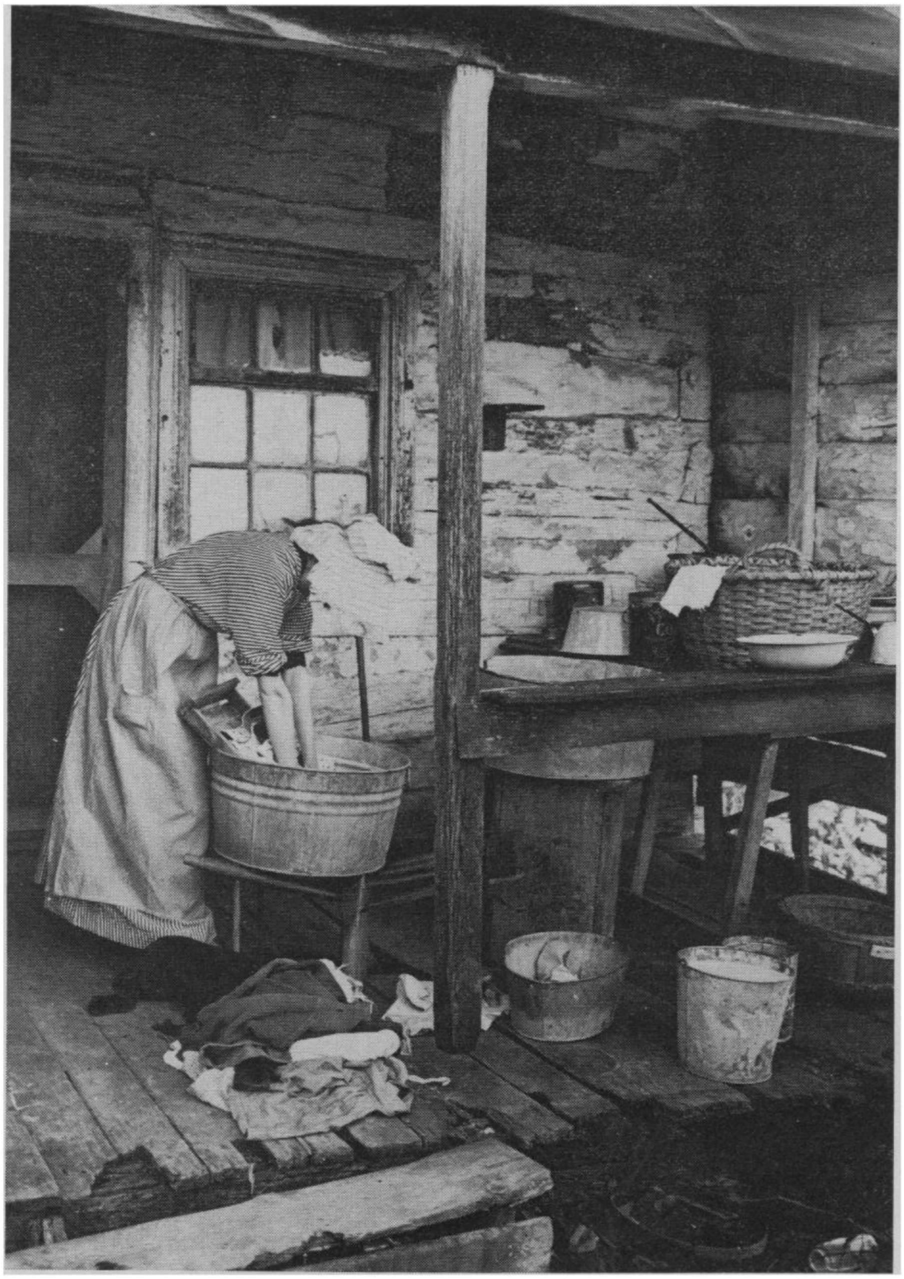
Harry Thomason's house near Washington, D.C., is a good example of what can be done. Water is circulated over corrugated aluminum collectors on the roof of his house and is stored, along with the solar heat it has picked up, in a 1600-gallon tank in his basement. Surrounding the tank are 50 tons of stones, which also store heat and provide a large heat-transfer surface. Air is blown over the rocks and circulated to heat the house. A key to the system's success is its use of large volumes of low velocity, low-temperature air (temperatures as low as 75° to 80°F) compared to conventional heating systems (140° to 160°F). Low-temperature operation means fewer heat losses, more efficient operation of the solar collectors, and more hours of use. Backup heat is provided by an oil furnace, which, according to Thomason, is needed only a few hours per week. A heat exchanger in the storage tank provides hot water. In summer, Thomason cools the storage reservoir at night with a conventional air conditioner and circulates cool air through the house during the day. One of the more effective of the older solar houses, it was designed and built by Thomason himself, a former patent attorney, and it illustrates many of the characteristics of any solar house—good insulation, collectors, thermal storage, and a variety of automatic controls not found in conventional homes (*2*). A measure of the interest in solar houses is that George Washington University, in Washington, D.C., now offers a course for potential builders and contractors of solar houses, taught by Thomason.

Several companies now offer solar collectors for a variety of purposes, and more sophisticated collectors (based on selective surfaces that absorb more sunlight, while emitting less thermal radiation than black paint) are being readied for market. Horace McCracken of the Sunwater Company in El Cajon, California, reports a brisk demand for his solar stills, which compete as a water supply with bottled water in arid parts of the Southwest. He is beginning to sell larger units as swimming pool heaters, now that natural gas for that purpose is being shut off (*3*). The Australian Beasley Solapak and the Israeli Miromit companies manufacture solar water heaters and either have or are seeking U.S. outlets for their collectors (*4*). Sunworks, a newly formed Connecticut company; Solar Systems, Incorporated, in Texas; Intertechnology Corporation in Virginia; and AAI, Incorporated, in Maryland all manufacture advanced solar collectors suitable for heating houses and commercial buildings (*5*). Even the big guys are getting into the act—both General Electric and Honeywell have produced collectors in experimental quantities and are exploring the prospects for commercialization. A word of caution to the venturesome—the collectors available today cost $6 to $25 per square foot, mostly in the higher range for small orders, and the durability of the selective surfaces on advanced collectors has yet to be established. All of the manufacturers report a deluge of mail, however, and if interest turns into hard orders, the cost of collectors may go down substantially.

There are other ways of heating a house. Wood stoves are back in fashion, and well-designed fireplaces can lessen heating loads for those who have an

Early reports indicate that the demand for motorcycles and other energy-saving forms of transportation may outstrip the supply this summer. [Source: Eric Poggenpohl, *Science*] ample supply of firewood. Heating with gas is not such a bad idea if you grow your own, and, while methane digesters (which produce the gas by anaerobic decomposition of organic matter) are not commercially available in the United States yet, several groups will sell you plans and instructions for building a system (*6*). The catch is that one family's organic waste does not produce enough methane to heat a house, although it may be enough for cooking purposes. If you own a pig farm, however, or live near a feedlot that is willing to dispose of its animal wastes, it may be worth looking into.

To be truly autonomous, of course, a house needs a source of electricity as well. Indeed, most heating systems depend on electrically driven fans or pumps. Short of putting a generator on the treadwheel in your gerbil cage, as one wag suggested, coming up with alternative sources of electricity is not easy. Photovoltaic cells generate electricity directly from sunlight, and an experimental house at the University of Delaware gets part of its electricity that way. But solar cells are still prohibitively expensive for household use. Small water-powered turbines are available for those fortunate enough to live beside a flowing brook (*7*). Windmills, long a forgotten technology in this country, are now experiencing a revival. The Davey-Dunlite Company of Australia and Elektro G.M.b.H. of Switzerland both manufacture wind generators suitable for home power application, and their products are available from the Solar Wind company in East Holden, Maine (*8*). Plans for home-built wind generators are also available (*9*).



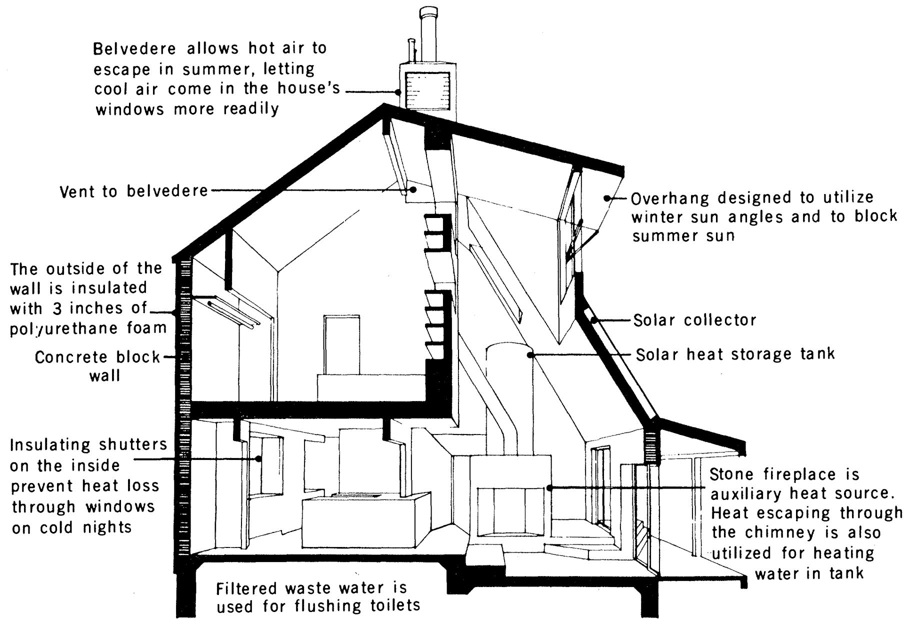
Self-sufficiency in energy does not have to mean a return to drudgery and discomfort, although it may mean a return to a simpler style of life. [Source: U.S. Department of Agriculture]

Because winds, like sunlight, are irregular, some means of storing electricity is necessary. In practice, a self-sufficient wind-generating system needs a wind generator, a tower to place it on, a bank of storage batteries, direct current to alternating current inverters, and a variety of control equipment—all of which makes the system expensive. Although wind systems compete well with gasoline-powered generators (especially in reliability) for remote installations, the cost of electricity from present commercial units is probably four to six times as much as the local power company charges. Power costs are rising dramatically, however, and less expensive American-made units may be on the market within a few years. It is also possible to hook a windmill system in tandem with the power company's supply, with automatic switching from one to the other when needed. (Reportedly, it is possible, with such an arrangement, to put excess wind-generated electricity back onto the power lines, thus running the meter in reverse, cutting the power bill, and using the utility as the storage battery for the system.)

Autonomous or nearly autonomous houses built recently include the Bob Reines house near Albuquerque, New Mexico, and the Henry Clews house near East Holden, Maine, both designed and built by their owners. The New Mexico house is a hemispherical dome, heavily insulated, heated by solar panels, and powered by windmills. A butane stove is the only conventional source of energy. The Maine house is of more conventional design. It is heated by three wood-burning stoves that consume about 8 cords of firewood a winter. Windmills provide power for lighting, small kitchen appliances, television, and a pump that supplies running water from a well. Propane gas is used for cooking and running a refrigerator, while gasoline is used for driving a chain saw to cut wood. Neither house is connected to utility services. Although these houses do not have all the comforts of a modern suburban development, they are not primitive.

The Modern Autonomous House

More elegant examples are under construction. The house of Nicky Wilson, near Martinsburg, West Virginia, will be an architectural showcase. It will include solar heating and both photovoltaic and windmill power generators, as well as conventional oil heating and utility connections for backup (*10*). The house will also have two built-in greenhouses, one for a small garden and the other for plants that will filter and refresh the air that is circulated through the house. Kitchen and human wastes will be composted with a Swedish clivus system, which converts them aerobically to compost and eliminates the need for a sewer hookup. Everett Barber's house, near Gilford, Connecticut, will get about 80 percent of its heat and electricity from built-in solar collectors and a pair of windmills, with backup by an oversized, oil-fired water heater and an electrical utility connection (*11*). A thick layer of polyurethane foam insulation will be sprayed on the outside of the concrete block walls, making the house extremely resistant to heat loss and giving it something of an adobe appearance. Barber's house will also incorporate a number of energy-saving features—heat from the refrigerator coil and the kitchen sewer is used to warm up water for the water heater; the fireplace draws air from outside the house rather than inside; insulated shutters for the windows are closed at night; and, in summer, air will be circulated through the house convectively, rather than blown by a fan.



A solar-heated semiautonomous house being built for Everett Barber in Guilford, Connecticut. [Source: Sunworks, Inc.]

Short of full autonomy, still another way to use solar energy is in combination with a heat pump. Heat pumps transfer heat by evaporating and condensing a working fluid—much like an air-conditioner or refrigerator run in reverse—and can pump two or three units of heat into a house for every unit of electricity required to drive the unit, depending on operating conditions. Most of the heat pumps available today are designed for air-to-air heat transfer and are sized for cooling rather than heating purposes. Even these would markedly reduce the cost of electric heating, which in some all-electric homes in the New York City area is reportedly running as high as $300 a month. Heat pumps designed for heating and for water-to-air transfer will soon be available from most major manufacturers. When used in combination with solar collectors, as, for example, in the condominium townhouses being designed for Richard Blazej, a Vermont builder, by Fred Dubin of Dubin, Mindell, Bloome Associates in New York City, the solar system provides a reservoir of lukewarm water. Even in the middle of a Vermont winter, a relatively small collector can provide 50°F water. Both the collectors and the heat pump can run efficiently under these conditions. Dubin expects the condominiums to use less than half the energy (in the form of electricity and backup oil heat) of conventional houses.

Solar air conditioners that run on a heat-driven absorption cycle are under development by a variety of companies, and commercial units are just becoming available (*12*). Reductions in the use of water (and thus, ultimately, energy at the treatment plant) can also be achieved. Most major plumbing manufacturers have faucet and toilet designs that cut back on water use. The Swedish clivus unit, which provides complete autonomy in sewage disposal, is now being manufactured by an American firm (*13*). The unit is essentially a tilted fiberglass box that accepts organic wastes, digests them aerobically by circulating air through the box, and produces at the end of a 2- to 3-year turnover period a dry mulch that is excellent fertilizer.

Housing design and construction techniques are another area in which there is considerable room for energy-saving improvements. According to David Hartman of Dubin, Mindell, Bloome Associates, a study the firm did in association with the National Bureau of Standards for the General Services Administration showed that heavier construction, and the resultant increase in thermal mass of a building, reduces the peak loads for thermal conditionings. They also found that insulation was more effective on the outside of the structure than on the inside. The incorporation of these and other energy-conserving features in new housing will not greatly help those who now live in drafty older houses, but most areas have companies that specialize in retrofitting existing housing with blown-in insulation.

Transportation—How Far on Foot?

Although the home is where most Americans use the majority of the energy they consume, transportation runs a close second. Here the principle villain—the family car or cars—is more easily identified, and the alternatives, unfortunately, far fewer. The typical American car converts gasoline to motive force with an efficiency of less than 20 percent and gets 12 to 15 miles per gallon. The readily available choices for reducing one's dependence on gasoline, in order of descending energy consumption, include a smaller car, a motorcycle, walking, and bicycling. Sales of bicycles in the United States have doubled since 1970 and for the past 2 years have surpassed automobiles in the number sold. Some

15 states are now financing construction of bikeways, although most cyclists must still face the risks of competing with automobiles. Sales of motorcycles are also booming, as are those of small cars.

Buses, subways, and cable cars, for those fortunate enough to live in a community with good mass transportation, also seem to be making a comeback. Several cities are experimenting with free or reduced fare service. The return of car pooling and of hitchhiking as means of getting to work offer obvious advantages from an energy-independence point of view. An energy-conscious transportation strategy may call for making fewer trips and living near places of work or mass transit lines.

Several other methods of travel are available, ranging from methane- and alcohol-powered cars and electric vehicles to a gas-powered pogo stick that is reported to get 500,000 hops per gallon. Converting an internal combustion engine to methane or methanol is not difficult. If you have a private still or one of the methane-producing digestors mentioned earlier and a supply of organic feedstock, you have the wherewithal for at least local transportation independent of the gas station. Neither methane nor alcohol is readily available along the highway, however, and methane-powered vehicles in particular (because of storage limitations) have a short range. Nonetheless, several municipalities are looking into the possibilities of operating fleet vehicles on methanol made from sewage sludge.

Electric vehicles are not new, but their reemergence from the world of the private hobbyist into the commercial marketplace is. Electric golf carts and forklift trucks are no longer a novelty, and nearly three dozen manufacturers have built prototype urban cars, delivery trucks, and buses (some of these vehicles are in limited production) (*14*). Electric motors are several times heavier than internal combustion engines of the same power, and lead-acid batteries add additional weight. Most electric car bodies are therefore built of fiber glass and aluminum to reduce weight. Few electric vehicles can go farther than 50 miles before the batteries must be recharged, and few are suitable for freeway driving. Nonetheless, electric cars are more efficient users of energy than present automobiles—electric motors are between 85 and 90 percent efficient, and electricity is generated and transmitted with an efficiency of about 30 percent, for a combined efficiency of 25 percent or more. Tests of an electric mail van in Cupertino, California, showed that its average fuel costs per mile were half those of a standard, 4-cylinder mail truck over the same route. The Post Office is ordering 350 electric vehicles for more extensive tests. The Avis Company will also be testing electric rent-a-cars in Chicago this year.

Fuel costs of less than 1¢ a mile are claimed for some lightweight electric cars, as is the advantage of almost no maintenance. Batteries, however, must be replaced every year or so, and they are expensive. Still, by charging-up his vehicle regularly at night, an electric car owner could commute right past gas station lines. What may be the prototype of networks of service and recharge stations for electric vehicles has been opened in the suburbs of Boston, Massachusetts. *Electric Vehicle News* (*15*) estimates that nearly 1000 home-built electric cars will be on the road in 1974, in addition to those commercially produced. There is even a small boom in electric motorbikes—a German company, Solo Motors, and a Massachusetts firm, Auranthetic Corporation, are both producing about 2000 bikes a month and selling them readily at prices in excess of $500 (*16*). It is only a matter of time before someone couples a windmill generator and an electric vehicle to demonstrate that autonomous commuting is possible even for those too lazy to ride a bicycle.

For most of us, there is not much that can be done to completely alleviate our dependence on centralized sources of energy. Indeed, many would argue on the grounds of overall efficiency that centralization is by far the preferable means of generating and supplying energy, that dependency on large industrial organizations for the essentials of life is the hallmark of technologically advanced societies. This may well be true, but gasoline lines, brownouts, and shortages of natural gas are reminders that the system is far from perfect. The consumer is surprisingly vulnerable, not just to the ice storm that can down power lines, but to the mistakes of planners over whom he has little control and to the whims of the oil-exporting nations. Under the circumstances, a little self-reliance is not necessarily a foolish policy. It is encouraging that there are individuals who wish to increase their autonomy of energy supply and who, in the process, may provide the rest of us with more options of the same kind.

References and Notes

1. If you can't find long johns and other warm clothes at your neighborhood department store. try some of the mail-order houses patronized by hikers and hunters.
2. Plans for Thomason's solar house can be ordered from Edmund Scientific Co., 555 Edscorp Building, Barrington, N.J. 08007, for $10.
3. A solar still with a capacity of 2 gallons per day costs between $150 and $500, depending on how automated it is; solar swimming pool heaters average $1000. Write Sunwater Co., 1112 Pioneer Way, El Cajon, Calif. 92020.
4. Information on Beasley collectors can be obtained from Bill Edmunds of the Solar Energy Digest, P.O. Box 17776, San Diego, Calif.
5. Addresses for information are Sunworks, Inc., 669 Boston Post Road, Guilford, Conn. 06437; Solar Systems, Inc., P.O. Box 807, Tyler, Tex. 75701; Intertechnology Corp., Box 340, Warrenton, Va. 22186; AAI, Inc., P.O. Box 6767, Baltimore, Md. 21204.
6. Mother's Bookshelf, P.O. Box 70, Henderson, N.C. 28739, sells a methane information package for $8. A subscription to *The Mother Earth News* (available from the same address) will keep you up to date on what's new in self-sufficient living ($8 a year for six issues). The New Alchemy Institute East, P.O. Box 432, Woods Hole, Mass. 02543 also has information on methane digesters.
7. See *Pamphlet A, Hints on the Development of Small Water Power*, available from James Leffel and Co., Springfield, Ohio 45501. Leffel also manufactures suitable turbines.
8. Solar Wind Co., East Holden, Me. 04429. Their pamphlet, *Electric Power from the Wind* (price: $2), provides general information on wind power systems.
9. Available from Sencenbaugh Wind Electric, P.O. Box 11174, Palo Alto, Calif. 94306 (this company also sells the Australian Dunlite equipment) and Windworks, Box 329, Route 3, Mukwonago, Wisc. 53149. Other companies with plans to manufacture windpower equipment are Environmental Energies, Inc., 11350 Schaefer St., Detroit, Mich. 48227 and ILS Laboratories, Star Route 103, Tijeras, N.M.
10. The house was designed by Richard Rittlemann of the architectural firm of Burt, Hill Associates, 610 Mellon Bank Building, Butler, Pa. 16001.
11. The house was designed to Barber's specifications by the New Haven architectural firm of Charles W. Moore Associates.
12. Arkla Industries, 930 East Virginia St., Evansville, Ind. 47701 sells one of the first suitable units.
13. For more information, contact Clivus Multrum, Inc., 14A Eliot St., Cambridge, Mass. 02138. They cost about $1000.
14. Several of the largest U.S. firms are Otis Elevator Co., Special Vehicles Division, P.O. Box 8600, Stockton, Calif. 95204; Battronic Truck Corp., Third and Walnut Streets, Boyertown, Pa. 19512; Electromotion, Inc., P.O. Box 323, Bedford, Mass. 01730; and Sebring-Vanguard, Inc., P.O. Box 1479, Sebring, Fla. 33870.
15. For those who want to follow the electric vehicle industry, this quarterly magazine is published by Porter Corp., P.O. Box 533, Westport, Conn. 06880, and costs $10 per year.
16. The North American distributor is Solo Klinmotoren GmbH, Burlington, Ontario, Canada. Auranthetic Corp. is located at 706 Adams St., Quincy, Mass.

Courtesy Stuart Finley Films, Falls Church, Virginia →