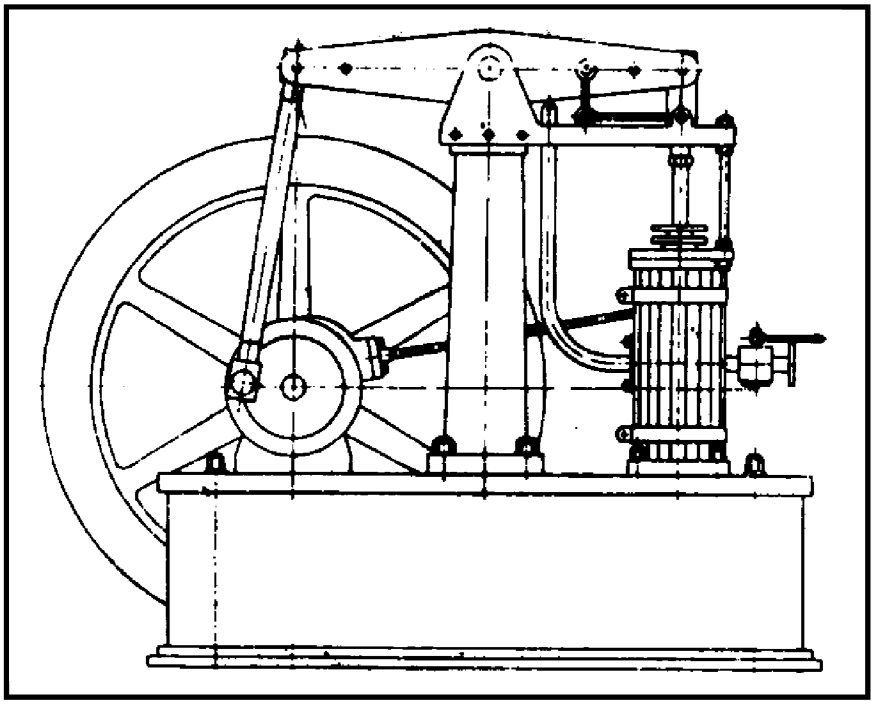

Energy: General

"It is the experience of most developing countries that energy produced through centralized thermal, hydroelectric and nuclear power stations rarely flows to rural areas where the bulk of the population lives. A typical distribution for such centralized power production is about 80% for urban industry (based on energy intensive Western technology), about 10% for urban domestic consumption, and only about 10% for rural areas."
—CERES: The FAO Review on Development, March-April 1976

The use of alternative natural sources of energy is attractive because of the uncertain price and limited availability of oil, the pollution that is associated with the burning of fossil fuels, the tremendous experiences and dangers of nuclear power, and a variety of other reasons. In developing countries the first reason is of particular importance because their industrial development, coming at a time of low cost plentiful oil supplies, has resulted in greater reliance on this single source of energy than is true in the developed countries, despite the fact that the latter use tremendously larger quantities. For industrialized countries such as the United States, practical and economically competitive alternative energy systems already exist that could replace the entire nuclear power contribution to U.S. energy supplies. (Editor's note: Wood space heating stoves [selling 1-2 million units a year] surpassed nuclear power in total contribution to U.S. energy supplies in 1980!)

For village level applications, there are many promising existing technologies. The five sections which follow explore of these in more depth: sun, wind, water, wood and biogas. These technologies are small-scale and necessarily decentralized . This, rather than any other technical inferiority, is the primary *reason earlier forms of these technologies were eventually passed over in the industrialized countries. While these systems cannot very effectively be used for the power needs of large industry, they can be well suited to the needs of villages and small communities. They can be low in cost relatively simple in construction and maintenance, made of materials available in villages and small towns, and non-polluting.*

With each price increase in the worlds diminishing oil supply, renewable energy sources are made more attractive. The decentralized supply of these renewable energy sources—wind power, solar energy, water power and biofuels—matches the decentralized settlements of the rural South. Planners and program administrators are increasingly convinced that these technologies have a major role in the energy supplies of rural communities.

Rays of Hope *makes the argument that the exponential increases in energy consumption characteristic of industrial societies cannot continue, and therefore industrial development in all countries will have to shift towards decentralization, conservation, improved energy conversion efficiency, and better matching of energy quality to end use needs.*

Other books in this section review the most attractive renewable energy technologies likely to fit the circumstances in the rural South. **Renewable Energy Resources and Rural Applications in the Developing World** *also notes the domestic and foreign policy implications that come with choice of energy strategy.* **Energy for Development: Third World Options** *points specifically to reforestation programs for fuelwood and soil conservation as high priorities in energy planning. A catalog of commercially available small-scale power generating equipment, entitled* **The Power Guide**, *has been introduced by ITDG. This book includes both renewable energy devices and diesel and gasoline engines.*

A good place to find an overview of technology options is in **Renewable Energy Technologies: Their Applications in Developing Countries,** which *includes coverage of some of the lesser known choices such as briquetting of agricultural wastes and use of vegetable oils as an engine fuel.*

The increasing acceptance of an important role for renewable energy systems, noted earlier, has led to proliferation of pilot projects. Economic feasibility has not been properly considered in many of these projects, a fault perhaps most common in large international and bilateral aid agencies, who should know better. **The Economics of Renewable Energy Systems for Developing Countries** *offers three case studies illustrating this problem, and a methodology for evaluating the economic appeal of any renewable energy project. Author David French notes that, in particular, large agencies seem to have forgotten that most of the rural poor do not use commercial fuels and thus cannot simply switch cash payments towards the purchase of new equipment:*

"Most renewable energy devices now tend to be attractive primarily to people already using costly commercial power. Just as is happening in the United States, for example, some Third World city-dwellers are discovering that solar energy may be cheaper than electricity for heating water .... Such systems will be of greatest use to the wealthy; there is little reason to suppose they will be of comparable interest to the poor."

In the rural South, most of the energy used is in the form of firewood and crop residues gathered and burned in cooking fires. Low-cost locally built cooking stoves can greatly increase the efficiency of cooking, reducing the demand for *fuelwood up to 40%. This would both slow the rate of deforestation and lighten the burden of long distance wood hauling. Technologies that use local materials and skills, such as improved wood stoves and village wood lots, are more likely to be immediately affordable than expensive devices such as solar pumps, photovoltaic systems, and biogas plants in almost all cases.*

Other renewable energy technologies relevant to developing countries include locally built water pumping windmills (increasingly attractive for small plot irrigation and community water supplies) and wind generators (more expensive but of interest where a small amount of electricity production has a high value); both can be found in the ENERGY: WIND chapter. Water wheels and water turbines could play an expanded role in rural crop processing and in supplying the energy needs of rural industries, as has been the case in China (see the ENERGY: WATER chapter). Direct solar technologies for crop drying, currently probably the most important area for solar energy use, are examined in CROP DRYING, PRESERVATION AND STORAGE. Solar home heating and cooling, water heating, cooking, refrigeration, water pumping and electricity production are all reviewed in the ENERGY: SOLAR chapter. The anaerobic fermentation of animal manures and crop residues to produce biogas and fertilizer is covered in the ENERGY: BIOGAS chapter, including two translations on Chinese biogas plants.

A significant locally available energy source is animal power, which could be made more efficient through the design of better pumps, crop processing equipment, harnesses, carts, and agricultural implements. **The Management of Animal Energy Resources and the Modernization of the Bullock Cart System** *(see review in the TRANSPORTATION chapter) examines the largely neglected topic, noting that for agricultural activities on the Indian farm, two thirds of all energy is provided by animals, while humans contribute 23% and electricity and fossil fields together amount to only 10%.*

Alcohol fuels have received a great deal of attention recently, bringing the hope that they could replace increasingly expensive and scarce gasoline. The technical requirements of alcohol production are presented in **Fuels from Farms** *and* **Makin' It On The Farm**. *Alcohol fuels can be made from crop residues and tree crops. However, large-scale alcohol fuel programs ignore these feed stocks in favor of more economically attractive grain, cassava, and sugar cane. In* **Food or Fuel: New Competition for the World's Croplands**, *Lester Brown argues that this will tend to reduce food supplies, as the major exporting nations could easily consume all their surplus crop in alcohol conversion programs. The first people to be affected will be the urban poor in developing countries.*

Pedal power offers some possibilities for use in small tasks that otherwise would require hand-cranking or high payments to the owners of engine-driven equipment. The small amount of power that a healthy person can produce (75 watts-0.1 hp continuously, 200 or more watts for brief periods) is best suited to short, intermittent tasks, such as the operation of small workshop equipment. While pedal-powered agricultural processing equipment, particularly pedal threshers, can be much more efficient in labor than traditional techniques, larger quantities of crops require the power available from draft animals, water wheels, or small engines. **The Use of Pedal Power in Agriculture and Transport in Developing Countries** *summarizes the potential applications, and is accompanied by books that present construction detail s for pedal-powered equipment.* **Bicycling Science** *(see review in TRANSPORTATION chapter) reviews the performance of human beings operating stationary pedal power units.*

Steam engines can be used for a wide variety of rural power requirements, and can be fired with agricultural residues; they are reportedly built in several small workshops in Bangkok. Five of the entries in this chapter are concerned with the design and construction of very small-scale steam engines and boilers, mostly in the range of 1-2 hp—equivalent to the pedaling power of 10-20 people. Steam engines are inefficient in conversion of fuel energy into work, and they are heavier and require more materials and space than small gasoline or diesel engines of similar power. Yet they are less technically demanding to make, with larger acceptable tolerances when fitting parts. They are probably most commonly found in small sawmills in the South, where a ready supply of saw dust, bark, and wood scraps is available. (For repair and maintenance of small gasoline engines, see **How to Repair Brigg and Stratton Engines** *and* **Small Gas Engines***, in the AGRICULTURAL TOOLS chapter.)*

The final two entries in this chapter are on electrical systems. One is a reference on installing electrical lines in small communities. The other describes synchronous inverters that allow the direct linking of wind generators or small hydroelectric units to the electrical grid, thereby avoiding the need for costly battery systems.

The Economics of Renewable Energy Systems for Developing Countries, MF 19-407, report, 67 pages, by David French, 1979, order no. PNAAG-864 microfiche copies $1.08, paper copies $2.00, from User Services, AID/ DIHF, 7222 47th Street, Chevy Chase, Maryland 20815, USA.

The author examines three projects employing some of the more sophisticated renewable energy technologies: solar pumps in Senegal, biogas plants in India, and solar-electric pumps in Chad. He presents a careful economic analysis and concludes that none of these technologies is now a good investment, nor does any of them appear likely to become a good investment in the next decade.

"Most renewable energy devices now tend to be attractive primarily to people already using costly commercial power. Just as is happening in the United States, for example, some Third World city-dwellers are discovering that solar energy may be cheaper than electricity for heating water ... Such systems will be of greatest use to the wealthy; there is little reason to suppose they will be of comparable interest to the poor."

"Rather than concentrating on devices of the sort described above, organizations concerned with the poor might seek to meet basic energy needs through simpler systems: village woodlots, improved wood stoves, hand or pedal pumps and grinders, hydraulic ram pumps, and so on. Emphasis would be on systems whose benefits were likely to be commensurate with their costs, and whose costs were likely to be within reach of the poor. Given this approach, ways might be found to make energy widely available to people most in need of it."

In addition to pointing out the dubious appeal of the higher cost group of alternative technologies, the methods of economic analysis clearly presented here can be used to help evaluate other renewable energy technologies. This report will also be helpful to people who need to understand the methods and concepts of analysis often used by major aid agencies.

Renewable Energy Resources and Rural Applications in the Developing World, MF 19-430, book, 168 pages, edited by Norman Brown, 1978, American Association for the Advancement of Science, $25.50 plus $1.50 postage and handling from Westview Press, 5500 Central Avenue, Boulder, Colorado 80301, USA.

This set of papers offers a valuable look at the potential for use of renewable energy resources in rural areas of developing countries. Norman Brown provides a thoughtful introduction to the topic:

"Choosing conventional large-scale capital-intensive technologies implies a priori decisions, conscious or not, about many important policies. These include the course of urban development, expanding industrialization, environmental impact, large-scale borrowing (or foreign investment) with long-term indebtedness and problems of debt servicing, and last but not least, the foreign policy stance dictated by these requirements ."

"On the other hand, the choice of small-scale decentralized power systems (e.g. solar heating, cooling, and generation of electricity; windmills; small-scale hydroelectric plants) implies a different set of a priori decisions. These include, for example, de-emphasis of western style industrialization as the sole or primary immediate goal of development; dispersal of industry and, perhaps, changes in financial mechanisms; and a shift from western agricultural techniques to emphasis on improvement of indigenous agricultural practices, with consequent reduced demand for energy consuming nitrogenous fertilizers. All of these factors could contribute significantly to a slowing down of migration to the cities and urban growth, with important effects on the rate of growth of dependence on commercial energy supplies."

The other papers include a general introduction to rural energy requirements, a description of the U.S. photo voltaic program, a look at the potential for solar energy use, an evaluation of wood waste as an energy source in Ghana, a summary of the process of methane production, and discussion of a wide variety of alternative energy technologies in Brazil. An article on wind energy conversion in India argues that water pumping windmills seem to be the most promising new energy technology in the rural areas. There is also a good historical summary of the development of water wheels and water turbines, and their importance in the growth of the rural economies of the United States and Europe (and China today).

"The history of small scale hydropower development provides sound suggestions of how to aid ... rural areas of developing countries (that have water power potential) in achieving an improved standard of life. . .The major role in this development was played by the simple water wheel ... Later the small turbine provided more power at a given site than was feasible with the water wheel ... (In the rural areas of the United States water turbine production) was rapidly taken over by blacksmiths and foundrymen who found it easy to make, in great demand, and an extremely profitable business ... By the middle of the 19th century the French turbine had been so radically altered by rural American craftsmen that American turbines began to take the names of their many improvers."

These mills showed the potential for rural industry based on decentralized power sources. They "turned out such household products as cutlery and edge tools, brooms and brushes ... furniture, paper ... pencil lead ... needles and pins ... watches and clocks, and even washing machines."

"For the farm they turned out fertilizers, gunpowder, axles, agricultural implements, barrels, ax handles, wheels, carriages. There were woolen, cotton, flax and linen mills; ... tannery, boot and shoe mills ... and mills turning out surgical appliances ... and scientific instruments."

Renewable Energy Technologies: Their Applications in Developing Countries, MF 19-440, book, 326 pages, by L.A. Kristoferson and V. Bokalders, 1991, £25.00 from ITDG.

This is a recommended single source treatment of the state of renewable energy technologies for developing countries at the beginning of the 1990's. In addition to the energy topics covered by the A.T. Sourcebook, this book provides relatively hard-to-find coverage of such topics as briquetting of agricultural wastes, the use of peat, vegetable oils as an engine fuel, and Stirling engines. The reader will get a sense of which options might be considered under his or her conditions. The six pages of summary information ("Abstracts") on each energy topic at the beginning of the book represent a good, concise overview of the whole field. For in-depth coverage of any of these topics, other books will need to be consulted.

Rays of Hope: The Transition to a Post-Petroleum World, MF 19428, book, 233 pages, by Denis Hayes, 1977, $4 95 from WW. Norton & Co., 500 Fifth Avenue, New York, New York 10110, USA.

Beginning with an overview of patterns of petroleum resources depletion, Denis Hayes shows that our planet cannot continue to support the way of life now characteristic of advanced industrial societies. With costs of delivering increasingly scarce petroleum skyrocketing, it will ultimately require more energy to deliver dispersed fuel in marginal deposits (e. g. tar sands and shales) than is available in the fuel itself. And while coal reserves are relatively plentiful, their use is limited by the capacity of the environment to process waste carbon dioxide. Public opposition to nuclear power is growing because of waste problems, rapidly rising capital costs, and vulnerability to accident and misuse (in weapons production around the world).

Following these arguments, most of this book explores more attractive, sustainable energy consumption patterns based upon direct solar, wind, water, and biomass resources. An analysis of energy use patterns in space heating and food and transportation systems shows that conservation efforts using technical approaches could save great quantities of energy: "A $500 billion investment in conservation would save the U.S. twice as much energy as a comparable investment in new supplies could produce." (In fact, since this book was published, another major oil price increase was followed by substantial investment in conservation in all of the industrial economies.)

Looking to the medium and long term future, Hayes also stresses the importance of policy and the pivotal nature of decisions made today: "Oil and natural gas are our principal means of bridging today and tomorrow, and we are burning our bridges. Twenty years ago, humankind had some flexibility; today, the options are more constrained. All our possible choices have long lead times ... inefficient buildings constructed today will still be wasting fuel fifty years from now; oversized cars sold today will still be wasting fuel ten years down the road ...."

Energy: The Solar Prospect, Worldwatch Paper 11, MF I 9-4 IS, 40 pages, 1977, by Denis Hayes, out of print; and The Solar Energy Timetable, Worldwatch Paper 19, MF 19-433, 78 pages, by Denis Hayes, a few copies available from Worldwatch Institute, 1776 Massachusetts Avenue N.W., Washington, DC 20036, USA.

In these two papers, Denis Hayes outlines possible strategies for a global transition to a "solar-powered world" within 50 years, an ambitious goal. In discussing solar resources, he notes that the possibilities range from the simple to the complex, and from the decentralized to the centralized. This makes solar applications adaptable in many different societies, rich and poor, urban and rural.

The Power Guide: A Catalogue of Small-Scale Power Equipment, MF 19-426, book, 240 pages, compiled by Peter Fraenkel, 1979, ITDG, out of print.

This is a guide to commercially available equipment. The authors list criteria for selection, but make no specific recommendations of equipment, as ITDG has no facilities for testing machinery. No prices are given, as they are rapidly changing. Names and addresses are listed for manufacturers and their agents, information services, and organizations doing R&D work on small-scale power production.

Major topics are: solar electric cells, solar engines, solar space and water heaters, wind generators, windpumps, hydroelectric units, hydraulic ram pumps, iron and steel cooking and heating stoves, methane digesters, steam boilers, wood gas producers, diesel engines, gasoline (petrol) engines, steam engines, alternators and generators, electric generating units, and batteries.

The lowest-cost small-scale energy devices, however, are rarely available from commercial sources, and cannot be found in this catalog Such devices are built within many developing countries. For more information on these see the other reviews in this chapter and the other energy chapters of the A.T. Sourcebook.

Energy for Rural Development: Renewable Resources and Alternative Technologies for Developing Countries, MF 19-412, book, 301 pages, National Academy of Sciences, Washington, D.C., 1976, out of print.

A summary of what was the state of the art of manufactured or already tested technologies frequently suggested as solutions to rural or individual family energy needs in developing countries. Covers direct uses of solar energy, wind power, hydropower, photosynthesis, microbiological conversion of plant materials to liquid fuels, geothermal energy and energy storage The text is primarily a technical and economic evaluation of the applicability of these systems based on production by current methods in the industrialized countries. The authors do not include in their calculations the potentially very different forms such technologies might take in developing countries. Somewhat out of date in 1985, following 10 years of experimental work around the world.

Energy for Rural Development (Supplement): Renewable Resources and Alternative Technologies for Developing Countries, MF 19-411, book, 236 pages, National Academy of Sciences, 1981, out of print.

This is a supplement to the 1976 book by the same title "Although there have been few remarkable new discoveries in the past five years, steady progress has been made in research and development on renewable energy resources and alternative technologies." This supplement includes information on new technologies developed during this period and on advances made in technologies described in the original volume. Like that volume, this report serves merely to direct the reader where to go for information, and is not intended to be a "how-to manual or detailed catalog."

Small Scale Renewable Energy Resources and Locally Feasible Technology in Nepal, MF 19-431, booklet, 60 pages, by Andreas Bachmann and Gyani Shakya, 1982, free from Swiss Association for Technical Assistance, P.O. Box 113, Kathmandu, Nepal.

A booklet filled with pictures of traditional and new technologies that can be seen in Nepal. Nearly 100 photos of stoves, solar dryers, watermills, microhydroelectric turbines, solar water heaters, biogas plants, and passive solar buildings.

Proceedings of the Meeting of the Expert Working Group on the Use of Solar and Wind Energy, Energy Resources Development Series No.16, MF 19-427, book, 147 pages, by the United Nations Economic and Social Commission for Asia and the Pacific, 1976, U.N. Publication Sales No. E.76.II.F.13, out of print.

This book contains reports and documents from a March 1976 conference in Bangkok.

Wind power: basic information and characteristics of different rotor types; pump characteristics; recommendations for activities in support of further development of wind power in the region; discussion of characteristics of Greek cloth sail windmills, industrially produced wind pumps, and wind generators; many drawings of simple low cost windmills and pumps; use and potential use of wind energy in India, Thailand, New Zealand, Australia, Korea and Indonesia.

Solar energy: sample drawings and discussion of solar water heaters, stills, cookers, driers, and pumps; conversion to electrical and mechanical power; use and potential use of solar energy in India, Japan, Australia, Southeast Asia, and Pakistan.

For both topics there is a list of references and organizations worldwide.

Renewable Energy Research in India, MF 19-429, book, 269 pages, Tata Energy Research Institute, August 1981, out of print in 1985.

This compendium reports on the activities of 64 groups active in renewable energy research in India. Reports are organized alphabetically within categories: government departments, academic institutions and universities, research institutions and industry, and state government and community agencies.

Pedal Power: In Work, Leisure and Transportation, MF 19-424, book, 144 pages, edited by James McCullagh, 1977, Rodale Press, out of print in 1985.

This is the broadest collection of practical ideas for pedal-powered equipment. The authors feel that human energy can be most efficiently harnessed using pedal-powered machines, including but not limited to the bicycle, and that such machines can make significant contributions in any society: "At the time when the 'appropriateness' of technology is being questioned daily, the bicycle, perhaps the most appropriate and efficient machine ever invented, is making a comeback in many countries." These claims are backed up with a wealth of information on past and present uses of bicycles and other pedal-powered machines, as well as potential future uses.

This volume contains most of the information found in the article entitled "Pedal Power" (reviewed in this section). An excellent chapter by Stuart Wilson is devoted to pedal-powered equipment currently in use or being developed in the South. Included are descriptions of various transportation machines, and stationary pedal machines, such as a two-person pedal-driven winch and a "dynapod" which uses a flywheel to smooth out power variations. Pedal-powered pumps shown include the traditional Chinese square pallet chain pump for irrigation and a two-person borehole pump capable of lifting water 100 meters. There are old catalog drawings of foot-powered cast iron workshop equipment, such as woodworking and metalworking lathes and jig saws. (Similar machines can he seen today in India and Sri Lanka.)

Another chapter gives a description and full set of building instructions for the Rodale Energy Cycle, as well as test results. The Cycle is a stationary pedal power unit which can be used to drive a variety of machines, from lathes and grinders to pumps, winches and a cable-plow. It uses a bicycle frame and various pieces of angle iron, bearings and pulleys. Some welding and drilling is required.

Construction details are provided for a rear wheel bicycle adapter to allow power to be taken from any ordinary bicycle. Both this and the Energy Cycle are straightforward and could easily be adapted to locally available materials.

With 72 photos and 65 illustrations, **Pedal Power** is an excellent idea book on the possibilities of using and/or designing pedal-powered machines.

Pedal Power, article, 18 pages, by Stuart Wilson, 1975, in **Introduction to Appropriate Technology**, MF 01-9 (see review).

A person on a bicycle is the most energy efficient moving thing that exists (measured in calories per unit of weight per unit of distance). By measuring the energy output of a bicyclist, Wilson has found that "the normal cyclist has an expenditure of about 75 watts—roughly 0.1 horsepower ... the fullest sustainable output of the human body, using the right muscles, right motions, and the right speed."

The author gives consideration to stationary pedal power, used to operate pumps, for example. A rotary pump is shown with pedal attachments. "It is such a simple type of pump and suitable for direct pedaling for heads of 3 to 8 meters that it is, I think, worth developing" Wilson notes that some traditional water lifting devices in India require 4 men to raise the same volume of water that one man on a pedal-power pump could lift.

An optimum stationary pedal power unit, called a "dynapod," is described. "It takes the drive forward and you can gear it down for something like a winch or gear it up for a winnowing fan ... One of the requirements in a stationary application is a flywheel to steady out the torque, and here the flywheel is made from a bicycle wheel with cement filling in between the spokes."

Other pedal-powered machines shown are the traditional Chinese square pallet chain pump (also called the "water ladder"); a two-person powered milling machine; a hand driven winnowing machine which could be adapted to use pedal power; a peanut thresher (see drawing); and a cassava grinder.

Notes on an improved cycle rickshaw (three-wheeled pedicab) are included, explaining how two bicycle "freewheels" are combined to form a differential—a device that allows a rickshaw with two rear wheels to turn corners with the two wheels rotating at different speeds. The author suggests a design for local production of bicycles in developing countries, relying on sheet steel and angle iron instead of imported steel tubes; he has built prototypes. The "Oxtrike," a rickshaw using these materials, also has a very low-cost 3-speed gearbox to allow easy starting and climbing hills.

Design for a Pedal-Driven Power Unit for Transport and Machine Uses in Developing Countries, MF 19-405, report, 27 pages, by David Weightman of Lanchester Polytechnic for the Intermediate Technology Development Group Transport Panel, 1976, out of print.

This report describes a proposed pedal-powered unit for use in rural areas of developing countries. The author discusses the need for and the desired characteristics of such a device, and the range of human power outputs that is possible. Ten photographs and a number of drawings are included.

An attached bicycle, an integral pedal drive mechanism, and a dynapod are compared as alternative ways to use pedal power efficiently for different machines and circumstances. The author lists a wide variety of agricultural and workshop equipment that is suitable for pedal power, including winnowers, threshers, grain mills, cassava grinders, maize shellers, winch plows, coffee pulpers, winches, blowers, air compressors, bandsaws, drills, grindstones, lathes, and potter's wheels.

For maximum utility and lowest cost, the author proposes a design for a one wheeled basic unit. It could be used to power equipment, and could have a two wheeled trailer attached to allow use as a tricycle for transport. It is not a proven design, but suggests an interesting avenue for further investigation.

Foot Power (Bike Generator Plans), MF 19-415, 4 pages, 1983, $10.00 postpaid from North Shore Ecology Center, 964 Greenbay Road, Winnetka, Illinois 60092, USA.

These are non-detailed drawings, with very little text. They show mechanical setup, and electrical wiring; the general idea of using a bike to run a generator. Three different designs.

The system provides a 12-volt power source and can be used to charge auto batteries. The bike can also be used to operate grinders and pumps.

Note: It is generally said that human beings can produce about 75 watts when pedaling at a comfortable speed that can be maintained for an hour or more. Also, 12-volt electricity requires very large diameter wires if carried over any distance; otherwise there will be large losses of electricity due to the resistance of the wire.

The Use of Pedal Power for Agriculture and Transport in Developing Countries, MF 19-436, report, 22 pages, by David Weight man of the Faculty of Art and Design of Lanchester Polytechnic for the ITDG Transport Panel, England, out of print.

"This report examines the existing and potential applications of pedal power for simple agricultural machinery and transport devices in developing countries." For these uses, pedal power is compared to other power sources, such as draft animals, electric motors, biogas plants, wind machines, and internal combustion engines. Built-in pedal and treadle mechanisms, separate pedal drive units, and bicycle-connected drive systems are all compared.

"Both treadle and pedal actions are used to drive machinery The treadle action is commonly operated by one leg, only using half the available power, but enabling the operator to support himself on the other leg and load the machine. Treadle mechanisms are commonly inefficient and much higher power outputs are obtained from the pedal crank arrangement." However, pedal drive systems restrict the operator's freedom of movement, making lathes, potter's wheels, and sewing machines better suited to a different foot-powered approach.

"If more widely used, the lower speeds and lower axle loadings (of pedal powered vehicles) could enable savings in rural road construction costs to be made . . . Certainly the Chinese transport system, being based on the bicycle rather than the car or lorry, indicates the particular suitability of pedal power to the transport requirements of developing countries."

No photos or drawings included.

Manege: Animal-Driven Power Gear, MF 19-402, 30-page booklet with separate 8-page leaflet containing instructions for associated machinery, by U.N. Division of Narcotic Drugs, 1975, out of print.

The manege is adapted to any task that can use mechanical power transmitted through a drive shaft—especially agricultural activities such as threshing grain. The booklet describes two sizes of the manege, along with five associated pieces of equipment that can be operated with it: thresher, chaff-cutting chopper, grinding mill, winnower, and root-cutter. All of the above pieces of equipment are on operating display at the Laboratoire de Techniques Agricoles et Horticoles de Chatelaine, near the U.N. office in Geneva.

"The animal-driven power gear works on the same principle as a bicycle ... an arrangement of levers and gears that transforms slow leg movement into the speedy rotation of a wheel .... Two wooden bars or levers, each about 4 meters long, are bolted to the center of the large horizontal input gear. They extend like two spokes of a large wheel." Speed of rotation is increased by a factor of 50. Equipment to be operated is located 10 meters away from the center of the power gear.

No complex or precision parts are necessary. The production of all the components in developing countries should not present serious problems. Gears are rough iron casting which can be made from scrap metal. Melting and pouring facilities are needed, as are sand molds. The gears are used just as they come from the mold— no finishing. Other metal parts could be forged by a reasonably-skilled blacksmith. Only machining requirement: a drill to cut holes for bolts to join the components. Animal fat can be used for occasional lubrication.

The instructions for use of the associated equipment give technical specifications and a description of the operation of each of these pieces of equipment.

Photos but no detailed plans are given for the manege and the associated equipment. With a great deal of imagination, only the manege could be constructed with this booklet alone. The U.N. Division of Narcotic Drugs may be willing to send technical drawings.

The Heat Generator, MF 19-437, book, 108 pages, by Reinhold Metzler, 1983, Swiss Francs 22.00 from SKAT.

The heat generator is essentially a fan turning in a closed box, converting mechanical power on the shaft into heat as it stirs up the air. In small water powered mills this may allow some very interesting possibilities for small industry applications for drying crops or boiling liquids. This book reviews some heat using small industries in Nepal, discusses the economics of the heat generator as compared to several alternatives, and provides construction drawings of the equipment. The author concludes that under certain circumstances a heat generator would have the lowest unit cost of energy.

The technical attractiveness of this technology is unfortunately not matched by its financial appeal, at least for Nepal. To make his case that the heat generator would provide low-cost energy, Metzler assumes the following: it will be used with a turbine mill that is already installed and underutilized, full capacity utilization of the heat generator will be achieved, maintenance costs will be low (3.5%), fuelwood for small industries will all be purchased, and a low real interest rate (after inflation) of 5.5% can be achieved on the invested capital ($800 plus 30% of the mill investment— $2100—for a 5-kw output). He neglects the facts that local firewood consuming units are often built at virtually no cash cost by family members, that in the rural areas firewood is usually gathered rather than purchased, that these small industries are usually seasonal and part-time, and that small investments in design improvements in small industry stoves and kilns can yield large fuel savings (e.g.. 33%). When all of these factors are taken into account, the heat generator is likely to produce energy that costs at least twice as much and requires an investment at least 10 times as much as the fuelwood alternatives.

In other countries and under other circumstances, there may be a place for this device, and therefore we include it here.

Hot Water, MF 19-438, booklet, 31 pages, by S. and C. Morgan, D. and S. Taylor, 1974, out of print in 1981.

Drawings, materials lists, and step-by-step construction details are given for three kinds of solar collectors, hot water storage tank connections (pressure and drum), and water heater adaptations for wood and coal burning units. Drawings are not to scale.

"If you are running a pressure system you must use a storage tank built to operate under pressure. An oil drum and similar units do *not* qualify. They will deform and burst under pressure greater than 10 pounds per square inch ... (However) a clean, 30-55 gallon drum will serve as a hot water storage tank for a *non-pressure* system."

The authors claim that "you can adapt any wood or coal burning unit to include a water heating device. Essentially this is a coil system. A tightly coiled copper tube is inserted into the chimney stack or stove pipe. The water feeds through the coil and into a storage tank." (Editor's note: The drawback to this kind of system is a large build-up of creosote condensation on the copper tubing, especially with inefficient stoves. This must be cleaned regularly; a heavy coating of creosote reduces the efficiency of heat transfer to the water, and increases the risk of a chimney fire.)

The Haybox, MF 19-419, pamphlet, 1977, Low Energy Systems, Ireland, out of print in 1985.

This describes the principles of a fireless cooker. Ideas for design and materials are given. For use with foods which can be cooked slowly (2-4 hours): beans, sauces, stews. The food is brought to a boil in a heavy pot, then removed from the heat and placed inside the Haybox. It cooks in its own heat which is unable to escape.

Food or Fuel: New Competition for the World's Cropland, Worldwatch Paper 35, MF 19-414, 43 pages, by Lester Brown, 1980, $2.00 from Worldwatch Institute, 1776 Massachusetts Avenue N.W., Washington D.C. 20036, USA.

This well documented paper claims that if present trends continue, the world's alcohol fuel programs will be taking food away from the poor, especially the urban poor in developing countries. Full scale national alcohol fuel programs could easily consume all of the surplus crops of the major grain exporting countries.

Operating a typical American ear 10,000 miles/year at 15 mpg would require almost 8 acres of cropland for the alcohol fuel—enough to feed 39 people in the developing countries or 9 people in the United States. (These figures do not include the amount of liquid fuel needed to produce the grain in the first place.)

In Brazil, "the decision to turn to energy crops to fuel the country's rapidly growing fleet of automobiles is certain to drive food prices upward, thus leading to more severe malnutrition among the poor. In effect, the more affluent one-fifth of the population who own most of the automobiles will dramatically increase their individual claims on crop-land from roughly one to at least three acres, further squeezing the millions who are at the low end of the Brazilian economic ladder."

"Brazilian officials claim that the production of energy crops will be in addition to rather than in competition with that of food crops. Yet energy crops compete not only for land but also for agricultural investment capital, water, fertilizer, farm management skills, farm-to-market roads, agricultural credit, and technical advisory services."

"A carefully designed alcohol fuel program based on forest products and cellulosic materials of agricultural origin could become an important source of fuel, one that would not compete with food production."

Fuel Alcohol Production: A Selective Survey of Operating Systems, booklet #FE-3, MF 19-416, 48 pages, 1981, $5.00 from National Center for Appropriate Technology, P.O. Box 3838, Butte, Montana 59702, USA.

Surveys eight intermediate scale fuel alcohol production operations in a brief yet pertinent and very informative overview. The plants covered demonstrate a cross section of the available options, and the accompanying diagrams and charts make this a valuable resource for those considering going into fuel alcohol production.

Fuel from Farms: A Guide to Small Scale Ethanol Production, MF 19417, book, 163 pages, by the Solar Energy Research Institute, 1980, accession no. SERI/ SP-451-519, paper copies $5.75 domestic, $11.50 foreign; microfiche $8.00 domestic, $16.00 foreign; from NTIS.

This Solar Energy Research Institute publication is a part of the Department of Energy's effort to encourage the production of alcohol for fuel in the United States. It "... presents the current status of on-farm fermentation ethanol production as well as an overview of some of the technical and economic factors. Tools such as decision and planning worksheets and a sample business plan for use in exploring whether or not to go into ethanol production are given. Specifics in production including information on the raw materials, system components, and operational requirements are also provided. Recommendation of any particular process is deliberately avoided because the choice must be tailored to the needs of each individual producer. The emphasis is on providing the facts necessary to make informed judgments."

This analysis is aimed at the American farmer, demonstrating how an ethanol plant can support and complement other farm activities. Surplus grains and spoiled or marginal crops can provide the feedstock base for ethanol production, which can then be mixed with gasoline or burned directly in farm vehicles. The remainder can be sold to blenders of "gasohol" (a commercially available fuel mixture composed of 90% gasoline and 10% ethanol). The solid byproduct can be fed directly to animals or mixed with other fodder as an animal feed supplement.

While ethanol can be produced from a wide variety of crops and agricultural byproducts and wastes, profitable production depends on many factors such as current prices of feedstocks, availability of a low-cost source of fuel for the distillery apparatus, and how much of the ethanol produced would be used directly by the farmer. Another key factor is high initial equipment investment for the cookers, wells, pumps, still, condensers, and storage tanks. The sample business plan includes a feasibility analysis of a 25-gallon/hour installation on a 1,200 acre farm and feedlot operation, and assumes an initial plant and equipment investment of nearly $125,000. This is hardly small-scale in most countries.

It is clear that farm-based production of ethanol is not the whole solution to increasing scarcity and cost of petroleum fuels. Even if all the crop land in the United States were devoted to cultivation of ethanol feedstocks, the fuel produced would not meet current demand from the transportation sector alone. A move toward renewable sources of energy is, however, crucial to a sustainable agriculture. Decentralized ethanol production may be a way for some American farmers to reduce their dependence on traditional fuel sources.

Makin' It On the Farm: Alcohol Fuel is the Road to Energy Independence, book, 87 pages, by Mieki Nellis, 1979, $2.95 plus $1.05 postage from Mieki Nellis, American Agriculture News, 603 North Main, Cleburne, Texas 76031, USA.

This low-cost report has been published in the belief that small-scale ethanol production can be an important step toward viability for the American family farm. "Community size alcohol plants using locally grown farm products could make towns independent of Big Oil almost overnight. Alcohol fuel plants would ... provide fuel, use up those 'burdensome surpluses' that are blamed for depressing farm prices, and provide a high-protein feed byproduct for local use that is oftentimes as valuable as the raw commodity that went into the alcohol ... The farmer has the advantage over large alcohol plants because he can put up a small plant in a few weeks, compared to a two-year lead time on large plants. The farmer can use his own wastes when they are available ... He can use the crops he grows best, produce as much fuel as he needs, adjust his livestock numbers for the amount of high-protein feed he will produce, and work at making fuel during slack times."

The core of this book is a discussion of how ethanol is produced by fermentation and distillation of mash made from grains and other crops. Several brief ease studies document construction and performance of privately and cooperatively financed plants producing up to 30 gallons of fuel-grade alcohol per hour, fired with crop residues and/or steam injection. All the plants described involve an airtight vat or tank for fermentation of the grain mixture, a vertical column through which alcohol vapors rise, and a condensing apparatus. Drawings and parts lists are provided for construction of a plant with three fermentation tanks and distillation columns. (How to generate the dry steam which vaporizes the alcohol in the columns is not explained.) The authors claim that this plant can produce about 30 gallons/hour of 192 proof alcohol (96% ethanol, 4% water).

Other chapters briefly cover simple solar ethanol stills, ideas for using waste irrigation pump heat in alcohol plants, and modifications to improve performance of engines burning alcohol fuels. Appendices include lists of alcohol plant manufacturers, informative papers, farm products that can be used to make alcohol, and a glossary.

Fuel from Farms (see review) gives a better cost and technical analysis of ethanol plants which produce a relatively high volume of high-quality alcohol. **Makin' It On The Farm** stresses a low-investment, do-it-yourself approach. For this reason it should be a more useful resource for many family farmers and groups in developing countries interested in alcohol fuels. These are the only two alcohol fuel books we are aware of that are not simply high-priced booklets full of exaggerated claims.

Steam Power, MF 19-435, quarterly magazine, 60 pages, $17.00 for one year from The Steam Centre, Station Road, Kirk Michael, Isle of Man, United Kingdom; out of print.

This magazine reports on the latest advances and most useful technologies in steam power. It covers many different steam power topics, such as vehicles, boats sawmills, engine plans, history, solar steam power, boilers, fuels, machine shop techniques for making equipment, and conferences.

Letters from interested individuals and many advertisements for kits and plans for fully functional steam engines help make this a useful magazine. Well-illustrated. Back issues are available.

Model Stationary and Marine Steam Engines, MF 19-423, book, 168 pages, by K.N. Harris, 1964, Model and Allied Publications, U.K., out of print in 1986.

A detailed treatment of the design of small steam engines for many different uses is provided in this book. Readers who would like to build small-scale steam engines should find it valuable. The model engines shown are 1 hp and smaller in rated power.

There are no steam engine construction plans contained in this book, but the design principles should be valuable when building a steam engine from plans acquired elsewhere. Knowledge of metalworking, including lathe techniques, is an important part of steam engine construction and necessary for effective use of this book. Many illustrations.

Model Boilers and Boilermaking, MF 19-422, paperback hook, 185 pages, by K.N. Harris, 1967, revised edition 1984, Model and Allied Publications, U.K., out of print in 1986.

Steam engines cannot operate without steam, and the steam boiler is where steam is produced and fuel is consumed. This book presents the theory and construction of small steam boilers. These boilers can be used to power engines of up to several horsepower. There are illustrations covering many types of boilers and fuel systems. Safety considerations are carefully outlined for both boiler construction and operation.

"Fig. 3-32 shows the Babcock, probably one of the most extensively used boilers in full-size pattern for both land and marine work."

A very useful book for anyone interested in producing steam boilers for steam engines or other uses such as heating.

The Planning, Installation and Maintenance of Low-Voltage Rural Electrification Systems and Subsystems, MF 19-425, book, 151 pages, 1979, VITA, out of print in 1985.

Originally compiled in 1969 by American electricians, this manual was written for the training of Peace Corps volunteers who were to be assigned to rural electrification projects in developing countries. An introductory chapter provides a simplified introduction to electrical theory. Succeeding sections discuss wiring of houses, wiring for distributing power to houses, and connection of a village-scale electrification system to a generation plant or other power source.

Some attention is given to the differences between electrical installations in rural areas of developing countries and in the U.S. For example, the authors suggest that the trainees should wire two homes, one with standard techniques and one with "techniques applicable to mud construction " Yet in fact, the subsequent discussion assumes availability of commercial U.S. cable, connectors, meters, fuseboxes, switches, and other components. And the reader is informed that (convenience outlets) are normally located about 12 inches above floor level. They should be placed near (2 or 3 feet) corners of rooms rather than in the center of the wall to lessen the chance that they will be blocked by large pieces of furniture. With this perspective, the authors have missed an opportunity to present information on simpler systems (providing 50-100 watts per house) commonly found in developing countries.

A brief section on "Planning Requirements" explains how to calculate materials, labor, and overhead costs of an electrification project. There is no discussion of the needs for electricity in rural areas, how new electric installations might complement existing sources of power, or whether rural people will be able to afford their new electricity. Still, this manual provides a good overview and bibliography on the fundamentals of electricity and electrification.

Gemini Synchronous Inverter Systems, MF 19-418, booklet, 11 pages, Windworks, out of print; for other information on inverter systems write to Omnion Power Engineering Corp., 188 Hwy ES, Mukwonago, Wisconsin 53149, USA.

A synchronous inverter is a device that allows the connection of small alternative energy systems to the large electric distribution networks (grids). All of the available power from the alternative energy system is converted to alternating current (AC) for normal use. Any extra electricity need is supplied by the grid, and any surplus electricity generated is fed back to the grid, where it can be used by other consumers on the same grid. In this way, the owner of a small wind generator, microhydroelectric system, or solar photovoltaic array can use the grid in place of a costly battery storage system, or in place of no storage system at all. A synchronous inserter could be used with a combination 10 kw diesel generator set and wind generator, for example, if the wind generator never exceeds 1/3 the diesel generator capacity.

Windworks has a booklet and three similar papers describing the theory behind synchronous inserters and the possible applications. Synchronous inverters are available for single phase and three phase equipment, and cost (in early 1976) $160 per kw capacity for small units, down to $40 per kw capacity for 1000 kw installations.

Independent Energy (formerly **Alternative Sources of Energy**), MF 19439, magazine, ten issues each year, 60 pages average length, $78 for one year subscription in U.S. and Canada, $96 for one year to other countries (airmail only), from Independent Energy, 107 South Central Avenue, Milaca, Minnesota 56353, USA.

"The magazine of the independent power production industry," ASE serves an audience of engineers and developers. U.S. government tax credits and other legislation requiring utilities to buy surplus electricity from private producers created a burst of investment in renewable energy systems in the U.S. in the 1980s. This magazine covers the relatively high technology, electricity-producing technologies: 200-kw wind turbines in wind farms with thousands of machines, water turbines for installation in existing dams and old abandoned sites, solar photovoltaics, and cogeneration systems. Lots of coverage of equipment components.

ADDITIONAL REFERENCES ON ENERGY: GENERAL

More Other Homes and Garbage is an excellent reference book on most small-scale alternative energy systems; see GENERAL REFERENCES.

Two books on the maintenance and repair of small engines are reviewed in AGRICULTURAL TOOLS.

The Employment of Draft Animals in Agriculture reviews the power associated with draft animals and the use of animal power gears; see AGRICULTURAL TOOLS.