DOCUMENT RESUME

ED 175 716 SE 028 754

AUTHOR	Polk, Joyce
TITLE	Solar Energy - Solution or Pipedream?
INSTITUTION	Mississippi State Univ., State College. Cooperative Extension Service.
SPONS AGENCY	Department of Energy, Washington, D.C.
REPORT NO	MEEC-37
PUB DATE	78
GRANT	DOE-EU-7 -05-5873
NOTE	13p.: For related documents, see SE 028 747-757; contains occasional light and broken type
AVAILABLE FROM	Mississippi Energy Extension Center, P.O. Box 5406, Mississippi State, MS 39762 (no price quoted)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Curriculum Planning; *Energy; *Energy Conservation; Environmental Education; *Science Education; *Secondary Education; *Solar Radiation
IDENTIFIERS	*Energy Education; Mississippi; *Solar Energy

ABSTRACT

This series of lessons and class activities is designed for presentation in a sequence of nine class days. The collection is intended to provide the student in advanced science classes with awareness of the possibilities and limitations of solar energy as a potential solution to the energy crisis. Included are discussion of the following: (1) Solar energy variables (weather, geography, and day/night problems); (2) Characteristics of solar heating and cooling; (3) Construction of a solar collection; (4) Electrical production by solar cell; and (5) Characteristics of solar electrical production. (RE)

SOLAR ENERGY -- SOLUTION OR PIPEDREAM?

by Joyce Polk

Prepared for the 1978 Faculty Development Workshop, Mississippi Energy Extension Center and Golden Triangle Regional Educational Service Agency cooperating

This teaching unit was prepared with the support of the U.S. Department of Energy (DOE), Grant No. EU-78-G-05-5873. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author, and do not necessarily reflect the views of DOE.

For more information on this teacher's unit or others, contact:

Mississippi Energy Extension Center
P.O. Box 5406
Mississippi State, MS 39762
(601) 325-3137

TITLE:

Solar Energy - Solution or Pipedream?

RATIONALE:

Solar energy has become a household word and is being proclaimed by many as the answer to today's energy crisis. The sun is the source of almost all the energy used on earth. It is free; it shines everywhere. But is solar energy technologically sound or just a gimmick? The purpose of this unit is to examine present and past users of solar energy and to research its projected uses.

GOALS:

Students will become aware of the possibilities and the limitations of solar energy as a potential solution to the energy crisis.

SUBJECT AND AREA:

This unit is designed for use in advanced high school science classes.

OBJECTIVES:

The student will identify the variables of solar energy - intermittancy (day and night) intensity (season and geography) and interruption (cloud cover weather conditions).

The student will be able to identify important characteristics of the technology necessary for solar heating and cooling.

The student will construct a simple solar collector.

The student will compare the wattage produced by a solar cell with conventional methods of energy production.

The student will identify the major characteristics of photovoltaic energy.

DAY 1

Display pictures that show solar energy in use.

Initiate a class discussion of solar energy uses with a question. Do we use solar energy in our lives? Can we put it to better use? How effective is solar energy? What are possible problems in utilization of solar energy?

Have students set metal panels -- red, yellow, blue, black, white, silver -- in direct sunlight facing the sun. (Teacher may want to involve students in painting panels with metallic paint.) Thermometers should be attached to each panel and students may be asked to make predictions as to which will be coolest and warmest. Temperature should be checked and recorded after several hours.

Direct students to watch newspapers, periodicals, and other media for reports on use of solar energy.

Ask students to find at least one example of experimentation or use of solar energy prior to 1940.

DAY 2

Discuss findings recorded in day one experiment with metal panel. Discuss the relationship of findings to seasonal colors of clothing. Does the color of the roof of a building affect its interior temperature?

Allow students to share findings of research .. signed on day 1.

Day 3

Have a resource person discuss the use of solar energy in heating and cooling. This might be an engineer or a builder who has used solar principles in construction.

DAY 4, 5, 6

Construct a simple solar collector and carry out activities two and three. (See attached activity list). Others may be used as the teacher and student desire. Explanation follows.

DAY 7

Develop and deliver a lecture on solar collectors, using information available through libraries or federal energy information sources.

Show film #0499 "Here Comes the Sun." (Listed in bibliography).

DAY 8

Using Factsheet 4, (this is included in unit material) introduce the concept of solar photovoltaic energy.

DAY 9

Use the following experiment showing wattage of solar cell. Develop the concept that solar cells may be an alternative source of energy.

Materials: solar cell, volt meter, ammeter

Procedure: Connect solar cell to volt meter and ammeter on a board. Take instrument outside and have students determine best angle of cell to get maximum volt and ampere readings. Record data.

Back in the classroom have students compute wattage by multiplying volts by amps. Convert to kilowatts.

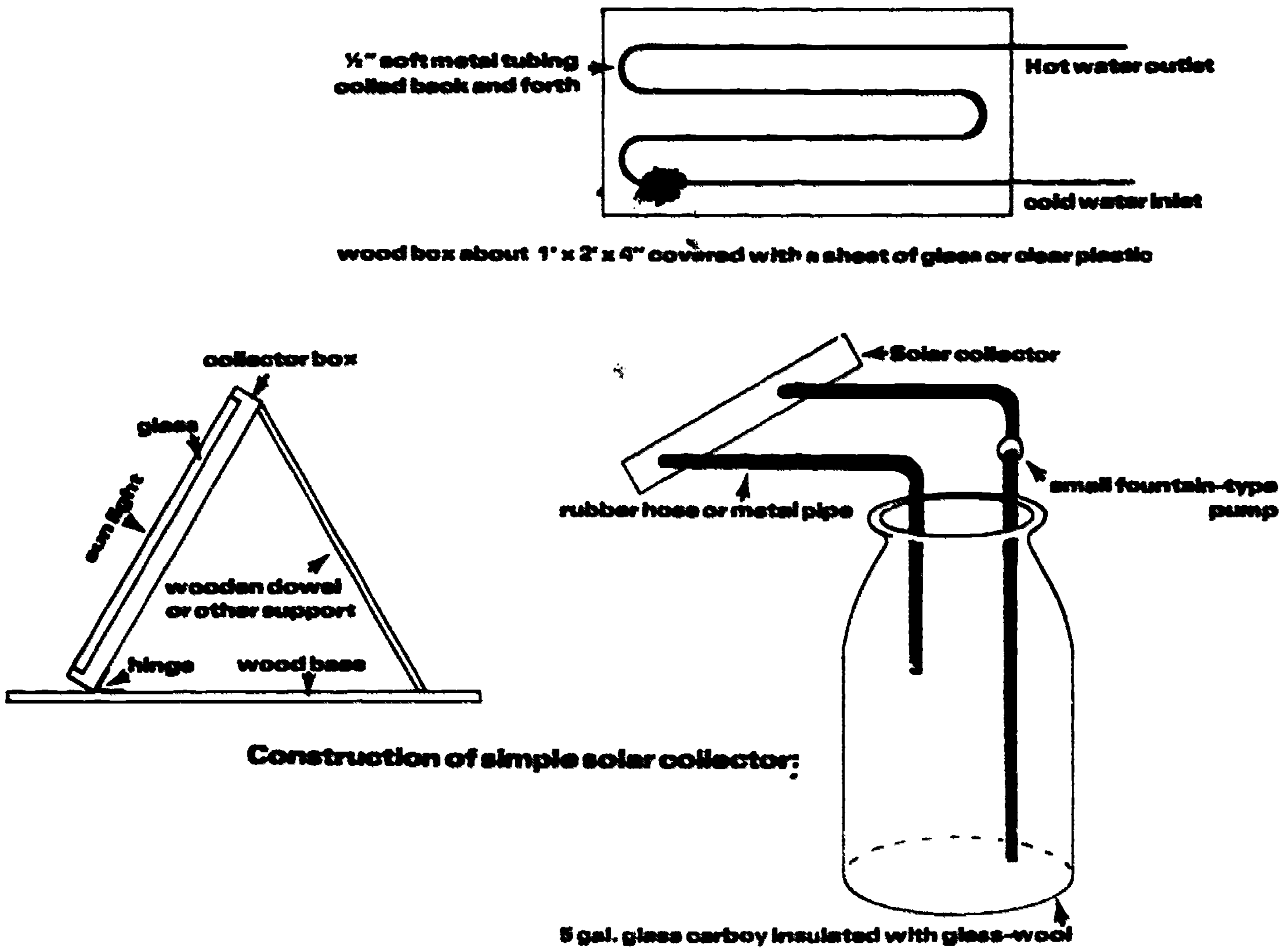
Questions for discussion:

1. How does wattage produced by the solar cell compare with the wattage required by some household appliances?
2. Could solar cells be used to power a city? a home?
3. How much surface area of solar cells would be required for power needs of a home?
4. What factors affect efficiency of a solar cell?

Background and technical information for this unit is attached in a series of fact sheets and publications which are available to all teachers. Sources for these teacher aids are listed in Bibliography, at the end of this unit.

Activity 1

Construction of simple solar collector:



Construct wooden box, place iron plate with tubing secured on surface inside, paint flat black, cover with glass and place on roof.

Water lines running from roof to classroom should be insulated. Soft rubber sheathing used by air-conditioner contractors should be ideal.

Pump should have a small flow rate but develop enough pressure to push water up to roof. Depending on climate, anti-freeze may be added to prevent bursting pipes in winter.

Recirculate water during daylight only and take temperature readings several times per day over a period of a few weeks. Determine maximum temperature reading.

Activity

Prepare three essentially identical collector systems and vary the tilt referenced to horizontal. Set one collector so measure of angle is equal to latitude above equator. Vary the other collectors and determine the most efficient placement for your geographic location.

Activity 3

Use three identical collector systems set at optimum angle. Connect the three heat reservoirs in series with each other. Determine if placing the collectors in series or parallel will be more efficient. Propose an explanation for your results.

Activity 4

To get more realistic results, place a load on your system by drawing off a small quantity of the hot water and make it up with cold. A flow rate of about .1 total volume per hour would be a reasonable load. Determine power rating of system by measuring flow rate and average temperature change. If possible collect data over several months.

Activity 5

To make the system more efficient, design and install a control device to detect the temperature increase in the collector and interconnect with the pump. The system should circulate water when there is a heat gain in the coil and shut off when not.

Activity 6

If small experimental system begins to operate effectively, design a larger model using a discarded hot water heater as the tank. Try to use the hot water produced for as many useful purposes as possible. Some examples are: hot water for washing glassware, design a heat exchange and use the heat to warm aquariums, use the heat to warm animal rooms, plant rooms or greenhouses.

HCP/U 3841-11

4. ELECTRICITY FROM THE SUN I
Solar Photovoltaic Energy

John M. Fowler

FACTSHEET

United States Department of Energy
Assistant Secretary for Intergovernmental and Institutional Relations
Education Programs Division

INTRODUCTION

As the electric bill rises steadily in spite of turned off lights and idle air conditioners, the sparkle of sunlight seems brighter and brighter. If only we could turn away from the fossilized secondary forms of solar energy and mainline it.

Solar radiation can be converted directly to electricity. This is accomplished routinely in the light meters built into popular camera equipment. The device which accomplishes this magic conversion, the solar cell, was developed in the 1950's at Bell Laboratories. The first strong commercial impetus came from the space program and much of the electronic equipment on the space vehicles is powered by similar devices. Solar cells are also used on communication and signaling equipment in isolated locations on this planet. To become a significant source of electrical energy for routine use, however, there must be several successful generations of research and development.

The best existing example of a large solar cell generator is the experimental 1000 watt (1 kw) array owned by the Mitre Corporation near Washington, D.C. It is constructed of 20 panels and each panel in turn contains 700 or so individual cells. It cost $30,000.

The present state of the art is summed up in the preceding three sentences. Solar cell arrays with large capacity for electric power production (1000 watts is about enough power for most household needs) can be constructed. They are, however, too expensive for practical use. Even with skyrocketing costs, conventional power plants can produce power at less than $1,000 per kilowatt.* The Mitre Corporation's array, at $30,000 per kilowatt, is the least expensive solar cell array (in terms of dollars per kilowatt) assembled up to 1975.

We will, in the sections which follow, describe how solar cells work, why they are expensive, and report on some of the budding ideas which may bring down their costs into the competitive range.

RESOURCES

The major attraction of solar energy is that it is free and plentiful. We have dwelt at some length in other "Fact Sheets" (see #7 "Solar Heating and Cooling", for instance) on the impressive size

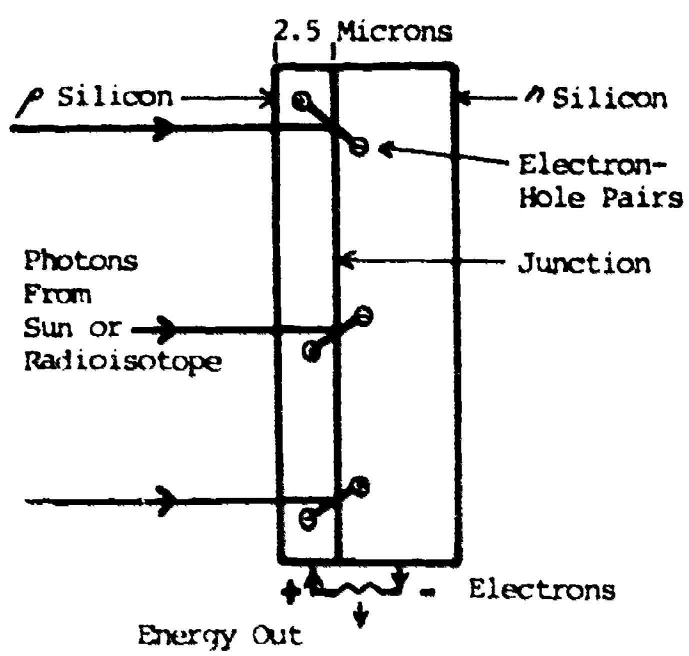
*Watts and kilowatts (1000 watts) are units of electric power. See the Glossary, Fact Sheet #18 for further definitions.

This material was produced by the National Science Teachers Association under contract No. EX-76-C-10-3841 with The Energy Research and Development Administration, now the U.S. Department of Energy. The facts, statistics, projections, and conclusions are those of the authors.

of the resource base. There is plenty of power available. The question is, how much can we get when it is needed-how do we run the lights at night? Even though solar cells do produce some energy from indirect light, storage will have to be provided for cloudy days. In Fact Sheet #7, there are maps showing the geographic and seasonal valuation of solar energy.

TECHNOLOGY

Although there are several ways by which radiant solar energy can be directly converted to electricity, the most promising method at the present is the "photovoltaic effect". "Photons," the "particles" which make up a beam of light, if they carry sufficient energy, can knock electrons loose from the atoms which they strike. The solar cell combines this property of light with the unusual properties of a "semiconductor"-the versatile devices which form the heart of transistors. A semiconductor consists of a junction between two dissimilar materials. A typical arrangement is shown below:



The p-region is transparent to light and very thin (about 3×10^{-4} cm or 0.001 inch). Photons of light entering this region, release electrons from the silicon atoms. The electrons flow in one direction across the junction and the holes move in the other direction. This sets up a potential difference, a voltage, and if circuitry is provided as shown, current will flow, electrons toward the positive terminal and holes in the opposite direction, and electric power will be available.

A high quality silicon solar cell is capable of producing a maximum current of about 30 milliamperes per cm^2 (0.030 amperes) and a maximum voltage of 500 millivolts (0.500 volts). The conditions for these maximum values are not, however, the same and the maximum power that can be generated in full sunlight is about 15 milliwatts/cm^2 (0.015 watts per square centimeter).

A typical solar cell is 2 cm by 2 cm, a surface area of 4 cm^2. Its power output is very small, about 0.60 watts and many cells must be connected together to obtain an appreciable power output. As an example, a 14 volt, one watt panel measures 150 x 150 x 30 millimeters (a surface area of 225 cm^2) and has a mass of one kilogram (about 2¼ pounds).

Silicon is the second most abundant material on the earth, it is the major constituent of common sand. It is thus not initially expensive, but to be efficient as a solar cell, it must be absolutely pure and, more importantly, it must be in a pure crystalline form. Such crystals are at present grown very slowly in small lots.

A cell is made by slicing a piece of single crystal into wafers 0.012 inches thick (wasting about half the crystal since the saw cut is about as thick as the wafer). Then very precise amounts of other materials are introduced into the two surfaces creating the n-type and p-type materials and the junction which is the boundary between them.

The requirement for extreme purity of the silicon and for a pure crystalline structure when combined with the need for great precision in the addition of doping materials, has so far required much careful hand work by highly skilled technicians and results in the high price. As an example, the basic 2 cm by 2 cm piece of silicon for a solar cell to be used in space costs about 40 cents, but the additional processing costs $4.00.

There are several approaches to reducing costs. Mass production systems are being designed to optimize each operation from the beginning, with sand as the raw material, to the finished cell. In a process being developed by Tyco Laboratories and Harvard University, a very thin die is lowered into molton silicon and silicon is drawn into it by capillary action (as water goes up in a thin tube). The silicon ribbon can then be pulled slowly through the die and holds that shape as it hardens. The ribbons can be cut and fashioned into solar cells without the costly grinding and polishing. Tyco hopes soon to be producing ribbons 50 to 100 feet long.

The other major direction for research and development is to improve the solar cell's efficiency. To generate 4000 Mw of electric power (about 1 percent of our present generating capacity) with 12 percent efficient solar cells would require 80 square miles of solar cell panels--about 100,000 tons of silicon.

Annual U.S. production of pure single-crystal silicon is about 500 tons at present.

The upper limit on cell efficiency is about 25 percent. Increased efficiency will lower the collecting area needed; doubling the efficiency cuts both the above figures in half. Other substances are being tried and one type, a gallium arsenic cell, with an efficiency of 18 percent was produced recently. Cadmium-sulfide cells also have their backers.

It is not impossible that new photovoltaic substances will be used. A cell made of a junction between glass and inexpensive polycrystalline silicon (a conglomerate of crystals rather than a single crystal) has demonstrated an efficiency of 7 percent and may provide an inexpensive solution. There is also experimentation underway with combinations of solar cells and sunlight concentrators--mirrors or lenses--which increase the output by focusing more sunlight on the cells.

PRESENT AND PROPOSED SYSTEMS

A solar cell industry is already in existence in this country, producing 1000 to 1500 m^2 of solar cells with a generation capacity of perhaps 100,000 watts annually for a market of more than $5 million per year. The space industry has been the major customer, but not the only one. Solar cells are used also at remote locations on earth and aboard private and commercial boats to charge batteries and power communication systems, etc.

Larger scale generation of electricity is in a much more primitive stage of development. The 1 kw solar array of the Mitre Coropration is being tested as a prototype household energy source. An auxiliary storage system is also under development and they will experiment with hydrogen production by electrolysis. The hydrogen can be used with a fuel cell to produce electricity on cloudy days.

A second approach is taken by the Institute of Energy Conservation at the University of Delaware. The center attraction for this study is Solar One, an experimental solar-powered house. The heart of the system under study at Solar One is a rooftop unit combining a solar thermal collector for heating and cooling with solar photovoltaic devices for electricity. The project director, physicist Karl Böer, estimates that almost 90 percent of the household energy requirements could be met.

With such a combination, overall efficiencies as high as 60 percent are expected. A novel feature is the two-way connection with the conventional electric utility system. During peak sunlight, the cells would produce more electricity than needed. This surplus would be fed into the utility network for use elsewhere. Since the utility load usually peaks in the daylight and in the summer, times when solar output is a maximum, this assistance would be appreciated and perhaps credited. Böer anticipates that solar generation of this type might reduce peak loads by 10 to 20 percent without the need for major electrical storage.

Solar One will be an important proving ground There are many difficulties to be worked out, ranging from the technical and economic relations with the utility, to the problems of dirt and bird droppings on the collectors. It is thus much too early to speak of costs, but one estimate sets the costs of a 3 ft by 4 ft solar panel at 93¢/ft^2, plastic and glass coverings at 83¢/ft^2, and insulation at 10¢/ft^2, for a total of $1.86/$ft^2$. To this Böer adds $3.50/$ft^2$ installation costs and projects electricty costs of 2 or 3 cents per kw-hr.

Hardly an example of existing practice and a literal "blue sky" proposal is the one put forward by Peter Glaser of Arthur D. Little, Inc. for a Satellite Solar Power Station. This ambitious plan calls for a satellite with two wing-like solar panels, each about 3 miles on a side. The satellite would be put into a synchronous orbit; fixed above a spot on the Earth (22,000 or so miles above the Earth's surface) and since it would always be in the sunlight, would receive about seven times as much solar energy as an Earth-based panel. The electric energy would be converted to microwave radiation and beamed to Earth where it would be collected and reconverted. It is calculated that the solar satellite would produce more energy in two years than was used to build it and put it in space.

A satellite of this size is about 10,000 times larger than any satellite which we have so far orbited and a host of others problems have to be solved. It is clearly a vision for the next century.

ENVIRONMENTAL EFFECTS

Solar cells have a generally benign direct environmental impact. The largest problem is the amount of land needed. If a target generation of 1 x 10 kw-hr/year is chosen (a reasonable target for early in the next century), then about 0.1 percent of the U.S. land will have to be dedicated to this purpose. This huge amount of land--20 million acres--covered with 10 percent efficient solar cells would produce about 6 percent of all electric energy we expect to use in 2020. It is a lot of land, but highways now cover 5 times as much land and crop land is 100 times larger.

Houses themselves--single family residences--cover half as much land as is required and much of the generation may be roof top. This not only saves land, but offers the possibility of reducing the need for transmission lines, an economic and aesthetic benefit.

There will be significant indirect environmental impact. The energy to process the millions of solar cells will inevitably add to the environmental burden. It may take years, as it did in the nuclear industry, for energy production by solar cells to catch up with the energy expended in their construction.

SUMMARY

Photovoltaic conversion of sunlight to electrical energy is presently accomplished, but at a high price. The manufacturers estimate costs of less than $15,000 for large orders, but this is still 15 to 20 times higher than the present most expensive nuclear or fossil fuel generation costs.

Mass production techniques from sand to cells, new methods of growing silicon ribbons, use of new materials, including polycrystalline materials and glass, and types of cells which use other effects than the p-n junction should eventually lower prices. In addition to the research, there are equally difficult problems of installation, storage, utility interconnection, etc., to be solved.

Solar power has become a popular issue, but some proponents expect too much too soon and the figures we have quoted should temper unbridled optimism. Many feel, however, that Federal optimism has been too bridled. The goals of the most recent National Solar Energy Research Development and Demonstration Program (ERDA-49) are for 100 Mw of photovoltaic generating capacity by 1985 and 30,000 Mw by the year 2000. In support of this, the funding is expected to grow from $5 million by 1980. It appears, however, that the popularity of solar energy in Congress is so great that more funds than requested will not only be authorized, but appropriated. The American people are turned on to the idea of free energy from the sun (at almost any cost, apparently), and the solar era may dawn more brightly and quickly than expected.

REFERENCES

1. Solar Energy for Earth, American Institute of Aeronautics and Astronautics, April 21, 1975, see esp. Chapter VII, "Photovoltaic Power," pp. 46-59.

2. "Solar Cells: When Will You Plug Into Electricity from Sunshine?" Jon F. Free, Popular Science, 205, 52-55, 230-121, December 1974.

3. "Energy Crisis Spurs Development of Photovoltaic Power Sources," A. Rosenblatt, Electronics, 47, 99-111, April 4, 1974.

4. "The Photovoltaic Generation of Electricity," Bruce Chalmers, Scientific American, 235 (4): 34-44, October 1976.

5. "Photovoltaic Solar Energy Conversion," M. Wolf, Bulletin of the Atomic Scientists, 32, 26-33, April 1976.

Factsheet Titles

1. Fuels from Plants (Bioconversion)
2. Fuels from Wastes (Bioconversion)
3. Wind Power
4. Electricity from the Sun I (Solar Photovoltaic Energy)
5. Electricity from the Sun II (Solar Thermal Energy Conversion)
6. Solar Sea Power (Ocean Thermal Energy Conversion)
7. Solar Heating and Cooling
8. Geothermal Energy
9. Energy Conservation: Homes and Buildings
10. Energy Conservation: Industry
11. Energy Conservation: Transportation
12. Conventional Reactors
13. Breeder Reactors
14. Nuclear Fusion
15. New Fuels from Coal
16. Energy Storage Technology
17. Alternative Energy Sources: Environmental Impacts
18. Alternative Energy Sources: A Glossary of Terms
19. Alternative Energy Sources: A Bibliography

Copies of these Factsheets may be obtained from:
DOE-Technical Information Center
P.O. Box 62, Oak Ridge, TN 37830

Printed 1977
Reprinted September 1978

[redacted]