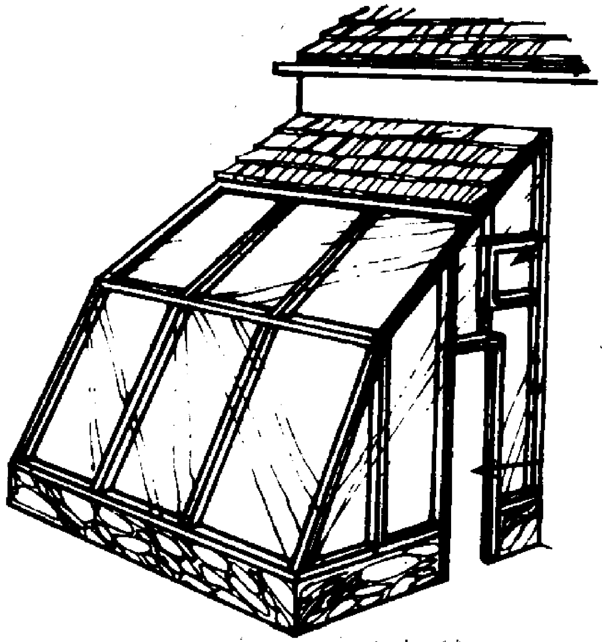

Energy: Solar

Increasingly, the term "solar technology" is being used to include any renewable energy system that directly or indirectly depends on the sun for energy. This includes waterpower, biogas, and wood fuels, for example, which are covered in separate chapters. This chapter is therefore concerned with direct use of solar energy.

Probably the most significant direct solar technology for the South is that of crop drying, which is covered in the chapter CROP DRYING, PRESERVATION AND STORAGE. Solar distillation for water purification has been covered in the WATER SUPPLY chapter.

In this chapter you will find materials on passive solar architecture for house heating, passive solar cooking for the tropics, solar greenhouses, water heaters, cookers, irrigation pumps, and photovoltaic cells. A good general survey of the technologies that may some day have relevance for the South can be found in **Technology for Solar Energy Utilization***; most of these, however, are not economically competitive at present.*

Several publications on passive solar architecture, now a booming field in the United States, are included. Passive solar design involves careful choices of building orientation, layout, location of glass windows, and materials to best take advantage of natural energy flows. Because they minimize the use of costly primary fuels for space heating and cooling, passive solar buildings will eventually dominate new construction in much of the United States. In North America and the other parts of the temperate zones, heating is usually the primary design objective. This is also true in parts of the Himalayas, the Andes, and other mountainous regions, where indigenous structures often reflect certain passive solar principles. In these areas of the South there is the potential for new applications of' recent advances in the field.

By contrast, the cooling of living spaces is the primary objective of passive solar design in the tropics. **Elements of Solar Architecture for Tropical Regions** *and* **Design for Climate: Guidelines for the Design of Low Cost Houses for the Climates of Kenya** *introduce the basic design considerations for passive solar cooling.*

Conventional greenhouses consume large quantities of energy to control the climatic conditions inside. Solar greenhouses, on the other hand, are heated primarily by the sun, and are often attached to houses to provide home heating as well. Low-cost designs using plastic sheeting and local materials may be of relevance in the mountainous regions of the South for supplementary home heating and food production. In the tropics greenhouses are probably mainly of interest because the vegetables grown inside require less water. Several publications reviewed here offer a look at current U.S. solar greenhouses.

Solar water heaters for domestic hot water are becoming more widely used in the industrialized nations as a response to the "energy crisis". They are well suited to temperate regions. A typical system consists of a flat plate collector and storage tank which holds water heated to about 140 degrees Fahrenheit (60 degrees Centigrade).

In tropical regions solar water heating systems can provide hot water for bathing, washing clothes and other uses. (Water heated in a normal flat plate collector does not boil, however, so this is not directly suited to water purification schemes.) Solar water heating in these circumstances is probably best used in health centers and urban homes where there is already a demand for hot water. Katmandu, Nepal is a good example of a city in a developing country with a well-established solar hot water heater industry.

For developing countries, the cost of materials for solar hot water heaters may make them rather expensive. There are more than a dozen ways to make a basic flat plate collector: there is some potential for very low cost designs, particularly if a low pressure (gravity-fed) system is being used. Such collectors can use metal other than copper, and even replace pipes altogether by using shallow tanks. The insulating material behind the collector plate can be local natural fiber such as coconut husks or rice hulls.

Solar cookers have been mentioned as a possible alternative in fuel-short and deforested regions. The 1962 publication **Evaluation of Solar Cookers** *offers a look at many designs, including most of those still being tested today. The high cost, awkward operation, slowness, and inconvenience of outdoor cooking have prevented this technology from finding a niche. Nevertheless, these devices remain a fixture at research centers and exhibitions, where they regularly amaze visitors. To our knowledge, despite two decades of scattered attempts, there are no examples of the successful introduction of solar cookers.*

The use of solar energy to drive engines for irrigation water pumps has recently received a great deal of attention. In this application, flat plate collectors provide hot water, which is used to heat liquid gas. The gas expands and drives the engine. The gas then passes through a condenser, where it is cooled by the well water, and the cycle is then repeated. This appears to be one of those solar energy applications that is technically but not economically feasible in developing countries. Though the costs seem to be dropping below $25,000 per installed kw of capacity (the level of a few years ago) they are a long way from being affordable. Locally-built water pumping windmills appear to be a far more cost-effective alternative in areas with even relatively low average wind speeds. In fact, the most thoroughly tested solar pump designs seem likely to remain technological dead ends, built in poor countries only through the intervention of rich country aid *programs. Some of the completely new concepts in solar pump designs may prove more fruitful.*

Photovoltaic cells that produce electricity from sunlight will have a place in water pumping and many other high value tasks as the price of these cells comes down significantly. For lowest cost and greatest simplicity, solar pump systems can be designed without electrical storage equipment, and such systems may one day provide important amounts of irrigation water to the world's small farmers. The photovoltaic cells themselves will continue to be a relatively high technology, imported product in most developing countries. The foreign exchange requirements for photovoltaic cell imports are likely to be a serious barrier to widespread use. In addition, while the decentralized energy production offered is well-matched to settlement patterns in the rural South, electricity is not an energy form well-matched to the energy needs of these communities, where cooking, draft power, and transport are the important energy consuming tasks along with irrigation pumping. A whole assortment of electrical equipment would be needed to store and make use of solar electricity, and very little of this equipment could be produced or afforded in the villages. The near-term applications are lighting and remote communications equipment in government buildings and the homes of the wealthy; these applications are already booming in some places because of the high cost of the alternatives. For an excellent introduction to the subject of photovoltaics and the associated equipment, see **Solar Powered Electricity** *and* **Solar Photovoltaic Products: A guide for Development Workers**.

The sun's energy is "available" everywhere, yet it is also a diffuse or low-grade energy form. This means that while solar energy is an excellent, low-cost means of creating temperature differences of tens of degrees for drying and heating, it is inevitably difficult and expensive to collect and concentrate solar energy to generate electricity or perform mechanical work. For this reason, drying, heating, and cooling are the most practical solar applications for most communities in the South.

Technology for Solar Energy Utilization, Document NO. ID/202, MF 23-563, 1977 conference report, 155 pages, 1978, in English, French, or Spanish, free to local groups in developing countries, $12.00 to others, Sales No. 78IIB, from United Nations Industrial Development Organization, P.O. Box 300, A-1400, Vienna, Austria.

This is a good overview of some solar energy technologies that may eventually have relevance for developing countries. Most of the solar technologies presented are technically feasible and proven. Because they are unusual they have attracted the attention of scientists and engineers looking for exciting new technologies to work on. Yet most of these technologies are far too expensive for use in the South. Indeed, probably the majority of the technologies presented would at present be reasonable only in an isolated desert region of a rich country. On the other hand, some of these technologies may one day prove economically attractive.

A good state-of-the-art review at the beginning of the book concludes that solar distillation, solar drying, and solar water heating (if needed) are currently attractive in some circumstances. Solar engines, solar water pumps, solar photocells for electricity, and solar refrigeration are labeled not yet attractive. Later, in the contributed articles, favorable evaluation is made of solar timber kilns for decentralized applications, and Tom Lawand provides a thoughtful examination of the potential for solar cookers and solar dryers. The rest of the articles (a solar electric power plant, conversion of solar into mechanical energy, water pumps, flat plate collectors, refrigeration and cooling, active space heating and cooling) review technologies which cost far more than the poor can afford.

UNIDO suggests the local manufacture of low temperature solar devices in the near future and applied research and development efforts for high temperature applications in the more distant future.

Recommended as a reference book for those active in the solar energy field in developing countries.

Solar Water Heaters in Nepal, MF 23-560, book, 27 pages, by Andreas Bachmann, 1977, free photocopies from SDC; also available from SKAT and ITDG.

Here is a rare example of a book on solar water heating from a developing country. BYS (Balaju Yantra Shala) Plumbing Division has built systems in Nepal to supply hot water for bathing, washing clothes and cooking. While no detailed drawings are presented, the BYS designs are discussed, component by component. Specifications for the collector and storage tank are given, along with qualitative descriptions of construction and maintenance procedures.

Two systems are described: 1) a thermosiphon (natural circulation) system with separate collector and storage tank, and 2) a "flat tank" collector, where the collector also functions as the storage tank. This is less expensive, but only supplies a small amount of heated water at a time

A Solar Water Heater Workshop Manual, MF 23-559, construction manual, 82 pages, 1979, Ecotope Group, out of print.

This manual is designed to be used in a teaching situation, with an experienced leader who can provide background knowledge and teach construction techniques. Four pages are devoted to organizing a training workshop.

Ecotope Group and Rain Magazine staff have run these workshops in the Northwestern U.S. for several years, usually teaching 30 or more people from a community organization to build a solar water heater in a two day period. By teaching members of existing groups together, skills are transferred to a naturally supportive network, and more solar water heaters are likely to be eventually constructed. This approach could be used anywhere, with many different technologies.

The manual contains step-by-step instructions, with drawings, for building and installing a solar water heater. This includes siting the system, piping for natural circulation, and various open and closed loop storage alternatives.

Bread Box Water Heater, MF 23-531, one large sheet of plans, $5.00 surface mail or $7.00 foreign airmail from Zomeworks, P.O. Box 25805, Albuquerque, New Mexico 87125, USA.

Drawings and a description of the principles, design, and construction of a simple and effective solar water heater are provided.

"Two tanks are painted black and placed in a glass-covered insulated box with insulated reflecting doors—the sun shines through the glass onto the tank and also bounces off the reflecting doors onto the tanks .... The reflectors on the box serve to wrap the sun around the tanks rather than focus the sun on the tanks .... The doors are opened during the day to receive the sun and then closed at night to conserve heat."

"The plans describe the construction of a solar hot water heater using two 30-gallon electric hot water tanks with electric back-up. (30-gallon drums can be substituted for the water heater tanks.) The plans also discuss the principles of the design so that an interested person can vary the construction and know generally what to expect. The plans stress the relative importance of different aspects of the design—where you must be very careful and where you need not be so careful."

The Passive Solar Energy Book, MF 23-544, 448 pages, by Edward Mazria, 1975, Rodale Press, out of print.

This was formerly the best book available on the design of passive solar homes and buildings. ("Passive solar" space heating relies on direct solar energy, the orientation of the structure, and the natural heat storing capabilities of selected floor and wall materials.) The format was chosen to allow the reader to go through the book in about an hour, covering only the most important concepts, and then come back for more detailed technical information on each topic. The excellent illustrations also make this a valuable tool for teaching basic concepts in a classroom.

The author begins with the fundamentals of solar energy and heat theory. He then introduces the major successful design elements and strategies, such as masonry thermal storage, Trombe walls, attached greenhouses and roof ponds. His presentation on building orientation, north side protection, and location of different kinds of living spaces helps illustrate how crucial these factors are to successful passive solar design. The important contributions offered by movable insulation, reflectors, and shading devices, and the concepts behind summer cooling are also discussed.

The author notes that "more energy is consumed in the construction of a building than will be used in many years of operation," and recommends the use of relatively low-energy-consuming materials such as "adobe, soil-cement, brick, stone, concrete, and water in containers; for finish materials use wood, plywood, particle board and gypsum board."

A full third of this book contains the information needed for calculating solar angles, solar radiation falling on tilted and vertical surfaces, shading effects, space heat loss in winter, solar space heat gains and auxiliary heating required. Data is included on the solar radiation (insolation) received and space heating needs for major U.S. cities and regions.

Highly recommended.

Homegrown Sundwellings, MF 23-537, book, 136 pages, by Peter van Dresser, 1977 and 1979, $7.95 plus $1.50 shipping and handling from The Lightning Tree, P.O. Box 1837, Santa Fe, New Mexico 87504, USA.

Peter van Dresser, one of the pioneers of solar-heated houses, built his first one in 1958. His book summarizes a two-year program to develop low-cost, owner-built, solar-heated houses. It should be read for its sound observations on sensible solar construction based on local materials, and as an introduction to passive solar home design. More extensive information for designing passive solar homes can be found in **The Passive Solar Energy Book** and **The Solar Home Book**.

Although "the Sundwellings concept is firmly rooted in the living construction traditions as well as the socioeconomic circumstances of a natural ecological region—the uplands of northern New Mexico ... it reveals principles of universal applicability .... To construct using renewable resources is not a sentimental fad in an area without exportable products to pay for imports .... In a low cash economy, it is the interactions of human resources with the immediate materials of the land that provide for the richness and fullness of life."

The total solar energy received in winter at sites in Montana, New Mexico and Arizona is greater than the requirement for home heating. The challenge is to store this energy effectively. "The basic strategy is to design the house so that its own masses—mainly walls and floors—are so placed, proportioned, and surfaced that they will receive and store a large measure of incoming solar energy during the daylight hours and will gently release this stored heat to the house interior during the succeeding night hours or cloudy days .... A traditional New Mexican floor—either of treated and filled adobe clay or of brick or flagstone laid over sand—is very well-suited .... Its sheer mass gives it great capacity to store this heat with a very slight rise in temperature. If we visualize such a floor 12 inches deep in a room 16 feet square with one exterior wall and an average window, warmed to a mere 72°F (22°C) ... it will store 40,000 BTUs of heat which will be released into the room as it cools down to say, 650F (18°C). This is sufficient heat to take care of a well-insulated room for 26 hours, with an outdoor temperature of, say, 20°F (-7°C)."

The Solar Home Book, MF 23-554, book, 293 pages, by Anderson and Riordan, 1976, 1987 second edition $16.95 from Brick House Publishing Co., Francestown Turnpike, New Boston, New Hampshire 03070, USA.

This is one of the best books that attempt to make the design principles of solar heated homes understandable and usable for the average person. The emphasis is on passive systems (in which the building itself acts as a solar collector and storage unit, without special circulatory systems). Also covered are systems that can be added to existing homes. A chapter on do-it-yourself methods includes insulation, window box heaters, and attached greenhouses. Altogether, there are about 40 pages on the design of solar water heaters.

"Homes can be designed to respond to local climates .... Simple low-technology methods are cheaper and more reliable than the many complex, high-technology devices being employed to harness the sun's energy .... Anyone with good building skills and a knowledge of materials can take advantage of these simple methods ...." Highly recommended for Americans and other people in temperate climates interested in building a solar-heated home.

Basic Principles of Passive Solar Design, MF 23-529, papery pages, by Fred Hopman, 1978, free from SDC (SATA) or SKAT.

SATA has reprinted this paper from the Taos Solar Association of New Mexico, USA. The author presents operating principles and design considerations for passive space heating and cooling systems, including examples of direct gain designs, Trombe walls, roof ponds, attached greenhouses and water circulation systems. Although the examples use Western architectural styles, this excellent introduction to passive solar principles is relevant to building construction in cold climates throughout the world.

Elements of Solar Architecture for Tropical Regions, MF 23-534, booklet, 23 pages, by Roland Stultz, 1980, 1983 edition Sw. Fr. 6.50 from SKAT; also available in Spanish; also available from VITA.

One of only a few publications on the design of solar buildings in tropical regions, where cooling and protection from heat are the major objectives. This booklet concentrates on proper building orientation; cross ventilation; reflecting, absorbing, and insulating building materials; shading with trees, shutters, roof overhangs and other techniques; and evaporation of water (in arid climates) for cooling. Tables indicate some of the different considerations for buildings in humid vs. arid regions. A good illustrated introduction to the topic; many of these concepts have long been a part of indigenous architecture in different parts of the world, but have begun to disappear in the last few decades.

Solar Dwelling Design Concepts, MF 23-551, book, 146 pages, American Institute of Architects Research Corporation, out of print.

This volume presents principles in easy-to-understand terms for both passive and active solar heating and cooling of homes. Intended for architects, the emphasis is on the integration of solar concepts with traditional Western home designs. Factors influencing design are also covered, such as climate comfort and choice of building site.

Thirty-two solar home designs are described, with architectural drawings, to show a variety of passive and active building concepts already in use. Although these designs are from the U.S., the concepts could be adapted by building designers in other temperate climates.

A Bibliography for the Solar Home Builder, MF 23-530, booklet, 38 pages, by Dr. Donald W. Aitken, 1979, out of print in 1986.

"The market is responding to the surging popularity of solar energy with a flood of books and reports .... Some of these are truly excellent, while others are thinly disguised attempts to sell something .... The following bibliography summarizes only the books and reports with which I am personally familiar and that I feel to be the most useful, honest, and worth the cost." This booklet describes 71 publications on solar home design, information for the beginning solar home builder, and advanced solar studies as well as a few general works on solar energy as an alternative for the future. It is especially useful because the annotations are cross referenced, with notes on which publications contain the most information on particular topics.

Also includes listings of solar energy societies and journals. A good "source book" on solar home building, oriented toward applications for the West Coast of the USA.

The Food and Heat Producing Solar Greenhouse: Design, Construction, Operation, MF 23-565, book, 159 pages, by Bill Yanda and Rick Fisher, 1980, $10.75 postpaid from John Muir Pubs., P.O. Box 613, Santa Fe, New Mexico 87504, USA.

An excellent construction manual for a low-cost attached greenhouse that can provide both some house heating and fresh vegetable production in cold climates. Many of these have been built by low-income families in the mountain regions of the western United States.

Although these designs come from a North American environment, it seems likely that they may be applied to the highlands of tropical countries and any colder areas of the globe where space heating is a priority. Attached greenhouses employ a "passive" solar heating concept. The structure acts as both a collector and a storage unit for solar energy, through the heat-absorbing combination of glass or plastic, concrete, adobe, stone and/or water-filled containers. During daylight hours, the last four of these substances store heat, and at night they radiate it to the living spaces. No expensive, complicated, or breakdown-prone devices such as pumps, heat exchangers, bulky collectors, or massive storage tanks are required. All that is needed is a good design and an active and alert person to regulate the vents, openings and natural energy flows in the dwelling.

An Attached Solar Greenhouse, MF 23-566, booklet, 18 pages, by Bill and Susan Yanda, 1976, $2.00 plus $1.50 shipping and handling from The Lightning Tree, P.O. Box 1837, Santa Fe, New Mexico 87504, USA.

"Solar greenhouses designed and built in northern New Mexico by the Solar Sustenance Project have proven that solar energy can be put to work now by low income families," state the authors of this short but stimulating booklet. Included are sketches, photos and a bilingual text in English and Spanish (the working drawings lack an effective Spanish translation). This brief volume preceded the more extensive construction manual **The Food and Heat Producing Solar Greenhouse** (see review).

Low-Cost Passive Solar Greenhouses: A Design and Construction Guide, MF 23-541, book, 174 pages, by Ron Alward and Andy Shapiro, 1980, $8.00 (order no. SHH-1) from the National Center for Appropriate Technology, P.O. Box 3838, Butte, Montana 59702, USA.

Considerations for building passive solar greenhouses for space heating and food production are presented in a very clear and thorough manual. Includes a review of alternatives, siting, detailed construction pointers for a variety of designs, operation and management methods, etc.

Highly recommended.

The Solar Greenhouse Book, MF 23-553, book, 344 pages, edited by James C. McCullagh, 1978, Rodale Press, out of print.

This book covers the design, siting, construction, use and maintenance of sun heated greenhouses. Such structures can be used from temperate regions to highland areas of the sub-tropics. Plans are presented for a variety of greenhouses for North American readers; others may find the general presentation to be valuable as well.

The effectiveness of these "passive" solar heated structures is dramatically shown by photos of greenhouses with snow outside and thriving plants inside. The appendix contains information on different types of glass and plastic window materials, suitable plants, available equipment, and a bibliography.

Proceedings of the Conference on Energy-Conserving, Solar-Heated Greenhouses, MF 23-546, book, 248 pages, edited by John Hayes and Drew Gillett, 1977, $9.00 ($5.00 to readers in developing countries) plus $3.00 shipping and handling from Marlboro College Greenhouse Conference, Attn: John Hayes, Marlboro College, Marlboro, Vermont 05344, USA.

This is a collection of papers and reports, with some plans for solar greenhouse construction. The topics covered include the theory, planning, construction and operation of solar greenhouses for food, heat and shelter. The reuse of household water and human wastes is also covered. The language is sometimes difficult for non-native English speakers.

"The greenhouse must also be looked at in light of its water conservation over field crop conditions. Authorities report water usage for greenhouse crops to be 1/10 to 1/30 of the field crop .... Tom Rolf of Silver City and the Chavez family of Anton Chico, devised simple systems to trap rain water and snow melt from the roofs of their homes, drain it into tanks in the greenhouse, and gravity feed the water to their plants."

Solar Photovoltaic Products: A Guide for Development Workers, MF 23-567, book, 127 pages, by Anthony Derriek, Catherine Francis and Varis Bokalders, revised edition 1991, ITDG (with The Stockholm Environment Institute and Swedish Missionary Council), £14.95 from ITDG.

Solar Photovoltaic (PV) panels have come down in price and become increasingly popular for use in providing small amounts of electricity in isolated locations away from the main power grids. PV panels still provide expensive electricity when measured on a kilowatt-hour basis, but this electricity often has a high value, and the alternatives can be even more expensive. The most valuable applications are typically water pumping, refrigeration, and telecommunications. There are more low-cost alternatives for lighting, although this is a common application of PV panels.

PV panels have high reliability and long expected lifetimes, and now cost about $4 per peak watt compared to $30 per peak watt in 1975. The authors emphasize "life cycle costing" in making their argument that solar photovoltaics have acceptable costs compared to the competition. However, these analyses always use a "discount rate" of 10%, which, while common in World Bank projects, does not accurately reflect the high interest rates and scarcity of capital typically faced at the local level. It is likely that a far higher discount rate better reflects the actual conditions and behavior of people in developing countries, and unfortunately this works against capital-intensive, long-life renewable energy technologies such as this one.

World maps of solar energy distribution during different times of the year are provided.

For the major applications, comparisons with alternatives are made, and sources of components and complete systems are provided.

Solar-Powered Electricity: A Survey of Photovoltaic Power in Developing Countries, MF 23-568, book, 87 pages, by Bernard McNelis, Anthony Derriek and Michael Starr, 1988, ITDG (with UNESCO), £10.50 from ITDG.

This volume is shorter, older, and less detailed than **Solar Photovoltaic Products**, which covers much of the same ground. However, this book provides more information in the short case studies, which help better understand the costs and problems faced in actual applications. Examples include water pumping, refrigeration, lighting, and rural electrification.

The Fuel Savers: A Kit of Solar Ideas for Existing Homes, MF 23-586, book, 60 pages, by Dan Scully, Don Prowler, and Bruce Anderson, 1976, $2.75 plus postage (limited number of copies available) from NORWESCAP, Inc., 350 Prospect Street, Phillipsburg, New Jersey 08865, USA.

A collection of 20 energy-conserving passive and active solar ideas and projects to be used on existing buildings in cold climates. Although intended for North American homes, we have included this book because the projects do not require manufactured solar components, and can be easily completed by the owner.

Included are insulating curtains and shutters, window box air heaters, greenhouses and a thermosiphon (natural circulation) water heater. A drawing and description of each project are given, without exact construction details; the energy savings or each project are discussed.

Useful only in cold climates as examples of simple, do-it-yourself energy conservation measures.

Window Box Solar Collector Design, MF 23-564, construction plans with text, large blueprint, 1978, $2.50 from Center for Rural Affairs, Box 763, Hartington, Nebraska 68739, USA.

A window box solar collector will heat a room. Air moves by natural circulation, requiring no fan. The six dimensional drawings in this design are somewhat hard to follow, but the design principles are clear. Local materials could be substituted in the design where needed.

Reaching Up, Reaching Out: A Guide to Organizing Local Solar Events, MF 23-548, book, 145 pages, by the Solar Energy Research Institute, 1979, stock number 061-000-00345-2, USGPO, out of print.

This "organizing manual" is designed to help groups and individuals organize themselves to achieve awareness of and control over the energy they use. Thirteen events are used as case studies, from solar water heater and solar greenhouse construction workshops to energy fairs and neighborhood energy conservation efforts. Suggestions are made for planning and carrying out these kinds of community events.

Half of the book is a bibliography on small-scale solar technologies (all U.S.), general organizing, and a directory of solar groups in the U.S.

The Solar Survey, Solar Energy: Suggested Readings, MF 23-557, booklet, 21 pages, 1979, $2.00 (order no. SHH-7) from National Center for Appropriate Technology, P.O. Box 3838, Butte, Montana 59701, USA.

A collection of 31 solar designs from various community groups across the U.S. The designs range from active water and air collectors to passive Trombe wall systems. For each entry, there is a short description and often a drawing (complete designs are not given). All were chosen as examples of low-cost, locally-built technologies.

The purpose of the survey is to exchange ideas and designs among community groups in the U.S. who work independently on similar projects. The specific technologies covered are not very relevant to developing countries.

A State-of-the-Art Survey of Solar Powered Irrigation Pumps, Solar Cookers, and Woodburning Stoves for Use in Sub-Saharan Africa, MF 23-562, book, 106 pages, by J. Walton, Jr., A. Roy, and S. Bomar, Jr., 1978, Engineering Experiment Station, Georgia Institute of Technology, out of print.

This is a survey of technologies which might help reduce the serious problems of deforestation and water shortage in the region just south of the Sahara Desert in Africa. Solar-powered irrigation pumps, solar cookers, and woodburning stoves are examined, and research recommendations made. Few construction details are provided.

Unfortunately, what seem to be the most promising technologies for carrying out the functions of lifting water and cooking are not treated in this volume. For example, low-cost, locally-made water pumping windmills (such as can be found in Crete and Thailand) appear to be cost-competitive in many moderately windy locations and far cheaper than the solar alternative. Improved stoves save more firewood per dollar than solar cookers and do not require imported materials.

This is a useful reference on solar-thermal irrigation pumps, which, at $25,000 per installed kw of capacity, seem forever doomed to serve as toys of rich country aid programs, and may even divert government funds in some countries from more useful pursuits. Solar photovoltaic pumping systems, which have more promise, are not covered. (Other renewable energy systems such as microhydroelectric turbines cost $600 to $2000 per installed kw of capacity, while locally-made water pumping windmills can cost roughly $2000 per installed kw of capacity.)

Evaluation of Solar Cookers, MF 23-535, booklet, 71 pages, by VITA, 1962 (reprinted 1977), out of print in 1985.

This 1962 report covers the early solar cooker designs, many of which are still being tried today. Cost (1962 prices), materials, cooking performance, and problems are presented for each of 12 parabolic reflector and 2 oven designs. Virtually all of the solar cookers that have been tested in recent years are based on designs already existing in 1962, or on ideas mentioned in this booklet.

The Solar Cookery Book: Everything Under the Sun, MF 23-550, book, 122 pages, by Beth and Dan Halacy, 1978, Peace Press, out of print.

The first third of this book is a construction manual for two types of solar cookers: a solar oven and a solar parabolic reflector hot plate. Most of the rest of the book is devoted to detailed descriptions of solar cooking methods, with many recipes for foods that can be solar cooked.

The Design and Development of a Solar Powered Refrigerator, MF 23-533, technical report, 74 pages, by R. Exell, S. Kornsakoo, and D. Wijeratna, 1976, $8.00 in Thailand, $10.00 in developing countries, $15.00 in developed countries, from Regional Energy Resources Information Center, Asian Institute of Technology, P.O. Box 2754, Bangkok 10501, Thailand.

This report describes work on an experimental solar refrigerator designed to be a village-size ice maker or cold storage unit. The experimental version can make 1-2 kg of ice per day in Thailand; larger capacities will be possible in future designs. The cost of the unit is figured to be $750. Ice produced in this unit is calculated to cost about 11 times the wholesale price of ice in Bangkok. This makes it unlikely that such units will be considered "appropriate village technologies" in the near future.

Refrigeration occurs in the night by vaporizing an ammonia solution. During the day, a flat plate collector uses solar energy to pressurize and condense the solution. This type of non-continuous refrigeration, while less efficient, has the advantages of needing no compressor or electricity. Thus it is suited to decentralized applications (operation requires only turning a few valves in the morning and at night).

Most of the report is quite technical. There is also a review of other solar refrigeration work from the last 30 years. Work on these concepts is continuing.

ADDITIONAL REFERENCES ON ENERGY: SOLAR

Proceedings of the Expert Working Group on the Use of Solar and Wind Energy; see ENERGY: GENERAL.

More Other Homes and Garbage has a very good section on passive and active solar energy systems; see GENERAL REFERENCES.

The use of photovoltaic cells for water pumping is covered in **The Potential for Small-Scale Solar-Powered Irrigation in Pakistan, Small-Scale Solar-Powered Irrigation Pumping Systems**, and **Solar Photovoltaics for Irrigation Water Pumping**, all in AGRICULTURAL TOOLS.